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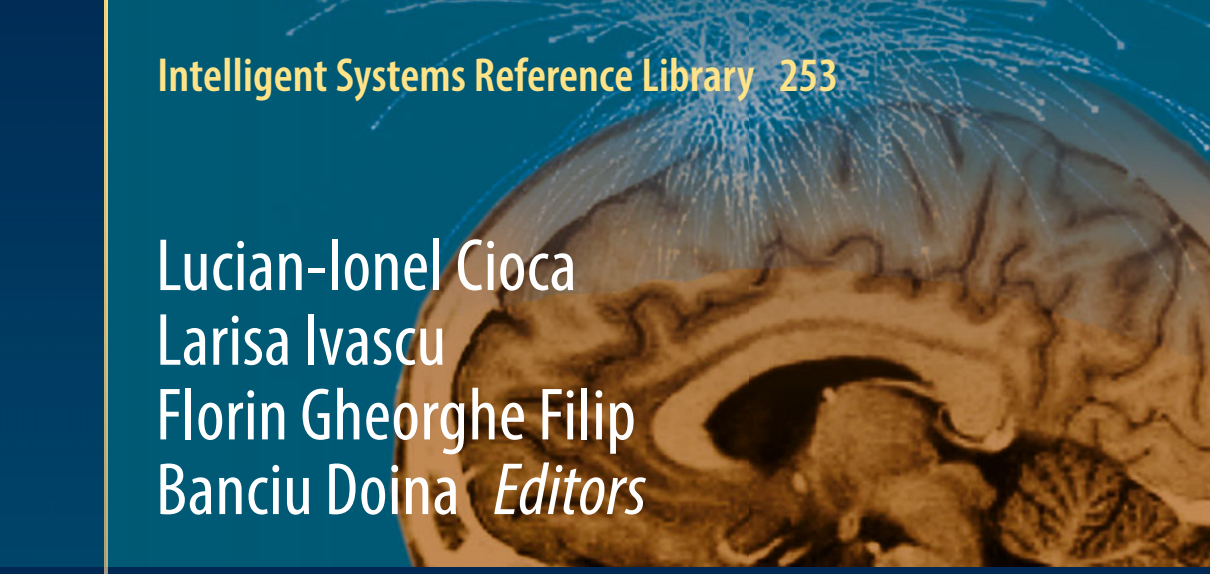

Lucian-Ionel Cioca
Larisa Ivascu
Florin Gheorghe Filip
Banciu Doina *Editors*

Digital Transformation

Technology, Tools, and Studies

Springer

Intelligent Systems Reference Library

Volume 253

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Digital Transformation

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ISSN 1868-4394 ISSN 1868-4408 (electronic)
Intelligent Systems Reference Library
ISBN 978-3-031-55951-8 ISBN 978-3-031-55952-5 (eBook)
https://doi.org/10.1007/978-3-031-55952-5

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Paper in this product is recyclable.

Preface

Incorporating technologies into organizational processes has become a priority for all industries to lead to important changes. All these activities are covered by the digital transformation that can lead to increased efficiency, agility, innovation, and the unlocking of organizational values. This approach is present in all fields, being intensively addressed and debated by researchers, teachers, and practitioners. The value offered to customers in accordance with their expectations represents a fundamental change for the organization and can be achieved through digital transformation. This multidisciplinary volume integrates research from different fields of activity outlining a picture of digital transformation (DT).

Digital transformation is presented in more and more companies that want to innovate and improve their level of competitiveness. The use of different tools, methods, and techniques for DT can contribute to a complete approach to organizational processes and to their efficiency. Digital transformation involves the adoption and use of new digital technologies to develop new products and services; modify existing ones; and develop new business models to increase efficiency, productivity, and competitiveness. DT contributes to the generation of organizational benefits, among which are the efficiency of processes, the reduction of human errors, the increase of productivity, the efficiency of costs, and the increase of the level of competitiveness. Indeed, a series of organizational barriers can be identified in the organizational approach for DT. Among these barriers are competences, abilities, costs, and the limitation of some resources.

This volume addresses DT in different domains and areas of activity. Starting from marketing to culture and education to health, mobility, and human resources. The complexity of the volume is given by the multidisciplinary and complex approaches that are present in the 12 chapters.

Sibiu, Romania — Lucian-Ionel Cioca
Timisoara, Romania — Larisa Ivascu
Bucharest, Romania — Banciu Doina
Bucharest, Romania — Florin Gheorghe Filip

Contents

About the Editors

Lucian-Ionel Cioca is a Full Professor at the "Lucian Blaga" University of Sibiu, since 2007. Since 2010 he is a Doctoral Advisor in Engineering and Management, and since 2012–present he is a member of the National Council for the Certification of University Titles, Diplomas and Certificates, the Commission for Engineering and Production Management, the Ministry of Education. Since 2017–present he is a member of the Specialized Certification Committee, the Ministry of Education, and since 2017–present he is a member of the Advisory Board for Research and Development and Innovation, the Ministry of Research, Innovation and Digitalization.

His research focuses on the following directions: management, human resources management, production systems engineering, ergonomics, circular economy, sustainability, occupational safety, and health management. He has published over 250 scientific papers, of which over 120 are indexed by Clarivate Analytics in the Web of Science.

He is the President of the Commission for Safety and Health at Work within the Romanian Academy of Scientists, the President of the Ardeleana Academy, and the Vice-President of the Institute for Research in Circular Economy and Environment "Ernes Lupan".

He is a professional membership: The Academy of Romanian Scientists, The General Association of Engineers in Romania, The Association of Doctoral and Excellence Activities in Business Engineering and Management, The German General Engineer's Association, The World Economics Association (WEA), United Kingdom, The Romanian Managers and Economical Engineers Association, and The Transylvanian Association for the Literature and Culture of the Romanian People.

Due to the recognition of his research, he is the Editor-in-Chief of the journal indexed in Web of Science and Scopus entitled: INMATEH—Agricultural Engineering (ISSN 2068-2239).

He is also an editorial board member of the following journals indexed in Web of Science, and Scopus: Polish Journal of Management Studies (ISSN 2081-7452), Quality-Access to Succes (ISSN 1582-2559), Sustainability (ISSN 2071-1050), and Safety (ISSN 2313-576X).

He is also an guest editor of the following journals indexed in Web of Science, and Scopus: Advances in Materials Science and Engineering (ISSN 1687-8434), International Journal of Environmental Research and Public Health (ISSN 1660-4601), Processes (ISSN 2227-9717), Sustainability (ISSN 2071-1050), and Safety (ISSN 2313-576X).

Larisa Ivascu (Ph.D. in Engineering and Management; MBA; B.A. Software Engineering) is a professor at Politehnica University of Timisoara, Romania, Faculty of Management in Production and Transportation, Department of Management, having more than 15 years of experience in programming, teaching, and research. She is the Head of the Entrepreneurship Office of Politehnica University of Timisoara and Director of Research Center for Engineering and Management. She is the President of the Scientific Committee of the Academy of Political Leadership and Vice-President of the Society for Ergonomics and Work Environment Management. She has extensive academic work: published 10 books, 10 chapters in national and international books, coordinated the editing of 4 books at internationally recognized publishing houses, and over 250 academic research studies or articles, being also part of international research bodies. She is a guest editor of important journals, a keynote speaker to various international and national events, being part of the national and international entrepreneur and academic projects.

More details can be found at: http://www.mpt.upt.ro/eng/research/pdf/CCIM/CV_Ivascu%20Larisa_eng.pdf.

Florin Gheorghe Filip was born in 1947. He graduated in Control Engineering at Politehnica Technical University of Bucharest in 1970 and received his Ph.D. degree from the same university in 1982. He was elected as corresponding member of the Romanian Academy in 1991 and became full member of the Academy in 1999. During 2000–2010, he was Vice-President of the Romanian Academy (elected in 2000, re-elected in 2004 and 2006). In 2010, he was elected President of the "Information Science and Technology" section of the Academy (re-elected in 2015 and 2019). He was the Managing Director of National Institute for R&D in Informatics-ICI Bucharest (1991–1997). His main scientific interests include optimization and control of large-scale complex systems, decision support systems, technology management and foresight, and IT applications in the cultural sector. He authored/co-authored over 350 papers published in international journals (IFAC J. Automatica, IFAC J Control Engineering Practice, Annual Reviews in Control, Computers in Industry, Large-Scale Systems, Technological and Economical Development of Economy, and so on) and contributed to volumes printed by international publishing houses (Pergamon Press, North Holland, Elsevier, Kluwer, Chapman & Hall, and so on). He is

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Banciu Doina a Full Professor at the University of Bucharest, Ph.D. in Systems Engineering (Politehnica University of Bucharest, 1989), is Vice-President of the Romanian Academy of Scientists, President of the Scientific Council of the National Institute for Research and Development in Informatics, ICI Bucharest (from 2017), member of the National Commission of Libraries since 2017, Director General of the National Institute for Research and Development in Informatics, ICI Bucharest (2001–2016), and member of the National Commission of Libraries (since 2017). She has numerous theoretical contributions regarding the computerization of public administration and libraries; effectively participated in the computerization of the National Library of Romania, the Carol I Central University Library as well as several information and documentation institutions. She is a NATO, European and national evaluator for ICT research projects. She has written 18 books and over 200 articles published in the country and abroad. She received the "Tudor Tănăsescu" award of the Romanian Academy, as well as numerous other national and international awards. She also received the title of Doctor Honoris Causa from several universities. She represented Romania in international working groups, and she led national and international research programs and projects; she was decorated with the Order of Faithful Service in the rank of knight.

Chapter 1
Drivers for Sustainable Digital Transformation in Public and Private Organizations

Florin Dragan, Lakhmi C. Jain, and Larisa Ivascu

Abstract Digitization, digitalization and digital transformation (DT) are important for public organizations and private organizations. Despite their importance, these steps are approached differently in organizations. Public organizations emphasize the importance of digital transformation, while public organizations make efforts to align themselves with citizens' demands from a digitalization perspective. So far, no study has presented (1) to what extent this transformation is underway and (2) what are the determining factors with particular emphasis on Romanian cases. This research was carried out in two directions: research carried out for public organizations and research carried out for private organizations. The research is completed with comparative assessments of digitization and digital transformation in public and private organizations. The results show that public organizations are intensively involved in the digital transformation, while public organizations try to find solutions to the various barriers and are at an average level of digitalization. The research concludes with future research directions and research limitations.

Keywords Sustainability · Organizational transformation · Digitization · Digitalization · Digital transformation · e-government

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L-I. Cioca et al. (eds.), *Digital Transformation*, Intelligent Systems Reference Library 253, https://doi.org/10.1007/978-3-031-55952-5_1

1.1 Introduction

Nowadays, digital technologies and digital tools are used in organizational processes and activities. The present studies show a high degree of digitization in the private and public sector. Digitization is happening successfully in private organizations, and public institutions are undergoing digitization [1–5]. Digital transformation is desired in the private sector, which is also a possible approach in the public sector. In the private sector, there are certain fields of activity that are at a high level of digitization, and some in which there is the possibility of improving the activity [6–11]. The public sector is made up of government and government-controlled enterprises and constitutes a part of the economy. This sector does not include private organizations, non-governmental organizations or other forms coordinated by individuals or companies. The private sector is the part of the economy that is not controlled by the state and is run by individuals and other entities [12–14] Private organizations sell tangible and intangible products (services) to generate revenue and income. Public organizations have as a secondary goal the achievement of positive financial results. The purpose of these public organizations is to contribute to the welfare of society and to develop products and services for the public [15–18].

Digitization is a fundamental process that consists in the conversion of physical (analog) elements into digital ones and organizes information into data units called bits. It is a very important process for digital technologies and represents the next step for digitization [19–23]. Practically, we cannot talk about digitization and digital transformation without the digitization process at the novel organizational level [14, 24, 25]. The digitization process consists in storing information and elements in computers, without changing their form. In practice, a conversion of hard/paper files or documents into digital documents is carried out. Digitization also realizes data recording. The result of the digitization can be an image, a sound, a document, a file, a signal. Here you can exemplify the scanning of a document and its storage on the computer [26, 27]. After placing the document on the computer, this digitization process ends. Digitization is the process by which processes are developed and workflows are changed to improve manual systems. Digitization uses digital technologies to change a business model and provide new financial results, improving organizational value and other targeted indicators [27]. An example in this sense would be the use of digitized data of buyers or individuals from different sources to automatically generate information from their behavior and use it in organizational marketing activities. Digital transformation involves the adoption and use of new digital technologies to develop new products and services, modify existing ones and develop new business models to increase efficiency, productivity and competitiveness [11–14].

In Table 1.1, an analysis of the important aspects for digitization, digitalization and digital transformation is carried out using specialized literature [4, 6–12, 28–31]. The main aspects and results obtained are:

- *Definition*—The definitions are different. These concepts are related to each other and cannot talk about digital transformation without digitization or digitization.

Table 1.1 Bottom line: digitization, digitalization, and digital transformation

Aspect	Digitization	Digitalization	Digital transformation
Definition	Digital representation of objects or attributes	The use of digital technologies and digitized data to activate or improve organizational processes	The digital transformation of the organization through the implementation of digital technologies
Input	Physical objects, physical files or documents or physical attributes	Digitized data, digital technologies	Organizational processes, digital technologies
Output	Digital files or document	Transformed organizational processes	Innovative organizational processes
Everyday efficiency	Reducing workload	Increasing efficiency through digital processes	Improving organizational capacity and obtaining immediate answers
Organization benefits	Reduction of workload and loss of information	Improvement of processes, reduction of organizational losses	Increasing organizational competitiveness
Transmission	The ease of storing digital information, the reduction of organizational resources	Ease of use of digital information, reduction of organizational resources	Ease of processing and optimization of digital information, reduction of organizational resources
Tech drivers	Systems for converting analog data into digital data. These drivers exist in most organizations and are basic elements in the current technological evolution	New business opportunities by improving operations using new technologies such as artificial intelligence (AI), big data, robotics and the Internet of Things (IoT)	New business models by improving processes and adopting innovative technologies. Technologies advance rapidly and digital transformation must use them
Comprehensive strategy	The digitization strategy requires changes in the organizational culture, vision, mission and strategic objectives	It includes emerging technologies for streamlining core operations to create value for stakeholders	Innovative strategies that include all organizational resources and innovative technology to develop new business models
Productivity	The first steps are being taken to increase productivity	Organizational productivity is increasing and there are fewer scraps	Productivity can reach optimal limits

Digitization realizes the conversion of the data. Digitalization involves improving processes with digital solutions, and digital transformation uses technology for new business models.

- *Input*—The entrances are different and present in the waterfall.
- *Output*—Outputs have an impact on organizational efficiency.
- *Everyday efficiency*—Efficiency is present from digitization to digital transformation. First of all, there is an improvement in organizational resources.
- *Organization benefits*—The results of these processes are different. Digitization implies a change in the task level. Digitization impacts operational processes, and digital transformation represents the strategic change in organizations.
- *Transmission*—The transmission of information is carried out at the level of each entity and uses digital data generated by digitization.
- *Tech drivers*—It involves a series of drivers that are approached differently by organizations. Each process involves other drivers.
- *Comprehensive strategy*—Each level of digitization, digitalization and digital transformation involves a certain strategic level. The guidelines must be comprehensive and accepted by the interested parties.
- *Productivity*—Each level of digitization, digitalization and digital transformation implies an improvement in organizational productivity.

Among the digital transformation components used are: software, E-Mail, videoconferencing solutions, websites, databases, application programming interfaces (APIs), hardware (computers, servers, datacenter), robotic process automatic (RPA), internet connections, additive manufacturing (3d printing), augmented reality (AR), mobile phones, advanced human computer-interaction, IoT and many others [6, 30, 32–34].

The Digital Economy and Society Index (DESI) is an index composed of 4 main dimensions human capital, connectivity, integration of digital technology and digital public services that highlight Europe's digital performance. For the year 2022, Romania's situation registers a score of 5.26% for digital public services, 3.79% for digital technology, 13.81% for connectivity, and 7.73% for connectivity [35–37]. The situation at the level of the member states of the European Union is presented in Fig. 1.1.

For the year 2021, Romania's situation registers a score of 4.54% for digital public services, 3.92% for integration of digital technology, 11.46% for connectivity, and 7.52% for connectivity. Romania improved its DESI scores in 2022 compared to 2021.

1.2 Public Versus Private

The digital transition in the public and private sectors presents certain particularities. Table 1.2, presents a series of evaluated factors for organizations in the two categories [1–23].

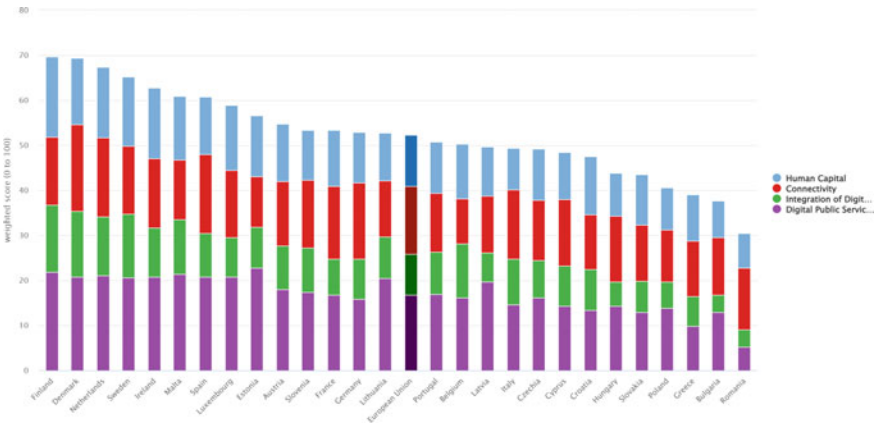

Fig. 1.1 Digital economy and society index for 2022 (European Commission)

Table 1.2 Comparative evaluation of the public and private sectors

Factors	Private sector	Public sector
Universal nature	The number of services, different and customized according to the company's field of activity	High degree of universality because the services are limited and not customized according to the user's characteristics or needs
Wide range of applications	It has a wide range of applications, dynamic and incorporating new technologies	It has a medium range of applications with a medium digitization impact
Digitalization impact	Stakeholders are assessed and involved	General tools are applied to evaluate the degree of citizen satisfaction are applied
Safety	High degree of safety thanks to the new technologies used	Average degree of safety due to the lack of updating of some technologies
Cyber security	High level of security thanks to the new technologies used	Average level of security due to lack of updating of some technologies
Budget	Available for digitization	Limited by local and central government regulations and rules
Success in digitization	Grown as an important component of the business environment	A stage in development, below average, which takes steps to improve the degree of digitization
Generation gap	It is covered by the technologies used and the work teams within the companies	It is felt especially among citizens and the less friendly solutions offered by public institutions
Employee	Qualified and regularly trained	Employees have general skills

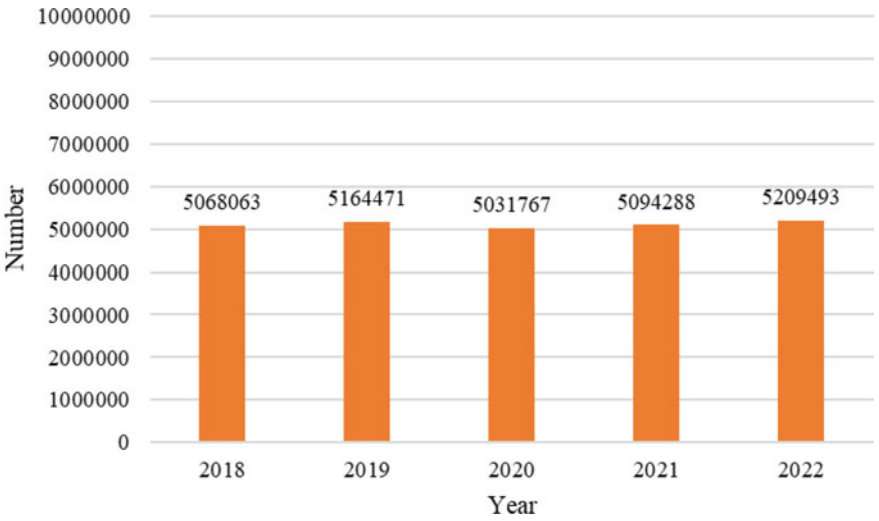

Fig. 1.2 The average number of employees for the period 2018–2022

At the Romanian level, the average number of employees is presented in Fig. 1.2. It can be seen that the situation does not show significant changes. In 1990, the average number of employees was 8,155,605 people.

Depending on the form of ownership, the situation of the employees is presented in Fig. 1.3. It can be seen that for the year 2022, there were the most employees in private ownership, 3,945,275 employees, and in the public sector, 1,264,218. The private sector registers more employees during the entire evaluated period of 2018–2022.

1.3 Digital Transformation in the Public Sector

For this study, the research was carried out by applying an online questionnaire using Google Form. This questionnaire was divided into 3 sections. The results of the research carried out between January and November 2023 are presented below. For this research, 995 valid responses were recorded from personnel working in the private sector. Management functions and execution functions were followed.

The results obtained for the first section are presented below. The age of the respondents is presented in Table 1.3. There were no respondents older than 65 years who work in the public sector. Most of the respondents are in the age category.

Figure 1.4 shows the level of education for respondents from the public sector. Most of the respondents have graduated from college or completed a master's degree. The percentage of respondents with secondary education is 23%.

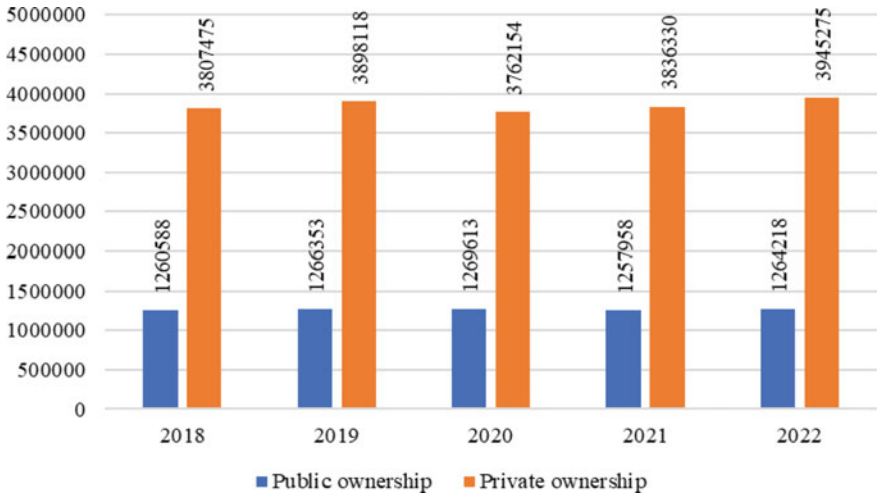

Fig. 1.3 Average number of employees by types of ownership

Table 1.3 What is your age?

Category	Number	Percentage
18–24	34	1.14
25–34	129	4.31
35–44	123	4.11
45–54	534	17.86
55–64	170	5.69
65–74	0	0
75+	0	0

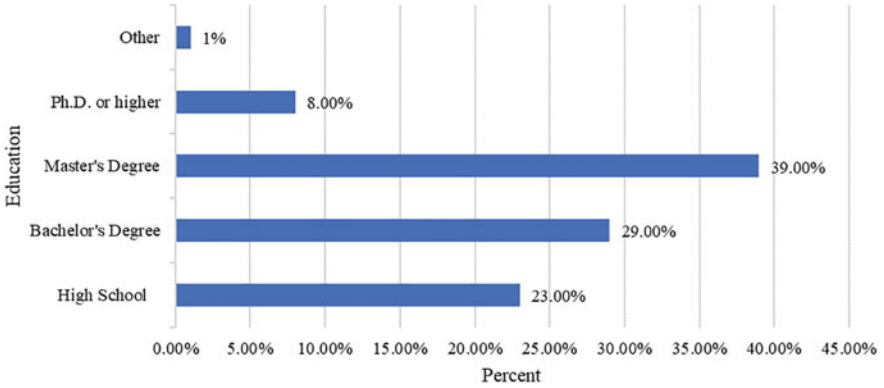

Fig. 1.4 The level of education

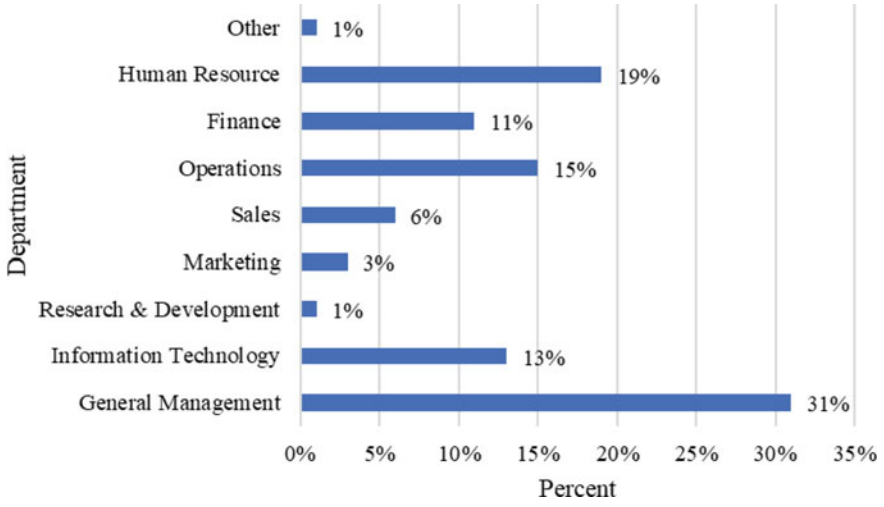

Fig. 1.5 The department of the respondent's activity from public sector

Figure 1.5 presents the public sector respondent activity from public sector. The research and development departments are less present in the activity of the public sector. Many of the respondents work in general management, human resources, and information technology.

The next section of the undertaken research evaluates organizational digital maturity. Different directions are evaluated to outline an image of digitization and digital transformation in the public sector. Several directions are evaluated using the Likert scale**,** Table 1.4. The directions evaluated are the digital maturity of the organization, 100% digital business, the digital business model, the organizational approach for digital transformation, the organizational approach for digitalization, the organizational approach for digitization, digital transformation for management/strategy, operations, products, employee engagement and human resources. From the responses received, the level of digital transformation appreciated by the respondents is below the average level. Public organizations are in the process of reaching 100% digitization. The organization's operations and management are taking steps for digital transformation.

Table 1.5 evaluates the drivers that influence digital transformation in public organizations. It can be seen that the government and the citizens play important roles in this endeavor. Competitors and suppliers do not represent drivers of increased importance.

Table 1.6 highlights the barriers identified in the digitization process. It can be seen that knowledge obtained the highest average score. Other identified barriers are low funds and infrastructure.

The results are presented in Table 1.7. The evaluated factors are strategy and organization, strategy for digital transformation, digital transformation culture, knowledge sharing, agility, and technology. It can be seen that technology is the most

Table 1.4 The public organization's digital maturity

	1 (Very low) (%)	2 (%)	3 (%)	4 (%)	5 (Very high) (%)
The digital maturity of the organization	2.00	67.00	23.00	5.00	3.00
100% digital organization	3.00	84.00	6.00	3.00	4.00
The digital organization model	3.00	56.00	21.00	13.00	7.00
The organizational approach for digital transformation	2.00	64.00	23.00	6.00	5.00
The organizational approach for digitalization	2.00	64.00	23.00	6.00	5.00
The organizational approach for digitization	2.00	64.00	23.00	6.00	5.00
DT for management/ strategy	2.00	74.00	11.00	8.00	5.00
DT for operations	2.00	68.00	16.00	9.00	5.00
DT for products	2.00	68.00	16.00	9.00	5.00
DT for employee engagement and HR	2.00	65.00	21.00	7.00	5.00

Table 1.5 Drivers for digital transformation

	1 (Low important) (%)	2 (%)	3 (%)	4 (%)	5 (Very important) (%)
Competitors	23.00	59.00	13.00	3.00	2.00
Citizen	7.00	6.00	62.00	23.00	2.00
Suppliers	23.00	61.00	11.00	3.00	2.00
Government	1.00	3.00	43.00	49.00	4.00
Others	7.00	67.00	14.00	4.00	8.00

Table 1.6 Barriers for digital transformation

Barriers	Average score
Low funds	4.56
No expert knowledge	4.78
No infrastructure	4.55
Legislation	3.40
No proper management	4.11

Table 1.7 Organizational factors for digital transformation

Factors	Average value
Strategy and organization	4.53
Strategy for digital transformation	3.23
Digital transformation culture	3.98
Knowledge sharing	3.92
Agility	3.01
Technology	4.78

Table 1.8 The result of digital transformation

Direction	Average value
Increase revenue	2.56
Market share	0
Reduce operating costs	2.32
Increase agility	2.34
Improve citizen satisfaction	4.53
Reduce the development time for new products/services	1.23

appreciated factor for DT by the respondents. Strategy and organization, culture and sharing knowledge register important results.

The results and organizational benefits for the digital transformation are numerous and are evaluated by 990 respondents. Among the DT results are increased revenue market share, reduced operating costs, increased agility, improved customer satisfaction, and reduced the development time for new products/services. The most important result is the improvement of citizen satisfaction and then agility. The results are presented in Table 1.8.

1.4 Digital Transformation in the Private Sector

The most used technologies are mobile (75%), Cloud (48%), AI (38%), IOT (42%), digital twin (29%), AR (19%), robotics (18%), and additive manufacturing (3d printing) (13%).

For this study, research was carried out by applying an online questionnaire using Google Form. This questionnaire was divided into 3 sections. The first section is dedicated to the respondent's profile. The second part is dedicated to digital maturity, and the last part was dedicated to organizational strategy. The results of the research carried out between January and November 2023 are presented below. For this research, 2990 valid responses were recorded from personnel working in the private sector. Management functions and execution functions were followed.

Table 1.9 What is your age?

Category	Number	Percentage
18–24	989	33.08
25–34	278	9.3
35–44	956	31.97
45–54	251	8.39
55–64	345	1.54
65–74	115	3.85
75+	56	1.87

The results obtained for the first section are presented below. The age of the respondents is presented in Table 1.9.

From the perspective of the level of education, the situation is presented in Fig. 1.6. It can be observed that the majority of the respondents have master's degrees.

From the perspective of the department where the respondents work, the situation is presented below, Fig. 1.7. It can be seen that there is a distribution of roles in different organizational departments. Many of the respondents are part of general management and information technology.

Depending on the business sector, the distribution of respondents is shown in Fig. 1.8. A distribution of the main sectors in Romania can be observed.

The second section of the research refers to the evaluation of the organization's digital maturity. Several directions are evaluated using the Likert scale, Table 1.10. The directions evaluated are the digital maturity of the organization, 100% digital business, the digital business model, the organizational approach for digital transformation, the organizational approach for digitalization, the organizational approach

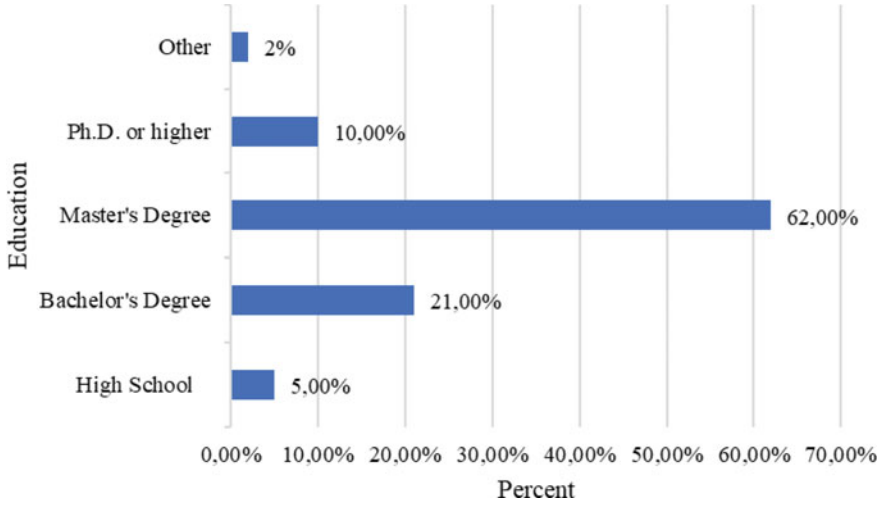

Fig. 1.6 Level of education

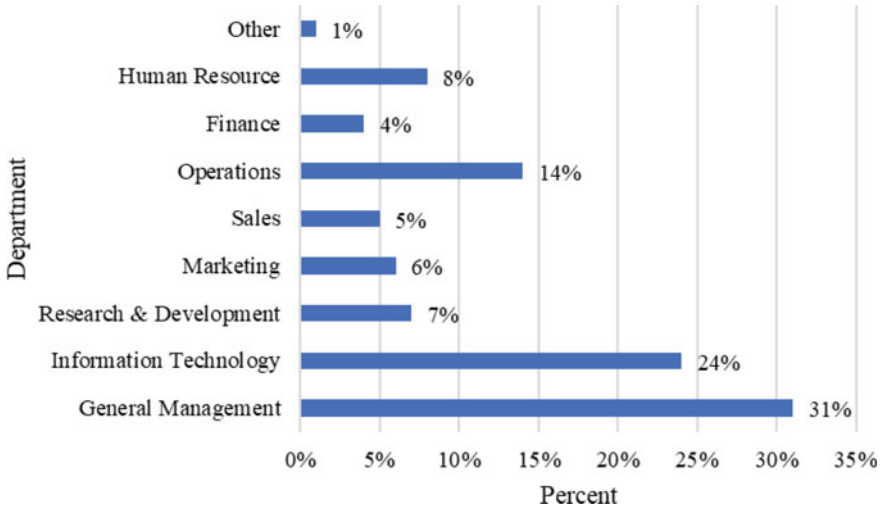

Fig. 1.7 The department of the respondent's activity

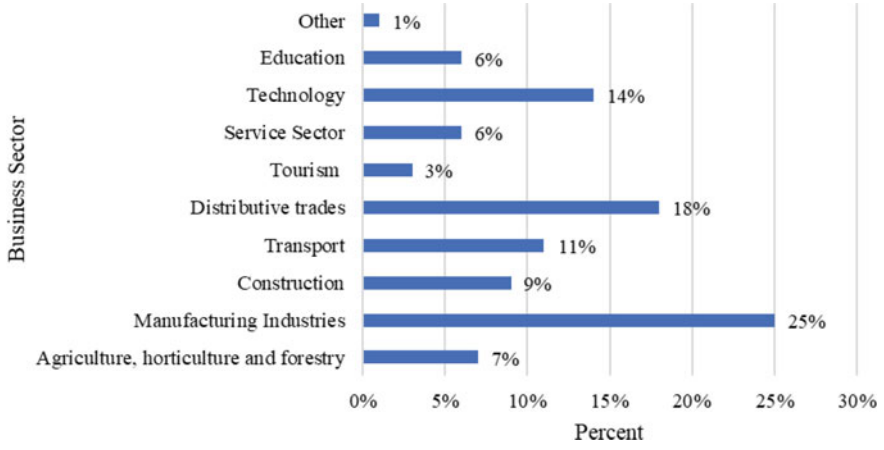

Fig. 1.8 Business sector

for digitization, digital transformation for management/strategy, operations, products, employee engagement and human resources. An average level of digital maturity and total digitization can be observed. Many of the organizations have a complete approach to digitization. Complex activities are carried out for digital transformation for management, operations, and products.

Table 1.11 presents the evaluation of drivers for digital transformation. It can be observed that the most important driver is the customer. The next most important driver, after the average value obtained, are competitors, then suppliers and the government.

Table 1.10 The private organization's digital maturity

Category	1 (Very low) (%)	2 (%)	3 (%)	4 (%)	5 (Very high) (%)
The digital maturity of the organization	2.00	7.30	46.40	35.30	9.00
100 digital business	3.00	13.00	33.00	40.00	11.00
The digital business model	3.00	15.00	37.00	34.00	11.00
The organizational approach for digital transformation	1.00	1.00	2.00	23.00	73.00
The organizational approach for digitalization	0.00	1.00	2.00	16.00	81.00
The organizational approach for digitization	0.00	0.00	0.00	2.00	98.00
DT for management/ strategy	3.50	8.00	14.00	21.00	53.50
DT for operations	3.50	7.00	13.40	27.60	48.50
DT for products	3.50	4.00	10.50	21.00	61.00
DT for employee engagement and HR	3.50	4.00	10.90	73.60	8.00

Table 1.11 Drivers for digital transformation

	1 (Low important) (%)	2 (%)	3 (%)	4 (%)	5 (Very important) (%)
Competitors	0.00	1.00	68.00	21.00	10.00
Customers	2.00	3.00	4.00	78.00	13.00
Suppliers	2.00	8.00	63.00	18.00	9.00
Government	2.00	11.00	69.00	12.00	6.00
Others	7.00	67.00	14.00	4.00	8.00

The third part of the research includes the organizational factors for digital transformation. The organizational factors for DT are evaluated in the present research.

The digital barriers evaluated in this research are low funds, no expert knowledge, no infrastructure, legislation, and no proper management. The most important barrier is the lack of solid knowledge and adapted infrastructure. The results are presented in Table 1.12.

The results are presented in Table 1.13. The evaluated factors are strategy and organization, strategy for digital transformation, digital transformation culture, knowledge sharing, agility, and technology. It can be seen that technology is the most

Table 1.12 Barriers for digital transformation

Barrier	Average value
Low funds	3.13
No expert knowledge	3.52
No infrastructure	3.35
Legislation	2.90
No proper management	3.13

appreciated factor for DT by the respondents. Culture and sharing knowledge register important results.

The results and organizational benefits for the digital transformation are numerous and are evaluated by 2990 respondents. Among the DT results are increased revenue market share, reduced operating costs, increased agility, improved customer satisfaction, and reduced the development time for new products/services. The most important result is the improvement of consumer satisfaction and then agility. The results are presented in Table 1.14.

Table 1.13 Organizational factors for digital transformation

Factors	Average value
Strategy and organization	3.99
Strategy for digital transformation	3.78
Digital transformation culture	3.98
Knowledge sharing	3.92
Agility	3.75
Technology	4.20

Table 1.14 The result of digital transformation

Direction	Average value
Increase revenue	3.87
Market share	3.76
Reduce operating costs	3.55
Increase agility	4.57
Improve customer satisfaction	4.78
Reduce the development time for new products/services	3.54

Table 1.15 Barriers for digital transformation for public and private organizations

Barriers	Implication
Cultural	In many fields, cultural factors represent an important barrier. Organizational culture plays an important role in this direction
Structural	The structural elements are important at the organizational level
Process	The complexity of the processes and their management can represent barriers
People	People and mainly employees are often reluctant to the digitization process
Information system	Information systems can often present certain peculiarities that make them complex

1.5 Barriers and Drivers for Digital Transformation

This chapter is based on specialized literature [5–16] and research undertaken for public and private organizations. Barriers and drivers for digital transformation are presented. The barriers for this approach are presented in Table 1.15. They are considered the most relevant directions with regard to the research undertaken. The barriers refer to directions cultural, structural, process, people, and information system.

Table 1.16 shows the drivers that contribute to DT. These drivers were selected based on specialized literature [6–19] and developed research. Thus, a list of the most relevant drivers was obtained.

Drivers and barriers must be evaluated by each organization and solutions identified for a correct and complete approach to DT. This subchapter represents a basis for public and private organizations.

1.6 Conclusions

Digitization, digitalization and digital transformation are important processes for public and private organizations. That is why the present research proposed to carry out a market research in order to outline a real picture of the involvement in these processes of the organizations in Romania. The results show that the two sectors, public and private, register different results from the perspective of barriers or drivers that contribute to DT. The level of digitalization maturity differs between the two sectors. The involvement of employees and the approach to digitization have particularities. These technological developments were anticipated in previous researches and represent a necessity of the current dynamism [38].

The limitations of the research refer to the fact that the research was carried out at the level of Romania. Future research will also target other member countries of the European Union and finally outline some profiles of the 2 sectors.

Table 1.16 Drivers for digital transformation for public and private organizations

Environment	Drivers	Implication
Internal	Vision, leadership, worldview	Strategic management elements are mandatory for digital transformation
	Data management	Important for every organization
	IT infrastructure, technology accessibility	It is mandatory that the infrastructure is suitable for the development
	Agility	If the level of agility is increased, the sustainable evolution of the organization is facilitated
	Resources	Resources are important to DT
	development of digital skills and training	Continuous training at the organizational level must exist in organizations
	Market share	Increasing market share is a direction aimed at by many organizations, correlated with increasing competitiveness
External	Institutional and regulatory framework	Legal frameworks facilitate the DT of organizations
	Competitors	Competitors are essential in improving the organizational position
	Customer/citizen	Clients are among the most important facilitators
	Digital technology evolution	Technological evolution forces organizations to innovate and get involved in digitization and DT

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Chapter 2
The Role of the Culture Institution on Digital Transformation of Society

Doina Banciu

Abstract The chapter presents the most important objectives of European Union for implementing digital transformation and developing citizens digital skills, in fact „digital culture for everybody". In this context, there are analyzed the most representative cultural institutions such as libraries, museums, theaters and presents their main actions to keep the balance between traditional life and digital environment. The chapter pay more attention to the public libraries and theirs roll in developing the citizen digital skills, beside their main objective as cultural knowledge hub. The work is focused on the Romanian case where the need of digital skills is very different from a group of citizens to others. It is described the Romanian public library system and concrete initiatives at the national level, having as principal objective the transformation of the libraries in the digital cultural hub for citizen digital skills improving. There are also analyzed the needs of citizens and the type of courses (curricula) which could help them to improve their digital skills. The chapter describe too, the opportunities and difficulties from the libraries point of view to reach such tasks. It is taken into consideration the level of digital development of ICT private sector and the universities capabilities in order to help libraries and librarians to bring the courses for developing citizen digital skills. The conclusions underline the need of a social pact at the national level for improvement the citizens digital skills.

Keywords Citizens digital skills · Library · Digital cultural strategies · Digital knowledge hub

2.1 Introduction

The digital transformation of society has a major influence on all fields of activity, including culture and education. The two fields are closely linked by common objectives regarding the formation of an individual and involvement in the society in which

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L-I. Cioca et al. (eds.), *Digital Transformation*, Intelligent Systems Reference Library 253, https://doi.org/10.1007/978-3-031-55952-5_2

he lives. The introduction of computers on a large scale in all activities made it necessary to form a digital culture for all citizens. On the other hand, the use of computers in everyday life has forced classical cultural institutions, such as museums, theaters, libraries, to adapt their own activities to the new forms of communication with users, readers and spectators. At the same time, cultural institutions are meant to support citizens to adapt to new technologies, so that phenomena such as the digital divide are improved and avoided. Libraries play an important role in this approach, especially public libraries that must provide an adequate environment for access to knowledge through modern means and procedures. The development of the Internet played an essential role in online communication [1].

The paper tries to show how public libraries can get involved in improving citizens' digital skills and implicitly contribute to the digital transformation of the community in which they operate.

Moreover, the role of libraries is also supported by international bodies in the field. The International Federation of Library Associations and Institutions (IFLA) underline the inclusion of libraries and access to information in national and regional development plans will contribute to meeting the global United Nations 2030 Agenda for Sustainable Development-The UN Sustainable Development Goals (SDGs). According to IFLA ("Access and Opportunity for All), the libraries can contribute to support Sustainable Development Goals by providing *public access to information and resources that give people opportunities to improve their lives, training in new skills needed for education and employment, information to support decision-making by governments, civil society, and businesses to combat* [2]. At the European level, the libraries can play an important role in touching the European strategy for digitalization.

2.2 European Strategy for Digital Transformation

On March 9, 2021, the European Commission launched a new strategy, entitled "EU's digital strategy/A Europe fit for the digital age", i.e. "A Europe ready for the digital age", which in fact represents a Strategic Plan until 2030 regarding the digital transformation of the member countries.

The objectives of the strategy provide for the introduction of information technology in the economic field, of public administration and the development of computer skills for all European citizens, simultaneously with the increase of communication speed.

To achieve these objectives, the European strategy considers four pillars regarded as important for the transition to the Digital Transformation of Europe by 2030. Some strategic objectives are presented below:

- Digital skills for citizens, in fact over 80% citizens to have skills in using information and communication technology (ICT)
- Developed infrastructure—GB connectivity and the use of 5G networks

- The business environment to use new technologies on a large scale. Thus, 90% of small and medium enterprises—SMEs should be able to use ICT at least at a basic level, and large companies should rely on "cloud" type systems and services.
- eGovernment—large-scale implementation of digital services in local and central public administration

European policies in the field of digital transformation have as their final objective the improvement of citizens' living conditions. The impact of ICT on the quality of life is demonstrated by international statistics showing the top countries according to the quality-of-life index.

Studies and experiences worldwide show that the use of new IT technologies contributes significantly to increasing the quality of life, provided that users, citizens, have sufficient digital knowledge and skills. In the specialized literature, the quality of life is measured by specific indices. The Quality-of-Life Index assesses the extent to which a country will provide the best conditions for a healthy, safe and prosperous life, and how ICT can support improving these conditions.

As global experience shows, the objective requirements for digital transformation assume that users are capable and interested in using ICT. The citizen must:

- Know how to use PC and ICT devices
- To have facilities in upgrading their ICT knowledge
- To be able to have free access to technology
- To be able to be trained and assisted free of charge to use the facilities of the systems and applications developed by the authorities.

2.3 Strategies of Cultural Institutions to Promote the Digital Culture

As general view, very briefly, the Cultural institution system has two types of entities:

- public administration bodies at central and local level—having as main objectives to develop the public policy and a culture management; cultural and local public administration institutions are included in this category
- culture public institutions (libraries, museums, theatres etc.)

Entities of the central and local public administration are usually included in the national strategies for the digital transformation of society, oriented towards e-government and e-administration processes. Digital transformation policies are developed by entities in the ICT field (relevant ministries, government agencies, etc.). The development of digitization at the government level also involves specific interoperability procedures for subordinate institutions, but with predilection in the sphere of institutional communication. Specific strategies are defined at the level of each field of activity.

At the level of cultural institutions, digital transformation requires the definition of an appropriate strategy before the use of technology "strategy before technology"

[3]. This approach is supported by most specialists, in fact digital transformation is more than just technology [4].

Without these master plans, sectors of activity develop in an uncontrolled manner, with the negative effects arising from this approach. In conclusion, if there is a governmental interest, cultural institutions are funded and can actively participate in the digital transformation of society (a conclusive example is that of the National Library of Singapore). Otherwise, concrete strategies and measures for the digital transformation of institutions that depend institutionally and implicitly financially on the public administration are the responsibility of the management of each entity (library, theater, museum, etc.).

Regardless of the type of institution, The Digital Transformation for Culture Public Institutions Has Two Components:

- ***Digital Transformation*** of institution itself
- ***Digital Transformation*** of products and services based on ITC offered to the users

These components have interdependent approaches, as the efficient operation of the institution's functional services—human resources, financial department, maintenance of building, etc.—directly influences the other component and vice versa.

As in the case of economic models, the digital transformation of cultural institutions allows the use of tools and methods that lead to the development of effective strategies for innovation, development and competitiveness [5]. Also, the use of ICT represents a "critical element" in the managerial practice of cultural managers, but used successfully positions an entity in successful positions [6].

The main **objectives** of cultural institutions could be summarized as following:

- Collect and preserve the national cultural collections (mobile and immobile heritage).
- Dissemination of information through traditional and digital tools
- Preservation and developing the national identity in globalization context
- Democratic access to the cultural information and national and international cultural heritage (any discrimination)
- Contribute to development positively of behavior and attitude
- Enhance the tolerance attitude to the other opinions and bodies
- Respect of the culture of other nations

Any cultural institution (including libraries) dial with the above objectives, more or less depending on this domain of activity. Particularly, libraries cover all of these objectives.

As other forms of culture, digital culture must be built through education systems, but also through new forms that can be used in classical cultural institutions (libraries, museums, theaters). The COVID-19 pandemic has shown that there can be forms of culture dissemination also through the means offered by new technologies. A few examples can reinforce these comments for the museums case.

Museums have moved to digitizing their collections, creating a virtual and interactive reality of exhibitions. Virtually all the world's great museums have understood the role of digital transformation in culture and adapted their services to new user requirements. The British Museum and the British Library, two iconic institutions in England, have adopted digital technologies to preserve their documents and objects, but also to democratize access to culture and cultural heritage [7, 8]. We must mention the Holocaust Museum in Washington which, through the digitization of products and services, contributes significantly to the knowledge of real history, accessible from any location on the world map [9].

Romanian museums have adapted to new technologies, especially in the area of communication. All major museums have created their own websites. The description of the museum and the programs it runs are accessible online. As far as the development of bean products is concerned, it cannot be said that they are significant achievements. The situation is similar in the case of theaters and other cultural institutions.

An initiative regarding the creation of the museum of immersive art (MINA—Museum of Immersive New Art), considered the largest center of new media art in South-Eastern Europe, must be emphasized. The museum was created at the initiative of private investors with the objective of creating a cultural environment at the intersection of art and emerging technologies. One of the objectives is, in addition to education through digital culture, the development of new digital skills. Visitors benefit from a virtual guide, a conversational avatar based on artificial intelligence.

Digital transformation and citizens digital culture cannot be met without the cooperation of institutions that had and have an important role in society's culture: public libraries. In the context of the digital transformation of the entire society, public libraries must adapt their own strategies to the new requirements.

The formation of digital culture is a continuous process, taking into account the dynamics of the development of IT products. Citizens' knowledge needs to use new technologies are increasing as the digital transformation embraces new and new components of socio-economic and cultural existence.

Public libraries are thus transformed into digital culture hubs to provide citizens with institutional conditions for using ICT when they need it.

A few examples of large libraries that have clear strategies and policies for digital transformation demonstrate the new approaches of these institutions.

The Library of Congress is recognized as the organization that responds to the challenges of society, moreover the first library that used the computer in its work. In 2019, after an analysis of how society is evolving, the Library of Congress defined its Digital Transformation Strategy 2019–2023—encompassing all of the library's core activities: collections, research services, US Copyright Office, research services specific for the Congress, services for the Blind and Print Disabled [10]. The objectives of the strategy included elements to encourage cooperation between users and librarians:

- Exponential growth of collections and intensive digitization
- Maximize content usage

- Supporting emerging research styles
- Long-term relationships with visitors
- Bridges between library and users
- Cultivating an innovative culture by encouraging staff through training, ICT tools, infrastructure, organizational culture
- Encouraging the implementation of innovations and trends (augmented reality, natural language processing, machine learning, investment in pilot projects for emerging technologies)
- Protection of collections and digital content).

Other public libraries, either local public libraries or first-tier libraries such as national libraries, have defined strategies to help their own librarians work with new IT products and also support readers in using ICT.

One of the large public libraries, the **New York Public Library**, has also defined its strategy for digital transformation entitled Digital Research Strategy 2021–2024, which includes strategic objectives specifically dedicated to increasing the professional knowledge of librarians so that they can cope user requests. This approach is a natural consequence of the development of users' computer knowledge, but also of the implementation of new computerized products and services within the library:

- quick and correct search/retrieval of information requested by users
- democratization of access to collections
- deep involvement in the achievement of the library's objectives through the continuous development of staff knowledge by providing training on the use of digital collection platforms and modern IT tools and the involvement of the public (users) in their own strategy.
- strengthening IT systems and infrastructure.

A representative example of the involvement of librarians in the digital transformation of society is the National Library of Singapore. Singapore's Ministry of Communications and Information (The Ministry of Communications and Information) has developed a strategy to develop—a digital society for all citizens—2021–2025—through which all Singaporeans can benefit from the advantages of digitization. Thus, at the level of the national library, within the National Library Board (NLB) it is decided to collaborate with users through a broad survey in which they are consulted, in accordance with the identified needs and the transformation of libraries into hubs for "digital learning" [11].

The National Library, through a structure entitled Libraries and Archives Blueprint 2025 (LAB25)—monitoring how the proposed objectives will be achieved between 2021–2025, in response to social, economic and technological changes. A key component of LAB25—is collaboration with communities, academia, individuals and industry solutions in support of citizens' needs [12].

After consulting questionnaires on their desires, the National Library Board (NLB) has identified five directions on which to focus. These directions are:

1. Lifelong learning – as challenge and competition
2. Library - Bridge to avoid the "digital divide"

3. Digitizing community events and creating a historical archive
4. Training citizens to develop ICT skills
5. Promotion of concepts specific to digital literature

Such examples can be found in many countries that have understood that digital transformation is a management, decision-making problem at the level of public authorities, but also at the level of institutions.

The general conclusion that can be formulated, in the case of public libraries, is that the digital transformation has as its main objectives the training of its own staff to have the highest possible skills in ICT, assisting readers to use digitized library services, participating in the training of citizens from the communities from which obviously, the efficiency of one's own activities is also part of it.

2.4 An Overview of Public Libraries in Romania

Following the models promoted by the great libraries of the world, public libraries in Romania can focus on strategies that involve, in addition to digitizing collections and offering services by capitalizing on them, active participation in the development of citizens' skills.

The Library Legal Framework in Romania is a law from 2002 that has been updated in 2011. According to the law, libraries have to have the following tasks:

- Libraries play a major role in the national supply of information to which all Romanian citizens have access, without discrimination;
- Information is a key factor in the development of science, economy and culture, and in the preservation of national identity;
- Librarians provide specialized assistance to any person/organization wishing to do research for personal, professional, scientific or commercial purposes.

According to the law, public libraries in Romania are subordinated to local authorities. The 40 county libraries belong to the County Councils where they operate, the Bucharest City Library is subordinate to the Capital City Hall, and the National Library depends on the competent Ministry (Ministry of Culture).

The big libraries in Romania started to introduce the new technologies in their activity since 1990, the main concern of the libraries was the introduction of computer systems to facilitate their activity (acquisition of documents, cataloguing, classification, creation of bibliographic databases, elaboration of bibliography, online access to databases). International norms of bibliographic description were adopted, ISBN numbers were given for books and ISSN numbers for periodicals. Gradually, gradually, libraries acquired equipment and software for the creation of online catalogs and online user access to databases. Documents were digitized for the creation of full-text databases. Many libraries in Romania have provided digital data collections to *Europeana (European Digital Library)* [13].

As the statistics show, the number of public libraries has been decreasing after 1990, and the operating conditions are often not adequate. However, public libraries, especially in rural areas, have an important role in the development of the culture of the population served, through the actions they organize or through involvement in the educational processes of the community.

Unfortunately, not all libraries could be computerized, and most libraries in rural areas have 1–2 PCs or no equipment at all. Even with this reduced endowment, in disadvantaged areas, citizens and students made contact with a computer in the library for the first time.

Figure 2.1 shows the distribution of public libraries at the level of each county.

In Table 2.1 "The Libraries distribution by category" is presented. It can be seen that the number of rural libraries is relatively high, but in relation to the number of urban settlements, there are villages that do not have libraries. Also, since they depend on the local administration (mayors and town halls), many lost their premises, were even abolished and did not receive subsidies for the purchase of publications or a budget for officials.

Figure 2.2 shows the dynamics of the number of libraries in the period 2004–2020.

Moreover, in the statistics on cultural consumption, it is found that there is a large part of citizens who use the facilities of new technologies for information,

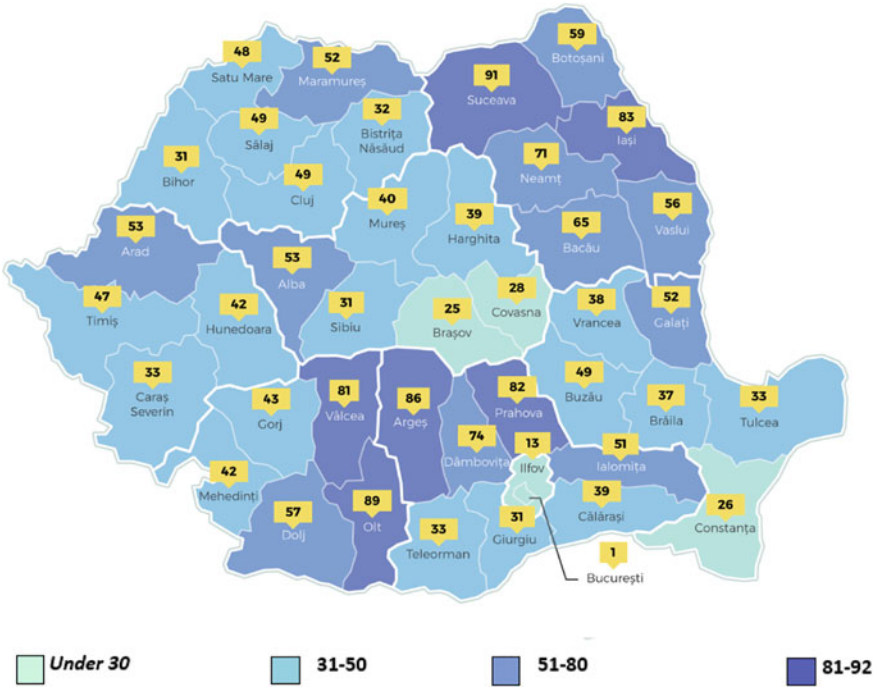

Fig. 2.1 Romanian Map of County public libraries. Distribution by county of the total number of public libraries. *Source* INS-Tempo, ART101C. INCFC, National Institute of Statistics, 2020

Table 2.1 (2019) Libraries distribution by category in Romania

Library type		Total	Percentage of total
National libraries		3	0.03
Publicly libraries:		2168	24
From which	Districtual	41	0.44
	Municipal and urban	250	3
	Communal/rural	1877	20
Higher education institutions libraries/university libraries		91	1
Specialized libraries		415	5
School libraries		6545	71
Total		9222	100

Fig. 2.2 The dynamics of the total number of libraries in Romania (2004–2020). *Source* INS-Tempo, ART101B. INCFC, National Institute of Statistics, 2020

socialization and purchases of cultural goods, such as books/CDs, discs, other digital media products.

An analysis at the level of the whole country on cultural consumption, it can be found that, under the conditions of the development of new technologies and their widespread use in the daily life of citizens, they must be prepared to be able to use them efficiently.

Tables 2.2 and 2.3 show citizens' cultural activities carried out on the Internet (according to the 2022 Cultural Consumption Barometer) [14, 15] (Fig. 2.3).

The involvement of libraries in some projects financed at the national and international level represented an impetus for the modernization of these institutions and, implicitly, for the adoption to the new requirements of the users.

The digital transformation of society as a whole, as well as European strategies and policies until 2030, oblige Romanian libraries to be active in this process.

2.5 Needs for Digital Culture of Citizens

In order for libraries to be able to support the communities in which they operate, extensive analyzes are needed that lead to answers to several important questions:

- What are the needs of citizens?
- Who will be the ITC trainers?

Table 2.2 The Main activities carried out on the Internet, according to their nature

Activities with a predominantly cultural character	Procent
Visiting the websites of museums/libraries, festivals/theatres/pages with cultural events	40
Buying books, CDs, theater tickets, tickets to cultural events, etc	26
Activities with a predominantly recreational character	
Watching movies or TV programs broadcast online (Netflix, HBO GO, Voyo, etc.)	51
To do online shopping of any kind	69
For computer/laptop/phone/console games	31
Activities with a predominantly informative/educational character	
Professional, school activities (email, video conferencing, etc.)	56
Reading books, textbooks, articles, etc.	47
Online participation to courses or tutorials	30
Mixed function activities	
For using social networks (Facebook, Instagram, TikTok, etc.)	88

Methodological note "Yes" answers were taken into account

Table 2.3 The profile of people who participated in cultural activities in 2022, according to age

	18–35 years old (%)	36–50 years old (%)	51–65 years old (%)	Over 65 years old (%)
Participation to the theater's performances	34	31	20	16
Went to the cinema	46	34	13	4
Participation at music festivals	35	36	20	9
Participation in a film festival	54	28	17	1
Participation in a theater festival	39	31	19	11
Going to the library to read/borrow books	33	27	22	18
Visited a historical monument or an archaeological site (eg palace, castle, church, monastery, gardens, old buildings, etc.)	29	31	24	15
Visited a museum, exhibition or art gallery	37	30	22	11

- How can measures be implemented at the level of digital culture hubs in libraries?
- How can financial resources be organized and what are they? (PNRR, budgetary resources, private funds or other forms, such as projects financed by international funds.

After a detailed analysis of the public library system in Romania and after discussions with the managers of several libraries, it was possible to identify some necessary

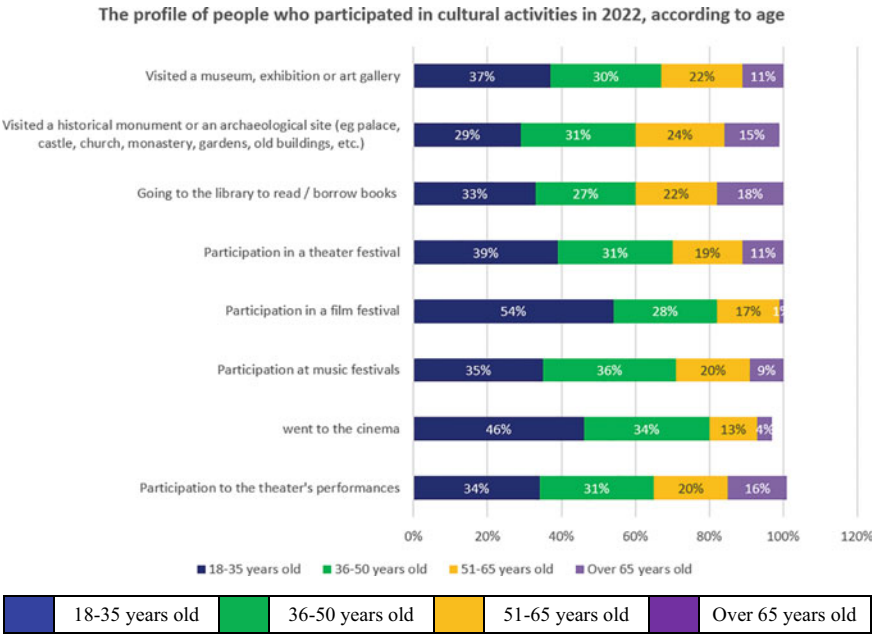

Fig. 2.3 The profile of people who participated in cultural activities in 2022, according to age

topics in which citizens should be trained. It should be emphasized that training requirements depend on the economic area in which the library exists; users located in areas of economic development or in areas where there are universities or large IT companies, need deeper and more solid knowledge in the field of ITC.

Mainly, six categories of topics of interest to citizens and, implicitly, associated knowledge were identified.

I. Basic knowledge in using PCs and other smart devices

- Brief description of PC, mobile, tablet, laptop hardware; how to start and how to close (ON/OFF).
- Windows: tree organization of files, search function by name, role of file extensions, how to save a file and where.
- Office applications: word, excel, power-point, copy-paste function.

II. Updating and improving basic knowledge

- Surfing the Internet: some types of browsers, google, how to create an email account.
- Other sites: News, Agriculture, sports, cuisine, TV programs, streaming, social media
- Communication applications: zoom, Webex, google-meet, Microsoft teams.
- Consultancy sites for various documents: how to upload and download a document.

III. Learning about free digital services for citizens (interfaces with public administrations)

- Description of some electronic payment sites: commercial and utilities;
- Creating user accounts and keeping passwords;
- Making payments and taxes electronically on dedicated websites.

IV. Retrieving information IA the internet (databases, search engines, etc.)

Internet search engines, information filtering, content organization and distribution.

V. Special knowledge

Knowledge of:

- Data protection, confidentiality and security,
- GDPR measures,
- Cyber security,
- Electronic signature.

VI. High level knowledge

Artificial Intelligence, different programming languages, AutoCAD, graphic design, media editing, etc.

Public libraries try to identify the needs of the community as rigorously as possible in order to provide users with the knowledge they need. Moreover, the World Bank, which financially supports the training program for librarians in Romania, tries to identify the specific training needs of librarians. The needs of the users' knowledge depend on the type of users or the community where the library is located. Where libraries are acting in disadvantaged communities, these courses have priority.

The management of library has to decide/those dealing with library management must decide which are the most suitable courses requested by the beneficiaries. Type IV-VI courses are specific to communities whose citizens already have basic knowledge and frequently use the computer in their private life or at work. It is noted that in communities with university centers and developed IT firms, public libraries must be able to offer appropriate courses.

2.6 Trainers for Library Activity

One of the most important issues to be resolved is related to the trainers who may be involved in the process. After some analysis, they could be:

- **Librarians**—must be initially trained to be able to transfer knowledge to citizens. The training of librarians who come into direct contact with citizens can be done through dedicated courses, supported by trainers selected according to the needs

of the library. Such a formula was adopted for public libraries in Romania, with funding from the World Bank.

- **Teachers**—The contracting of teachers from schools and universities to train librarians, but also citizens where appropriate, can be done in areas where there are university communities. Table 2.4 shows the existing universities in different areas of the country. In these cases, it is necessary to establish cooperation agreements between educational institutions and libraries.
- **Trainers** with appropriate knowledge, who are usually licensed persons who work for a fee (i.e. request financial rewards for the work done). This procedure involves attracting funds from private sources or financing through local budgets.
- **Staff from private ICT companies** interested in promoting their products. Trainers from IT companies can provide such courses only to the extent that the respective private companies want to finance them. The goal would be the promotion of one's own IT products or the identification/selection of personnel capable of being later employed in the company (practically, the training is done on library resources).

It is obvious that the areas where companies producing software or providing IT services are developed can be found/identified interested companies and associated trainers respectively.

Table 2.4 The distribution of existing universities in the development regions of Romania

ROMANIA development region	Number of universities	NOTES
North–East Development Region—Bacău, Botoşani, Iaşi, Neamţ, Suceava şi Vaslui *(counties)*	13	9 Iasi + 2 Bacau + 1 Suceava + 1 Roman
South–East Development Region—Brăila, Buzău, Constanţa, Galaţi, Vrancea şi Tulcea *(counties)*	6	4 Constanta + 2 Galati
South–Muntenia Development Region—Argeş, Călăraşi, Dâmboviţa, Giurgiu, Ialomiţa, Prahova and Teleorman *(counties)*	4	2 Pitesti + 1 Targoviste + 1 Ploiesti
South–West Oltenia Development Region—Dolj, Gorj, Mehedinţi, Olt şi Vâlcea *(counties)*	3	2 Craiova + 1 Targu Jiu
West Development Region—Arad, Caraş–Severin, Hunedoara şi Timiş *(counties)*	11	7 Timisoara + 2 Arad + 1 Lugoj + 1 Petrosani
North–West Development Region—Bihor, Bistriţa-Năsăud, Cluj, Sălaj, Satu–Mare şi Maramureş *(counties)*	14	10 Cluj Napoca + 4 Oradea
Central Development Region—Alba, Braşov, Covasna, Harghita, Mureş şi Sibiu *(counties)*	6	2 Sibiu + 1 Brasov + 2 Tg Mures + 1 Alba Iulia
Bucureşti–Ilfov Development Region—BUCHAREST and Ilfov county	16	
TOTAL	73	

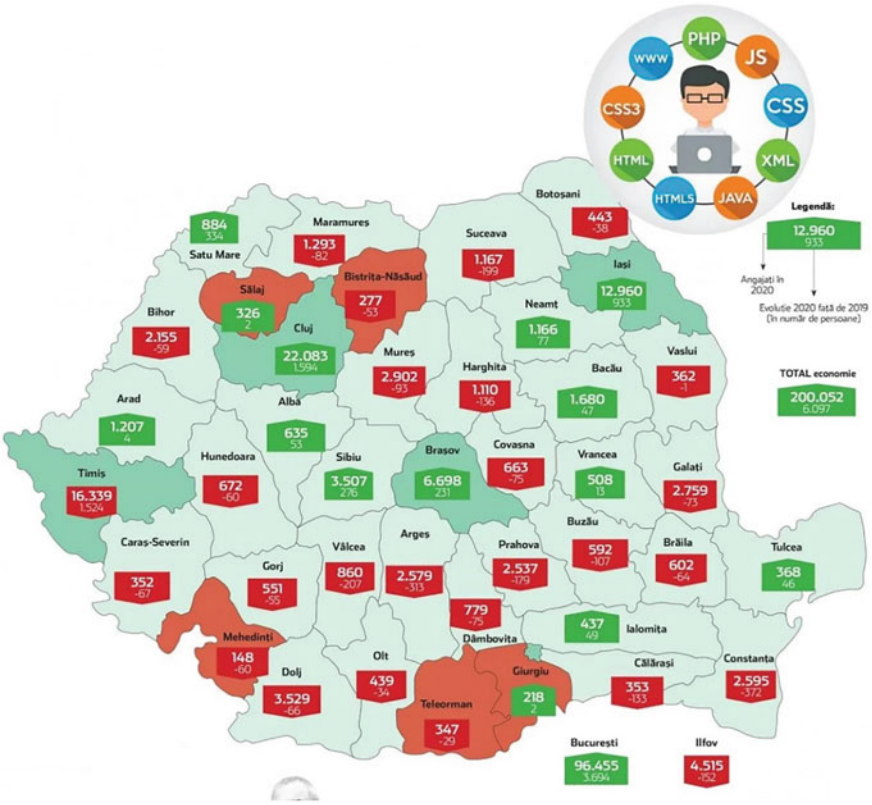

Fig. 2.4 The county distribution of the employees in the IC&T field Trainers with adequate knowledge (certified trainers). *Source* https://www.reddit.com/r/Romania/comments/seog2p/harta_itistilor_pe_judete_in_2020/

The use of trainers from private companies can be a solution in the conditions where means are found for the co-interest of these companies. The library management must have a well-developed communication system and have professional relations with as many environments as possible in its community. Figure 2.4 shows the number of people working in IT in each county of the country.

2.7 Financial Resources

Financial resources represent an important element without which it is impossible to proceed to the implementation of procedures to support the raising of citizens' skills.

The financial resources can come from different sources, either from the state budget or from attracted sources.

- *Public funds*—All public libraries are financed from local budgets. Local budgets must provide the necessary funds for the operation of libraries, but—most of the time—local administration has priorities that do not include libraries
- *Private funds* (companies that need IT staff or IT companies)
- *Projects* financed by the National Recovery and Resilience Plan financed by the EU
- Projects financed from research and development *programs,* financed at national and international level.

The *National Recovery and Resilience Plan* (**PNRR**) financed by the EU has a program dedicated to the financing of the libraries. The program was managed by a government entity—the Authority for Digitization of Romania. The program is entitled "Investment 17—Funding schemes for libraries to become digital skills development hubs" [16].

At the end of project, over 100,000 citizens will be trained for using ICT devices and products at the national level. In addition, a large number of librarians will get ICT advanced knowledge.

The budget for the whole country is 37,000,000 euro. In a first call only the County Councils had the right to apply. The duration of the projects was 3 years. Two types of projects with different objectives and budgets were defined:

(a) Renovation/modernization (including expansion) of the central headquarters of the county library and equipping it with computers and technical equipment, to be transformed into a hub for the development of digital skills = for 5 projects at national level, financed with 2,585,000 euro/project.
(b) Renovation/modernization (including expansion) for at least 3 libraries: rural, municipal (including county) or city (at least 1 in a rural area) and equipping them with computers and technical equipment, to be transformed into digital skills development hubs.

    - Purchase/modernization of IT equipment for at least 26 libraries, of which at least 8 should be from the rural area!
    - Development of basic skills—digital literacy, communication, media education, digital content creation, digital security and digital entrepreneurship education, for a minimum of 2,500 citizens from disadvantaged communities.

The funding was 585,000 euros/project. In the conditions of application, the following parameters were foreseen:

- Number of trained trainers: 50/county project
- Number of libraries included: 28/county project
- Number of citizens from disadvantaged areas who must be trained to improve digital skills: 2,500/county project

Funding for each project includes the provision of ICT equipment and devices, training for librarians and library renovation.

After the first call, the results were not as expected. The number of applicants (July 2023) was small, 14 counties out of 41 (34.14%), which led to the decision to update the application guide and resume the call.

In the next call, the requirement that the project have 28 libraries was waived, the minimum number being 11, but at least 4 libraries must be from a rural area. In addition, library consortia are allowed to participate in the project, even if they are not part of the same county. In this way, it is safe to assume that the number of applicants will increase for the benefit of disadvantaged communities.

An analysis of these projects shows that a nationwide network of public libraries can be built so that a national system of digitally connected libraries can be built. Thus, any user, no matter where s/he is, can have access to digital data funds from any library.

Funding through the "Library Funding Schemes to Become Digital Literacy Hubs" program enables the building of a system of interconnected libraries. A possible schematic diagram is shown in the Figs. 2.5 and 2.6, respectively.

For such a system, a series of legislative regulations are needed to match the existing legislation with the specific requirements of the digital transformation of libraries.

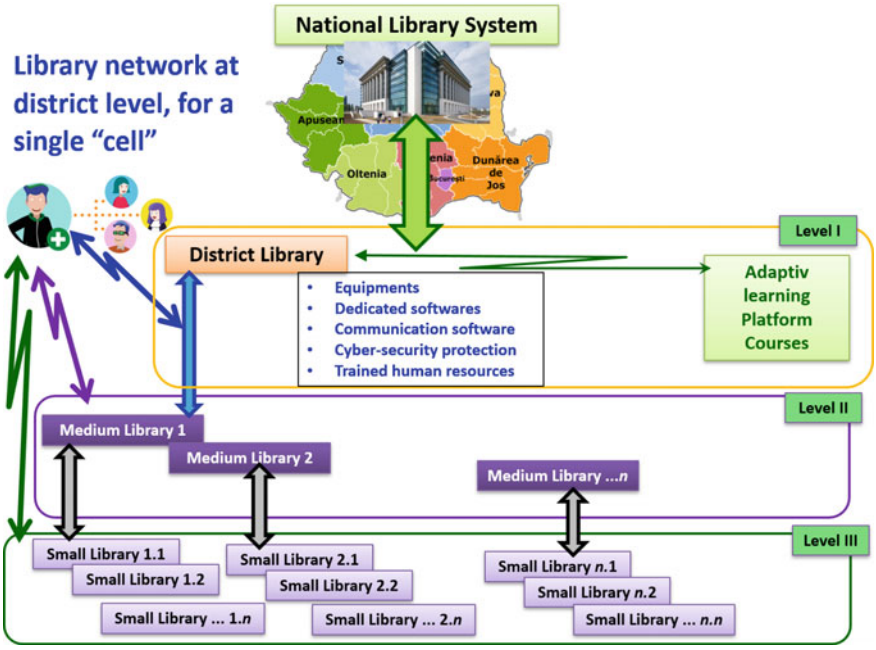

Fig. 2.5 Library network at district level, for a single cell

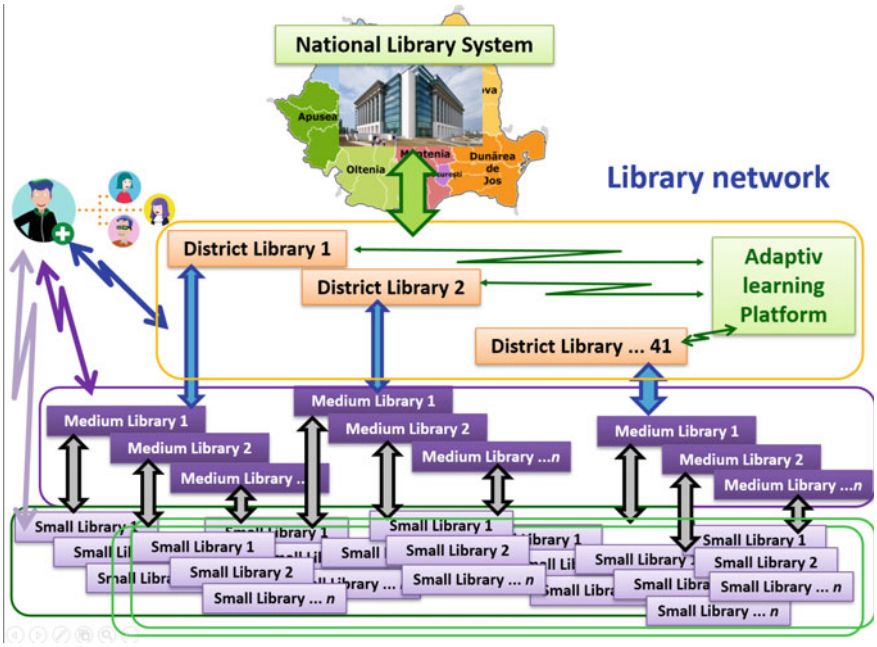

Fig. 2.6 The library network

The library network at district level can be implement by projects financed through PNRR. Each small library can get a minimum ICT equipment so that it will be able to connect with medium size library. The district library will play the role of digital hub. It will have performed equipment in order to communicate and access digital information from other libraries from country or abroad.

In the Romanian case, several conclusions emerge:

- Citizens' ICT skills are an objective necessity in Romania
- County libraries can provide a suitable environment for the development of ICT knowledge through digital hubs
- Most urban and rural libraries need to be supported by improving ICT infrastructure
- Human resources employed in libraries do not have sufficient skills for teaching ICT at all levels according to citizens requirements.
- There are ICT human resources outside the libraries for user training
- Financial resources could be found if there is a clear objective and a strategic plan
- There was no national strategy to address the digital transformation of libraries and the development of citizens' ICT skills

Taking into consideration the above conclusion and the reality at national level, a SOCIAL PACT among central and local administration, schools and universities, private sector, NGO-s seem to be a realistic solution to achieve the main objective:

increasing the skills of citizens in the field of ICT, by investing in Library hubs of digital culture.

2.8 Conclusions

Cultural institutions organize their activity in such a way as to become active actors of the digital transformation. Reputable institutions are at the forefront of this endeavor, while maintaining a balance between tradition and innovation.

Libraries (along with education systems) are basic factors in avoiding the "digital divide", promoting new technologies and increasing the skills of citizens in the use of ICT.

Through appropriate policies and strategies, libraries can achieve the specific objectives of the digital society.

The use of ICT in libraries can significantly contribute to the digital transformation of society. The policies and strategies addressed by libraries are part of this objective.

Training librarians and supporting citizens to acquire skills in the use of ICT contributes significantly to increasing quality of life, thus achieving the objective of the EU program on the digitization of member countries.

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Chapter 3
Artificial Intelligence in Marketing. Current Status and Future Research Agenda

Lidia Alexa, Marius Pîslaru, George Cristian Nistor, and Marius Alexa

Abstract Emerging technologies such as artificial intelligence (AI), IoT, big data analytics and machine learning are driving transformative changes in enterprises and society, with marketing professionals worldwide seeking optimal AI solutions for their tasks. In this context, the present analysis aims to examine the potential for transformation that artificial intelligence (AI) holds for marketing activities and processes. This investigation focused on two research questions: (1) *What are the main uses of AI instruments in marketing activities*, and (2) *What are the current topics and future research directions for AI adoption in Marketing?* The investigation was carried out by applying bibliometric and conceptual network analysis techniques on articles explicitly including "marketing" and "artificial intelligence" inside their titles, published from 2019 to 2023 and indexed in 2 academic databases, namely Web of Science (WoS) and Scopus. The results revealed a surge in published studies focusing on various elements of AI in marketing centered around three interconnected concepts: artificial intelligence, big data, and marketing.

Keywords Artificial intelligence · AI · Marketing · Marketing AI · AI-enabled marketing · Big data · Marketing operations

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L-I. Cioca et al. (eds.), *Digital Transformation*, Intelligent Systems Reference Library 253, https://doi.org/10.1007/978-3-031-55952-5_3

3.1 Introduction

Artificial Intelligence refers to "intelligence exhibited by machines" [1] and although it might sound novel, it is by no means new. The phrase was initially introduced in 1956 inside a proposal put out by a distinguished collective of mathematicians and computer scientists who convened a workshop known as the "Dartmouth Conference" [2].

The AI definition from the Oxford Dictionary presents AI as "the theory and development of computer systems able to perform tasks normally requiring human intelligence, such as visual perception, speech recognition, decision-making, and translation between languages".

Artificial intelligence (AI) refers to the capacity to imbue machines with human-like intellect, enabling them to execute a wide range of activities, varying in complexity. The primary objective of AI is to facilitate machine learning, reasoning, and job execution. Artificial Intelligence (AI) is grounded in three core principles: machine learning, neural networks, and deep learning [3]. These technologies enable machines to process large volumes of data to generate market intelligence effectively [4].

The impact of AI on various industries, including marketing, is undeniable. Williams et al. (2019) indicate that AI plays a vital role in successfully implementing Industry 4.0, leading to improved product consistency, productivity, and reduced operating costs. Hildebrand (2019) considers that "AI is more than just technology: it's creating a new economy. AI is creating new forms of competition, value chains, and novel ways of orchestrating economies around the world" [2].

Based on a survey conducted by Balakrishnan et al. (2020) at McKinsey Analytics, almost half of companies have used artificial intelligence (AI) in a minimum of one of their operational areas. Furthermore, it was found that among the enterprises utilizing AI, three-quarters of them had a notable 10% increase in customer satisfaction [5].

Based on the findings of the 2023 report, a substantial majority of respondents anticipate that general artificial intelligence (AI) will have a noteworthy and potentially disruptive influence on the competitive landscape of their respective industries over the next three years. According to the survey results, over 33% of the participants said that their firms employ generative artificial intelligence (AI) on a regular basis in at least one specific area. This implies that out of the organizations that have reported adopting AI, almost 60% of them are utilizing generative AI. The predominant applications of generative AI tools are commonly observed within the domains of marketing and sales, product and service creation, as well as service operations [6].

Artificial intelligence (AI) has emerged as a significant technological phenomenon with implications for all industries, including marketing [7].

The aim of the analysis is to assess the current scholarly research investigating the importance and implications of artificial intelligence (AI) in marketing, as well as to identify potential avenues for future research.

3.2 AI in Marketing

Artificial intelligence (AI) has become an indispensable tool in marketing due to its ability to facilitate the analysis of extensive datasets, automate various procedures, and facilitate data-informed decision-making. Consequently, AI has contributed to developing more efficient marketing strategies and enhanced customer experiences. [8].

The significance of artificial intelligence (AI) in several marketing domains has been confirmed by contemporary research [9]. Intelligent content platforms can be employed for content marketing purposes, wherein personalized material is generated by considering user behavior and preferences [10]. Artificial intelligence (AI)-driven chatbots and virtual assistants have the capacity to augment client experiences through the provision of immediate support and tailored suggestions [11, 12]. Artificial intelligence (AI) also enables the adoption of predictive analytics, allowing organizations to anticipate client needs and tailor marketing strategies accordingly [13].

That is why, we support the Marketing AI definition as "the development of artificial agents that, given the information they have about consumers, competitors, and the focal company, suggest and/or take marketing actions to achieve the best marketing outcome" coined by Overgoor et al. [14].

The subject matter of AI-driven marketing has been gaining significance and garnering increasing interest among researchers worldwide. A substantial corpus of prior research evaluates the effects of artificial intelligence (AI) on diverse marketing functions [1, 2, 15–17]. Paschen et al. (2019) use an input-processes-output lens to explain AI in marketing. They define six core AI system-building components and show how combining them turns data into knowledge. This perspective enhances B2B marketing knowledge by acknowledging the necessity for further scholarly research on AI and B2B marketing. [18]. Strandvik et al. (2014) examine how AI marketing technology affects consumers' utility, hedonic, and buy intentions. The findings show that AI marketing technology's accuracy, intelligence, and engagement experience increase consumers' utility and hedonic value. Additionally, perceived usefulness and hedonic values influence consumers' buying intentions. The study found that perceived hedonic value affects purchasing intention more than utility value [7].

The value propositions offered by AI in marketing are indicative of its expanding role. In Vlačić et al. (2021) opinion, the prime emphasis of AI-based marketing (AIMB) lies in "transaction-oriented (utilitarian) value propositions", rather than "relationship-oriented (hedonic) value propositions". [19]

Artificial intelligence's impact on the dynamics of customer-brand relationships is evident as well. According to Damioli et al. (2021), artificial intelligence (AI) exerts a significant influence on the efficacy of communication with chat-bot agents, the dynamics of customer-brand interactions, and customer response. This discovery highlights the influence of artificial intelligence (AI) in improving marketing results and enhancing client contentment [20].

Indeed, Amazon has achieved a high level of proficiency in machine learning, to the extent that one-third of its commercial operations are attributed to a machine learning-driven feature known as recommended purchases. According to Domingos, a significant proportion, around 75%, of movies viewed on Netflix are derived from the company's recommendation system, which is powered by machine learning technology [21].

Another noteworthy indication of the growing significance of the issue is associated with the proliferation of literature reviews on the topic.

An instance of topic modelling utilizing natural language processing was carried out by Mustak et al. (2021). They discovered ten study topics, which were subsequently categorized based on two primary pillars, namely (1) consumer research and (2) organizational and strategy-related research [22].

Vlačić et al. (2021) extensively analyzed existing research on AI and marketing. They employed content and multiple correspondence analysis techniques to examine the data and identified four prominent themes that emerged from the literature: (1) "marketing channels", (2) "marketing strategy", (3) "performance", and (4) "segmentation, targeting, and positioning" [19].

Chintalapati and Pandey (2021) conducted a comprehensive investigation to ascertain the most pertinent and citable evidence regarding artificial intelligence applications in marketing. Their study encompassed five primary functional themes and nineteen sub-functional themes, namely (1) "integrated digital marketing", (2) "content marketing", (3) "experiential marketing", (4) "marketing operations", and (5) "market research" [23].

Verma et al. (2021) conducted an analysis of a comprehensive dataset consisting of 1523 articles and 57 reviews, totaling 1580 documents. The researchers saw a discernible shift in the research landscape during the last phase, commencing in 2017, wherein scholars increasingly included emerging technologies such as Big Data, Neural Networking, and Machine Learning into their investigations [24].

Mariani et al. (2022) performed a bibliographic coupling analysis on a dataset consisting of 4488 articles. Through this analysis, the researchers identified eight distinct clusters, each associated with specific thematic areas. These clusters encompassed topics such as (1) "memory and computational logic", (2) "decision making and cognitive processes", (3) "neural networks", (4) "machine learning and linguistic analysis", (5) "social media content analytics", (6) "social media and text mining", (7) "technology acceptance and adoption", and (8) "big data and robots" [25].

Thakur and Kushwaha (2023) conducted a bibliometric analysis using a dataset of 317 documents sourced from the Scopus database. Their analysis revealed the presence of four prominent thematic clusters in artificial intelligence in the marketing field. These clusters encompassed the topics of (1) "data mining and deep learning in decision support systems", (2) "big data and generative AI in marketing", (3) "AI-enabled commerce", and (4) "chatbots and marketing Tech". Notably, these clusters cover the most current themes within the marketing AI research field [9].

In conclusion, the literature review emphasizes the diverse and significant influence of artificial intelligence (AI) on marketing endeavours. It reveals that AI is already exerting its impact with various intensities on nearly all aspects of marketing,

ranging from customer experience to marketing automation and even extending to the decision-making processes [2, 26].

3.3 Research Methodology

In the dynamic and evolving marketing environment, incorporating Artificial Intelligence (AI) has manifested a paradigm shift, promising unprecedented efficiency, and insights. To better understand the multifaceted role of artificial intelligence instruments in marketing strategies and operational frameworks, we address two critical research questions (RQs):

RQ1—*What are the main uses of AI instruments in marketing activities?* The analysis will aggregate findings from diverse studies to map out the spectrum of AI applications and identify how these technologies are being leveraged to drive marketing innovations and efficiencies.

RQ2—*What are the current topics and future research directions for AI adoption in Marketing?* The focus is on AI's potential and aims to identify gaps and opportunities for future investigation.

The methodology chapter delineates the research design, including the selection of analytical tools and frameworks, data collection methods, and the criteria for evaluating AI's impact on marketing. Through a systematic approach, we aim to provide a comprehensive understanding that is both reflective of current practices and anticipatory of future trends.

The first step of the analysis consisted of identifying and understanding the objectives in advance, as well as creating the criteria for inclusion and exclusion. Furthermore, establishing a procedure that outlines the justification for the identification and assessment of published research to be incorporated and articulated [27, 28] has been accomplished.

The research was performed utilizing Web of Science (WoS) and Scopus, two highly respected academic databases. The study commenced by conducting a name string search in two databases, specifically "Artificial Intelligence in Marketing" and "Artificial Intelligence and Marketing". Table 3.1 displays the inclusion and exclusion criteria.

As a result of the multifaceted character of the subject matter, the certification requirements were limited to the "title" level. Since the subject has been receiving a growing amount of attention since 2019 [29], the inclusion criteria were limited to peer-reviewed academic papers that were published after 2019. This was done to ensure that the analysis reflects the most recent knowledge and insights with greater scientific accuracy.

Table 3.1 Inclusion and exclusion criteria

Inclusion criteria		Exclusion criteria	
IC1	Articles with the keywords "Artificial Intelligence and Marketing" in the title	EC1	Articles that did not include in the title the keyword specified in the inclusion criteria
IC2	Articles with the keywords "Artificial Intelligence" "AND/OR" "Marketing" in the title	EC2	Duplicates found using digital object identifier
IC3	Articles written in English language	EC3	Non-English publications
IC4	Articles published in journals	EC4	Book chapters, dissertations, and conference papers

3.4 Results and Discussions

An analytical survey of the Web of Science Core Collection literature, specifically targeting the confluence of artificial intelligence and marketing by including both terms in the title from 1991 to 2023, yields 114 recorded entries. This dataset is primarily composed of articles, which constitute a significant majority at 80 entries. A closer inspection of the temporal distribution of these publications reveals an accelerating trend in research output; 75 articles, accounting for 93.75% of the article subset, were published in a concentrated period from 2019 to 2023. This pronounced increase suggests a heightened academic and industry focus on integrating artificial intelligence in marketing practices, aligning with the rapid development and increased accessibility of AI technologies during this time frame.

The Australasian Marketing Journal, Industrial Marketing Management, and Journal of Business Research emerged as the most prolific sources within this collection, hosting the highest number of articles on the subject.

The exploration of the Scopus database has revealed a collection of 79 documents that intersect the disciplines of artificial intelligence and marketing. A substantial majority of these documents, precisely 70, which constitutes 94.5%, have been published in the recent four-year span between 2019 and 2023.

The most quoted article in both databases is "How artificial intelligence will change the future of marketing" (Davenport et al., 2020) with 472 citations in WoS and 637 in Scopus. The top 10 most quoted articles according to Web of Science are presented in Fig. 3.1.

We conducted a comprehensive keyword co-occurrence analysis with the intention of delineating the intricate web of interconnected concepts within our scholarly corpus: the concepts that are conceptually close to one another are the keywords that are found in the same keyword co-occurrence networks. On the other hand, the closeness of keywords to other keyword co-occurrence networks and keywords can be interpreted as the degree to which these two concepts are related to one another. The analysis was conducted using the VOSviewer package [30] and the

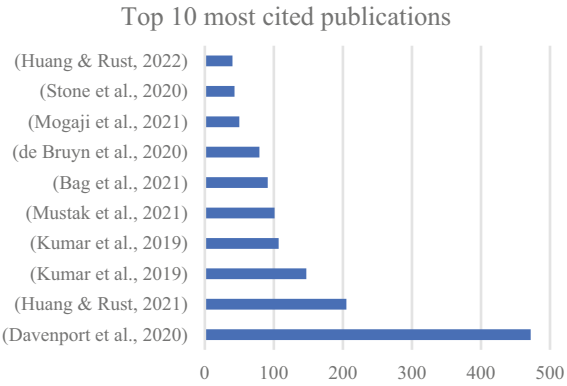

Fig. 3.1 Top 10 most cited publications

results presented in Fig. 3.2 enabled us to outline the relationships between diverse concepts, as evidenced by their joint occurrences.

During the knowledge mapping process, individual nodes represent keywords, while the connections between nodes indicate the repeated occurrence of word pairs. The co-occurrence frequency of these terms across multiple articles is denoted by the relative strength of the link connecting each pair. Consequently, the co-occurrence network serves as a highly effective depiction of the amassed knowledge on a particular subject, encompassing its fundamental knowledge elements and valuable

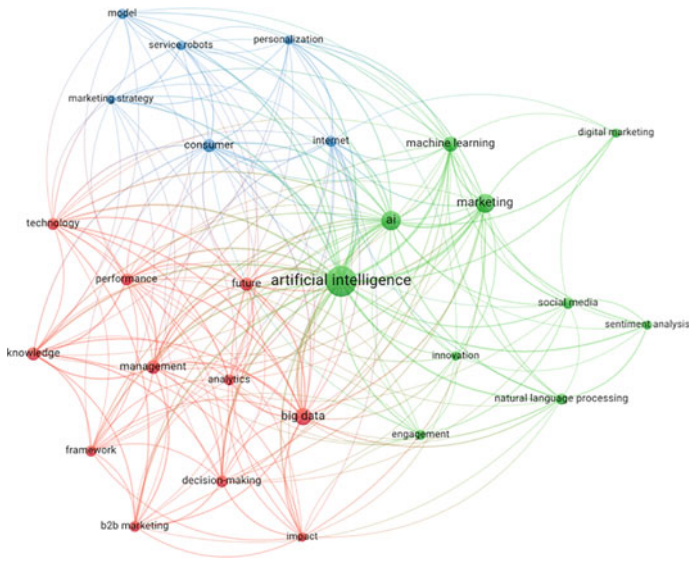

Fig. 3.2 Keyword co-occurrences and connections on artificial intelligence in marketing

insights. These elements and insights are determined through patterns and the robustness of connections between keywords that are present in the scholarly literature [31, 32].

In the context of the keyword co-occurrence analysis, we successfully identified the terms that exhibited the greatest frequency of occurrences. This is visually depicted through the relative sizes of the circles in our co-occurrence analysis visualization. In our investigation, we assigned names to the keyword co-occurrence networks based on the terms with the highest occurrence frequency. These keywords were artificial intelligence (AI) (Fig. 3.3), big data (Fig. 3.4), and marketing (Fig. 3.5). In the subsequent sections, we will examine the networks of keyword co-occurrence for each concept.

Artificial intelligence is the central element of the analysis with connections to all elements included in the research. Multiple studies confirm the fact that AI will transform all sectors and industries and all spheres of the organizational functions from business models to customer service, and consumer behavior [4, 9]. The advanced technology and knowledge are inevitably creating changes in structuring the functioning frameworks and business models as more and more companies integrate AI into their operations [5, 25].

The term "big data" refers to a type of data that is characterized by its large volume, high velocity of development, and diverse range of data types. The concept of big data has four essential qualities, sometimes referred to as the 4Vs: (1) volume, (2) velocity, (3) variety, and (4) veracity [33]. This opportunity provides marketers with a substantial platform to refine and elevate their decision-making strategies, enabling them to leverage more data-driven insights, employ advanced analytical tools, and

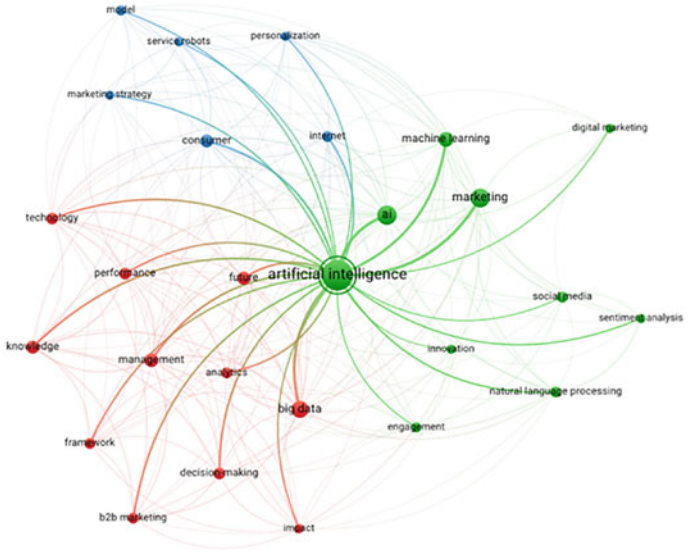

Fig. 3.3 Keyword co-occurrences and connection for artificial intelligence

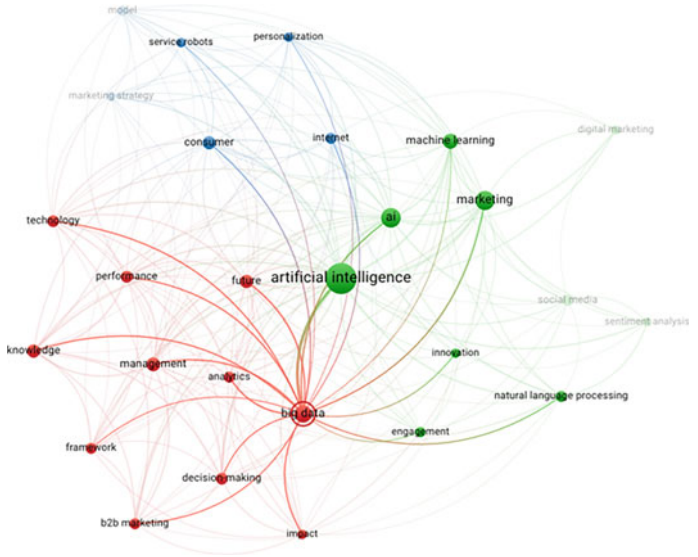

Fig. 3.4 Keyword co-occurrences and connection for big data

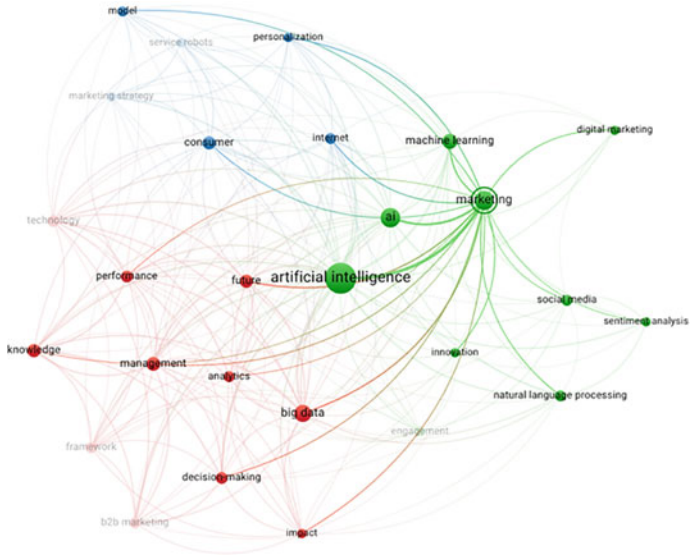

Fig. 3.5 Keyword co-occurrences and connection for marketing

make more informed choices that align with both current market trends and consumer behavior [34, 35]. Additionally, using big data in marketing analytics has transitioned from a novel concept to a mainstream strategy integral to deriving marketing insights. By harnessing vast amounts of data, organizations are now able to uncover intricate consumer patterns, predict market trends, and personalize marketing efforts with greater precision. This widespread adoption of big data analytics in marketing not only enhances the accuracy of marketing campaigns but also fosters a more data-centric culture within organizations, leading to more informed decision-making processes across various business functions [25, 35–37].

The outcome-oriented character of these investigations is reflected by the fact that performance and impact considerations are also an essential part of the research. There is a significant presence of artificial intelligence research that links big data analytics with effect, management, and business performance, as indicated by the co-occurrences of keywords on the left side [23, 24].

As anticipated in an analysis that centers on the knowledge structure of artificial intelligence and marketing, the concept of marketing appeared as a significant subject matter.

The analysis reveals a strong connection with digital marketing, as integrated digital marketing is a predominant research theme in the literature [23]. The use of marketing automation to boost profitability, create and maintain connections with clients, and attract new customers is another trend that is becoming increasingly prevalent. [37, 38].

Personalization presents strong network connections as it is one of the ways to create value for customers through AI instruments use [4, 10, 35, 37, 39].

Sentiment analysis and social media present a strong connection [40] also endorsed by Thakur and Kushwaha (2023) study which confirmed the two as the prevalent forms of marketing related to big data and digital marketing [9].

Decision-making also presents a strong network connection as it is currently one of the trending topics recognized in the literature [9], emphasizing the use of marketing algorithms in decision-making processes.

Impact, knowledge, and performance present significant connections with marketing as well, highlighting the importance of results and the fact that leveraging vast amount of data is the key to providing impact in marketing activities [4].

The study has unearthed a significant gap in academic research, particularly concerning the ethical, privacy, and potential negative implications of AI in the realm of marketing. Given artificial intelligence's remarkable capabilities, it is imperative that academic research efforts in marketing AI evolve to address these critical aspects. Here, we elaborate on the implications of this gap and potential future research directions in the academic domain.

Ethical frameworks in marketing AI: research in marketing AI should prioritize the development of comprehensive ethical frameworks tailored to the specific marketing context. This involves exploring the ethical considerations of AI-driven consumer targeting, personalized advertising, and persuasive techniques. The request

for research on the ethical aspects of marketing AI is present in the literature, as one of the main future research trends [23].

Privacy-preserving marketing AI: researchers should investigate advanced techniques and algorithms for privacy-preserving and delve into secure data sharing, differential privacy, and federated learning, ensuring that marketing professionals can access the latest tools and methodologies that safeguard consumer data.

Negative effects of marketing AI: academic researchers should lead the way in examining the potential negative consequences of AI in marketing. This includes studying how AI-driven marketing can contribute to information overload, consumer scepticism, and potential backlash.

Algorithmic bias and fairness: research should focus on algorithmic bias and fairness issues specific to marketing AI and provide insights into how algorithms can unintentionally reinforce stereotypes or exclude certain demographic groups from marketing campaigns and propose methods to mitigate these biases [41].

Customer trust: research can contribute to a deeper understanding of factors influencing customer trust in AI-driven marketing [37]. This includes investigating the role of transparency, explainability, and accountability in building and maintaining trust.

Ethical data handling: academics should actively engage in research related to ethical data handling in marketing AI by examining data anonymization, informed consent, secure data storage, and the responsible use of customer data throughout the marketing process.

Several limitations are included in the analysis. The first drawback pertains to the fact that the study only included papers from WoS and Scopus. Therefore, it is recommended that future research incorporate publications that are indexed in Google Scholar and other databases. The second constraint pertains to the inclusion criteria, which only contained the keywords that were mentioned in the title, as well as the fact that the research only covered publications that were published between the years 2019 and 2023. When conducting future research, it is recommended that the search for keywords be expanded to include the abstract text, the articles, and the publication years.

3.5 Conclusions

It is now evident that artificial intelligence has gained momentum and practical significance in the present and future of businesses and has enormous potential in marketing.

Artificial intelligence has the ability to automate company operations and processes, generate insights about consumers and markets, and improve customer experiences; the possibilities are virtually limitless.

However, there is still a need for systematic literature reviews that provide an extensive understanding and insights into the research pattern in AI-driven marketing and also need to extend further our understanding of the potential negative influence

of its' s use in terms of ethical aspects, privacy risks, data handling, algorithmic bias, and the potential impact on consumer trust.

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Chapter 4
Digital Enhancement of the Military Decision-Making Processes

Mădălina-Ioana Bădilă and Lucian-Ionel Cioca

Abstract Before analytically studying digital development, it is good to briefly recapitulate approaches adopted in the military environment concerning the decisions on which leaders operate and how they influence the current professional structure and behavior. First, the leading digital currents in the defense field are discussed, contributing to explaining the phenomenon, compared with the descriptive approaches to the decision-making process and its modifications. Behavioral aspects of military leadership are presented, with evolutionary, institutional, and attitudinal factors and techniques. The digital current in the field of defense section in most documents does not exist in the literature on the military environment, and this concept defines the context necessary for the analysis. The fundamentals of future research demonstrate the degree of usefulness of the study. We explain the decision-making paradigm, indicating digital applications on goods and services, including different hierarchical levels. Strengths and limitations of implementing modern means of adjusting the decision-making process are also be evaluated. Finally, we highlight the role of digitization in explaining leadership strategies in the military system in this dynamic context and the changes related to organizational structural transformation.

Keywords Digitalization · Military system · Decision-making process · Eco-innovation · Military leaders · Digital transformation · Military capability

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L-I. Cioca et al. (eds.), *Digital Transformation*, Intelligent Systems Reference Library 253, https://doi.org/10.1007/978-3-031-55952-5_4

4.1 Introduction

New technologies led to a drastic rethinking of military management. However, digital tools alone are insufficient for efficiency because they require well-trained soldiers capable of exploiting the effects of new technology based on an appropriate doctrinal framework [1].

The digitization of the military, utilizing artificial intelligence, virtual assistance, and modernized command-and-control systems marked the beginning of the fourth industrial revolution.

The digitalization of the Army provides an opportunity for leadership to overcome challenges with the help of the internet and cloud storage devices. This allows information resources to be stored online in digital format and accessed by users worldwide [2]. Additionally, decision-makers can now access various information resources quickly and easily.

Interaction with digital resources is adapted to new requirements that facilitate movement, troop detection, vital supply routing, protection capabilities, financial payments, refinement of technical systems, technological research, increasing security, communication possibilities, and conceptual transfer. A highly dependent relationship is observed between military operations and technological innovations that aim to increase the force's capabilities. The information environment becomes essential to the military command spectrum, through which leaders collect, disseminate and act on information. A result of complex hierarchical transfer involves decisional outcomes for all lead levels. The best military decisions generate an appropriate conceptual and operational response to future threats.

Computerized means use information storage, analysis, and decision support for individual and structured commands at lower costs. Moreover, highly complex representation systems function to understand the operational environment so correct decisions can be designed, developed, and achieved—modern methods for decision-making aim to raise the quality of command and execution. The development of decision theory and recent technological progress have provided commanders with greater visibility in planning operations, identifying inconsistencies, and determining alternatives to initial plans [3].

NATO has always relied on its intellectual and technological superiority to maintain its military power. However, the rapid pace of change in technology among our adversaries and operating environments has posed a challenge to the Alliance's ability to stay ahead and maintain maximum maneuver freedom. To enable Multi-Domain Operations (MDO), NATO must adopt a new data-centric, modular, and agile approach to capability development. This approach will allow NATO to maintain its edge. Digital transformation is vital to enable NATO to conduct MDO. It will ensure interoperability across all domains, improve situational awareness, facilitate political consultation, and support data-driven decision-making. By 2030, NATO will provide a digital-ready workforce, agile, digitally enabled processes, and advanced technological solutions. Innovation is a crucial driver for digital transformation. It provides the tools, techniques, and mindset to experiment and constantly innovate.

The ACT Innovation Branch has leveraged innovation since 2012 and is a crucial stakeholder supporting NATO through this transformational process.

Why is the digitization of military decisions necessary? There are several reasons to justify the choice of military leaders:

- Identifying the level of professional performance of employees.
- Establishing the strengths and weaknesses of personnel and work techniques.
- Enabling new means of improving performance.
- Ensuring electronic basis for rewarding the staff after contributing to achieving the organizational objectives.
- Motivating the staff through the appropriate equipment on the premises.
- Establishing new needs for training and career development.
- Adjusting the performance potential of leaders.
- Obtain new information necessary to plan future military actions.

Improved and innovative collaboration has several benefits, one of which is the enhancement of accuracy and speed of operations. A new manufacturing era that integrates advanced technologies with human intelligence has brought about a positive impact on decision-making by increasing the customization and flexibility of processes. Enhancement equals products that meet unique individual needs and are flexible to adapt to changes [4] quickly. These improvements can create a more efficient, productive, and sustainable defense system [5].

Organizations must have tools to make decisions that strengthen their ability to develop robust relationships. *Decisions involve investments in sustainable technological systems, facilities, and equipment and adopting eco-innovative practices for beneficiaries and suppliers. Assessing the current level of eco-innovative capability and creating opportunities for its development is crucial to managing the military system.* By continuously enhancing the eco-innovative capability, organizations can establish a solid foundation for a sustainable future and become a research model for a new NATO capability.

Eco-innovation involves not only technological advancements but also organizational, institutional, and social innovations [6, 7]. An intelligent development approach focuses on utilizing existing technological strengths and local industrial composition [8]. This approach allows us to understand that circularity can be viewed as an extension of related variety, which in this case, revolves around a technological innovation that brings about several organizational innovations.

Incorporating digitalization into military decisional management is essential for improving operational performance, enhancing resilience, ensuring viability, and effectively managing risks and disruptions [9]. Various researchers [10–13] emphasize the impact of digital technologies such as smart contracts, additive manufacturing, robotics, virtual and augmented reality, advanced manufacturing technologies with sensors, and blockchain-based smart traceability on SCM. Therefore, building robust decision systems that can withstand disruptions, recover quickly, and minimize costs is imperative.

According to other research by Ivanov and Dolgui, the concept of digital supply chain twins is a cutting-edge digitalization strategy that enables businesses to enhance

their risk management and resilience capabilities [14]. The COVID-19 pandemic has underscored the importance of digital tools in monitoring supply chains and ensuring transparency [15]. To manage supply chain risks effectively, it is essential to map the supply chain, analyze historical and current disruption risk data, and utilize real-time data analysis to make reactive and predictive decisions. This approach guarantees visibility and continuity across global organizations [16].

In the future, these systems have the potential to enable command and control structures in headquarters to use different hierarchical structures that require fewer personnel, thereby reducing costs and improving efficiency. However, implementing such technologies can present unforeseen challenges and thus requires thorough experimentation [17].

Our chapter delves into the efficacy of the digital framework in enhancing decision-making processes in military operations through empirical analysis. Our assessment demonstrates that leaders can identify vulnerabilities and risks and enhance contingencies, opportunities, and resource allocation for optimal investments. These scientific findings contribute to the emerging field of military command by providing valuable insights and practical tools for military decision-makers and practitioners seeking leadership optimization.

The paper is structured on sections. We present the research methodology after introducing the relevant literature. The methodology section offers a SWOT review, focusing on digitalization as a catalyst for digital strategic transformations. A proposed conceptual design then discusses military digital transformation. Finally, we conclude with the impact of the digital aspects and future development directions.

4.1.1 Literature Review

The power of real-time data integration in the military is truly remarkable. By analyzing data from various sources, military organizations can detect irregularities and potential threats before they escalate, allowing for proactive decision-making and implementing necessary mitigation strategies.

By maintaining a comprehensive view of supply chain status, military leaders can optimize their resilience and anticipate potential disruptions in even the most challenging and rapidly changing environments. This data-driven approach promotes collaboration and information sharing, which enhances situational awareness and allows for timely response to disruptions. The military is experiencing a transformative impact thanks to real-time data integration, and it is truly inspiring to witness how technology is enhancing our national security.

The digitization of decisions refers to the promotion and use of the tools of technological and managerial methodologies, respectively, of the methods and techniques that contribute decisively to achieving the objectives of the areas managed rather than using traditional managerial tools in conditions of efficiency. The decisions of the managerial system must be approached correlatively, combined in such a way

as to enhance its contribution to the amplification of the overall digitization and, implicitly, of the organization [18].

Receiving, processing, and disseminating established the success of military action due to a fundamental concept in the middle of the new transformations—the network. Defined some time ago under the acronym NCW—Network Centric Warfare, it has been experienced in recent operational theatres such as Bosnia, Kosovo, Afghanistan, Iraq, and Ukraine. Effective military decision-making depends on the command-control process, which involves gathering information, communicating effectively, and making consistent decisions. The Command Control Communication Computer Intelligence Surveillance Reconnaissance system is crucial for improving efficiency because it may require a paradigm shift [19].

Ivanov and Dolgui have presented a pioneering decision-making framework that enhances the feasibility of digital transformation. This framework ensures the seamless transfer of vast data volumes, facilitating data-driven decision-making and expediting information flow within an organization [20]. The process is powered by state-of-the-art technologies such as intelligent automation, robotics, the Internet of Industrial Things, Big Data, Digital Twins, and Artificial Intelligence [21]. The organization is equipped with interoperable systems, multi-scale dynamic modelling and simulation, intelligent automation, cyber-solid security, and interlinked sensors, ensuring dependable real-time information flow. Nevertheless, current various approaches to digital technologies are influenced by telecommunications infrastructure and internet access.

Digital technology innovations that apply to the military decision-making system expose different fields of application, as can be observed in Fig. 4.1.

As information moves swiftly, nearly instantaneous decisions must be made to balance the demands of safeguarding and upholding the supply chains. Mourtzis and Panopoulos argue that it is imperative for governments to understand the proper methods of gathering and analyzing data to facilitate the decision-making process. This approach would effectively manage the demand, inventory size, overall service capacity, and logistics functions of the ecosystem and its stakeholders [23].

Managers worldwide are increasingly involved in supply chain efficiency, for which various functions are adapted, especially given the widening access to the data network. There is a noticeable increase in the level of automation in supply chain management from a physical evolution and materials management standpoint [24]. In large companies, digitization is most visible in distribution centers through the trend of multi-automation of different areas such as storage, material handling and packaging [25].

Making decisions is a crucial theme in the research literature of management. According to Bai et al. [26], a diverse range of decision-making methods have been widely employed across various fields. These include sustainable supplier selection [27], supplier sustainable development [28], evaluation of sustainable practices [29], and selection of green technology [30], among others. Numerous scholarly articles have extensively reviewed a range of multi-criteria decision-making methods pertaining to decisional aspects [31–33]. Among the most widely adopted sustainable decision-making methods are the analytic hierarchy process, analytic network

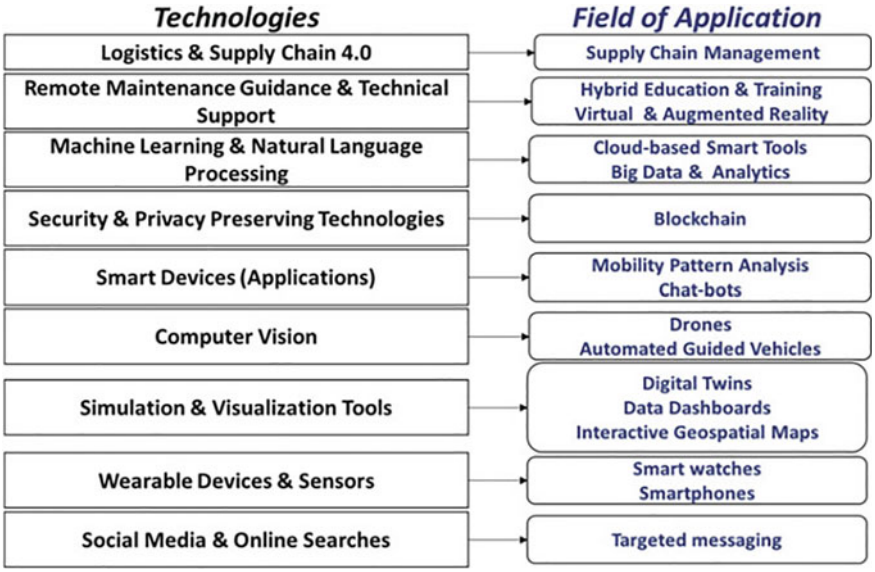

Fig. 4.1 Various digital technologies integrated after the pandemic period [22]

process, fuzzy set theory, rough set theory, data envelopment analysis, mathematical programming, and genetic algorithms [34].

Based on their research, Xie, Joo, and Matusiak discovered that the progress of information and communication technologies, combined with the widespread use of computer networks, has led to the development of digital repositories that provide effortless access to workflows [35]. These repositories foster authentic inquiry and allow military personnel to conveniently access online resources, creating a more adaptable decision-making atmosphere for leaders.

A study conducted by Ivanov et al. defines cloud sourcing as a model that manages third-party physical and digital assets in a supply chain enabled by networks [36]. Recently, the military has adopted Industry 4.0 concepts, including using technology with digital platforms. Implementing cloud features in related supply chains is characterized by factors such as multi-structural dynamics, platforms, digital supply chains, ecosystems, and visibility. Additionally, the dynamic composition of services with buyer/supplier roles that change frequently, resilience and viability, and interwoven supply networks with a focus on the circular economy are notable features.

Sourcing decisions go through transactional stages through internal and sales servers, which act as online storefronts or catalogues; this interface manages the procurement process, from selecting requirements to awarding supply contracts. Specialists provide the ability to issue purchase orders. In the internal environment, staff can use existing applications in the market to communicate within an electronic community [37]. Throughout electronic transactions, the innovations are supposed to reduce procurement costs and the consumption of paper printing of supporting

documents, which can cause delays in obtaining the necessary products. Also, other electronic transaction facilitation priorities are approved using certain websites and addresses [38].

Integrating all processes brings us closer to informational strategies for optimizing significant management levels: infrastructure, operations, tactical, and strategic management. Investing in advanced technology can protect supply chains from future disruptions, while also enabling remote work.

4.1.2 Critical Analysis of Decisional Support

The following paragraphs explore technologies and methods that can aid in digital transformation and the advancement of innovative decision-making processes within the military.

Access to newly written works is crucial for decision-makers in today's digital age. *Digital methods have become preferred to communicate military dispositions within internal networks. Leaders must maintain and promote these methods to ensure the sustainability of future military-technical systems.* Digital documents store institutional databases safeguarded by regulations concerning classified information. These databases are only accessible to specific users who have a "Need to know." The contents of missions or tasks are either born digitally or transferred with the security department's approval.

Converting decisions into digital formats is now a common practice in the military. Access to documents is now easier [39], and more instruments can be allocated for preservation for longer periods of time. Technology has made training easier and more efficient by providing leaders with the necessary resources, like computers, tablets, mobile phones, interactive applications, games, virtual lectures, videos, and smart boards. Technological tools improve retention, making it easier for leaders to make informed decisions.

Digital means of communication are becoming increasingly popular in formal activities. This includes interaction through applications, websites, channels, simulation games, videos, and other authentic materials, such as course platforms or virtual joint meetings. These tools allow leaders to interact with foreign peers, independent of time or location.

Ensuring decisional processes, even in digital environments, requires leaders to regularly increase the disposition amount due to high flexibility and particularization.

On the other hand, exploring digital environments represents an acceptance from leaders to develop their decision-making skills for better performance control. Thus, extensive autonomy acquires abilities to adapt to current trends or future training. Leaders in the Army follow at least a few steps for selecting technical tools, adapting, and applying them in foreign missions. *Engaging with technology takes caution and information protection. Empowering military leaders with digital tools only produces unique solutions since it can significantly improve performance through eco-innovation capability.*

According to Chalakova, training is a meticulously planned and organized process involving active interaction and the creation of ideal conditions to enhance future officers' methodological and practical training. This type of training can significantly impact the performance of junior command staff when carrying out their functional duties [40].

In military operations, adjusting to rapidly changing environments is crucial to ensure that command support is effective and efficient. Trif argues in his paper that a multidimensional approach that includes various interconnected components, such as risk assessment, contingency planning, information sharing, resource allocation, and robust decision-making processes, is necessary [41]. The author concludes that integrating these elements in military organizations can help develop proactive strategies to anticipate and mitigate disruptions, enhance adaptability, and maximize operational effectiveness.

Other factors justifying the need to implement digitization, in addition to motivation for performance, management feedback and support for training programs, could also be considered:

- The improvement of employees is an immediate and direct result of digitization; we know that the imposition of new digital means for employees also means feedback related to the performance expected from them on the job, thanks to the exchange of information regarding professional development opportunities.
- Secondly, taking decisions of an administrative nature will mean the retention or promotion of skilled personnel, as well as the secondment in case of matching to other positions.
- The third factorial area presented by the research is seen as an indicator of the success of staff training programs. Ultimately, digitization is a starting point for new professional, career-related programs.

The utilization of digital simulation is a valuable tool for decision-makers to analyze and compare key performance indicators. This enables them to identify areas for performance evaluation and enhance resilience, specifically in terms of response time, inventory, and service levels.

4.1.3 Theoretical Framework

In university centers abroad, there is active involvement in the digitization processes of libraries and educational spaces, opportunities supported by accessing European funds. There exists a significant inclination to modernize and evolve new methods for transferring scientific and professional knowledge. This pursuit is deemed crucial to bolstering the efficiency and efficacy of our organization's operations and to remain competitive within the industry. Undoubtedly, digitizing decision-making processes will represent a valuable source of information for developing current professional, scientific, or programmatic activities, especially at the highest levels. In this way,

the work tasks expose digital ideas related to informing the staff about the digital potential and using the organizational resources offered.

The transmission of the commander's intent and delivery electronically causes respondents to process information through qualitative and quantitative methods, presented graphically, tabularly or with diagrams, audio representations and video files. Recognizing the benefits and ease of utilizing electronic resources to assist with decision-making is crucial. In the military, technology is increasingly pervasive [42]. As affirmed by Oakleaf, and digitization provides access to a wide range of e-books, magazines, films, databases, software, and other educational resources that can be advantageous for all [43]. The evident influence in the formation of new ways of working convinces us to rethink the existing communication technologies, from which a series of findings emerge:

- All technologies contribute to optimizing technical systems.
- Increase informational resources' importance, place, and role in the organization.
- Saving workspaces, due to informational storage capacities.
- Broadening the horizon towards knowledge of technology.
- The transhumance of traditional learning to hybrid, homogeneous spaces.
- Expanding ways of using laptops and mobile phones as emerging devices specific to innovation and modernization of education [44].
- The space reorganization for the dismissal of jobs related to innovative devices.
- Mobilizing staff to perform tasks from multiple work locations without needing a fixed position.

Professional capital is developed in parallel with the technological advancement of organizations, according to established European standards [45, 46]. Lynch emphasizes that modern technologies are crucial in preserving, protecting, and promoting society's cultural and scientific values [47, 48].

The perpetuation of digitization is contingent upon implementing measures that monitor staff access to various categories of information, with explicit rules regarding creating, duplicating, and disseminating information. Digitization facilitates scientific and research work by enabling individuals such as scientists, students, and other interested parties to access digitized scientific content from remote locations [49].

Digitization offers several advantages, such as the availability of databases, protection of sources, and storage in a new digitized form [50]. Additionally, digitization allows digital cultural treasures, such as texts, databases, images, sound, graphics, and web pages, to exist anywhere, in any language and human domain. However, the current digital era presents challenges due to inadequate operations and network risks. The content offered to multiple users overlooks data collection, development, creation, organization, maintenance, and sharing, which is critical to education and other social subsystems [51].

Organizing the digitization of decisions empowers leaders to create, share, and apply information [52]. A knowledge-based structure refers to the degree to which the organization supports knowledge and promotes learning and development for successful management and operations [53]. Digital structuring adjusts the organizational environment to constantly changing market conditions [54]. Technology

involves specialized personnel who determine how information will be obtained, stored, retrieved, and mobilized through the system and includes ICT and other similar technical skills of organizations [55, 56].

Organizations may call on the skills of suppliers, distributors, contract manufacturers, or business and logistics partners to meet the requirements of the beneficiaries/market and respond quickly. This improves the organization's performance by realizing internal functional processes faster, more accurately, and cost-effectively. Additionally, leaders gain insight into the actuality of technologies developed for production, internal processes, or service provision.

ICT (information and computer technologies) helps organizations build and execute adequate system knowledge in identifying, disseminating, integrating, facilitating, and timely processing of correct information across all business areas and partners. Thus, digitizing decisions allows organizations to process and implement knowledge resources accurately and in the right combination with other resources, ultimately optimizing business performance [57].

Knowledge storage and data protection are critical for organizations to ensure the storage and security of all knowledge resources. As the loss of stored knowledge can hinder the success of organizations, theft or illegal use can harm activities, operational efficiency, and performance [58].

Environmental scanning is an inherent managerial process for military organizations. Management strategies and decision-making processes rely heavily on analyzing the environment, the adversary, or the international context. An analysis of the organizational environment highlights external factors that influence organizations in national security, including economic, political-legislative, technological, and ecological factors [59]. Technological factors are of particular interest to our approach as they leave a mark on military organizations due to the reaction time of the military according to equipment renewal processes. Military institutions depend on allocating budget funds and the need for innovation that employee training in the technical field, investments in products, processes, the level of development, and the quality of public service required. The penetration of emerging technologies stands out by increasing public spending on research and innovation, strictly in infrastructure.

4.1.4 Overall Decision-Making Performance

Firstly, we initiate the research session with a situational diagnosis of the objectives of the digital transformation. This first step consists of:

- Defining the main activities, objectives, and work processes.
- Defining the causes of digitalization: the staff's competence level, the established tasks, and management risks.
- Establishing access limits for employees.
- Detailed organizational analysis.

- Means of staff involvement.
- Establishing action plans, depending on the activities.

The decisions represent the primary source of information for the military staff regarding the field of duties performed, through which the inadequacies of training or information regarding professional progress can be identified. In the future, military decisions will involve other knowledge, skills and abilities, which leaders must develop for possible promotions and transfers. Digitalization planning aims to document the legitimacy of decisions and verify compliance with legal provisions.

The organizational culture generates the understanding of digitalization through the dominant values of the managerial culture, which have a particular specificity in the military organization. An innovative decision belongs to a competitive leader and will not be accepted in a traditional structure, regardless of the hierarchical position.

How do we approach digitization? A correct perception of the purpose of digitization by all categories of personnel is necessary to increase its credibility in the framework of the decisions made.

In concern of the organizational size, there are many differences between public and private institutions because the former is subject to a legislation, a remuneration system, and a standard methodology with specific criteria and working methods. In recent years, most actors begun developing evaluation systems for staff performance.

Strategic guidelines impose clear decision-making criteria consistent with the organization's mission, objectives, and strategies. An establishment of decisional typology within the military organization includes numerous specific variants in this sense, but we will outline an individualized version in Table 4.1.

Some relevant examples from the sphere of rulings, orders or decisions established following military personnel gatherings and meetings which relate to digitization are the following:

- Technological change.
- Moving patrimonial elements within own structures.
- Changing the field of activity.
- Extending or reducing working hours.
- Updating the investment plan.
- Resizing expenses related to technical systems, technologies used, and software.
- Considering the establishment of a new organizational architecture.
- Making decisions to establish new functional positions.

The performance of an organization is determined by the degree of decision-making required to solve the problems it faces. This is calculated by dividing the number of decisions made to address the problems faced by the organization in a specific time interval by the total number of problems faced during that period.

Another performance is the degree of application (operationalization) of the decisions, which determines actions initiated in the field managed to implement the decisions. This performance indicator completes the whole management and organizational echelons. However, the potential for performance resides in the quality of managerial decisions, which can be highlighted by:

Table 4.1 Decisional framework

Organizational decisions	Social decisions	Individual development decisions	Procedural decisions
• Evaluation of the concordance of individual decisions and contributions with objectives • Job description and adjustment of professional requirements • Improving organizational effectiveness • Ensuring balanced responsibilities • Matching existing resources and functions	• There is the possibility of making individual contributions concerning norms to attract feedback from superiors • The leader subordinate's dialogue • Individual knowledge of contributions to the achievement of the organizational objectives • Perception of position and relationships in the hierarchy	• The individual's possibility to know the chances of development depends on their performance and the organization's objectives	• Accomplishment of permanent diagnosis of resources • Career management (promotion, demotion, change of position) • Identification of training and improvement needs • Dimensioning of earnings • Improving interpersonal relationships • Notifying structural deficiencies and updating qualification grids

- Scientific substantiation ensures pertinent information regarding the problem to be solved and the use of appropriate tools for strategic decisions.
- Empowering the decision—given by the effective involvement of the people with the authority.
- Leadership is considered because of the necessary knowledge, qualities, and skills to capitalize on the official authority conferred on the position offered through the authority.
- The appropriateness of the decision, respectively, the adoption and application of the decision in a time interval considered optimal, determines its usefulness.
- Integration into the whole of economic decisions—implies, on the one hand, the outline of some objectives specific to the categorical system of objectives and, on the other hand, a horizontal correlation, in the sense of harmonizing the decisions adopted by managers at the same hierarchical level.
- The appropriate wording of the decision—finding the digital elements in its text, the parameters (the decision-maker, the objectives, the methods of achievement, the necessary resources, the date of adoption, the date of application, the place of application, the person in charge and the opportunity), as well as the quality of the decision-making acts.
- Compliance with strategic-tactical methodology involves representative decision-making stages.
- Ensuring quality decision-making acts through the competencies (knowledge, qualities and skills, the regime of authority), the accuracy of the chosen criteria, substantial options, and the realism of the effects.

- The correspondence between the decision-making requirements of the position and the decision-making intensity of the management processes.
- The distribution of the management functions on process components (work processes, aggregation formulas, tasks, attributions, activities, and functions) with their economic importance, relevance, and contribution to achieving the objectives.
- The correspondence between the typology of decisions and the content of the latest management trends.

4.1.5 Designing Digitization in the Defense Sector

Secondly, the increasing seriousness of the management bodies around responsibility makes the transition to the second step—the design of the digitization process, which aims at the following steps: specifying the aims pursued, fixing the activities, tasks, responsibilities, and necessary resources; drawing hierarchical links and the functional organization chart; analyzing the functions involved in digitization.

Transforming the organization's mission to reflect sustainable goals is a leadership ambition that challenges leaders to draw on the necessary expertise to plan and implement sustainability solutions. In the military, the number of senior positions that include sustainability skills has increased, although the exact number of people with these skills is unknown. That is why we are looking for the performance potential of leaders with fluency in crucial sustainability topics. The recommendation for those organizations that lack this type of staff is to provide the necessary training to acquire the knowledge necessary to achieve eco-innovative objectives, as illustrated (Fig. 4.2).

From the digitization process transposed in Fig. 4.3, decisions emerge that unite human resources, means of work and material resources. The combination of the three determines added value for digital transformation through:

- Operation—structural digitization.
- Transport—digitization of means of transport and location.

Fig. 4.2 Military digitization process. Authors' conception

Fig. 4.3 Components of digitization. Authors' conception

- Storage—digitization of quantitative-value records and storage methods in a more secure environment.
- Evaluation—digitization of organizational results assimilation methods.
- Development is the general digitization of the organization with a sustainable contribution.

Driving technologies accumulate a wealth of information. They go through analysis processes, generate optimal solutions, and transform them into managerial decisions, which must be timelier in the organization.

The work in the military system is associated with the design of activities and documents that serve the purposes of defense of the country. The quality of the work does not have stable benchmarks because, in this situation, it is difficult to quantify the added value of the work, but its characteristics can be established and improved by the employees; they are the benchmark of the quality of the service offered. Digital solutions are on the management agenda, transforming individual requests of institutional eco-leaders into eco-innovative objectives. The latter deals with eco-innovative requirements in standardized internal processes by adequately enriching work tasks, taking innovation initiatives and showing responsibility in action. Concerns in this direction are few, as indicators for measuring digitization have yet to be possible. However, it is increasingly evident that traditional work organization supports productivity improvements by implementing digital means with a managerial desire to implement a sustainable digital framework.

4.2 Methodology for Decisional Foundation Regarding the Performance of Military Leaders

Thirdly, as soon as we perceive the digitization design, we examine the tasks related to the staff assigned to the following functions. The third step is critical in a public institution, as the analysis of the distribution of internal responsibilities determines the opportunity of individual work, at least through the following factors: performance indicators: periodicity, importance of the task performed, duration of work, acquired knowledge; assignment to functional positions: assignment of tasks and equipment specific to functional positions.

4.2.1 Background Information About the Context

The military hierarchy is distinguished from other hierarchies by the division into various social groups and the social distance between the positions occupied by the different categories of personnel: officers, military majors, non-commissioned officers, contract military and troops. The study of modern armies in developed countries reveals that too much social distance between officers and non-commissioned officers, as well as between them and the troops, negatively influences the morale of the latter. It is essential to understand the effects of social stratification in the military organization, as this complex approach also determines the stratification of the decision-making process. Considering only the opinion of one or another category of the military generates a distorted image and, hence, the limitation.

Military leadership teams attract success by defining new strategies and long-term management policies, which incorporate current operational decisions, among the strategic ones, specific to long-term plans. If the leader chooses to act effectively, then the mission and the assumed strategic objectives will define their policies and immediate decisions regarding the progress they hope to make and the risks of achieving these objectives.

Projecting digitalization in the future requires current military leaders to be involved in an extensive documentation and planning process. It involves the successive completion of mandatory phases such as:

- Documentation and analysis regarding how other military leaders make similar decisions regarding the involvement of digital means in defining modern management strategies and policies.
- Analyze of the present level of performance and the potential risks that come with digitization comparatively.
- Establish reasonable, mobilizing, and achievable objectives, starting from the organization's previous performance, similar institutions' performances, and the possibilities offered by the virtual environment.

4.2.2 Research Questions and Objectives

This research paper aims to investigate how digitalization impacts decision-making in the military sector, and to identify the promises and challenges associated with these new tools. Several research questions have been formulated to achieve this goal.

The first research question aims to determine what digitization entails and how it differs from previous management strategies. This question is critical because it provides a fundamental understanding of the key features of decision-making, which will serve as a foundation for the subsequent research questions.

The research objectives of this study are to provide a comprehensive understanding of this paradigm, identify the opportunities and challenges of digital decision-making tools, explore the role of military policies in enhancing orders, and investigate the current readiness of military units. The findings of this study will be valuable to the strategic level of leadership and researchers interested in understanding the impact of technology on the defense sector by identifying strategies for the successful implementation of digitalization.

Overall, this research aims to contribute to the existing literature by providing a comprehensive overview of these tools, their promises, and threats and identifying key aspects that require attention to enable successful decisions. The research questions and objectives will guide the study and ensure that the findings provide valuable insights into the future of military leadership. This research paper focuses on several objectives, including:

- Reviewing relevant literature.
- Conducting empirical research based on observing [60] military experiences.
- Analyzing the use of innovative support in decision-making by military leaders to identify the strengths, weaknesses, opportunities, and threats required to support the formulated research questions.

4.2.3 Research Procedure

In this chapter, we consider a four-step methodology detailed in each section. The RCE approach (recommendation-cause-effect) serves military leaders who exceed the amplifying of the decision regarding the digital future of military units. This involves several successive stages, consisting of:

- Measuring the digitization-risk ratios for each functional area and making reasonable estimates on how increasing or decreasing the use rate of digital means would influence organizational performance. Leaders must formulate rational decisions based on current information about such an activity.
- The correct and objective assessment of each field of activity and the establishment for each case of the weak and strong points, vis-à-vis the digital segment on which it can operate.

- Defining the digitization objectives for the coming years, with the reference that it is expressly a complex of strategic objectives, through which the accepted digitization will satisfy development needs in all its aspects.
- The implementation of an efficient control upon digitization, in the center of which work technique is placed, as well as the reduction of the adverse effects of its use.

The first area of interest of the management apparatus is the decision-making tools, which are the methods and techniques used in the exercise of management decisions.

Regarding decisional efficiency, we highlight that the measurement is related to performance, and the relevant aspects related to this dimension are summarized in Fig. 4.4.

Regarding the weaknesses of the technologization of military decisions, we highlight some aspects in Fig. 4.5.

List of strengths
Engraving managerial characteristics of order, discipline and rigor, by promoting advanced managerial tools and by focusing on rigorous decision-making methodologies.
Ensuring favorable conditions for the rapid transfer to a genuine participative management that allows the active and responsible involvement in establishing new decisions.
The creation of favorable premises in the spirit of personnel categories, with a beneficial effect on the quick, contextual resolution of problems.
Facilitating better exploitation of the creative-innovative potential with substantiated decision-making and operational solution to tactical problems.
Generating a work climate conducive to performance, both through technological task dimensioning and through appropriate accountability of their holders related to the consequences of the adopted decisions.
Amplification of the predictability: the outline of realistic objectives, the establishment of operational priorities ensures accurate managerial method prints.
Ensuring a noticeable scientific dimension to the overall management by promoting and respecting operating technologies and major components.
The facilitation of management redesign, the quality of decision-making, informational and organizational remodeling methodologies depends on the functionality of digital components.
Creation of standardized forms for most documents and reports, which reflects a reduction in the workload.
Drafting as many documents as needed
The inclusion of a relatively large volume of documents, in which information is indispensable in making periodic decisions.

Fig. 4.4 List of strengths regarding the digitalization of decisions

List of weaknesses	
	Difficulty in performing the decision-making due to the lack of an informational system.
	Non-transmission of information on the system vertical, because of the disassociation of methodologies with decision-making system.
	Partial compliance with the decisional principles due to budget utilization, and inssuficient transmission of information.
	The existence of a deficit in the unit of automated information processing means.
	Non-compliance with the recommended managerial scientific methodology, structured in phases, by specific content.
	Reducing the effects generated by the technological operationalization of the decision-making tools.
	Enduring other exogenous causes, of an objective nature (lack of strategy, the environment instability, the crisis).
	The presence of internal causes such as the insufficient use of the evolved tools, lack of order of priorities for the most important problems, insufficient training.
	Informational disparity of many documents, but not all contribute to decisions; this generates redundancy or overloading of informational circuits.
	Failure to outline the information route in time; lack of informational circuits, which determines inconvenience in obtaining information and not sufficient qualitative exploitaiton.
	Specifying informational procedures in reports for algorithmic calculation. A poor internal regulation causes data disorder in procedures.
	Delayed communication due to manual means of processing information; the insufficiency is caused by multiple input in different programs that are not interconnected, making updating difficult.

Fig. 4.5 List of weaknesses regarding the digitalization of decisions

4.2.4 Causal RCE Issue Report

After analyzing the technological reporting to the military decision-making system and the information resulting from the decision-making process, several strengths and central dysfunctions and vulnerabilities can be determined, as illustrated in Table 4.2.

4.3 Results

Our approach involves designing more sustainable tools and reducing waste throughout implementation. Incorporating advanced technologies requires a restructuring of production lines and the development of a workforce that is capable of functioning in a more technology-focused environment [61].

An advanced digitally designed system integrates predictive maintenance, digital twins for equipment and safety monitoring, and various other safety software and systems to mitigate risks. Essentially, military leaders are promoting sustainability by creating digital tools that are easily recyclable and reduce waste in the decision-making process.

Advanced analytics, through real-time data integration, allow for quick, data-driven decisions on supply processes, design, and overall efficiency and effectiveness. For instance, integrating 3D printing technology to produce military equipment customized to the precise measurements of individuals would be a future step in incorporating digital tools into equipment decision-making frameworks.

This digital approach enables leaders to make decisions that cater to the unique needs of individual units or beneficiaries while still maintaining efficient and cost-effective product supply, maintenance, repair, or replacement processes.

Table 4.2 Causal reporting

Identification of strengths			
No	Strengths	The cause considered	Effects
1	Increase in labor productivity	Changing performance indices at a more alert pace	Intensification of the image and increase in beneficiaries
2	Implementation of a new management	Increasing complex objectives; increasing the importance of management processes efficiency	Facilitation of direct participation in the adoption of decisions
3	Decisions of the majority are multi-criterial	Several criteria to substantiate decisions	Improving the quality of decisions
4	Decisions submit the qualitative empowering indicators	Compliance with the designated tasks	Correct fit in the decisional parameters
5	The permanence of typed documents	The high degree of procedural formalization	Streamlining procedures by speeding up coding, standardization and typing flows
6	Essential supervisory documents	Delimitation of duties, tasks, and operational competencies	Fulfillment of elemental or derived objectives
7	Covering processes in the architecture	Delineation of duties, tasks, and competencies at the position level	Meeting individual performance goals
8	A stable workforce with a balanced structure	Compliance with the correlation with the specifics of the defense activity	National defense of a superior quality
9	The high proportion of technical staff	The activity requires a more significant share of specialists	Efficiency in meeting objectives
10	High professionalism of the decision-makers	Leaders' concern for maintaining the level of training	Making decisions more efficient, reflecting favorable results
11	Exclusive providing of the national defense service	New acquisitions of defense capabilities	External demand has an arising trend; defense services have a high degree of trust
12	Technical systems used to achieve the planned objectives	Investments in critical infrastructures, technical systems, and significant programs	Superior quality due to the modernization of technical equipment and infrastructure
Identification of main weaknesses			
No	*Weaknesses*	*The cause considered*	*Effects*
1	Unfavorable economic situation	Decrease in average salary	Decrease in labor productivity

(continued)

Table 4.2 (continued)

Identification of strengths			
No	Strengths	The cause considered	Effects
2	Registration of reductions in the state budget	Decreased performance and supply flow	Delayed invoice payments Reducing the number of employees
3	The reduced number of tools used	Low degree of training and development	Negative influence on efficiency; decreasing the quality of decisions
4	Reduced degree of complexity of the managerial tools used	Implementing management by objectives without correlating results with benefits; Practicing delegation without competencies	Negative influence on the efficiency of managerial activity Decreasing the quality of decisions
5	Failure to adopt current decisions	The decision-maker is not permanently connected to changes	Decisions do not adapt to new situations
6	The decision-making structure discerned towards the upper echelon	Lack of realistic strategies The tendency to transfer solution to higher levels	Increasing the weight of tactical decisions and amplifying the operational dimension of management
7	Reduced scientific substantiation for some of the adopted decisions	Decision-makers do not use decision-making techniques and methods in the elaboration and implementation of decisions	The risk of errors in the adaptation of decisions
8	The existence of documents with insufficient content	The low focus of leaders Lack of a system of objectives for all categories of personnel	Poor delimitation of the attributions of the functional departments and operational
9	Existence of circuits Long informational	The high degree of complexity of the information circuits from the issuer to the beneficiary	The information no longer reaches the recipient in the form initially issued
10	Manual means of processing data	The processual means are not adapted to the needs	Communication delay
11	Inadequate procedural delimitation of some structural components	Lack of appropriate documents Lack of a categorical system of objectives for performers;	Decreasing the efficiency of work processes Diminishing liability Low degree of involvement

(continued)

Table 4.2 (continued)

Identification of strengths			
No	Strengths	The cause considered	Effects
12	Partial compliance with organizational principles	Some documents must be updated, and subordinates cannot perform the assigned tasks	Affecting performance due to lack of concrete objective absorption and resource status
13	Disrespecting the organization's guidance	Lack of agreement between tasks, responsibilities, and competencies	Nullity of functional description, task, and responsibilities indication
14	Reduces computerization of the military management	Deficient equipment for modern information processing means	Manual information or difficulties in adopting strategic and tactical decisions
15	New sourcing methods, safer for cost estimation	Disinterest in emerging cost estimation methods	Significant impact amplifies decisions under conditions of uncertainty and risk
Establishing opportunities			
No	*Guidance*	*The cause considered*	*Effects*
1	Management modernization	Maximizing essential modern tools: management by objectives, management by budgets, delegation, dashboard, meeting	Adaptation to the requirements of applicants Use of worktime by balancing solutions for all problems
2	Use of management based on budget requests	The need to determine autonomous operative structures which elaborate, launch, execute and monitor the budget execution	The existence of logistical support to facilitate the achievement of objectives Ensuring the objective-results-benefit ratio
3	Calling for new instrumentation in decision-making	The decision-making structure orients the management functions of hierarchically superior managers The use of new methods	Facilitating the optimal decision-making option Solving problems related to current activities
4	The use of modern cost calculation methods	The use of the award method as a reliable method of supply (the best quality-cost ratio)	The adoption of certain decisions based on the obtained costs, the amplification of the efficiency of the contract awarding
5	Adoption of current decisions	Lack of current decisions	Fulfillment of individual and specific objectives

(continued)

Table 4.2 (continued)

Identification of strengths			
No	Strengths	The cause considered	Effects
6	Improving the degree of endowment with IT requirements	Reduced degree of computerization of management lines and their connection	Shortening informational circuits The correct adoption of decisions by decision-makers as a shortening of the communication
7	Training improvement by participating in various courses	Decreasing staff specialization and the preponderance of secondary education	Increasing the number of specialist decisions and staff qualification criteria
8	Delimitation of responsibilities and competencies	Failure to comply with internal organization	Fulfillment of individual objectives Obtaining personal satisfaction
9	Elaboration of documents to formalize the structuring	The existence of organizational documents with insufficient content	Exercise of operational duties, as well as the tasks of some managerial and executive positions
10	Maintaining a high level of professionalism	Concern for maintenance and increasing the level of training by participating in specialization and improvement courses	Increasing decision-making performance Maintaining leadership trust through external collaboration
11	Effective budget use	Giving importance to the optimal management of the budget only by a part of the decision-makers	Compliance with the imposed deadlines and the correlation with increasing the efficiency of managerial activity
Establishing threats			
No	*Guidance*	*The cause considered*	*Effects*
1	Eliminating frequently occurring functional errors	Update rating system types	The multiplication of consistent means of supporting the professionalization of all military personnel, of combating and eliminating the misconduct
2	Eliminating frequently occurring functional errors	Implementation of a scientific basis for performance evaluation	Correlation of the salary level and that of the attributions and responsibilities
3	Eliminating frequently occurring errors	Balancing staff turnover	Updating the salary level for civil servants
4	Eliminating frequently occurring functional errors	Balancing staff turnover	Overcoming high-tech barriers with a staff aligned to technology, relevant for external relationships

(continued)

Table 4.2 (continued)

Identification of strengths			
No	Strengths	The cause considered	Effects
5	The development of the technological dimension in the world of production	The negative dynamics of the changes taking place in the economic, social, and cultural environment	The increase in the interest shown for capitalizing on the advantages of the digital environment
6	Transposition of general, holistic principles into practice	Lack of valuable specialists who contribute to the creation and transmission of knowledge	Fuzzy ideas on the development of human resources, systematic training, learning by action, development, and quality

Quickly responding to current military movements and upper-echelon hierarchical needs enables them to stay ready in an increasingly rapidly changing operational field, as seen in Fig. 4.6. The most important aspect of adopting digital tools is reducing the environmental footprint and recognizing a circular economy in the military.

Great attention must be directed to allocating all military units with sufficient digital resources to maintain the decision-making flow necessary for modern military actions so that this digital literacy is achievable among all categories of military personnel to achieve decision-making performance. Moreover, the development of artificial intelligence and accelerated digitization will leave behind leaders who today need access to IT&C equipment, digital data, or mentoring in communications and informatics.

Future digital teams will work with robots and human resources adapted to this context, promoting practice and an organizational culture offering a collective chance to apply best practices. In this way, the personnel benefiting from the new technologies will also discover new means of integrating them into the military decision-making area, which will determine the openness and interest in this field, even in the case of the young generation of leaders. We emphasize that this phenomenon is even more readily accepted as the generational segment includes younger ages, facilitating the accumulation of new digital skills.

Communication and interaction functions among the military will take shape through new dialogues, audio and video presentations, and robotic assistance in training classes or as technological support during missions. VR glasses or creative forms of oral presentation will replace reports and instruction so that the military can be more virtually present in various training places or better understand how to carry out the assigned mission and the future battle space. Fast and secure training management shortens the time to complete tasks and individual performance objectives and increases the success rate.

After retrieving the information from designated staff, leaders determine how to provide soldiers. This could be done through a mobile app or by printing cards, depending on what is feasible in the field. However, using high-tech tools may be

Fig. 4.6 SWOT matrix

impossible due to military and informational policies, internet connectivity problems in remote areas, or security concerns once exercise-specific details are entered.

Facilitating the decision-maker's ability to track expenditures related to specific eco-innovative items, such as multiple sustainable purchases or software expenses within a military unit, determines a paramount performance. Moreover, monitoring these innovations in military capabilities and the outcomes produced by their use is equally critical. It is crucial for those in decision-making positions to consider the impact of their choices on resources and their utilization and seek sustainable solutions for practical decision-making. A robust defense system should consider

inputs from eco-innovation processes on both sides, including strategic planning, force planning, resource planning, and risk management. Operational eco-innovative inputs are vital for describing current operations and providing valuable information for future capabilities.

4.3.1 Digitalization of Strategic Efficiency

The fourth step of digitization design for the defense sector materializes through transformation efficiency. The eco-innovative objectives met at the highest standards and quality targets will be reflected through a series of requirements, meaning:

- Organizational performance indicators are workload, results, and capabilities.
- Optimal digital solutions: automation, reorganization, computerization, equipping, software.
- Quality credentials of the work performed: control indicators, level of satisfaction of the beneficiary, qualification of trust in the organization.

This research presents a digital transformation strategy aligning the current state with the long-term military vision. The strategy incorporates real-time data for better decision-making and reduced resource consumption. Many institutions are rethinking their management model and how their added value can support digital activities in terms of online supply, work, education, and partnerships with:

- High ambitions in the digitization field have brought outstanding virtual and robotic innovations. The decisional processes have been simulated and facilitated in virtual workspaces due to increased risks of physical contact affected by the former coronavirus threat. System management optimizes digital tools for communication needs, including briefs, websites, online stores, mobile apps, and virtual platforms in fields where remote work is not feasible [62], like the military. Digital representations of avatars are used to express authority or status, even in the military.
- The entire management network currently influences applications and virtual opportunities to communicate with personnel or other partners.
- Virtual boards, journals and weekly online newspapers are tools that integrate digitization in the Army.
- A beneficial way to ensure the continuity of educational programs is to consider platforms that transcend traditional teaching methods. This tool is being constantly updated. The most crucial advantage for military educational institutions was the training service itself due to the modernization of material background and modernization objectives. By this, we refer to investments in proper educational devices, such as those delivered annually to former military students. Technology maintains the relationship between management, all employees, teachers, and students.

- Also, traditional books and libraries have been updated to virtual ones, and library software has become a tourist sight for visitors.
- Writing reports and documents by hand has been replaced with PC writing. Technological criteria hire personnel because today's tasks include PC workload, electronic platforms, electronic supply, communication and reporting with upper echelons, internal communication and information flow, and decisional dissemination.
- Payments are under mandatory legalization on electronic billing systems, making payment monitoring easier.
- A new reality increased the use of webpages informing personnel on the status of extracurricular activities, accommodation facilities, transportation, food, and delivery services.
- Rethinking management represents a strategy that leaders must consider when it comes to using digital tools.
- For example, maintaining institutional hygiene and health protection remains an important objective, and several replacements build investments in digital systems that allow hygienic functions.

4.3.2 The Results of the Analysis of the Military Decision-Making Subsystem

The decisions adopted in the Army refer to the procedural and structural components. Most decisions are adopted for the organization and coordination of personnel, although solutions represent each of the five managerial functions. This highlights the balanced treatment of managerial priorities. Also, we find the adopted decisions in balanced proportions, which shows the average orientation of the military leaders.

Based on such judgments, we can formulate at least five *potential strategies* to ensure a favorable digitization of military decisions as the primary support of leadership performance, namely:

a. The growth decisions, by assuming a broader decision-making spectrum, simultaneously with the neutralization of those operations high-risk IT.
b. Implementing systematic control over the digital tools used fixes a digitalization fixation model through which management can determine the level of performance obtained as accurately as possible based on the resources allocated.
c. More efficient control over the difficulties of using new means, starting from a more objective assessment of individual risk, and continuing with the development of digital security practices.
d. Ensuring growth in innovative decisions by diversifying the portfolio of purchased products and services other than those of representation and technical editing of supporting documents.
e. A more effective control regarding investment expenses, in particular those of digital operation, which can be systematically rationalized and optimally sized.

Condition list for enhanced military decisions

Criteria	The nature of the variables involved	The implications on the time horizon	The weight of the decision-making	The frequency	The category of the decision-maker	The qualitative level	The time required for implementation
Condition 1	The decisions are certain	Decisions are tactical in nature	The decisions are mostly multi-criteria	Decisions are adopted at regular time intervals, but without much information and previous research	Military decisions are integral at the strategic, operative level, as well as among the tactical one	The decisions of the military leaders are not scientifically substantiated	The military decisions fall according to the specific degree of opportunity
Condition 2	A maximum probability of achievement	In military units, leaders adopt medium and short- term decisions (1 year), with particular importance for personnel	The single-criteria weight is small	They reflect a positive aspect, namely a clear record of the decisions taken	Tertiary decidents present a rather serious involvement in the adoption of decisions	The internal analysis is certified by the specialists in each functional field, circumscribed by the necessary professional competence and approval	The most important stage is choosing the optimal course of action by using military decision-making tools
Condition 3	The decision-maker know the environment well	The hierarchical route follows the decision-making powers assigned to the level of the leaders	Leaders adopt complex solutions on military technical systems	The risk of errors is reduced, and leaders can implement those decisions that lead to the fulfillment of missions	Within all hierarchical lines, it exists the need to approve decisions, which prolongs their application time	The adopted decisions contribute to the achievement of the annual objectives	
Condition 4	The rest of the decisions are in uncertain or risky conditions	The rest of the decisions are strategic					

Fig. 4.7 Conditions for enhanced military decisions

Figure 4.7 shows specific decision-making categories applicable to the military environment, whose accomplishment refers to the detailed aspects.

Therefore, we note that among the most effective decision-making methods, the knowledge incorporated in technologies occupies a leading place among the organizational procedures encountered at military units.

4.4 Discussions

Today, artificial intelligence-enabled systems offer improved information and decision-making, increasing the pace of activity and human understanding [63]. AI technology presents many opportunities to improve access to information, facilitate better decision-making, and expedite tasks. In the future, AI support could enable more efficient command and control structures, reducing the need for many personnel. However, while this technology can bring cost savings and increased efficiency, it also presents unforeseen challenges that require thorough experimentation. AI has the potential to overcome human limitations, but we recognize that it may contain inherent biases and overlook significant changes if not trained with appropriate data. In other words, we validate the consecutive opinion: Machine learning, if designed to emulate the human brain, is also vulnerable to bias. It may fail to

consider the potential for significant changes and instead, operate solely within the confines of the data used to train it in the first instance [62].

The former limitation of the organization was due to the procedural establishment and document design, while modern work is related to the processing and handling of files (receipts, reports, studies). This way, the digitization of decisions is based less on instinct and more on analysis and foresight. In this work, new situations often appear, accentuating the enrichment of digital skills, for which autonomy to show responsibility is also needed. Concerns for digitalization raise the issue of key performance indicators, and the achievement of productivity in specific missions will define productivity through digitalization.

Digitization in the military field is organized within the Annual Coordination Plan to implement digitization projects. The strategic directives prepared at the level of the Romanian Army aim to coordinate all activities for implementing this type of project, regardless of the field.

The computerization of military administrative services means upgrading communications and IT equipment (computers, printers and copiers used in local network mode), purchasing high-performance software packages, licenses for the implemented management systems, maintenance solutions for own sites, and hiring competent human resources. The modern technique newly introduced in the military system creates additional duties and responsibilities compared to the conventional ones, for which the officers and the leading personnel are responsible for carrying out the assigned missions safely and efficiently.

The correctness of digitization of decisions largely depends on the quality of the methods used, which implies:

- Validity of the results obtained (ability to reflect the need).
- Fidelity of determinations (ability to provide identical results upon repeated application).
- Equivalence of results (how to reach the same result).
- Internal homogeneity (several components of the same instrument, measuring the same element, indicate the same result).
- The instruments' sensitivity (the ability to measure the real difference between the subjects).

As future proposals, at the level of the Romanian military structures, there are pilot intentions to digitize payment methods for serving meals. The daily activity flow will supplement the validation of the material goods by barcodes to track the equipment throughout the immobilization on the source-beneficiary route.

Accessing the technological solutions in a simplified form ensures monitoring of all military-technical systems, including maintenance and maintenance works, after which periodic analyses and statistical reports extract relevant computer parameters. Some examples of this could be real-time location, resource consumption, functionality errors, routes taken, and personnel identification.

The management of material assets will undergo additions to the purchase of innovative machine tools necessary in the equipment maintenance process. The software for the quantitative records will interconnect different management applications

Table 4.3 Proposals for digitalization

Hardware platforms	Variety of recorded information, creation of data storage and processing platforms, with the possibility of access from any smart device
Data planning	A large volume of records, which depends on better information planning
Data privacy	Ensuring the security of information and its users
Data availability	Use of a wide range of devices that can work seamlessly, with the limitation of users changing the settings of the devices
Proper networking	Removing existing dangers in cyberspace and ensuring functionality within normal technical parameters

that use radio frequency technology only because of accreditation by authorized structures.

The requirements pursued by future leaders will include content analysis, going through digital materials in their entirety, verifying registered sources, paying attention to chronological data or publication of materials, biometric authentication, and use of antimalware solutions. Finally, increasing vigilance in using digital devices is imperative to avoid possible attacks or security threats.

Particular attention should be paid to existing social media platforms through which military-specific content is distributed and used even by specialized military personnel. The information features included in this type of post respect the confidential regime and do not compromise the interests of the Romanian Army.

An online platform is currently used to reserve and check the availability of military hostels, cabins, sanatoriums and recreational and sports facilities in the ministry's heritage, accessibility being ensured only to active or reserve military members.

Also, a series of computerized applications use the specialized departments' current activity to carry out the specific functional attributions of keeping military personnel and equipment in operative condition. These applications have specific operators and system administrators whose responsibilities regarding classified data protection are evident.

Real-time reporting using devices and other technical systems will improve efficiency because it provides leaders with information faster than systems that depend on human intervention. From a managerial point of view, at least five directions are substantially influenced by the digitized mode of operation, according to Table 4.3.

4.5 Conclusions

This research study provides significant insights into the managing levels of military organizations confronting the digitalization challenge. By embracing technologies such as blockchain, IoT, risk radar, and AI, military leaders can bolster resilience,

enhance risk management, and promote transparency while fostering collaboration, strengthening hierarchical relationships, and increasing operational efficiency. Building a decisional process supported by advanced technologies will effectively mitigate the effects of digitalization, making command more competitive in operations. Embracing digitalization is critical to staying viable in today's ever-evolving peaceful and conflict landscape. The research targets in this paper concern the following aspects:

- Computerization of accessing databases for various information, reports, and facilities owned by the ministry.
- Monitoring personnel, technique, consumption, and alternative solutions implemented.
- Decision automation by adopting technological means or similar technical solutions.
- Robotization of those activities, including palletizing, containerization, material goods handling and ultra-modern techniques.
- Involvement of the military academic environment in the development projects of eco-innovative capabilities.

For an optimal design, safer and more efficient options will satisfy operational and interoperability requirements if manufactured and maintained effectively. Operational capabilities surpass testing, evaluation, homologation, prototype acceptance, program review, and manufacturing process validation. Optimizing decisions on the industrial prototypes will not only initiate small series production but will entail promising stable, reproducible, and efficient system projects. Future decisional process validation will provide a realistic portrait of the operational performance while commanders establish action plans. A decisive systemic configuration establishes the defense capability assessment. The most critical decisions will impact the environment, and measures for reducing ecological risks will be of the utmost consideration, especially for an up-to-date life cycle reassessment and adequate resource design [63].

Knowing the digital standing of the military organization at a given moment and relying on the performance expectations associated with digitization formulated for the military leadership, the problem is that concrete action methods obtain superior results. The digitization of each decision must be done carefully since any increase in digital means also entails an increase in risk exposure. The essential element of managerial action must be based on rational digitization and aim at obtaining a decisional surplus while limiting vulnerabilities related to exposure in the virtual environment.

Most importantly, promoting convictions among managers and staff that expanding to digital dimensions of the decision-making process will ensure ease in fulfilling additional objectives. However, we assume that any large-scale expansion of specific digital tools can simultaneously generate severe imbalances that get uncontrollable.

We do not want to end our study without mentioning that effective leadership behavior requires digital prudence on the part of any military leader, especially since

there are all kinds of tendencies to abandon some practices that are not compliant or ethical. Digital maturation will certainly involve balancing the changes due to digitization and the promotion of digital products and services for which not all military units currently have sufficient professional experience.

Digitization provides information, but management must process it to have a more eloquent picture of future performances and the decisions to achieve them. The military management of the future will empower high-performing eco-leaders entrusted with delegating innovative decisions and green teamwork to achieve better performance.

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Chapter 5
Standardization and Interoperability—Key Elements of Digital Transformation

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Abstract Digital transformation is a complex process that involves integrating new technologies into existing business practices to optimize operations and enhance performance. Standardization and interoperability are crucial elements of this process, as they facilitate seamless communication and collaboration between different systems, devices, and platforms. This paper examines the importance of standardization and interoperability in the context of digital transformation, highlighting their role in enabling organizations to leverage the full potential of emerging technologies such as the Internet of Things, artificial intelligence, and blockchain. The paper reviews current standards and protocols across various industries and identifies emerging trends that are likely to shape future interoperability requirements. The findings suggest that while standardization and interoperability may present challenges in terms of implementation and maintenance, they are essential for organizations seeking to stay competitive in a rapidly evolving digital landscape. Ultimately, this paper underscores the need for continued investment in standardization and interoperability as critical components of successful digital transformation strategies. Currently, a large part of the problems encountered by institutions in their digitization efforts is the lack of interoperability of existing IT systems and applications, deficiencies in the interconnection of used databases and the lack of common standards. These problems become increasingly difficult to solve as more and more online applications or services are conceived and implemented without a functional interoperability and standardization framework. To address these issues, measures

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L-I. Cioca et al. (eds.), *Digital Transformation*, Intelligent Systems Reference Library 253, https://doi.org/10.1007/978-3-031-55952-5_5

are needed to facilitate the digital transformation of all interested organizations, not just those in the public sector. Under these conditions, the EU's standardization framework must adapt to the constant evolution of technology markets, as standards are vital for interoperability.

Keywords Digital transformation · Interoperability · Standardization

5.1 Introduction

The transition from an industrial society to a knowledge society is considered to be irreversible [1], and the pace of said transformation taking place extremely fast at a global level. In this globalization context, technology has blurred the boundaries between different sectors of the economy and institutions, as people are increasingly interconnected and engaged in a global race of competitiveness and knowledge. Concepts such as "standardization" and "interoperability" are becoming key concepts of the digital transformation of institutions in contemporary society.

The value system allows today's societies to master the rapid developments in technology, which constantly maintain social and economic progress but also social cohesion [1]. To better describe these trends, a set of reference values have been defined that characterize the knowledge society and are on the way to being assimilated into the collective mind. Thus, we can mention [4]: competitiveness based on social inclusion; lifelong learning; social innovation at the expense of technological innovation; participation in lieu of representation; interdependence instead of independence; and added value.

Digital technologies and the new business models emerging from digital transformation often do not align seamlessly with the conventional regulatory frameworks that regulators typically employ to manage markets. That is why new approaches to the regulation of digital technologies have been created or are being developed to preserve their innovative character, agility, flexibility and resilience.

5.2 Digital Transformation

Digital transformation is a complex process that requires careful management and has significant implications for an organization's strategy. These implications have been detailed in the dedicated literature [1, 4], etc., highlighting five areas in which digital transformation (through digital technology) has changed the paradigm (constraints) under which an organization's business model operates. These areas are consumers, competition, data, innovation, and value.

The first area of digital transformation is represented by consumers. In the digital era, our world is increasingly characterized by customer networks rather than traditional mass markets. In this new paradigm, customers are actively interconnected

and engage not only with organizations but also with one another. Customers are continuously interacting and influencing one another, thereby moulding the reputations and brands of organizations. Their adoption of digital tools alters how they find, assess, buy, and utilize products, as well as how they communicate, interact with, and remain engaged with various brands. The dynamics of competition have evolved. In the past, companies competed against similar competitors for the same customer base, often utilizing comparable supply chain partners and requiring analogous production resources. We are currently moving towards a world with fluid industrial boundaries where we have „asymmetric competition"—where firms/corporations compete against each other, in certain markets—and "digital disintermediation", which turns long-standing partners into competitors [4].

As a consequence of these changes, there has been a significant shift in the competitive arena. Instead of being a zero-sum game fought among comparable competitors, it has increasingly turned into a competition for influence among companies with varying interests and business models. Each firm is vying to gain more influence and control in catering to the ultimate needs of the consumer.

Data lies at the heart of the digital transformation journey. Companies that excel in transforming their data into quickly actionable insights secure a significant edge in the competitive market. Data generation occurs through interactions—either between a customer and a business interface, among customers within the business's network, or internally within the organization.

Today, businesses utilize this unstructured data with analytical tools to discover fresh perspectives and solutions concerning customer behavior and demands. Consequently, this unlocks new value, positioning data as a fundamental resource across all business departments. It emerges as a strategic asset that demands ongoing development, implementation, and protectionInnovation is the creation, refinement, and introduction of novel ideas to the market. Historically, innovation unfolded in linear stages, emphasizing the delivery of a fully-developed product. Decisions about these products were typically made by management and top executives, relying on their instincts and analyses, which carried a substantial risk of costly failures. However, the advent of digital technologies has fostered alternative approaches to innovation. These new methods are characterized by ongoing learning and swift experimentation, enabled by digital tools.

Digital technologies facilitate the early and continuous testing of ideas, allowing for immediate market feedback throughout the innovation process, from initial development to product launch. Companies now focus on developing minimum viable products (MVPs), enabling them to run experiments with actual users. This approach enhances learning, reduces expenses, and supports hypothesis testing. The result is a more efficient process that saves time and money while also decreasing the financial risks associated with failure, thereby boosting organizational learning. In this case, by value, we mean the value that a business offers to its customers. Before the digital revolution, the value of an organization was relatively stable. Products were updated, marketing campaigns changed and operations improved, but the value delivered remained the same. Today, however, the value delivered to customers must be able to evolve in such a way that technology can be exploited to extend or enhance

that value. Confronted by the necessity of digital transformation across these five key sectors, modern organizations require innovative strategic frameworks to effectively adjust and prosper in the era of digitization. Each sector presents a foundational strategic theme, serving as an initial step in developing a digital strategy for an organization. These five themes provide a guide as to how the constraints of traditional strategy can be changed, thereby achieving new opportunities for building a business or achieving public policy involving the use of digital technologies.

5.3 Standardization and Interoperability—Key Elements of Digital Transformation

Standardization

Standardization is the process of implementing and developing technical standards based on the consensus of various parties including companies, users, interest groups, standardization organizations and governments [5]. Digital technology standardization occurs at national, regional, and international levels through various organizations, including companies, professional bodies, trade associations, NGOs, intergovernmental bodies, and Standards Development Organizations (SDOs). At the regional level, SDOs evaluate standards and guidelines from international entities like the European Committee for Standardization and the Observatory for ICT Standardization (EUOS). They work with other regional SDOs to avoid duplications and leverage the collective knowledge and engagement of stakeholders in these bodies.

In this scenario, regulatory authorities, as key stakeholders, should participate in creating voluntary standards, such as joining technical committees of national standards bodies. This involvement ensures the standards align with regulations, should authorities opt to reference them.

The regulatory approach, while innovative, might not fully meet the diverse needs of the international digital transformation landscape, marked by varying capabilities and priorities. Developing countries often have different digital transformation needs and capabilities compared to wealthier nations. Standards, therefore, are vital for equitably driving digital transformation worldwide. Standards are voluntary guidelines or rules that formalize information, providing specifications and technical details for a wide range of products, materials, services, and processes. They are especially crucial for technology-based products.

Standards cannot be created in a vacuum; they are formed within a regulatory framework that adapts to the challenges of digital transformation and technologies, also considering sustainability issues.

Standards play a key role in tackling technological and societal challenges posed by digital technologies. They set crucial benchmarks for safety, security, reliability, efficiency, interoperability, and trust. Often acting as preliminary voluntary regulations, these standards provide expertise and gather support from innovators, leading

to regulations that minimize risks and create a conducive environment for both innovators and investors. Numerous international organizations and professional groups have developed specializations in digital standards, including the International Organization for Standardization (ISO), the International Electrotechnical Commission (IEC), the International Telecommunication Union (ITU), the United Nations Industrial Development Organization (UNIDO), the Institute of Electrical and Electronics Engineers (IEEE), and the G20.

Digital standards, which are specific to digital technologies, are ubiquitous in our daily lives. They make it possible for various devices to communicate with each other, support the sharing of information, and outline, for instance, security protocols for Internet of Things (IoT) devices. These standards encompass a broad spectrum of technologies and associated infrastructures, devices, applications, and services. Among the types of digital standards, we can mention: Internet technical standards, Web standards, Network and infrastructure standards, and Open standards.

Interoperability

Ever since the launch of the first version of the Digital Agenda [2], the European Commission has declared its objective to achieve an increased degree of interoperability at the level of all public IT systems within the European Union. The objective was achieved through the realization of interoperability policies, frameworks and architectures. Among them we would like to speak briefly of the following: European Interoperability Reference Architecture (EIRA), European Interoperability Architecture (EIA), European Interoperability Framework (EIF), etc.

European Interoperability Reference Architecture

Given the increasing volume of information exchanges (cross-border and cross-sectoral) between public administrations in Europe, the need for interoperability is greater than ever. Thus, the ISA 2.1 initiative [3] (which refers to the definition and description of the EIA—European Interoperability Architecture) introduces a reference architecture to guide European public administrations in their work to provide interoperable European public services for businesses and citizens.

The European Interoperability Architecture (EIA) action is part of the Interoperability for European Public Administration (ISA) solution. It provides two assets: the European Interoperability Reference Architecture (EIRA) and the mapping tool.

EIRA represents the reference architecture for digital public services at European level. It defines the capabilities needed to enhance interoperability as a set of Architectural Building Blocks (ABB). It is aligned with the European Interoperability Framework and is divided into four options described below. EIRA is based on SOA (Service Oriented Architecture), uses the Archimate modeling language and emphasizes the importance of interoperability in the public sector. EIRA is technology neutral and provides semantics common that will later be clearly used between implementations through Solution Architecture Templates.

European Interoperability Architecture (EIA)

Technological advancements are driving the modernization of public administrations, resulting in a growing volume of information exchanges among public administrations across Europe. Consequently, the demand for interoperability within Europe is at an all-time high to support these information exchanges. Developers of solutions in various public sector domains concur that interoperability and reusability are critical elements in the creation of any effective solution. In order to become truly interoperable, a European interoperability architecture (European Interoperability Architecture—EIA) was created through which public administrations in Europe must coordinate at cross-border and trans-sectoral level, when developing digital solutions to avoid the risk of creating new digital barriers in the interaction between administration, companies and citizens (G2G, G2B, G2C). Thus, the following needs are identified:

- common terminology to design, evaluate and communicate e-government solutions: public administrations need a common terminology to design, evaluate, communicate and identify solutions in the form of software modules—the so-called "building blocks" (common operating frameworks, tools, services)—used to provide the general public with interoperable digital services;
- a number of stable interfaces for digital public services: public administrations must define stable interfaces between digital public services so that other stakeholders can rely on them to be able to build new agreed public digital services;
- overview of the already existing software modules ("building blocks"): public administrations must be aware of the already existing software solutions, which have been developed by other stakeholders.

EIF—European Interoperability Framework

Under the Digital Agenda for Europe, a key initiative of the Europe 2020 Strategy promoting intelligent, sustainable, and inclusive economic growth, the European Commission implemented the Communication "Towards the interoperability of European public services". This action seeks to develop a unified approach to enhance efficient interoperability among European public administrations.

The European Interoperability Framework (EIF) forms part of a collection of initiatives aimed at enhancing interoperability. It offers advice to European public administrations regarding the creation and provision of European public services. Comprising 25 recommendations for these administrations, the EIF, in conjunction with the European Interoperability Strategy (EIS), is intended to assist European public administrations in progressing towards a digital single market.

5.4 Conclusions

In conclusion, this paper aims to provide a comprehensive analysis of the digital transformation journey, standardisation efforts, and interoperability challenges faced by public administrations in the European Union (EU).

The study has underscored the importance of embracing digital technologies as a means to enhance efficiency, transparency, and accessibility in the delivery of public services. The EU's ambitious digital agenda has set the stage for member states to leverage digital transformation as a catalyst for modernizing their public administration systems.

Through a preliminary examination of the EU's standardisation initiatives, it has become evident that a harmonized framework is fundamental in promoting interoperability among various public administration systems. The adoption of common standards enables seamless information exchange, fosters collaboration, and improves the overall effectiveness of e-government services across EU member states.

However, it is evident that interoperability remains a complex challenge for public administrations, primarily due to diverse legacy systems and different degrees of digital maturity among member states. Overcoming interoperability barriers necessitates concerted efforts to align policies, establish common protocols, and promote the use of open standards across the EU.

To successfully navigate the digital transformation journey, public administrations in the EU should prioritize key areas such as investing in digital infrastructure, fostering a culture of innovation, and fostering data-driven decision-making. Additionally, collaboration between governments, private sector entities, and citizens is crucial to ensuring the design and implementation of user-centric digital services that meet the diverse needs of the European population.

In conclusion, the digital transformation, standardisation, and interoperability of public administration in the EU is a complex and multi-faceted process. While progress has been made, further work is required to achieve seamless integration and enhance the digital experiences of citizens and businesses across the European Union. By actively addressing the identified challenges and embracing the opportunities presented by digital technologies, the EU can continue to evolve its public administration systems and position itself as a global leader in digital governance.

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Chapter 6
The Role of .RO Domains in Enabling Digital Transformation: A Study on the Evolution of Digital Society in Romania

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Abstract In just a few decades, the concept of the information society has transitioned from a vaguely established idea attempting to predict the future of humanity to a tangible reality that encompasses the entire globe. This rapid progress in the field of information technology and communication has resulted in the majority of our everyday devices, such as computers, televisions, home appliances, and even vehicles, being imbued with smart technology that is intended to benefit society. While the evolution of the internet is linked to technological advancements, it is also heavily influenced by social factors that give rise to new consequences for our society. Given the fast-paced evolution of the Information Society, it is essential to keep up with the changes. In Romania, the .RO domains play a crucial role in shaping the country's information society. However, these domains are often targeted by attacks, and continuous measures must be implemented to ensure the Internet operates smoothly in the country. The management of .RO domains involves several specialized applications, and their development and security are an ongoing project. Despite the remarkable technological advancements made in recent decades, the physical location of a business or organization remains crucial. In this regard, national domain names are of significant importance. The Romanian Top Level Domain is a

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L-I. Cioca et al. (eds.), *Digital Transformation*, Intelligent Systems Reference Library 253, https://doi.org/10.1007/978-3-031-55952-5_6

vital component of the information society, and its dependability and safety are fundamental for social, economic activities, and the smooth operation of online services. Although the Domain Name System is often viewed as merely a technical task, its administration involves many factors, such as infrastructure stability, system security, and resource allocation. DNS is not solely a function of Internet governance, as it encompasses technologies that contribute to the functioning of the Internet. The DNS embeds content, and conflicts over property rights may arise concerning domain names that contain text (letters and/or numbers). The system must have several checkpoints that sanitize and verify content access. Security plays a key role in Internet governance, and this issue is a significant concern at both the country and ccTLD level, as well as for Internet governing bodies such as ICANN and IANA. Organizations responsible for Internet governance continuously update their security policies and offer training and advisory sessions at various levels to counter security threats. At the ccTLD level, security is a continuous topic as the risks associated with it cannot be tolerated.

Keywords Digital transformation · Digital society · Information society · Cctld domains · DNS · Digital reliability

6.1 Introduction

In an astonishingly short span of time, the concept of the information society has transcended its speculative origins to manifest as a concrete global reality. The trajectory of this transformation, powered by rapid advancements in information technology and communication, has ushered in an era where the very fabric of our daily lives is interwoven with smart technology. From computers to televisions, home appliances to vehicles, the infusion of intelligent capabilities seeks to enhance and optimize the experiences. Yet, this evolution of the internet, while deeply rooted in technological progress, is definitely entangled with social dynamics that give rise to profound ramifications for the world we inhabit.

The journey to the digital age, even though short as a time-frame, constitutes a narrative of ceaseless innovation and interconnectedness, a peak of human ingenuity and adaptability. In its nascent stages, the internet was an experiment in communication, linking disparate nodes across a scarce digital landscape. However, the internet's transformative journey has proven to be a captivating tale of exponential growth and evolution. The connectivity that it engendered transcended geographical boundaries, rendering the planet to a community where information flowed continuously, blurring the borders between cultures, languages, and ideologies.

But we must acknowledge the fact that the internet's evolution cannot be encapsulated by technological progress alone. The paradigm shift that the world witnessed is equally underpinned by intricate interplays of linguistic, social, economic, and cultural factors. The convergence of communication technology with societal aspirations paved the way for the information society to flourish. As individuals and

communities embraced digital platforms, new dimensions of identity, expression, and interaction unfolded. The rise of social media platforms, online marketplaces, and virtual communities reshaped not only how we communicate and consume, but also how we perceive ourselves and others in the realm of cyberspace.

In this landscape of profound change, country code top-level domains (ccTLDs) have emerged as pivotal players in shaping the contours of the digital society. These specialized domain extensions, denoting specific countries or territories, have evolved beyond mere technical identifiers to embody national identities and digital presence.

The cctld domain extensions are assigned to a specific country, state, or territory based on their respective ISO country code. ccTLDs serve as a powerful indicator to both search engines and users, demonstrating that the content of a website is specifically tailored for a particular country or region. It's important to note that ccTLDs are designed to target geographic locations, rather than a specific language. The importance of ccTLDs as a driving force for the current digital society lies in their ability to facilitate local connectivity within the global expanse of the internet. These domains foster a sense of belonging, enabling individuals, businesses, and institutions to craft a distinct online identity that resonates with their geographical origins.

Initially considered mere markers for computer networks, country code domains have evolved into symbols reflecting national cultures, identities, and priorities [1]. The role of ccTLDs extends beyond cultural representation; it encompasses economic empowerment, digital sovereignty, and inclusive participation. As digital platforms become integral to governance, business and communication, ccTLDs provide nations with the means to assert their presence in the digital sphere, driving economic growth and fostering innovation. Furthermore, they play a crucial role in ensuring digital accessibility and inclusivity. By promoting local language usage and tailoring online experiences to regional contexts, ccTLDs empower diverse populations to engage with the digital realm on their terms.

Amidst the dynamic landscape of the information society, where global interconnectedness and digital innovation converge, in Romania the .ro domains constituted a pillar into shaping the nation's digital trajectory. Romania has a distinctive .ro domain extension, and its case offers a vivid illustration of how ccTLDs can play an indispensable role in drawing the contours of the country's information society.

As the internet surged forth as a transformative force, Romania too embarked on a journey of digital exploration. The adoption of the .ro domain extension marked a pivotal moment in this narrative, signifying Romania's digital entry point onto the global stage. Beyond being a mere alphanumeric sequence, .ro domains encapsulate a nation's virtual identity, becoming the digital facades through which, the world perceives and interacts with Romania.

In the context of Romania's information society, .ro domains have catalyzed multifaceted developments reverberating across various dimensions of society. At the heart of this impact lies the establishment of a distinct digital presence that encapsulates Romania's cultural heritage, entrepreneurial spirit, and intellectual endeavors.

With the .ro domain extension as a canvas, individuals, businesses, and institutions craft narratives that echo the nation's history, achievements, and aspirations. These domains are the keystones of Romania's virtual identity, narrating stories of innovation, creativity, and resilience.

In a transition period, shortly after the fall of the communism, .ro domains have emerged as enablers of economic growth and digital empowerment. Now, in an era where public services, e-commerce and online transactions are defining the commercial landscape, the .ro extension constitutes a trusted emblem that signals reliability and authenticity. Local businesses that harness .RO domains position themselves within a global marketplace, leveraging the domain's association with Romanian culture and values. This not only fosters consumer trust but also reinforces a sense of economic self-determination—a pivotal facet of Romania's evolving information society.

Furthermore, the evolution of Romania's .RO domains has catalyzed a culture of digital innovation and self-expression. Individuals and communities have harnessed the power of these domains to construct digital narratives that challenge conventions, ignite conversations, and drive change. Whether through blogs, online forums, or artistic platforms, .RO domains serve as the foundation upon which the nation's digital creators articulate their visions and contribute to the vibrant tapestry of the information society.

6.2 The Internet and Domain Names

The virtual realm that has become an integral facet of contemporary existence, known colloquially as the World Wide Web (WWW), operates as a global conduit for information exchange across the expansive network of the Internet. The inception of this transformative phenomenon traces back to the year 1991, when Tim Berners-Lee, in his capacity at CERN, laid the foundational framework for the HyperText Transfer Protocol (HTTP) and web servers. This pioneering effort catalyzed the evolution of what we now recognize as the interconnected digital tapestry we navigate daily.

The intricacies of this interconnected expanse materialize through a series of intricate processes. The engagement with the online ecosystem is initiated through the invocation of requests, facilitated by the Domain Name System (DNS). This pivotal system takes on the responsibility of three distinct yet interwoven aspects: first, it assigns unique and discernible name and numerical markers to each online resource, lending coherence to the otherwise vast and sprawling digital landscape. Second, it orchestrates a distributed technological ecosystem, encompassing servers, databases, nodes, and transport protocols, all harmonizing to orchestrate the symphony of online interactions. And third, it encompasses the oversight of governing institutions charged with the administration and maintenance of this multifaceted domain name system.

The Internet has consistently been under governance, albeit not in the conventional way of nation-state governance, given its no-border capacity. Instead, it involves

coordination and control across borders, dispersed among various entities such as the private sector, established governmental bodies, emerging global institutions, and occasionally, even citizens themselves.

The governance of the Internet constitutes now a pressing geopolitical issue, moving from a technical concern confined to a specialized community to a significant topic on governments' policy agendas. This heightened interest in Internet administration is generated by the increased significance of the digital economy. Most, if not all, industries rely on the Internet for operation, with digital trade accounting for trillions of dollars annually. Internet policies deeply impact individual civil liberties and shape political discussions, particularly concerning elections [2].

While humans find domain names easy to remember, computers lack the same understanding of these catchy labels. Instead, they must convert these names into numeric addresses to access the requested information. This translation process led to the creation of the Domain Name System (DNS), designed as a hierarchical structure resembling a pyramid. To decipher a domain name, a computer initiates a query with the lowest name server in the hierarchy. If no answer is obtained, the computer ascends the hierarchy, continuing until it eventually finds success [1]. At the pinnacle of this hierarchy stand the root zone servers, pivotal in identifying the name servers housing root zone files for all top-level domains.

Root servers stand as indispensable elements of the Internet's infrastructure. The functioning of web browsers and various other online tools hinges on their operation. While there still is a misconception that only 13 root servers exist prevails, reality paints a different picture. The number of server instances is much larger, more than 600, there are indeed only 13 IP addresses allocated for querying distinct root server networks [3]. The original DNS architecture's limitations dictated this count—initially, a single server occupied each of the 13 IP addresses, mostly concentrated in the United States.

The Domain Name System's administration follows a hierarchical model with distinct managed sections, or "zones," and the root zone standing on top of the hierarchy. Root servers are the DNS nameservers within the root zone, equipped to handle queries for records stored within the root zone itself. They can also guide other inquiries towards the appropriate Top Level Domain (TLD) server. TLD servers, one tier beneath root servers in the DNS hierarchy, play a crucial role in resolving DNS queries.

When a user inputs a web address into their browser, it triggers a DNS lookup. This process originates at the root zone during an uncached DNS query. The lookup then traverses down the DNS system hierarchy, encountering TLD servers, specific domain servers, and potentially subdomain servers. Ultimately, it connects with the authoritative nameserver for the correct domain, housing the numeric IP address of the desired website. This IP address is then sent back to the user. Remarkably, despite the multiple steps involved, this process occurs swiftly.

6.3 RoTLD—Romanian Top-Level Domain

Despite widespread awareness among the populace that ".ro" signifies the Romanian Top-Level Domain (TLD), knowledge regarding the organizational structure of these domains and the governance of the country code TLDs (ccTLDs) remains limited. The stewardship of the ".ro" domain falls under the purview of the National Institute for Research and Development in Informatics (ICI Bucharest). As indicated by its designation, ICI Bucharest is dedicated to national research.

From the decade spanning 1980–1989, Romania grappled with a significant technological divide. The dissemination of technical and scientific information was markedly hampered by prohibitions on public institutions against subscribing to foreign research and development publications.

Technological isolation was breached in December 1992 when ICI Bucharest established its inaugural online connection with Vienna University, employing the TCP/IP protocol. Subsequently, on February 26, 1993, ".RO" domains were activated within Romania, facilitating services across various protocols, including telnet, ftp, gopher, wais, netfind, and www [4, 5].

The spread of the internet has ushered in noteworthy transformations in Romanian society. This emerging connectedness has propelled individuals into a global citizenship, enhancing their understanding of digital rights and the potential benefits of the digital world. The internet has become a foundational infrastructure for the development of novel products and services, contributing to economic development and the refinement of processes in various domains, such as business-to-business, as well as government interactions with businesses and individuals.

ICANN, the Internet Corporation for Assigned Names and Numbers, is a nonprofit public entity with a global membership dedicated to the secure, stable, and unified management of the internet. ICANN fosters competition and crafts policies regarding Internet Unique Identifiers. Its involvement in managing the DNS significantly influences the growth and progression of the internet.

To communicate with someone over the Internet, you have to input a distinct address into your computer—either a name or a numerical identifier. This address must be unique to ensure that computers can locate each other. ICANN is the entity that synchronizes these unique identifiers globally. Without such synchronization, a universal Internet would not exist.

In more technical language, ICANN assists in orchestrating the duties of the IANA—Internet Assigned Numbers Authority. These duties are critical technical services that are fundamental to the ongoing functionality of the Internet and the Domain Name System (DNS).

Originating in the 1970s, IANA stands as one of the Internet's longstanding regulatory bodies. Currently, these services are carried out by Public Technical Identifiers (PTI), a specialized entity formed to perform IANA's functions for the community. PTI is affiliated with ICANN, which is a non-profit organization internationally constituted by the Internet community to manage various key responsibilities. PTI is tasked with the operational roles of coordinating Internet Unique Identifiers and

upholding the community's trust by delivering these services in a neutral, responsible, and efficient manner [6, 7].

At the national level, on February 26, 1993, ICI Bucharest has registered with IANA the top-level addressing domain (TLD) ".ro" in the Internet (Fig. 6.1), thus creating its own identity of Romania in the Internet addressing space.

Although IP addresses were assigned to users from Romania and the ".ro" domain was registered with IANA, Internet connectivity for Romania was only possible at European level, users from Romania did not have Internet connectivity with America, the reason being that the National Science Foundation from The USA did not allow the routing of addresses for Romania and Bulgaria due to the restrictions imposed by COCOM for the countries that had been part of the communist group. Following the steps taken by ICI Bucharest through the University of Vienna on April 16, 1993 reclassified the country codes RO (Romania) and BG (Bulgaria) in the state W (favored nations), the NSFNET network immediately allows traffic routing for Romania and Bulgaria. As a result, April 16, 1993 is the date from which Romania

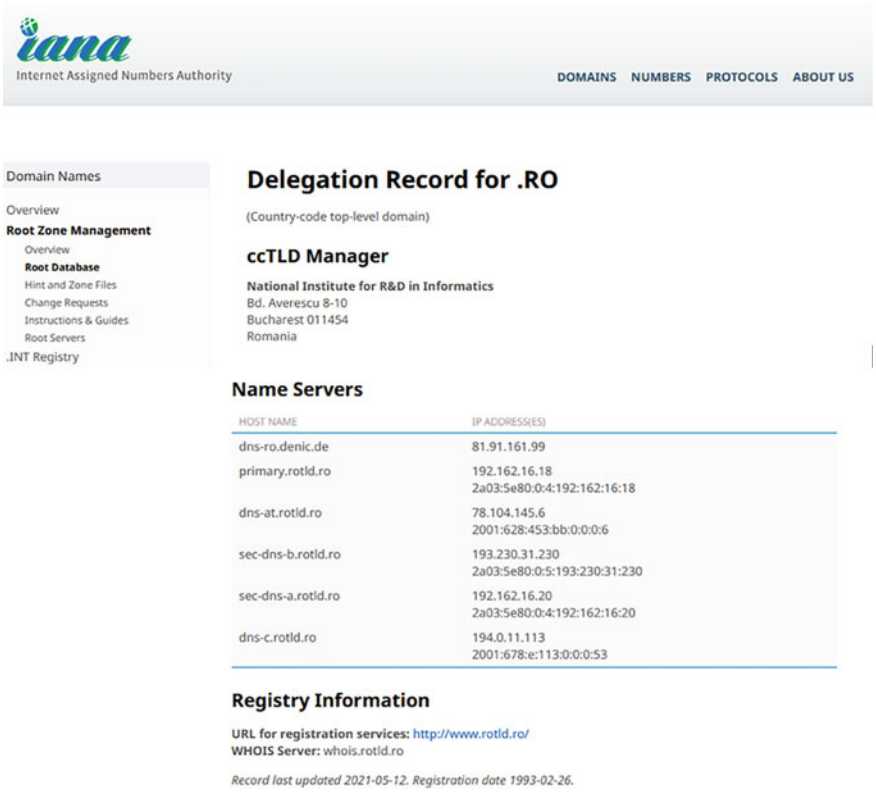

Fig. 6.1 IANA registration of the top-level addressing domain (TLD) ".ro". *Source* https://www.iana.org/domains/root/db/ro.html

has full Internet connectivity with America, and through America with the whole world [6].

The system for distributing Internet number resources, such as IP addresses and AS numbers, operates on a global scale and is structured as a hierarchical registry. This system has undergone significant developments and refinements over the past 20 years. It is designed to allocate these critical digital assets in an organized and scalable manner, ensuring that the growing demands of the Internet are met efficiently and with foresight for future expansion.

Figure 6.2 delineates the hierarchical framework for the distribution of Internet number resources, commencing at the apex with the Internet Assigned Numbers Authority (IANA). From IANA, these resources are disseminated to a quintet of Regional Internet Registries (RIRs): AFRINIC, APNIC, ARIN, LACNIC, and RIPE NCC. Each RIR then allocates these resources to its constituent members, which are Local Internet Registries (LIRs). Notably, within the APNIC structure, which services the Asia Pacific region, there exists an additional layer comprising National Internet Registries (NIRs). These NIRs further partition and distribute resources to their own members, thereby completing the distribution chain from global authority to national and local entities.

Presently, there are five RIRs, each serving a specific region:

- AFRINIC, or the African Network Information Center, established in 2005, administers resources for the African continent.
- APNIC, known as the Asia-Pacific Network Information Center, was established in 1993 and caters to the Asia Pacific region.
- ARIN, the American Registry for Internet Numbers, founded in 1997, is the governing body for Internet number resources in North America.

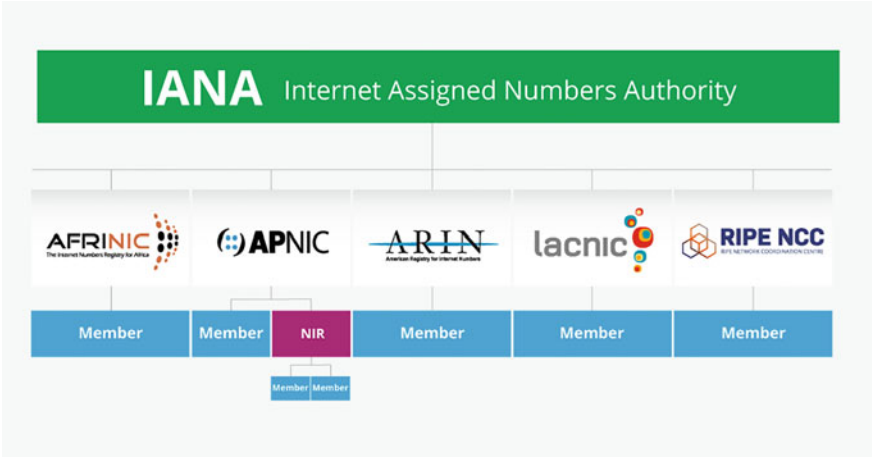

Fig. 6.2 Global structure of the registries' system. *Source* https://www.ripe.net/participate/internet-governance/internet-technical-community/the-rir-system/IRstructurediagram_2014.png

Fig. 6.3 RIR—Regional internet registries. *Source* https://www.ripe.net/participate/internet-governance/internet-technical-community/the-rir-system/RIPENCCServiceRegionMAP_April201402.jpg

- LACNIC, the Internet Addresses Registry for Latin America and the Caribbean, began its operations in 2001 and is in charge of South America and the Caribbean regions.
- RIPE NCC, the Réseaux IP Européens Network Coordination Center, was established in 1992 and serves Europe, Central Asia, and the Middle East (Fig. 3).

Local Internet Registries are entities that function under the jurisdiction of Regional Internet Registries and are typically managed by Internet Service Providers (ISPs). These ISPs further allocate IP resources to their customers. Additionally, various enterprises or institutions may fulfill the role of an LIR. ICI Bucharest gained recognition as an LIR in 1992, distinguishing itself as the inaugural registry of its kind in Romania, responsible for the distribution of IP addresses and the assignment of AS numbers. The list of Local Internet Registries (LIR) that offer services in Romania is available at https://www.ripe.net/membership/indices/RO.html [8].

Considering the trend that exists worldwide and ICANN's recommendations regarding the introduction of global competition in domain name registration, partnerships were established in January 2001 with other companies ("registrar" in ICANN terminology), especially ISPs, but also with other organizations interested in providing services for the registration of .ro domains, in order to develop a shared RO registry. "Shared registry" does not contradict the single registry principle. The registry is unique, but direct access is provided to registrars for domain registration services.

The registrars' access to the domain registration and administration system is through the EPP (Extensible Provisioning Protocol) and REST protocol.

A system of registration and annual maintenance is a necessary requirement to align ".ro" domains with policies adopted by all countries in the world. In Europe,

gradually, all countries have switched to time-limited domain registration country code and renewal if the applicant wishes to continue using the domain name.

Also, the annual registration and maintenance system has the advantage of leading to the unblocking of ".ro" domain names that were registered in approximately 25 years of existence of the ".ro" domain and which are currently no longer used, either the companies that requested them have disappeared, or the person who requested them no longer needs those names at present.

The .ro domain, representing Romania on the internet, was previously registered for an indefinite period. This meant that once registered, a .ro domain would remain under the ownership of the registrant without the need for annual renewal fees. This system differed from international practices and created challenges in maintaining domain infrastructure and managing domain name dispute.

In this regard, on March 1, 2018, RoTLD implemented the registration and annual maintenance system for ".ro" domains. They will be registered or renewed for a limited period of time, minimum 1 year and maximum 10 years. This change was prompted by the need to align with European and international standards, where annual pricing had long been established practice. In addition to achieving alignment, this transition had the effect of releasing a substantial number of dormant domains, previously untouched due to the absence of a maintenance fee.

The transition to annual pricing had practical implications for domain owners, registrars, and RoTLD itself. Registrants must now manage annual payments to maintain their domains, increasing the commitment and responsibility associated with .ro domains. Registrars and RoTLD must implement systems for processing annual renewals, creating new revenue streams and ensuring the continued operation of the domain registry. A notable benefit of annual pricing was the revival of abandoned domains. Previously, many domains had been left unused because there was no requirement for an annual maintenance fee, and registrants had no incentive to release them. With the new pricing model, unused domains were released back into circulation, providing opportunities for new registrants and potentially stimulating the domain market.

As the Registry for the .ro domain, ICI Bucharest works with Registrars from all over the world that offer domain names with .ro extension to the end-users. Administering the registrations, ICI is the "data controller" for the registration data of domain name holders. Its Partners process the registration data of the domain names' holders, on ICI behalf, being "authorised by the data processor" for this activity [9].

The introduction of annual pricing for .ro domains in 2018 marked a significant shift in Romania's domain registration system, aligning it with European and international standards. This transition had legal and practical implications, including the creation of a contractual relationship between domain registrants and RoTLD and the revival of abandoned domains. Ongoing transformations in Romania's domain name industry necessitate persistent scrutiny to comprehend their effects as the domain name marketplace progresses. RoTLD has bolstered its security protocols, resulting in a reduction in system-wide susceptibility. The deployment of DNS Security Extensions (DNSSEC) aims to fortify the system, with all users being encouraged to adopt

this added layer of protection. DNSSEC uses asymmetric crypto algorithms. Through the usage of DNSSEC, all recordings of a domain from the DNS zone are digitally signed and published aside these signatures. The public crypto keys are distributed as well by using the DNS system. The Client (resolver) that validates the DNSSEC data, uses the root server's public key that is considered to be secure and follows through all the DNS levels for the name's chain authentication. Every domain signed with DNSSEC must have at parent a DS (Delegation Signer) type record so that a client that resolves the name to be able to verify the trust chain [10].

6.4 Digital Transformation in Romania

It could be suggested that the information society is fundamentally a society built upon information, yet this description scarcely captures the essence of our contemporary societal structure.

Tracing back to the 1970s, the seeds of today's information society were sown with the advent of IT concepts and products that sparked a wave of informational ideologies and movements. The technological revolution began with the invention of the microprocessor, leading to the gradual acceptance of the information society concept, which solidified with the internet boom—its principal driving force.

In Romania, the turn of the 21st century still saw the construction of the information society as an expansive, intricate, and protracted endeavor, with its foundations lying in technology, finance, economy, society, and culture. Innovations have made it clear that nations intent on progress cannot afford to delay, and Romania, being part of the EU and NATO, must promptly address the demands set forth by European and international advancements.

The digital transformation of societies encompasses a wide range of changes in the way individuals, businesses, and governments leverage digital technologies to enhance productivity, connectivity, and overall quality of life. Romania, like many other countries, has embarked on a transformative journey towards becoming a digitally advanced nation.

The digital landscape in Romania has seen significant improvements over the past decades. These have had a positive impact on various sectors, including the economy, education, healthcare, and public services. Romania's digital transformation has made it more competitive on the global stage and has created new opportunities for businesses and individuals in the digital sphere. The availability of high-speed internet has expanded significantly in Romania, reaching more remote and rural areas, was a two-way benefit—access to content generated an increased need for new and improved content, better websites, better digital services provided by government and public administration. This increased connectivity has facilitated greater access to online services and information.

6.4.1 Developments in Digital Evolution

In recent decades, Romania has made significant strides in embracing digital technologies, driven by a combination of factors, including government initiatives, private sector investments, and growing internet penetration. The country's digital evolution has been marked by several notable developments:

- Internet Penetration—Romania boasts a high rate of internet penetration, which is a fundamental precursor to digital transformation. According to data from the World Bank, internet usage in Romania has steadily increased over the years, with a growing number of citizens gaining access to the digital realm. The widespread availability of the internet has been instrumental in expanding opportunities for communication, e-commerce, and online education.
- E-Governance Initiatives—The Romanian government has undertaken several e-governance initiatives aimed at enhancing public service delivery, transparency, and efficiency. These initiatives have included the digitization of administrative processes, online citizen services, and the introduction of electronic identification systems. The digitalization of government services has not only streamlined interactions between citizens and the state but has also set the stage for more robust digital transformation across various sectors.
- Business and Innovation—The business landscape in Romania has witnessed a surge in digital innovation. Startups and established companies alike have embraced digital solutions to improve operations, enhance customer experiences, and create new market opportunities. The growing ecosystem of tech startups and innovation hubs in cities like Bucharest has played a pivotal role in driving economic growth and technological advancement.

6.4.2 Key Aspects of .RO Domains in the National Digital Landscape

Thanks to digital technology's rapid advancement, data is now at our fingertips more than ever before. It's become straightforward to gather, scrutinize, and make sense of information in ways that were once complex and time-consuming [11]. At the heart of Romania's digital evolution is the influence of .RO domains in crafting the country's digital terrain. Serving as Romania's country code top-level domain (ccTLD), .RO domains have been instrumental not just in establishing an online identity for Romanian bodies but also in driving digitalization throughout different industries. The significance of .RO domains can be observed through several key aspects:

- National Identity and Branding—The .RO domain extension is a symbol of Romania's online identity and a powerful branding tool. It serves as a digital representation of the country, fostering a sense of national pride and facilitating the

online recognition of Romanian entities, whether they are businesses, educational institutions, or government agencies.

- Trust and Credibility—Domain extensions play a critical role in establishing trust and credibility in the online world. A website with a .RO domain instills confidence in users, indicating that the entity is registered and operates within Romania. This trust factor is especially important for e-commerce, where consumers seek assurance in their online transactions.
- Encouraging Local Innovation—The adoption of .RO domains has spurred local innovation in web development, online services, and digital marketing. Romanian businesses have been incentivized to build a strong online presence, leading to the development of e-commerce platforms, content management systems, and other digital tools that support local and international consumers.
- Digital Inclusion—The availability of .RO domains has contributed to digital inclusion, allowing a broader range of individuals, businesses, and organizations to establish their online presence. As a result, smaller enterprises, community organizations, and individuals have been empowered to participate in the digital economy and connect with a global audience.

In the 2022 Digital Economy and Society Index (DESI), Romania is positioned at the bottom, ranking 27th out of the 27 EU Member States. It falls behind in various aspects of the human capital dimension, notably in the area of basic digital skills where it is well below the EU average. However, Romania stands out for the high percentage of women working as ICT specialists (where it ranks 2nd) and the number of ICT graduates (ranking 4th). To meet the EU's Digital Decade objectives for basic digital skills and ICT specialists, Romania needs to significantly accelerate the development of its digital skills.

On the connectivity front, Romania fares much better, marking its highest scores in this category. With 57% of households adopting fixed broadband at speeds of at least 100 Mbps and 87% coverage by fixed very high-capacity networks, Romania exceeds the EU average. This progress is key to achieving the Digital Decade goal of full gigabit network coverage for all households by 2030.

However, when it comes to integrating digital technology and providing digital public services, Romania's performance is notably weak in comparison to other EU countries. Only 22% of SMEs show a basic level of digital interaction, and just 17% of enterprises exchange information electronically, the lowest in the EU. The general level of digital adoption is low, and progress is slow, hindering the Romanian economy from fully leveraging the benefits of digital technologies. This situation is exacerbated by the very low provision of digital public services for both citizens and businesses [12].

The Recovery and Resilience Plan of Romania aims to tackle the country's digital gaps by allocating EUR 5.97 billion, which represents 20.5% of Romania's total funds, towards digital initiatives. The most considerable portion of this funding is dedicated to the seventh component (Digital transformation), although digital measures are included in all components.

The official internet domain name of the Government of Romania is GOV.RO. The registry for GOV.RO subdomains is governed by Government Decision no. 1480/2008. This policy outlines the terms for usage and the establishment of a .GOV.RO internet subdomain within the public administration [13]. This domain name has been operational for over twenty years and hosts the Government's website.

The Romanian government has taken steps to digitize its services, making it easier for citizens to interact with public institutions online. This includes services related to tax payments, business registration, and more. An example of successful transformation, related to .ro domains, was the partnership between ICI and the platform *ghiseul.ro*, a specialized public platform for online payment of taxes. Through this, the payments for .ro domain fees could be online. In 2016, ICI was awarded "Best online Collector of Taxes and Duties" prize from ghiseul .ro [14].

As acknowledgement of the importance of the domain names, the new NIS2 (Network and Information Systems) Directive, also known as the NIS2 Regulation that has the goal to enhance the overall cybersecurity of the European Union (EU) by establishing a framework for the protection of critical infrastructure and digital services. The new Directive recognizes the ccTLDs as essential services [15]. Therefore, Ensuring the reliability, resilience, and security of the domain name system (DNS) is crucial for safeguarding the internet's integrity, which is indispensable for the ongoing stability of the digital economy and society. Thus, this Directive ought to apply to registries of top-level domains (TLDs) and providers of DNS services. These entities should be seen as organizations delivering recursive domain name resolution services to the general public, which allows internet end-users, or providing authoritative domain name resolution services that third parties can use.

In the realm of domain management, RoTLD has implemented a proactive policy for validating domain holder information. This approach includes procedures for conducting random data checks, ensuring that registrants maintain accurate and up-to-date details for their .ro domains. This proactive stance reflects RoTLD's commitment to enhancing the integrity of the .RO domain ecosystem.

6.4.3 Challenges in the Covid-19 Pandemic

The onset of the coronavirus pandemic ushered in a new era of digital communication, transforming the ways societies and individuals interact. The pandemic underscored the heightened role of online networks in our everyday lives, illustrating that the digital domain reflects not only our social interactions but also our cultural, environmental, and material concerns. The digital landscape became a lifeline for remote work, education, healthcare, and social connections, reinforcing its centrality in our contemporary world [16]. Yet, alongside these benefits, the pandemic also exposed a pressing issue—the proliferation of disinformation. Disinformation has emerged as a significant social problem with the capacity to capture considerable political and public attention.

The impact of .RO domains on the field of education has been substantial. Academic institutions have adopted .RO domains to establish their online presence and deliver educational content. The online education sector has witnessed a surge, particularly during the COVID-19 pandemic, and .RO domains have been instrumental in enabling seamless transitions to remote learning. This section explores how .RO domains have been used by educational institutions to reach students, enhance the e-learning experience, and provide crucial resources to learners.

The era of digital technology, while providing unparalleled levels of connectivity and access to information, also presents new challenges such as the swift dissemination of inaccurate or deceptive information. This situation highlights the critical need for diligence in upholding the accuracy of information in the digital realm and in tackling the spread of misinformation and disinformation online. RoTLD has actively addressed any incidents that have arisen, and has worked in conjunction with relevant authorities to counteract misinformation.

RoTLD remains committed to preserving the integrity and security it has built over the years. The organization consistently ensures that the software it utilizes is rigorously tested for vulnerabilities, and continues to invest in advanced network infrastructure to maintain robust security. In the post-pandemic era, it is clear that the interplay between proactive domain management policies, the role of digital communication, and the challenge of disinformation is a complex and evolving landscape. It is incumbent upon all stakeholders, from domain registrants to regulatory bodies, to adapt and respond to these dynamics as we navigate the digital future.

6.5 Conclusions

As the digital sphere continues to expand, language and accessibility remain paramount considerations and the .ro domains shine as torchbearers in this aspect, fostering linguistic inclusivity and regional representation. By encouraging the use of the Romanian language in web addresses, we not only cater to the local population but also foster a sense of belonging within the broader Romanian diaspora, contributing to an information society that transcends geographic boundaries, nurturing connections that extend far beyond the nation's physical borders. From cultural representation and economic empowerment to linguistic inclusivity and creative expression, .ro domains exemplify the dynamic interplay between technological advancement and societal transformation. As Romania navigates the complexities of the digital age, its .ro domains stand as testaments to the nation's resilience, ingenuity, and enduring presence in the digital transformation landscape.

.RO domains have become a vital component of Romania's digital transformation. They serve as a symbol of national identity, foster trust, stimulate innovation, and promote digital inclusion. This research paper has explored the profound influence of .RO domains in facilitating and accelerating digital transformation in Romania. The study delved into the evolution of digital society in Romania and some

of the specific challenges and contributions of .RO domains across various sectors, including business, education, e-governance, and social connectivity.

RoTLD, the National registry for Romanian Top-Level Domains, is acting towards respecting the principle of freedom of expression in Internet and universal access to information and knowledge as basic premises of a knowledge society.

The digital presence of entities with .RO domains has been associated with trust and credibility. Users have come to recognize .RO websites as authentic and reliable sources of information and services. This has been particularly important for e-commerce, where trust is a pivotal factor influencing online transactions. The paper also addresses the positive impact of .RO domains on e-governance and public service delivery. Government agencies that have embraced .RO domains have enhanced their online presence, making it easier for citizens to access information and services. The digitalization of government services has not only increased transparency but has also streamlined administrative processes.

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Chapter 7
Digital Transformation of Teaching and Learning in Environmental Engineering for a Sustainable Education

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Abstract The higher education system is currently facing both opportunities and challenges because of digital transformation, or the use of different types of technology by both teachers and students. Digital transformation is crucial for many different fields and university study programs, including the field of engineering, because it produces effective solutions capable of improving the design processes of many innovative products in the educational field and resolving a variety of issues. Tomorrow's engineers, as well as the engineers of today, need to be able to handle the current challenges like climate change and global health that are on the United Nations' list of priorities. Benefits that digital transformation brings to higher education systems include the simple distribution of instructional materials, collaborative learning, fostering students' creativity, more effective use of time, and cost savings. Utilizing data in real-time and the acceleration of industrial activities supported by the digital transformation have had a significant impact on engineering, having a real

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L-I. Cioca et al. (eds.), *Digital Transformation*, Intelligent Systems Reference Library 253, https://doi.org/10.1007/978-3-031-55952-5_7

contribution in building a more sustainable future and ensuring a better understanding for managing different environmental issues. Accordingly, the main objective of the current work is to emphasize the significance of digital tools for improving sustainable education in environmental engineering, as well as the impact of digitalization on environmental engineering.

Keywords Digitalization · Higher education · Engineering · Sustainability · Environment · Learning · Smart tools · Information and Communication Technology

7.1 Introduction

Digital transformation involves the use of technological innovations that allow improvement across economic sectors. Simultaneously, the increasing use of ICT (Information and Communications Technologies) has generated and continues to lead to changes in education. Ever since the second decade of the twenty-first century, higher education institutions have had the responsibility of developing a new action plan for incorporating technology into learning environments [1]. The Covid-19 outbreak accelerated digitalization and the use of technologies like video conferencing, streaming, and online collaboration portals, and students can take courses remotely without having to interact in person [2]. Nowadays, different digital tools have been implemented in the educational system, such as the internet of things (IoT), Artificial Intelligence (AI), cloud computing, which have led to environmental, social, and political changes [3]. However, they are still analyzed at a micro level, with universities having to invest more time in digitalization development [4].

The main beneficiaries of the digital technologies within the educational sector are students and professors because they have been subjected to many different changes in society, especially during the spread of the SARS-COV-2 virus [5, 6]. However, sustainable development depends also on technological transformation and is influenced by the level of knowledge at present time, the conceptual model, and the measurement of the accumulated impact [7].

From different perspectives, the adoption of digital technology in educational institutions (as universities) is seen as necessary. First, the numerous technologies used in higher education institutions lower the risk of student dropout, make it easier to distribute educational resources, and enable access to information both in-person and remotely [8]. Students can simultaneously develop the skills necessary for future employment trends, including critical thinking, creativity, and innovative thinking [9].

Furthermore, to create a sustainable future, higher education systems are providing funding for the conception and execution of clean technologies, also referred to as green technologies [10]. Additionally, students learn how to minimize their negative environmental impact by addressing climate change, increasing energy efficiency, and finding more effective waste management techniques [11].

Fig. 7.1 The 17 sustainable development goals [13]

According to the 2030 Agenda of the United Nations, universities are essential to accomplishing the Sustainable Development Goals (SDGs) (Fig. 7.1), which bring important benefits to higher education system, such as expanding the fields of training, research, and innovation [12]. Moreover, it offers universities the opportunity to form close ties with the government and various industrial sectors [13]. According to the Barcelona declaration [14], engineering education with the support of universities must be able to fulfill several tasks, such as:

- promoting multidisciplinary work
- stimulation of creativity and critical thinking
- the incorporation of humanities disciplines
- increasing interest in the problems related to globalization
- highlighting the importance of a holistic approach
- encouraging self-learning
- integration of values, skills, and knowledge in teaching [14].

Therefore, the current work aims to provide an overview of different existing tools that are used in higher education and how they contribute to sustainable development. There is also a focus on how digital transformation influences environmental engineering.

7.2 Digital Transformation for a Sustainable Development

In accordance with sustainable management, digital transformation is considered the fourth industrial revolution that involves beneficial changes for society, such as easier access to medical care services, reduction of energy consumption, modernization of transport systems, and optimization of production processes [15]. Corporate Social Responsibility (CSR) is based on three pillars (environmental, economic, and social) (Fig. 7.2) that integrate into the Triple Bottom Line (TBL) [16]. The triple bottom line is a strategy designed to progressively analyze the social, financial, and environmental performance of a business. Applying the principles of sustainable development to different projects using the sustainability indicators can help companies minimize their risks, reduce their expenses, and achieve their goals, the project manager being the person responsible for identifying changes and errors that may appear throughout the project [17]. Higher education institutions have recently supported various businesses with their digital transformation by developing tools to support sustainability on a global scale. For example, the Ohio State University researchers have developed a series of control algorithms for their implementation in hybrid electric car prototypes. When the driving cycle was known, the offline optimization process was utilized to find the global optimum using the "Equivalent Consumption Minimization Strategy" (ECMS) local optimization method. At the same time, optimal adaptive strategies (AECMS) could be designed with this method to achieve almost adequate results in situations where the drive cycle is unknown [18].

Also, a series of CSR standards were developed, which are recognized at the international level and aim to prevent failures in organizations. This category includes the following standards: Social Accountability 8000 (SA 8000), Eco-Management and Audit Scheme (EMAS), UN Global Compact, ISO 26000, Global Sullivan Principles, GRI Guidelines, and Organization for Economic Cooperation and Development (OECD) Guidelines for Multinational Enterprises. One of the most used standards currently is ISO 26000 [16]. The ISO 26000 standard helps organizations contribute to sustainable development by providing guidance on how to integrate socially responsible behavior [16] to be able to understand what is meant by corporate sustainability and social responsibility [19].

Considering the circular economy's fundamentals, digitalization brings to the fore digital technologies aimed at increasing resource efficiency [20, 21]. Many universities across the world have started actively participating in achieving the Sustainable Development Goals, implementing a range of study programs to stimulate critical and analytical thinking in students. Some examples of areas on which different study programs of universities focused are the following: agriculture and food, climate and environment, energy efficiency, and infrastructure planning [11].

The study program agriculture and food enable students to obtain the knowledge and abilities needed to address the sustainability issues of agricultural systems by developing knowledge about the principles of sustainable agriculture, smart farm management, and food safety control [11]. Rapid population growth has led to increased demand for food, fiber, and feed. Consequently, nanotechnology is arising

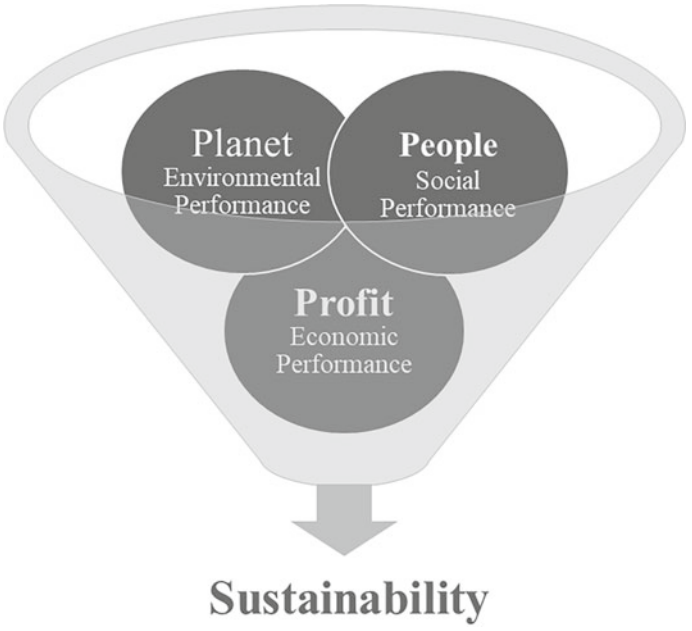

Fig. 7.2 The elements of the triple bottom line [7]

as one of the most innovative technologies to transform the food and agri-food industries. Nanotechnology supports the development of urban agriculture and improves the food products' safety and quality by reducing the use of pesticides and preservatives, improving the genetic modification of plants, and improving the level of hygiene in food processing [22]. At the same time, digital technologies such as smartphones, geographic information systems (GIS), and AI enable real-time monitoring of global agriculture [21].

The climate and environment study program aims to prepare students so that they are able to solve global challenges related to the environment, such as climate change [11]. Climate changes are increasing progressively and are caused by the increase in the degree of urbanization, globalization, and the emission of greenhouse gases. To assess the loss of biodiversity and its effects on biogeochemical cycles, global food security, and other climate factors over a long period of time, digitization is critically necessary. The Global Biodiversity Information Facility (GBIF) is an intergovernmental organization that allows access to scientific data on biodiversity through web services. The Internet of Things (IoT) application has contributed to progress the environmental monitoring process, which consists of distribution optimization, field sampling, experimental analysis, and data collection, which allows the connection between sensors to receive data in real time [21].

The energy efficiency study program provides students with the knowledge required to handle concerns related to environmental sustainability and energy,

including accessing renewable energy technologies, or creating a sustainable transportation system [11]. Digitization has been an important factor in energy production and distribution for many years. For instance, modeling is done every day to determine how much electricity is needed given the weather. The use of wind turbines and photovoltaic panels has many benefits, including producing electricity wherever it is needed and reducing costs, but at the same time, existing systems need to be updated to shape the supply of electricity to the grid. When consumers use smart meters, they can avoid using electricity during peak hours. Smart grid-level energy systems can also transmit surplus energy to charge electric vehicles or generate hydrogen [21], which is considered an energy vector. Moreover, proper electricity management promotes energy efficiency, decreases carbon dioxide emissions, and mitigates climate change.

The infrastructure planning study program presents students with the main innovative solutions to achieve a sustainable lifestyle by analyzing urban planning strategies and infrastructure-related challenges [11]. Over time, there have been several changes in the production process of products and services thanks to digital tools, on which the fourth industrial revolution is based. The fourth industrial revolution is concurrently guided by the following directives: improving production quality, reducing waste, and customer orientation. Thus, the key objective of industries is to put into practice a waste management system and transform by-products into finished raw materials (Fig. 7.3). Another rather important aspect to emphasize is the construction of a sustainable infrastructure for the transport of goods, the decrease in greenhouse gas emissions, and the optimization of costs. The smart factory is the basic element needed to achieve the desired results. These factories are an interconnected system of machines through Cyber-Physical Systems (CPS). Cloud computing technology is central to the interconnection of cyber-physical systems, enabling the extraction of data and the identification of answers to be provided by self-organizing systems. This type of factory improves production using virtual manufacturing technologies and conserves energy in the power grids it is connected to manage the energy supply. Additionally, it is needed to highlight how the fifth industrial evolution, which emphasizes the individualized needs of customers, is just starting to emerge [21].

7.3 Using Digital Technologies for Adding Value to Higher Education

Virtual education involves incorporating contemporary technology into the process of teaching and learning [23]. Digital technologies were introduced in the educational field to lower the number of time-consuming activities of the professors, saving energy, and allowing students unlimited access to information, enhancing their interest in learning. Additionally, these tools decrease negative environmental consequences [24]. Among the most used technologies used in higher education are listed:

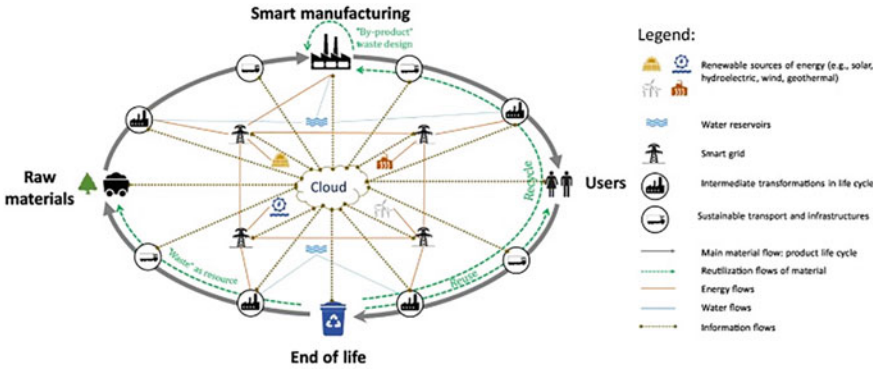

Fig. 7.3 The life cycle of a product [21]

- Cloud Computing
- Artificial Intelligence (AI)
- Internet of Things (IoT)
- Blockchain.

7.3.1 Cloud Computing

Cloud computing represents a system for providing computing services, including servers, applications, and databases (Fig. 7.4). Users aren't asked to have technical knowledge of the distribution infrastructure for these resources [23]. Based on the implementation models, this service has been classified into public cloud, private cloud, community cloud, and hybrid cloud [25].

- *The public cloud* is one of the models that provide services to a larger number of clients using the same shared infrastructure. It also has a low cost, reduces delivery time, and can be owned by educational institutions [25].
- *The private cloud* allows access to resources exclusive to an organization, offering a high level of security when data is shared [23, 25]. Compared to the public cloud, it has certain usage restrictions, which costs more than the public cloud [25].
- *The community cloud* is a type of infrastructure designed to be used by a certain community with common goals [23].
- *The hybrid cloud* represents a combination of the public and private cloud and performs distinct functions within the same organization. It allows the storage of sensitive data and, at the same time, provides high scalability in the public area to cope with the large number of requests. The resources offered by hybrid cloud have low costs [23, 25].

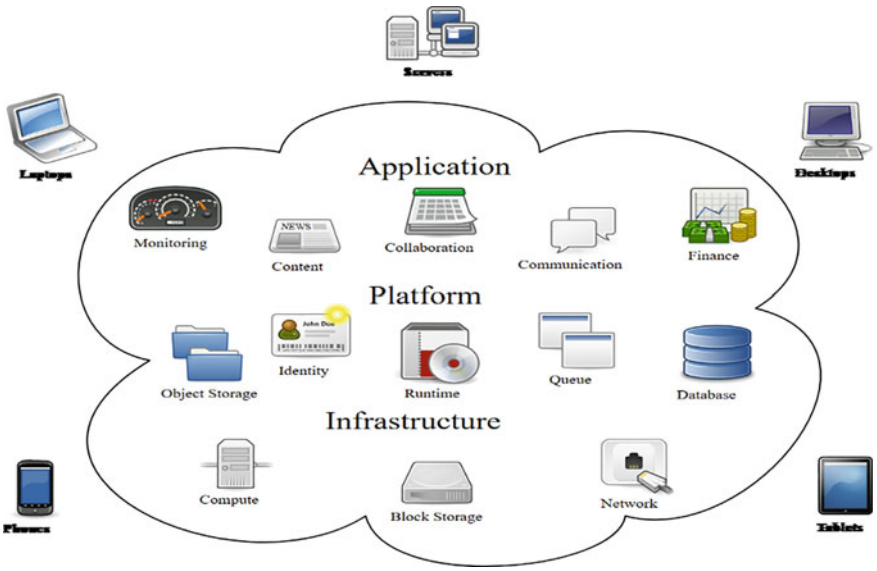

Fig. 7.4 Cloud computing services [26]

The cloud must meet five key attributes, as follows: broad network access, measured service, on-demand self-service, rapid elasticity, and resource pooling. These characteristics allow academic staff, students, and additional stakeholders to access a variety of resources from any device, regardless of location. At the same time, it supports the development of affordable, high-quality education available to all people worldwide. For adopting cloud services, the higher education institutions must have a well-defined strategy, which consists of identifying cloud computing requirements, assessing the effectiveness of this technology in terms of cost and time, and choosing the solution for efficient system migration [26]. For example, in Ethiopian universities, the necessary factors for the adoption of cloud computing services were determined using the TOE-DoI integrated framework ("Technology-Organisation-Environment" and "Diffusion of Innovation") [27].

The integration of cloud computing services in the educational environment brings a series of advantages that can help solve some of the challenges we face today:

- Minimises costs
- Manages large amounts of data efficiently and securely
- Allows universities to develop research infrastructures
- Gives professors the ability to teach in different ways and help students manage projects
- Reduces the carbon footprint
- Helps to quickly procure, provision, and deploy new applications [28].

7.3.2 *Artificial Intelligence*

Artificial intelligence is "*a technology that imitates human intelligence*" to perform certain tasks and improve performance. This consists of natural language processing, image recognition and allows systems to develop based on experiences without explicitly programming them. For instance, the educational application ELSA Speak uses artificial intelligence to help people improve their English-speaking skills. Artificial intelligence's application in the academic environment has progressed at a rapid pace in the past few years, especially during the COVID-19 outbreak, encouraging the digital literacy of both teachers and students. Artificial intelligence also increases student engagement by selecting teaching material based on their interests, personalizes learning processes by identifying the best teaching methods, and allows the professor to monitor student performance [29, 30]. Higher education institutions can use early warning systems to identify students who are in a situation of dropping out of higher education, receiving microloans to complete. Moreover, AI software can observe in real time if students are exposed to certain risk factors or when they were last at the library [31]. However, for the implementation of these systems to be optimal, several aspects must be considered:

- Identifying the needs of students and academic staff
- Evaluation of the impact these systems have on students and the results obtained
- Training users on the shortcomings and benefits of these tools
- Ensuring the protection of students' data [31].

Additionally, understanding how knowledge on AI influences sustainable development is important for students. AI enables the fulfillment of 134 targets for the sustainable development goals. However, to provide an overview of the work of AI, the sustainable development goals have been divided considering the three sustainability pillars and dividing the objectives into economic, environmental, and societal objectives. On the other hand, AI presents certain disadvantages that inhibit the fulfilment of some of its objectives [32]. Some examples of the effects of AI advantages/disadvantages on societal, environmental, and economic goals are presented in the following paragraphs.

Economic Objectives

AI can favor the creation of new products and services, stimulating consumer demand and generating new revenue streams. At the same time, it may widen the gap between developed and developing countries, increasing the demand for workers with certain skills while others are being laid off [33].

Environmental Objectives

AI supports the creation of low-carbon energy systems that drive renewable energy integration and energy efficiency, all of which can help combat climate change. AI can also help prevent marine pollution by automatically detecting oil spills. Despite these

competencies, AI-related ecosystem information can lead to resource exploitation [32].

Societal Objectives

AI has the potential to raise population standards of living by helping to develop smart cities that consider the principles of the circular economy. These smart cities allow the construction of water collection and treatment facilities, the use of photovoltaic and wind systems to produce renewable energy, and the replacement of road transport based on fossil fuels with electric vehicles. At the same time, all these advanced technologies can lead to additional requirements for obtaining a job [32].

7.3.3 Internet of Things

The Internet of Things is a global network that makes it possible to connect various systems, services, and devices to the Internet infrastructure so they can communicate with each other and the outside world. This has three components: hardware, middleware, and presentation, which contribute to the development of energy-efficient wireless systems that can be incorporated into nearly any kind of device [34].

From year to year, there is a growing demand for universities to incorporate digitization into all their activities. A university that fully integrates technology encourages lifelong learning and promotes collaborative research. The digital campus is based on two important components. The first component consists of the end-to-end IT services delivery platform that ensures network connectivity and security for all campus services. Multiple IoT applications are included in the second component that support teaching and learning activities to improve student experiences. IoT applications differ from conventional applications because they prefer to analyse data captured by sensors rather than user data. IoT applications can be applied in several fields [34].

Energy management. IoT sensors allow the use of energy only on demand, reducing both costs and the carbon footprint. Campus security. Security systems based on the Internet of Things use cameras to detect hazards in real time. Student monitoring. A student monitoring system based on the IoT has been developed. Each student received a low energy Bluetooth card to make them easier to identify. Students' health. An Internet of Things (IoT)-based ambient intelligence-assisted health monitoring system (AMIHMS) has been found by researchers. IoT sensors collect data related to students' health, which is then processed to generate accurate measurements of health parameters [35]. At the same time, the IoT helps students share ideas with teachers and peers on various platforms, giving them access to remote educational tools [36]. In addition to the benefits that the IoT can bring to universities, it also presents a series of challenges that include:

Cloud Computing

Many universities use the hybrid cloud to host IoT applications, and it is necessary that the latency time be reduced due to significant growth in audio and video content, the necessity of having operational enterprise networks, and the number of requests for teaching technologies [34].

Security and Privacy

IoT applications collect a large amount of data using technologies such as 4G, 5G, and NFC (near field communication), and universities are urged to develop reliable systems to protect data due to the increasing number of cyber-attacks in recent years. At the same time, the data must be available only to users who identify themselves [34, 35].

Scalability and Reliability

The large volume of data generated by the introduction of IoT applications in the educational system must be analysed to capture the information. Following several studies, a social recommendation system based on parallel computing and Hadoop was developed that offers customized learning materials to students. The services developed by the IoT should be sustainable, but to achieve this, universities must have enough money to purchase and maintain these devices [36, 37].

Ethical Concerns

The IoT provides higher education institutions with applications that support online courses and raise the standard of the research. However, it is also necessary to address ethical issues. Both professors and students need to be trained in all the features of a technology to use it correctly and defend against various frauds. On the other hand, the use of the IoT represents real support for students with special needs. It allows these students to repeat experiments without causing great financial damage [35, 37].

The Funding

Considering the rapid way in which information technology evolves, the constructions for its implementation continue to grow every year. In these circumstances, universities are encouraged to identify effective strategies for financing state-of-the-art technological infrastructure and services [34].

7.3.4 Blockchain

Blockchain is a revolutionary technology used to transmit and store data securely. It can be applied in the medical, banking, financial, and educational fields. Higher education institutions have become users of this technology, as it ensures the transfer of data between them through smart contracts without allowing the falsification or counterfeiting of students' diplomas. Academic results can also be shared securely

between different types of universities, such as in the case of the Erasmus mobility programme. On the other hand, companies show strong resistance to adopting this technology because they cannot accurately verify the skills and qualifications of students when they are recruited for a job. Thus, a modernization of this technology is necessary [38].

Blockchain platforms, such as Khan Academy, Tutellus, Sony Global Education (SGE), and TeachMePlease (TMP), have many significant advantages. Students can save their assignments and projects they worked on one device, and after a longer time, they can improve them using another device. Distributed data storage protects websites and servers against Denial of Service (DoS) attacks. Professors can protect their inventions and patents by saving them in a chain that is highly encrypted. They can only be accessed by authorised users. Also, universities can receive virtual tokens as a reward for the integrity of saved data, which can be used to purchase other educational services [39].

7.4 Tools for Environmental Engineering Education

To evaluate, plan, carry out, and manage environmental projects and solutions, environmental engineers work with a variety of instruments. Some of the best practices for implementing environmental engineering tools in higher education are discussed in the paragraph that follows.

7.4.1 Engineering Sustainability Map

The Engineering Sustainability Map (ESM) is a tool developed with the aim of introducing education for sustainable development in the field of engineering [40]. This map contains the knowledge and skills that every student should possess until the conclusion of the undergraduate programmes [12], being categorized according to four sustainability competencies, which are:

- applying ethical principles
- critically contextualizing knowledge
- using resources sustainably, and
- participating in community processes [41].

The map was designed within the EDINSOST2-SDG project, considering the sustainable development objectives that must be implemented in all engineering programmes. Miller's pyramid, consisting of four steps, was used as a learning strategy: "knowing", "knowing how", "demonstrating", and "doing". The method used to create the sustainable engineering map went through the following steps.

- grouping the workforce into four independent groups (A, B, C and D)

- analysing the 68 learning objectives for sustainable development by group A and their correlation with the learning outcomes obtained in the "EDINSOST1-SDG project"
- rewriting learning outcomes in certain cases
- examination by groups B, C and D of the previously carried out activity.

At the end, the four groups convened to deliberate on the distinctions among the criteria and to formulate the learning objectives. It's also crucial to emphasize that this map is intended to be transversal so that it is accessible to locations outside of the project's scope. [12].

7.4.2 Sustainability Presence Map

The Sustainability Presence Map is a tool that enables the determination of the percentage of sustainability in higher education programmes [12]. This map was built based on a series of questions addressed to teachers. In advance, the teachers must also answer a questionnaire used as a key element in conducting the interview [42].

The questionnaire's goal is to ascertain what the instructor thinks the students learn from the tasks they perform during the course. It is recommended that professors clarify how each learning outcome on the sustainability map is incorporated into the courses they teach. They can answer the questions using a "four-point Likert scale" ("nothing", "a little", "quite a bit", "a lot"). This questionnaire is transversal and can be used in other fields of knowledge [12].

The methodology for simplifying the design and validation process of the questionnaire is described.

- The researchers in the working group created the first version of the questionnaire.
- The other researchers from the validation group checked the material and suggested possible changes. To formulate each question, the direct relationship with ESM learning results was analyzed
- There was a meeting of all the members where the material was reviewed a second time. Also, the team's proposals were discussed
- The final questionnaire was created using an online collaborative word processor for editing and a shared drive for file storage after the outcomes of the first two revision iterations were reviewed [12, 42].

7.4.3 Sustainability Presence Map

Experts around the world are becoming increasingly concerned about the effects of plastic particles, particularly microplastics and nanoplastics, on the environment. The use of a smart microscope offers the opportunity to determine microplastics

and nanoplastics using microscopic techniques. Considering that plastic objects, regardless of their origin, have the ability to absorb organic or inorganic pollutants on their surface and to transfer them to different types of ecosystems, it raises the need for effective monitoring at all levels of environmental pollution. By using microscopic techniques—which are thought to be the best tools to combine with other analytical techniques to perform in-depth analyses of plastic particles—plastic fragments can be identified and studied. These processes are classified as green tools because they require the least amount of energy, reagents, and solvents [43].

7.4.4 Sustainability Presence Map

The geographic information system (GIS) is a system used to store, process, and digitally analyze geographic data with the help of a computer. GIS is also an effective tool for environmental data analysis and planning that allows more efficient management of resources by capitalising on geographic information with analysis tools that support planning [44].

In the context of environmental engineering education, universities focus on educating experts in Environmental Sciences. Students are prepared to use geographic information systems to acquire, analyze, and visualize data using cartographic techniques in three courses (GIS for Environmental Scientists, Spatial Landscape Analysis, and Advanced Analysis in Geographic Information Systems).

At the same time, two primary approaches have been identified for GIS education: teaching about GIS and teaching with GIS. The "teaching about GIS" approach focuses on a series of operations that include tools and processes related to the acquisition, modification, and visualisation of spatial data so that students become familiar with GIS software. The "teaching with GIS" approach consists of teaching Spatial Analysis of the Landscape using concrete GIS applications. Students learn to use these applications to solve real-world problems. To highlight this type of spatial analysis of the landscape, which consists of evaluating the impact on human activity, a model based on the idea of "Inquiry-Based Learning" (IBL) was developed. Systems such as Global Positioning System, Learning Management System, GIS Server, Database management systems, were used to make the use of GIS applications more efficient [45].

7.5 The Impact of Digitization on the Evolution of Environmental Engineering

Environmental engineering aims to protect and conserve raw materials to meet human needs and to remove polluting agents from the environment [46]. The impact of digitization on the evolution of environmental engineering has become a complex subject

due to the significant advantages it brings. Even if utilizing digital technologies has both a positive and a negative impact on environmental sustainability, the advantages of this process are significant [47].

The Positive Impact

Digitization supports sustainable development enhancing the efficiency of waste management, pollution control and reduction, increasing resources, and manufacturing sustainable products [46, 48]. Most researchers tend to support the opinion that digitalization has more positive effects on environmental issues than negative ones.

Waste Management

The accumulation of increasingly large amounts of waste represents a global environmental problem caused by the increase in urbanization and population growth. One of the strategies currently being addressed to reduce the public health risks posed by waste involves the use of digital technologies such as artificial intelligence, the Internet of Things, and blockchain [47]. The following table illustrates some of the applications of different digital technologies used in waste management (Table 7.1).

So, an increasingly effective instrument for advancing environmentally friendly waste management techniques is Artificial Intelligence. For instance, combining the AI algorithm Harmony Search with a smart vehicle helps to improve electrical and electronic waste management processes by optimising the waste collection route (Fig. 7.5). The number of collection points targeted by this algorithm is quite high (from 1.2% to 6.6%) compared to other algorithms. Moreover, this model of vehicle can be used in densely populated areas of cities because the body of the collection

Table 7.1 The use of digital technologies to reduce the amount of waste

No	Tools	Applications	Reference
1	Artificial intelligence	Mobile collection of electrical and electronic waste	[49]
2	Internet of Things	Treatment of food waste	[50]
3	Internet of Things, Artificial intelligence, Cloud	Waste segregation The development of smart trash cans	[51]
4	Blockchain	Reducing the amount of waste generated by COVID-19 vaccines	[52]
5	Smart security systems	Offers effective solutions to identify the main factors that pollute the environment	[53]
6	Artificial intelligence	Forecasting of waste generation	[54]
7	Internet of Things	Waste management in smart cities	[55]
8	Blockchain	Optimization of Blockchain-based solid waste management traceability system	[56]
9	Artificial intelligence	Intelligent robots and digitalization in the circular economy value chain-focused waste handling	[57]

vehicle allows the waste load from both sides, and a hydraulic lift is installed on the back side. The correct and efficient collection of electrical and electronic waste leads to a reduction in the impact of hazardous substances (such as heavy metals, lead, mercury) on the environment and human health. At the same time, the use of mobile applications enables collection on demand from consumers [49].

In another study, researchers evidenced that the IoT can contribute to the improvement of the process of anaerobic digestion (Fig. 7.6). A reactor with continuous stirring was designed, installed, and used for the treatment of food waste in order to produce biogas, used as a source of renewable energy. The IoT connected to this digester monitors process parameters (temperature, pH, and redox potential) in real time remotely [50].

Another example is IoT, together with deep learning, has created a system for segregating waste into different categories, considering their physical properties.

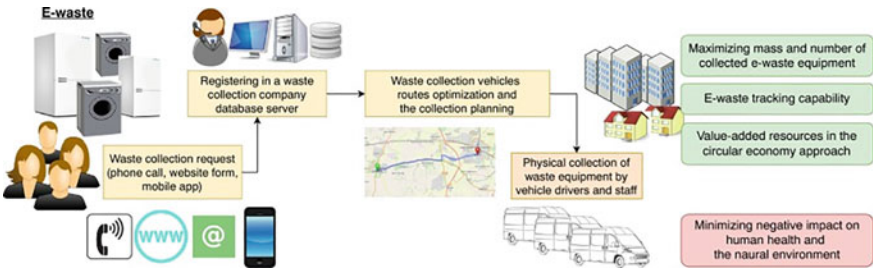

Fig. 7.5 Stages of mobile collection of electrical and electronic waste [49]

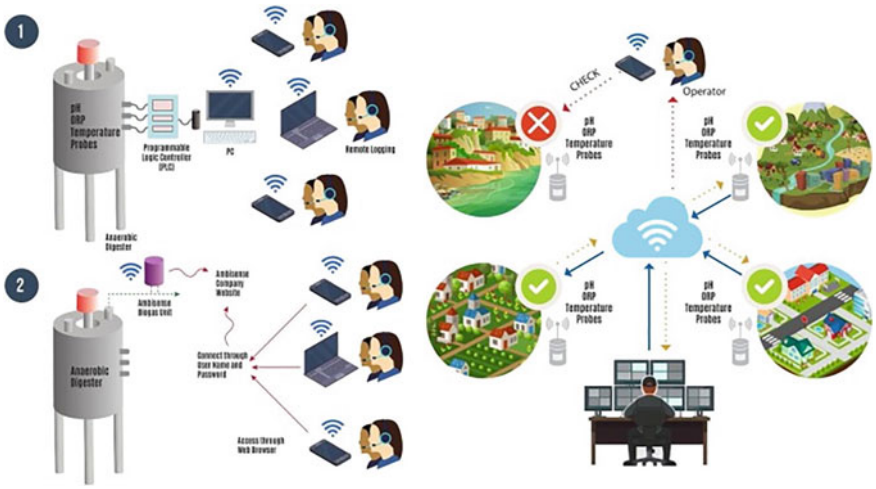

Fig. 7.6 Remote monitoring of anaerobic digestion [50]

Pre-trained models for waste classification were trained using transfer learning techniques. At the same time, smart trash cans have been developed using both the IoT and cloud application that send alerts when these are full [51].

To lessen COVID-19 vaccine waste, a blockchain-based approach comprising five stages—registration, commitment, production and delivery, consumption, and waste assessment —was put forth, generated by two causes: overproduction and underuse. The entire COVID-19 vaccine life cycle consists of these five stages, which can be managed by multiple Ethereum smart contracts that hold people accountable for any waste they produce and make it simple to locate the source. The "Interplanetary File System" (IPFS) was used to reduce the cost of large files stored by participants [52].

Pollution Prevention and Control

Crude oil processing, mining operations, pharmaceutical manufacturing processes, and the widespread use of pesticides are considered major sources of soil, water, and air pollution [20]. Pollution control strategies consist of minimising the impact of pollutants on human health and the environment, while the prevention of pollution implies the reduction of pollutants in the air [46]. Innovative digital technologies offer a wide range of solutions that allow for reducing greenhouse gas emissions, combating climate change, and treating wastewater [20, 46]. IoT sensors allow the temporal and spatial analysis of PM2.5 concentrations, which are suspended particles with a maximum diameter of 2.5 μm. The data was collected every two minutes and uploaded to the cloud, where it was used to explore near-real-time forecasting potential [58]. In another research study, a suitable storm forecasting model based on an "Artificial Neural Network" (ANN-SFM) was developed to establish the level of storm surges with lead times of 5, 12, and 24 h [59]. Also, the bidirectional deep learning machine (DBLM) was developed, which showed remarkable performance in terms of reducing nitrogen oxide emissions and improving boiler efficiency [60].

Sustainable Management of Resources

This concept refers to utilizing natural resources in a way that can satisfy the needs of current and future generations without being completely consumed and without causing damage to the environment. Some of the strategies that ensure the sustainability of resources refer to the use of renewable energy sources (photovoltaic panels, wind turbines), the implementation of water conservation measures (collection of rainwater from the roof), the design of ecological houses, and the promotion of biodiversity [61]. In this case, it was considered necessary to integrate digital technologies to improve the previously presented strategies [46]. For example, the Feedforward artificial neural network can estimate the amount of energy generated by PV panels, thereby helping to model the PV solar power generation system that is dependent on historical production data and meteorological conditions [62].

Manufacturing Sustainable Products

Sustainable production is the process of creating goods and services that are characterised by low energy consumption, low resource use, and pose no danger to both consumers and workers [63]. The four stages of the process of creating value

are: creation, manufacturing, shipping, application, and cleanup [47]. The growth of sustainable intelligent production has advanced along with the development of digital technologies such as the IoT, big data combined with cloud computing, and AI [64]. How these technologies affect the sustainable production processes is displayed in Table 7.2.

The Negative Impact

Digitization can negatively affect the environment, both because of the high consumption of energy and resources used for the development of technologies [65] and because of the difficult management of electronic waste such as photovoltaic panels [66]. Globally, PV waste is incinerated, landfilled, or recycled, promoting environmental degradation and the loss of valuable materials [66]. In particular, the recycling of these photovoltaic modules leads to an increase in environmental impact factors (global warming potential, abiotic depletion potential). Moreover, the chemical treatment of compounds in photovoltaic systems allows the generation of many different toxic compounds, favoring the occurrence of acid precipitation and presenting great risks to human health. Also, the carbon dioxide emissions resulting from the transportation of photovoltaic waste to the recycling site represent another source of pollution that favors the occurrence of climate change [67].

The production process is also responsible for its negative effect on the environment, use, and end-of-life of digital technologies. The production of digital technologies requires a large amount of materials, including microchips, semiconductors, displays, and sensors. The huge demand for sensors has increased from 4.4 billion (2015) to 11.2 billion (2021). Instead, the production of semiconductors leads to the release of volatile organic compounds and dopant gases in the air, the pollution of water with acids, metals, and cleaning solutions, and the production of large amounts of waste (solvents). The Life Cycle Assessment (LCA) highlighted the fact that a dynamic memory chip requires 1.2 kg of fossil fuel to produce it. The negative effects resulting from the use of digital technology consist in high energy consumption and the generation of carbon dioxide emissions. These emissions are associated with data storage and are 5 kg of carbon dioxide per TB per year. On the other hand, data transmission is a large energy consuming process. At the end of life, basically a very small number of technological components are recycled. For example, for Radio Frequency Identification (RFID), which is made of materials such as aluminum, copper, silver, there are no significant recycling systems, as a lot of waste is produced, which represents a huge risk for the health of the population [47].

The extraction of mineral resources required to make Information and Communication Technology (ICT) products is an additional negative impact of digitization. Degradation of natural resources, water contamination, and disturbance of biodiversity are just a few of the major negative effects this process has on the environment. These are important reasons for starting to improve the procedures and application of the regulations in this field. The amount of electronic waste is growing at an alarming rate every year, and this presents an increasing environmental risk. Reducing the flows

Table 7.2 The effects of digital technologies on sustainable production processes

Internet of Things				
Design stage	Production stage	Transport stage	Usage stage	Recovery stage
Integration of suppliers and customers in the design process, promoting the saving of resources and energy by customising the design of the product Improving design performance by interconnecting data from later stages of the product life cycle Optimisation of material consumption by introducing intelligent programming in IoT platforms	Communicating between machines and sharing information related to various errors, changing requests, and setting parameters Monitoring and introducing defective products into the production process for improvement Carrying out some proactive environmental activities by collecting data related to waste management and the consumption of materials and energy	Reducing the number of wrong deliveries and the waiting time Minimising transport frequencies and distances	Providing feedback to improve design and production processes based on monitored and collected data Reduction of time and transport of onsite support	The development of a system of collection, disassembly, sorting, and reuse, which allows closed-loop manufacturing, and the promotion of several life cycles
Big data combined with cloud computing				
Design stage	Production stage	Transport stage	Usage stage	Recovery stage
Supporting product design and providing more options needed for design by analysing data from different production scenarios Reducing material handling costs and energy consumption	Extending the life of equipment Satisfying customer requirements	-	Automatically determining the best path while a ship is in operation Reducing the amount of fuel that is used	-
Artificial Intelligence				

(continued)

Table 7.2 (continued)

Internet of Things				
Design stage	Production stage	Transport stage	Usage stage	Recovery stage
Design stage	Production stage	Transport stage	Usage stage	Recovery stage
–	Increasing energy efficiency and quality performance Significant decrease in defect rates	–	–	–

of this kind of waste and improving recycling technology is critical to minimize this threat.

A substantial amount of physical hardware must be used to accomplish the digital transformation, and both producers and consumers require a lot of resources and energy to produce and utilize these products [68].

7.6 Conclusions

In the current chapter, some of the most important digital technologies that bring improvements to higher education with focus on environmental engineering have been identified and highlighted. These technologies favour remote communication between teachers and students, offer personal data protection measures to maintain confidentiality, and allow students access to various platforms, stimulating their interest in education, creativity, and critical thinking. Also, they allow the integration of the sustainability component in the university curriculum [69], developing a series of educational programmes that offer a series of reliable solutions for achieving the Sustainable Development Objectives, being focused on combating climate change, improving the quality of food products, promoting renewable energy technologies, and efficient waste management. On the other hand, the impact of digital transformation on the environment was presented. Artificial intelligence, the internet of things, and blockchain can be applied as solutions to reduce a large amount of waste (electronics, food, plastic) by implementing a collection system in smart cities [70–72]. Various models built based on artificial intelligence can detect pollutants in the air [73]. The modelling of energy consumption, considering the intelligent monitoring of the data, aims to estimate the amount of energy needed depending on the weather conditions and consumer habits [21]. Cloud computing technology combined with other digital technologies can control water quality, air pollution levels and hazardous waste contamination [74]. However, technological applications present a series of challenges related to the high energy consumption required to develop these digital

applications and the recovery of secondary materials at the end of the life of electronic waste that affect the environment and people exposed to various toxic compounds.

Digitization is an important process that must be implemented in all areas, it takes time and significant costs, but the advantages are important that provide significant results and satisfaction. Regarding digitization in the educational field, future environmental engineering practitioners can gain experience by using smart devices and programs that support them to develop and accumulate information and skills in an efficient and harmonious way.

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Chapter 8
Promoting Self-image in the Online Environment

Mihaela Laura Bratu and Lucian-Ionel Cioca

Abstract Self-image refers to how we perceive our own physical, emotional, cognitive, social, and spiritual characteristics. The way we perceive ourselves depends on the degree of self-esteem (self-appreciation, self-respect, self-acceptance) that we have. The purpose of the chapter is to analyze the concept of self-image, through the two facets, self-appreciation, and self-criticism, starting from the values of youth promoted in the online environment. At the same time, the necessary steps to build a personal communication strategy are identified, through which is promoted the self-image of youth in the online environment, to obtain a job. Personal branding in the online environment, focused on authenticity and good reputation, has an impact on career, job, personal and family relationships, all under the careful evaluation of public opinion. In the end, Public Relations techniques, and practices specific to the online environment are described, by which people can avoid image blunders and emotional trauma.

Keywords Online environment · Self-image · Communication strategy · Personal branding · Public opinion · Image blunders · Emotional traumas

8.1 Introduction

The online environment has become an integral part of our daily lives, supporting our social and professional needs. The profile picture is carefully chosen, as aesthetic as possible and to capture our favorable features as well as possible. Any post attracts comments, which reinforce our perception of ourselves.

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L-I. Cioca et al. (eds.), *Digital Transformation*, Intelligent Systems Reference Library 253, https://doi.org/10.1007/978-3-031-55952-5_8

"Promoting Self-Image Online" is organized around three key concepts: self-image, self-promotion strategies, and potential dangers on online environment.

The chapter presents theories related to self-image, to understand the way of formation and the means of influencing it in the online environment.

To provide a precise analysis of the concept, feedback from the latest developments in bibliographic research was used. This was supported by a systematic literature review together with bibliometric analysis based on the similarity visualization technique.

Figure 8.1 includes the graphic abstract of the chapter and the concepts addressed.

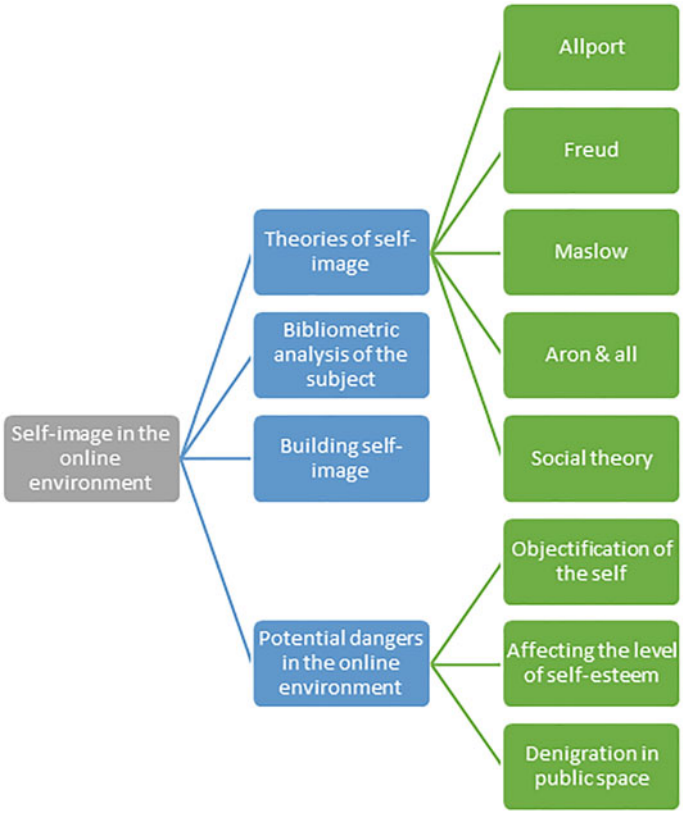

Fig. 8.1 Graphic abstract of the chapter

8.2 Conceptual Delimitations

8.2.1 Gordon Allport's Theory. The Formation of Human Personality

The formation of the individual's personality takes place from the first moment of life, according to Gordon Allport's theory. The development of the human personality is done around the unifying core "Proprium", which comprises eight human characteristics [1].

1. Sense of bodily self—awareness of one's own body.
2. Self-identity—awareness of one's own continuity.
3. Self-esteem—autonomy.
4. The extension of the self—"mine".
5. Self-image—develops as a reverential response to feedback from reference persons.
6. The rational self—rational plans to combat instinctual drives.
7. Central efforts—the formation of intentions and objectives that give meaning to one's life.
8. The knowing self—the self's ability to observe all its functions listed above [2].

8.2.1.1 Self

The sense of bodily self develops through organic sensations and external stimuli. Awareness of one's own body is formed with the help of perception, as a process and as a primary object image. In a broad sense, perceptions are complex sensory processes and, at the same time, primary images, containing all the information about the concrete properties of objects and phenomena, under the conditions of their direct action on the analyzers [3]. The observation of one's own body, oriented towards the goal of self-definition, represents a complex form of perception that is formed in a very close relationship with activity, language and thought.

It is noted that in the context of personality, the notion of self occupies a central role. In a broad sense, the self is the totality of information that an individual can access about his or her own person. Perceived information can have two sources of origin, from the contextual situation—the social environment and from the material stored in the memory [4].

Regardless of the source, self-knowledge is formed from the perceptual-motor system, which allows the individual to distinguish and differentiate himself from the rest of the world. From an ontogenetic point of view, according to Fig. 8.2 [4], the individual is born with the ability to perceive his own self [4].

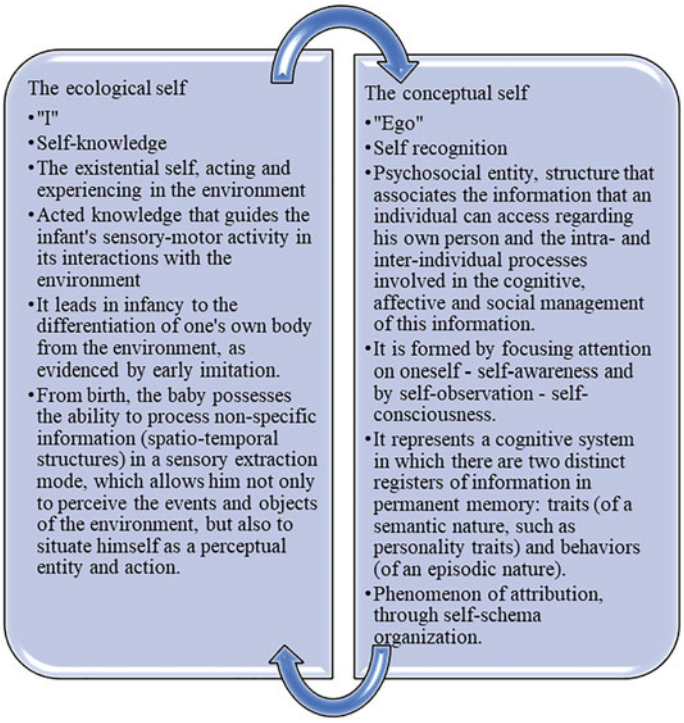

Fig. 8.2 The ontogenetic formation of the self

8.2.1.2 Self-defense Strategies

The self, as a valued psychosocial entity, is defended by alarm systems and defense mechanisms [4]. Greenwald [5] proposes the metaphor of a "totalitarian ego" that protects its own organization by resorting to three types of strategies, generally unconscious: self-centeredness, self-will, and cognitive conservatism [4]. Egocentrism is the tendency to give more importance in cognitive processing to information about oneself than to others. Everyone tends to believe that most people act or judge the same as him (false-consensus effect). Self-beneficence refers to the individual's tendency to attribute success to one's own person and to refuse to accept any responsibility for failure. Cognitive conservatism denotes the tendency to use information in such a way that it confirms previously formed judgments about oneself (confirmation bias).

Self-verification strategies are oriented towards maintaining a coherent self-view for oneself and for the other. In general, we estimate that others are more like us than we are to them and that we spontaneously tend to take ourselves as a reference point for comparisons [4]. These phenomena reflect a mechanism of self-centered assimilation, compatible with the idea that the self is endowed with the cognitive properties of a prototype.

Self-defense strategies are both cognitive, as previously stated, and behavioral. We exercise control over the personal information accessible to the other, and self-presentation strategies allow us to offer a favorable self-image or mitigate devaluation, through various behaviors.

8.2.1.3 Self and Social Identity

Belonging to and identifying with particular social groups influences the contents and processes of the self. Social identity is that part of the self-concept that derives from belonging to groups [6]. Social categorization occurs when social identity is taken as a database for self-definition, especially in the comparison between you and your fellow man in the context of intergroup comparisons [4, 7]. Self-categorization [8] determines a series of phenomena of accentuation of intergroup similarities. Group membership joins current research on the influence of culture on self-concept: individualism versus collectivism. In Western societies, the self is socially constructed as an autonomous entity determined from within the subject, while in other cultures it is the interdependence between individuals and between individuals and the social context that gives the self its primary meaning [9]. It was especially shown that, in self-descriptions, the private, public, and collective aspects of the self are not present in the same proportions in “individualist” or “collectivist” societies [10].

8.2.2 Sigmund Freud’s Theory. Personality Structure. Psychoanalysis

Psychoanalytic theory, created by Sigmund Freud, states that much of what we think and do is determined by unconscious processes, according to Fig. 8.3 [11].

In Fig. 8.3, the human mind is compared by Freud to an iceberg. The diminutive part above the water is the conscious—our current consciousness—and the preconscious, all the information that is not "in our mind” at present, but we can bring to consciousness if asked to do so. The biggest part of the iceberg, the deep part, is the unconscious, a storehouse of inaccessible impulses, desires, and memories that affect our thoughts and behavior. Along with the theory of unconscious processes, Freud also focused on the determinism of human behavior, according to which all thoughts, emotions and actions have causes, and the most common causes are unsatisfied drives and unconscious desires. Four types of behaviors, dreams, humor, forgetting and involuntary mistakes ("Freudian missed acts”) serve to reduce psychological tension by satisfying forbidden impulses and unfulfilled desires [11].

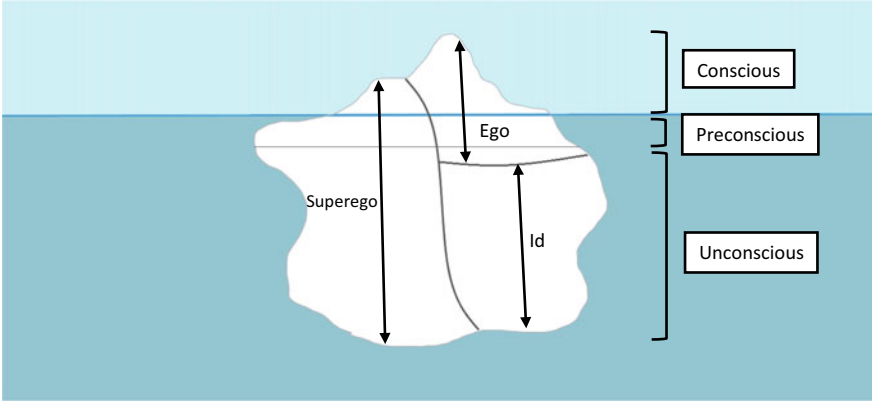

Fig. 8.3 Modelul structural al minții creat de Sigmund Freud

8.2.2.1 Personality Structure: ID, EGO, SUPEREGO

According to Freud's theory, personality has three major systems that interact to direct human behavior: the self, the ego, and the superego.

The ID is the most primitive part of the personality, from which the ego and superego later develop. It appears in newborns and consists of the most primitive biological impulses or instincts: the need to eat, drink, eliminate waste products, avoid pain and obtain sexual pleasure. The sex drive and the aggressive drive (aggression) are primary biological instincts that will instinctively determine the entire personality throughout life. The self seeks the immediate gratification of all these drives and operates on the pleasure principle: it seeks to obtain pleasure and avoid pain, regardless of external circumstances [11].

The EGO obeys the reality principle: gratification of impulses must be postponed until the situation is appropriate. The child quickly realizes that not every impulse will be immediately gratified: hunger cannot be satisfied until someone gives it food, the elimination of waste products will be delayed until you reach the toilet, etc. Thus, the ego is the main executive factor of the personality: it decides which self-drives will be satisfied and in what way. The ego mediates between the demands of the self, the conditions of the external world, and the demands of the superego.

The SUPEREGO is the forum that judges whether actions are right or wrong. In a general sense, the superego is the internalized representation of society's moral values and principles. It represents the consciousness of the individual and his image of the ideal moral person (ideal ego). The superego develops in reaction to parental rewards or punishments. Violating the standards of the superego, or the mere impulse to do so, produces anxiety—beginning with the anxiety of losing parental love. Anxiety is largely unconscious, but can be experienced as guilt.

The three components of the personality are often in conflict: the EGO delays gratification that the ID immediately desires, and the SUPEREGO fights both the EGO and the ID because their behavior often violates the moral code it represents.

In well-integrated personalities, the EGO exercises firm but flexible control, the governing principle being that of reality. In Fig. 8.3 it is observed that the whole ID and large parts of the EGO and SUPEREGO are found in the unconscious, only small parts of the EGO and SUPEREGO being in the conscious or preconscious area.

8.2.2.2 Personality Dynamics

Freud identified a number of principles that govern personality dynamics, according to Table 8.1 [11].

8.2.3 The Motivation of Human Behavior. Abraham Maslow's Theory

The two previously described theories of Allport and Freud on human personality brought two perspectives on the notion of self. Abraham Maslow's theory introduces the temporal idea regarding the formation of the self-image, the ontogenetic evolution of individual needs and their hierarchy.

In his book, Motivation and personality [12], Maslow argued the need to take into account in the assessment of motivation all the characteristics of the person, taken as a whole, and especially the hierarchy of his needs, the gradual satisfaction of which is the key to the complete realization of the person. Humanistic theory explains why when we have several needs at the same time, we choose a certain order in which we satisfy them. Also, the theory states that only a small number of people end up satisfying their last two levels of the pyramid [12].

Maslow states that there is a hierarchy of individual needs, starting from the primary biological needs and reaching more complex psychological motivations, which become important only after the primary needs have been satisfied [3, 11, 12]. According to Fig. 8.4, the satisfaction of physiological needs is followed by the need for security, and then by the need for belonging and love. The fourth place in the pyramid is occupied by the need for esteem and status: to have achievements, to be competent and to gain recognition. Following the direction to the top of the pyramid, the cognitive needs, to know, understand and explore, are satisfied; the aesthetic needs of symmetry, order and beauty, and finally, at the top of the pyramid, there are self-autorealization needs: the need to feel fulfilled and to realize one's own ideal.

According to Fig. 8.4, self-esteem and status are identified at level 4 out of 7. The positions that precede them are physiological, security and love needs, so we can make a correlation between the levels of needs and the age at which they begin to manifest. After being fed, feeling safe, and receiving affection, children begin to develop self-esteem around age 7. The needs that follow self-esteem are cognitive, aesthetic and finally self-realization needs. Maslow also identified a picture of personal qualities characteristic of self-realizationed people, as well as a series of

Table 8.1 Principles governing personality dynamics

Conservation of energy	There is a standard amount of psychic energy for any individual, called libido
	Suppressing a forbidden act or impulse causes its energy to seek an outlet, a discharge into another part of the system, possibly in a disguised form
	E.g. Aggressive impulses expressed in disguised form through participation in car races, playing chess, or sarcastic remarks
Anxiety and defense	Individuals who feel the urge to do a forbidden thing experience anxiety
	Anxiety reduction is done by expressing the impulse in a disguised form that will avoid punishment from society or the superego
	Defense mechanisms or strategies to avoid/reduce anxiety: repression, rationalization, recoil, projection, intellectualization, clearing, displacement
	Defense mechanisms become maladaptive if they are the dominant way of responding to problems
Suppression	Impulses and memories that are too frightening or too painful are excluded from consciousness
	Memories that evoke shame, guilt, self-condemnation are most often repressed
	Repression rarely succeeds completely. Repressed impulses return to consciousness in the form of anxiety
Rationing	Rationalization is attributing logical or socially expedient reasons to our actions so that we appear to have acted rationally
	E.g. Aesop's fable with the fox rejecting the grapes because they were sour
Reaction formation (recoil)	Individuals conceal a motive within themselves by forcefully expressing the opposite motive
	E.g. The overly loving mother with the child she didn't want, to reassure herself that she's a good mother
Projection	Protects against unwanted attributions by overattributing them to other people
	E.g. When you are aggressive with those around you and, in order not to lose self-esteem, you convince yourself that they deserve it
Intellectualization	Attempting to detach from a stressful situation by treating it in abstract, intellectual terms
	E.g. the doctor detaching himself from the patient, in order to act competently and for emotional protection
Denial	It occurs when the external reality is so unpleasant that the individual refuses to acknowledge the existence of the unwanted reality
	E.g. The mother who acts like her child doesn't have the disease she just found out about

(continued)

Table 8.1 (continued)

Conservation of energy	There is a standard amount of psychic energy for any individual, called libido
Displacement	Through the displacement mechanism, a motive that cannot be satisfied in one form is directed to a new form of satisfaction
	E.g. Unexpressed erotic impulses are redirected towards art, poetry and music, and hostile impulses towards sports involving physical contact

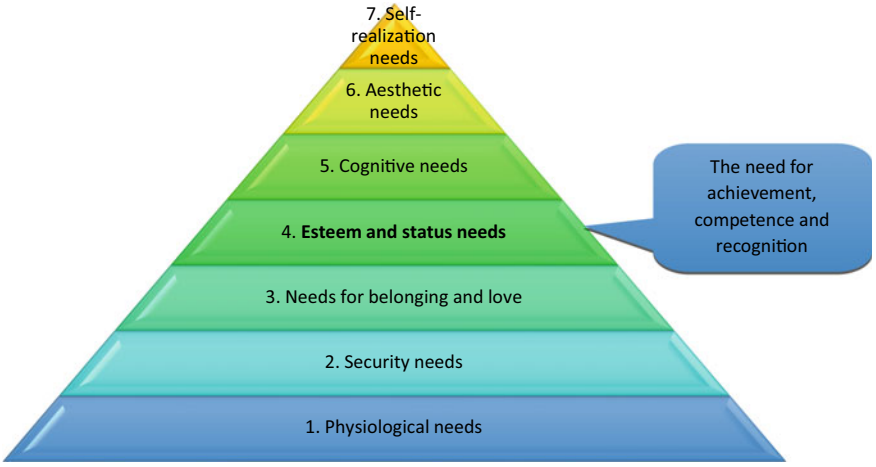

Fig. 8.4 Pyramid of needs according to psychologist Abraham Maslow

behaviors that lead to the satisfaction of the highest level of needs, among which are: effective perception of reality, tolerance of uncertainty, acceptance of self and others so such as, focusing on problems, creativity, unintentional nonconformity, objectivity, listening to one's own feelings in evaluating experiences, unpopularity, honesty—without masks or games, assuming responsibility, capacity for hard work [11, 12]. The listed traits paint the picture of the accomplished adult, self-assured and fulfilled, with a strong and well-grounded self-image.

8.2.4 Aron, Norman, and Aron's Theory: Love and Self-expansion

Love seems, in the context of the subject of the chapter, a meaningless approach. We fall in love and love, we all say, because it makes us feel good, because it's instinctual or because it's sexual attraction. However, there are three sociopsychologists who have stated that the first motivation of falling in love is the need for self-expansion [13]. According to Aron, Norman and Aron's theory, affective relationships produce

Fig. 8.5 Inclusion of the other in self

self-expansion, or increase our potential capacities and resources in various ways [11, 13]. As we grow closer to a person, we access the other's resources, perspectives, and identities that help us fulfill our personal goals, a process based on the desire to experience the positive feelings that result from such a process of expansion. The mentioned study [13] was based on an experiment that concluded that first-year students who fall in love have significantly greater and more diverse self-descriptive ability than those who do not fall in love.

So the act of love, in addition to the fact that it makes you know yourself, makes you identify with the person you love, to the extent that you lose your own identity. The phenomenon of self-expansion signifies precisely the identification of the self in both the self and the other. For example, when you are in love, you may feel that you are calm and indulgent, when in fact your partner is like that, and you are probably the opposite. According to the researchers Aron, Aron and Smollan [14], the inclusion of the other in itself can be done according to a graphic model presented in Fig. 8.5, which represents both the degrees of inclusion and a sample, a test, based on which predictions can be made regarding the vivacity of the relationship of persons. The greater the identification, the more the couple tends to stand the test of time in the relationship.

8.2.5 Social Self-perception Theory. Self-image in the Social Environment

Social psychology is the branch of psychology that studies how the individual becomes a member of social groups and exercises their specific functions. As a member of social groups, the individual has a set of values and interests that are benchmarks in communication and with the help of which he issues value judgments and feedback on group members [15–18].

In a narrow sense, it seeks to understand and explain how our thinking, feelings and behaviors are influenced by the presence of other people (actual, imagined or actually involved).

In the context of the chapter, there are the subject and the object of the post, two, as in any other communication: the sender and the receiver. In this context we are talking about social psychology and social perception, as the object, the receiver of posts.

Any interpersonal relationship (communication in the online environment) begins with the perception of the partner. This fact implies the subject-subject relationship. Although it follows the general laws found in the perception of physical objects,

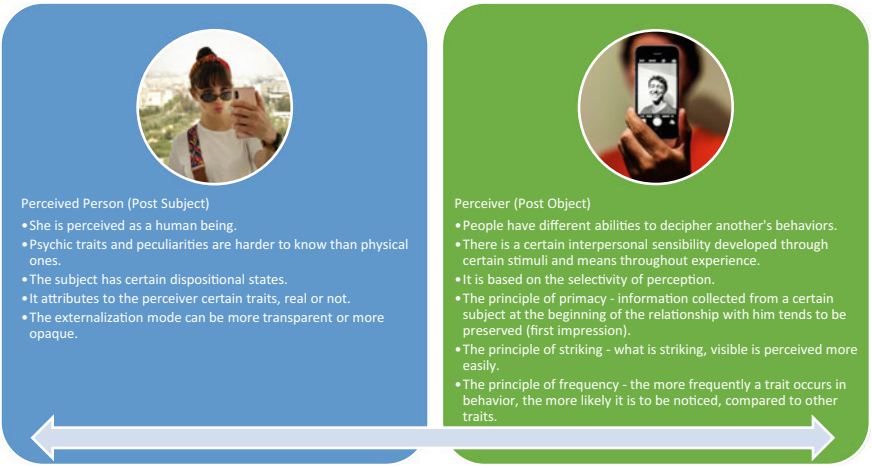

Fig. 8.6 Characteristics of the subject and object of the post (Images taken without copyright from https://unsplash.com/s/photos/selfie on 25.10.2023)

social perception has a different nature, characteristics that individualize it, being dependent on the particularities of the stimulus we come into contact with. Figure 8.6 illustrates the traits of the perceived person—the subject of the post versus the traits of the perceiver—the object of the post.

8.3 Promotion of Self-image in the Online Environment

8.3.1 Subject Analysis Using the Bibliometric Method of Scientific Mapping

In order to analyze the promotion of self-image in the online environment, the bibliometric method of scientific mapping was chosen, using the VOSviewer software. It is known for its powerful graphical interface and its ability to make visual maps. Bibliometric analysis facilitated the mapping of large volumes of scientific literature, thus ensuring the quality of the information used and the results generated [18–22]. The process began with an exhaustive search of the Thomson Reuters Web of Science Core Collection (WOS) database, recognized as the most reliable for bibliometric studies. It searches among editors and shows no bias towards them. To ensure quality, the results from the WOS were quantitatively limited, and the database was chosen from previous searches in the literature on self-image promotion.

The sample for the analysis of online self-image promotion included articles indexed in English in Web of Science, totaling 343 entries. The bibliometric analysis was useful for classifying the research and identifying thematic similarities. The Web

of Science sample has been exported to the required format and saved locally to a master file. Network analysis was done using VOS Viewer, where a network consists of items and links. These links may represent the co-occurrence of subject headings, bibliographic connections, or co-authors. Important item properties are highlighted by weights and cluster membership, with significant items highlighted by a larger circle. Colors indicate belonging to a group of closely related elements. The distances between items provide a graphical illustration of the strength of their connections. The scientific mapping of the literature, carried out by bibliometric methods, had the purpose of reviewing the research on the promotion of self-image in the online environment. Reviews based on bibliometrics do not analyze the substantive findings of the studies, but provide insight into the general trends, composition and intellectual structure of the field of knowledge [18, 19, 22].

The analysis of self-image promotion keywords in the online environment showed two clearly distinct areas, according to Fig. 8.7. The red cluster has the word Study as its central element, and the green cluster targets the promotion part that focuses on Approach.

Cluster 1, Study, includes 64 items, among which we mention: study, research, analysis, relationship, role, behavior, identity, experience, effect, implication, response, difference, participant, attention, perception, communication, gender, culture, impact, importance, interaction, facebook, young person. Cluster 2, Approach, includes 34 items, among which we mention: approach, learning, paper, problem, performance, feature, object, change, application, system, technique, algorithm, experiment, vision, accuracy, robot, speed. It is observed, according to Fig. 8.7, that the approach to the subject in the specialized articles is polarized into two distinct groups: cluster 1—the psychological approach to the subject and cluster 2—the technical approach to the subject.

In Fig. 8.8, Cluster 1 is analyzed, on three levels of deepening the subject.

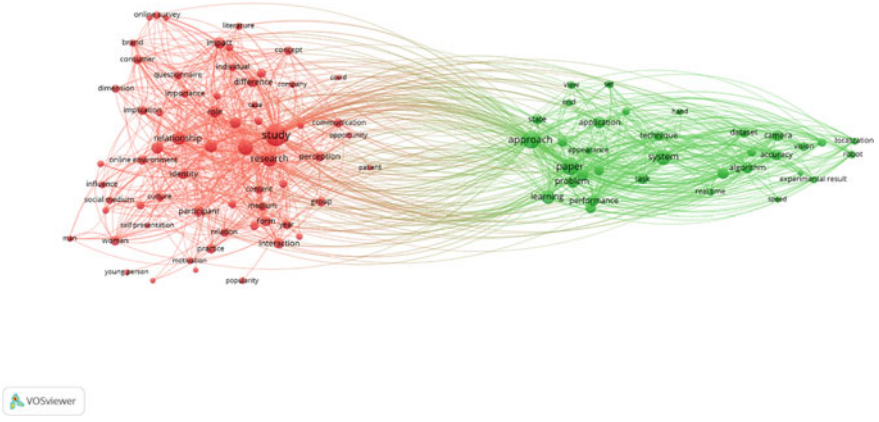

Fig. 8.7 Analysis of keywords regarding the promotion of self-image in the online environment

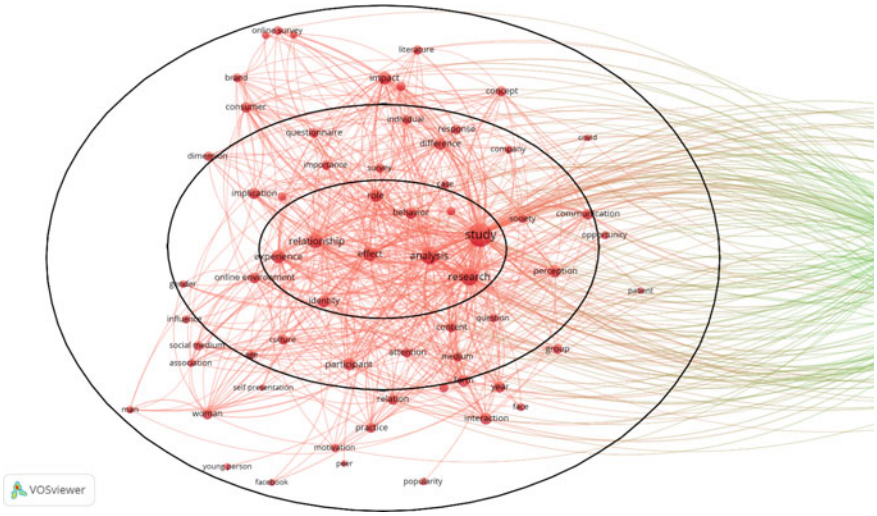

Fig. 8.8 Level analysis of Cluster 1

As can be seen from Fig. 8.8, level 1 refers to action, level 2 to environment and level 3 to subject. Level 1, that of action, includes the words relationship, experience, identity, role, behavior, effect. Level 2 refers to the online environment, culture, age, attention, content, perception, communication, society, difference, response, individual, engagement, gender. Level 3 widens the scope of research to: social environment, associations, men, women, self-presentation, facebook, young person, motivation, equality, relationship, interaction, year, face, group, patience, opportunity, impact, consumer.

Cluster 2, which includes technical terms regarding the analyzed subject, is presented in Fig. 8.9.

According to Fig. 8.9, Cluster 2 is not organized by levels but includes two topics of interest: the visible part of the online environment and the background part regarding the promotion of self-image in the online environment. The first tier refers to appearance, feature, problem, learning, approach, technique, hand, state, object, performance. The second circle refers to the data set behind the interface, camera, sensor, robot, real time, algorithm, vision.

Regarding the distribution over time, according to Fig. 8.10, most of the articles were written in the period 2016–2019, and the evolution was in the sense of migration, moving the emphasis from technical aspects (Cluster 2) to psychological aspects (Cluster 1).

In conclusion, the analyzed articles define the promotion of self-image in the online environment as a relationship involving men and women, of different ages and cultures, with different roles and behaviors, who communicate, interact, and get involved, having motivation as an energetic support factor and who practice,

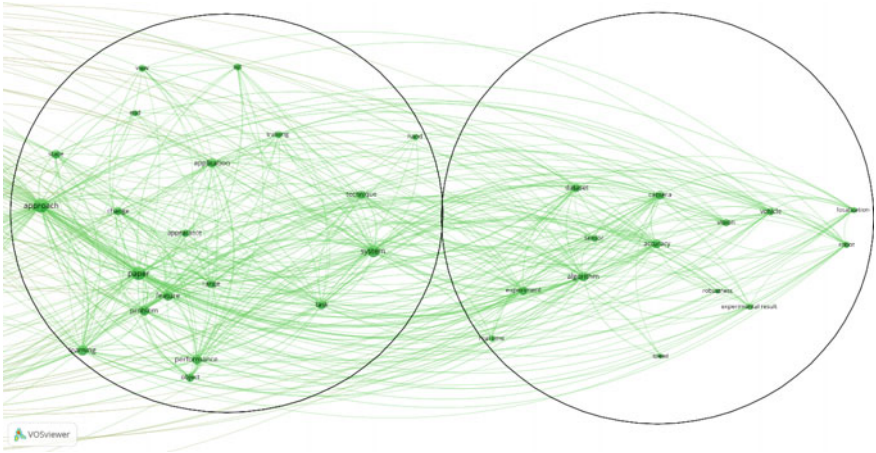

Fig. 8.9 Cluster 2 level analysis

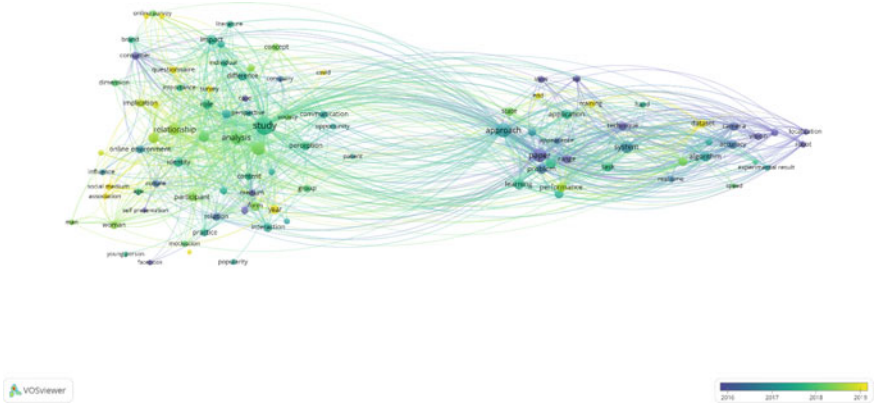

Fig. 8.10 Visualization of subjects correlated with the years of article appearance

produce and perceive contents, using the psychic function of attention. The relationship produces effects and determines the influence of the people involved, using the online environment.

8.3.2 Building Self-image in the Online Environment

The online environment is a vast and dynamic arena that has become an integral part of our daily lives. In this digital space, people interact, communicate and share information at an unprecedented speed and scale [23–29]. It is an ever-changing

virtual world where technology is advancing rapidly and social platforms, news sites and online communities are influencing how we perceive and construct our identities. This environment offers significant opportunities for self-image promotion, but also challenges in managing and maintaining a positive and authentic online presence.

The construction of self-image in the online environment starts from the idea of visibility and shaping a personal metaphor, including digital tattoos, fingerprints and digital doubles [30]. The online environment allows us to describe our physicality, our personality, interests and personal history through images and words [31]. Even employers look for certain traits in the description of potential candidates that are relevant to them. While the current concerns of cybermedia are to focus on issues related to privacy, people in the online environment seek visibility, trying to achieve a balance between concerns related to overexposure and the perceived dangers of invisibility [30]. There are companies that broker, sell online reputation management services, making people's profiles visible and relevant to their personal image. These strategies are part of personal brand advertising strategies and public relations strategies.

The key words regarding building an image in the online environment, according to the treatise written by Badau [32], are: content, communities, collection, transparency, conversation, independence, persistence, openness, social structure and connectivity. Building the image in the online environment begins with the SWOT analysis on the social coordinate, and from it the objectives are deduced, with the clear and precise identification of the results that everyone wants [32]. Next comes the development of an action plan, which includes the choice of tools that suit personal goals and the building of communication relationships and contacts. Social relations are based on reciprocity, positioning, involvement, thinking out of the box, respecting the norms of civilized behavior, friendship and influence. In the final, the online reputation management stage, which represents the process of monitoring online results with the aim of influencing the way users perceive the brand of the person involved [33–39].

8.3.3 Potential Dangers in the Online Environment

8.3.3.1 Objectification of the Self

Self-objectification is the tendency to treat an individual not as a person with emotions and thoughts, but as a carnal being or object. Andrea Dworkin [40] associates objectification of the self with male pornography consumption. Women of all ages tend to internalize an external observer's perception of their physical self as a result of cultural programming and pressure, thus reducing themselves to an object [31]. In contact with the media, where the physical appearance is paramount, objectification becomes chronic, through the exposure of images that emphasize the appearance, the body, rather than the character. The specific behaviors of a person who objectifies himself are excessive looking in the mirror, frequent selfies, self-critical attitude

towards his own appearance, frequent comparison with other images in social media, as well as the tendency to expose images of his own person that induce the idea of sexuality, images in which certain parts of the body are exposed [31, 41–43].

Self-objectification produces negative effects, including low self-esteem, depression, anxiety, panic attacks, negative body image and eating disorders—anorexia and bulimia [31, 40–46]. Research has shown that the more time spent on social media sites, the more young women want to be thinner [45] and monitor their weight fluctuations more closely. According to the same study, people who watch traditional forms of media, TV, newspapers, magazines, were not directly concerned with body image. Means of communication that use only images, such as Instagram, increase objectification and body image problems [31]. A new model of absolute beauty is thus developed, directly exposed to the gaze of all, who evaluate it not only visually, but also through comments, the phenomenon leading to the excessive objectification of the self.

8.3.3.2 Affecting the Level of Self-esteem

Self-image is influenced by the level of self-esteem we have [47]. Self-esteem refers to the level of self-appreciation, self-respect, and self-acceptance. A person with a high level of self-esteem does not need to show off online, expose themselves excessively or seek the approval of others.

Low self-esteem comes from a poor perception of one's own person, but also of all the roles the person has: they may perceive the job as a failure, and also the family, the relationships with those around them, etc. The signs of affecting the level of self-esteem are negative thoughts about oneself: hatred, contempt, the belief that you are not good enough, that the world does not accept and respect you, frequent self-judgment, inability to make decisions, lack of self-confidence, fear of failure, comes when you spend time for yourself or spend money [47, 48]. The negative self-image creates a vicious cycle, causing the person to sink deeper into helplessness and demotivation, leading to an inability to achieve social success and professional performance.

Affecting the level of self-esteem can be improved by mentally changing the cognitions about one's own person: positive dialogue with oneself, eliminating comparison with others, improving the desire to strive for perfection, eliminating self-blame, focusing on positive things, valuing positive things [47, 48].

8.3.3.3 Denigration in Public Space

Areas subject to public attention and evaluation are career/school, work, family and personal relationships. Their exposure in the online environment gives all people—observers—the opportunity to comment, to issue value judgments and to evaluate everything that exists in the public space. Both praise and criticism are expressed publicly, and any mistake is charged, potentially leading to vilification. As in medieval

times, the humiliation is public, so is the exposure to the stake, and the execution is broadcast live, ultimately leading to the ruin of an individual's entire career or even his entire personal life.

The online environment is cosmopolitan in terms of the values it transmits, and each person believes that they are entitled to an opinion, regardless of their level of training, understanding or experience in the field addressed. At the same time, every person in the online environment should know and apply the line between freedom of expression, a constitutional right, and denigration in the public space.

Cyberspace has been recognized as a fertile environment for the use of various hostile, direct and indirect behavioral tactics targeting individuals or groups. Defamation is one of the most used cyberbullying tricks to actively damage, humiliate and denigrate the target's online reputation by sending, posting or publishing cruel rumors, gossip and untrue statements. Previous relevant studies report that they detected profane, vulgar, and offensive words mainly in English [49–53].

8.4 Conclusions

The chapter successfully integrates theories from prominent psychologists such as Gordon Allport, Sigmund Freud, Abraham Maslow, and others. This integration provides a holistic understanding of self-image formation and promotion in the online space. According to Allport, self-image is a step-in personality formation and develops from the first day of life. At the mental level the individual develops cognitive and behavioral defense mechanisms that tend to transform that unique combination of traits into a prototype. Social identity is formed as a result of belonging to groups. Freud brings further clarifications regarding the self, by explaining the three essential concepts: conscious, preconscious, and unconscious, in which the ego, superego and self are found. Personality dynamics are influenced by several principles necessary for adaptation. Maslow believes that human needs have a hierarchy, and self-image is found at the top, through self-actualization. The phenomenon of self-expansion is done through the act of loving the partner, illustrated by Aron et al. They state that the greater the loss of self-identity in love, the greater the expansion of the self. Finally, the self-image was approached in a social context, through the subject-object perceptual dynamic.

The analysis of articles over time reveals a shift from a focus on technical aspects to psychological aspects. This evolution suggests a growing awareness and emphasis on the psychological and social dimensions of self-image promotion in the online environment. The bibliometric analysis highlights two distinct approaches to the promotion of self-image: a psychological approach (Cluster 1) and a technical approach (Cluster 2). Understanding these approaches can inform strategies for individuals seeking to enhance their online self-image.

The discussion on building self-image in the online environment emphasizes the importance of strategic planning, including SWOT analysis and goal setting. Online

reputation management emerges as a crucial aspect, involving the continuous monitoring of one's online presence to influence how others perceive the individual. Exposure of self-image in the online environment generates to observers both emotions, expressed through emoticons, and cognitions, exposed in comments to posts in text form. Subjects' self-image suffers when individuals either do not have a formed self-image or do not have a positive self-image. It is observed that young people are much more vulnerable to developing vicious circles of blame, uncertainty, anxiety, and vulnerability [47, 48]. And adults with unrealistic self-image, who do not know their qualities and flaws, can enter this vicious circle, which can end in anxiety, depression, bulimia, or anorexia. How self-image is formed is primarily the responsibility of parents, who should build a balance between criticism and praise, so that both children and future adults can maintain this balance. The self-image develops in parallel or based on a set of values, which are also transmitted through the family. In the online environment, values can be very different, as can the balance between criticism and praise. Most of the time, the criticism is not constructive, it only reaches the level of bullying, malice, and the praise is also not sincere, the perspective offered on one's own person being quite false.

As future research direction we propose to explore the link between individuals' online self-image and their offline behaviors and relationships is an intriguing direction. Understanding how digital self-perception translates into real-world actions can provide a more comprehensive understanding of the implications of online self-presentation.

The findings underscore the need for comprehensive media literacy education programs. Society must be equipped with the skills to critically evaluate and navigate the complexities of online self-presentation. Educational initiatives should focus on empowering individuals to discern between authentic self-expression and curated digital personas.

The prevalence of online self-objectification and its potential impact on mental health suggests a pressing need for digital well-being initiatives. Platforms, educators, and mental health professionals should collaborate to develop resources and tools that promote a healthier online environment, fostering positive self-perception and resilience against negative social comparison.

Policymakers should consider implementing regulations that promote responsible content moderation and algorithmic transparency. Platforms should be incentivized to prioritize user well-being over engagement metrics, and users should have greater control over the visibility and dissemination of their online self-images.

Building positive online communities that encourage authentic self-expression and mutual support is crucial. Social media platforms, in collaboration with community leaders, can play a role in fostering environments where users feel empowered to share various aspects of their identities without fear of judgment or unrealistic societal standards.

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Chapter 9
Are Computers Able to Understand Art?

Laura Florea, Corneliu Florea, and Constantin Vertan

Abstract Art is deeply connected with subjectiveness and human perception has a great insight in understanding and interpreting art. In this chapter we follow the attempts of computer vision researchers to teach computers ways of understanding artistic paintings. Can computers "see" past the abstraction and can they understand the deeper, intuitive levels in art? Are digital tools able to help in such a subjective and delicate domain? We will discuss methods that analyze paintings for the recognition of artistic style and artistic influences, which can help the art historians and curators from art museums. We will delve into algorithms for recognizing the subject in a painting and how a computer can get past the abstraction of art. Furthermore, we will analyze how the computer vision researchers tried to overcome the limited data by teaching computers to paint new pieces based on known art masterpieces. Based on these techniques, computer vision can help indexing big datasets of images or can provide the normal, untrained viewer of paintings with new art that they might enjoy or help them discover how to perceive the artworks using hints from color palette or attention gathering details.

Keywords Art · Computer vision · Painting understanding · Style recognition · Synthetic art generation

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L-I. Cioca et al. (eds.), *Digital Transformation*, Intelligent Systems Reference Library 253, https://doi.org/10.1007/978-3-031-55952-5_9

9.1 Introduction

The interpretation of our environment relies heavily on visual information. Consequently, a single glance at a scene can provide a person with a substantial amount of pertinent information. Artists skillfully manipulate visual information using diverse representations harnessing the importance of the sense of sight to craft compelling experiences and to engage and to fascinate viewers. In parallel, machine learning techniques have proven to be particularly efficient in resolving image identification problems with convolutional networks consistently outperforming human capabilities. Consequently, there has been a surge in interest in the past decades in determining the performance of distinct algorithms in scenarios with different levels of abstraction. Or figuratively speaking, "the machine learning hammer hit art too". In this chapter we are trying to assess to which extent.

The ubiquity of cameras in diverse settings led to a demand for advanced technology capable of processing the rich information conveyed by images. In response, the computer vision domain has made substantial strides in permitting digital systems to localize, identify, and categorize scenes and objects within images and videos that record natural scenes. However, paintings can include large amounts of abstraction. Furthermore, a person examining a painting can draw complex conclusions that go beyond simply recognizing a battle, a person or a seascape depicted in the art. Even individuals without formal training in art history can form opinions regarding a painting's style (artistic movement), the artist that possibly created it, the subject of the painting, etc. Clearly, the exactness of such assumptions relies on the viewer's familiarity and expertise in the field of art history.

Computer vision techniques have been employed in tackling various tasks in relation to digitized artistic paintings. Image analysis combined with machine learning sought to recognize the artistic genre, the style movement, the author, aimed to establish which part of the image draw viewer attention and in which order (which is known as saliency detection) and looked also to create synthetic images that replicate aesthetic qualities of paintings. The remainder of this chapter is divided into two major parts: the first part is dedicated to presentation and analysis of relevant works in analyzing and understanding art. The second part summarizes the evolution of attempts to create images that replicate art. The chapter ends with concluding thoughts.

9.2 Recognizing and Analyzing Art

Starting from the pure meaning of the word, paintings are "pictures created by putting paint on a surface"; this means that they exist in the physical and not necessarily in the digital domain. However, over the past years, there has been a rapid expansion in the quantity of digitized art collections that are now accessible to the public, spanning from classic, to contemporary and modern works of art. They have been obtained by

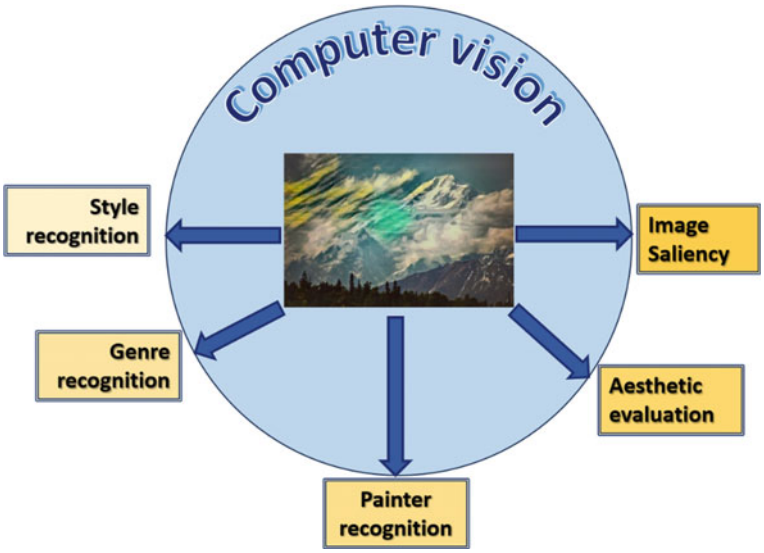


Fig. 9.1 The main applications of the computer vision in analyzing and understanding art

photographing the original paintings. Typically, these collections contain annotations from art historians and curators, including information about the artist, the genre, the artistic movement, the brushing style etc. Thus, the significance of these datasets lies not only in their preservation of valuable art pieces, but also in the inclusion of diverse annotations that enable their use in various machine learning tasks. The fact that such large, annotated collections of digitized artworks are available enables the potential to develop machine learning systems that automatically store, archive, and retrieve this pool of data and even create new artworks. For instance, labels indicating the artist's name can be employed for tasks related to author recognition, while artistic movement annotations can be leveraged to train a system in discerning the artistic movements a new painting aligns with. The following presentation will start with an enumeration of digital collections that act as databases for machine learning tasks and will follow with a condensed presentation of results with respect to various tasks. The main applications that use machine learning and computer vision in art analysis are synthesized in Fig. 9.1.

9.2.1 Databases Containing Annotated Works of Art

The extensive digitization efforts undertaken in recent decades have notably expanded the accessibility of art collections on the internet. Art platforms such as WikiArt, ArtUK or Google Art Project have curated a diverse range of art collections

along with basic metadata, making them accessible to public via the web. These digitized repositories provide a convenient means to explore and appreciate artworks from diverse museums and galleries globally. Museums typically provide a much broader spectrum of exceptionally well-crafted metadata. By combining precise metadata with high-quality photographic representations of their collection items, art-centric datasets prove invaluable for visual examination of artworks as well as for in-depth art analysis, enabling exploration from various angles and perspectives. In this section we will focus on describing datasets most used in automatic analysis of art in the last years.

A condensed list would include:

- WikiArt [1] (https://www.wikiart.org/) is presently among the most extensive online repositories of digitized paintings. Having the goal to accumulate a diverse range of artworks from around the world and make them accessible to the public, WikiArt is a frequent choice for art-related research projects including the ones that use automatic techniques. Presently, the collection boasts over 250,000 artworks sourced from various parts of the world, from more than 3000 artists. The artworks included cover a broad spectrum of historical periods and a large set of annotations including author, series, artistic movement, period, art movements, type, etc. The dataset is constantly growing and encompasses not just paintings, but also other various forms of artwork like sculptures, posters, or sketches.
- Painting-91 [2] is a set of 4266 paintings by 91 distinct artists, annotated by both painter and artistic style. Styles refer to schools of arts and encompass abstract expressionism, baroque, constructivism, cubism, impressionism, neo-classical, pop art, post-impressionism, realism, renaissance, romanticism, surrealism and symbolism.
- Pandora 18k [3] is a comprehensive digital dataset of paintings, annotated with labels indicating their respective art movements. It consists of over 18,000 images spanning 18 art movements, ranging from approximately 700 to nearly 1,200 representations for each artistic movement.
- Rijksmusem from Amsterdam made public through their API the Rijksmusem dataset [4] which encompasses metadata for 650,000 objects within museum's collection, providing information on artist, type, material and year of creation for each item.
- Web Gallery of Art contains over 40,000 images annotated according to their type of art, artist, periods, and style. The images are taken from various museums and art sites. The collection can be accessed by the website https://www.wga.hu/index.html
- Art500k [5] is a cumulative collection of previous mentioned databases downloaded at a small resolution to ensure that copyrights are not infringed, and usage can be limited only to machine learning systems. The collection contains about 500.000 images with annotation with respect to title, author, genre, drawing medium, scene.

This list contains only the newest and most used efforts, since in the earlier period small sets of works have been gathered manually to form limited collections of

images and information about organization and benchmarking for machine learning was made available with the machine learning/computer vision community in mind.

9.2.2 Automated Painting Description

Starting from the annotations from the existing datasets, computer vision researchers first focused on classification tasks such as recognizing the artist [6, 7], scene type or genre [8], artistic movement [9, 10], media [11] or even years of creation. These automated predictions can assist art curators in examining paintings and efficiently managing extensive art collections. Recently, the widespread of mobile technology has spurred museums [12] and cultural sites [13] to create applications capable of autonomously identifying features of the art presented to the visitor and delivering pertinent details or additional information.

Classification of artistic movement or authorship of a painting are difficult challenges. The characteristics that make a painting belong to expressionism or that allow the viewer to recognize the art of Klimt are not easy to evaluate objectively. Works of different artists are connected to their predecessors and contemporaries and to artistic movements from a certain period. Even more, paintings by the same artist can exhibit different particularities based on the frame time they were painted. Also, a certain work of art can contain a mix of characteristics from different artistic movements.

There are two main categories of existing approaches based on the chosen methodology: classical computer vision techniques and deep learning ones, specifically Convolutional Neural Networks (CNNs). Classical methods involve the manual extraction of traditional features for classification. This entails researchers manually designing features like edge detection and texture analysis. On the other hand, CNNs are engineered to autonomously build high-level deep convolutional feature representations for predictive tasks. One significant benefit of CNNs is their capacity to discern and understand intricate patterns in images without necessitating explicit and detailed feature engineering. In recent times, various strategies have emerged to choose the most effective features for CNNs, thereby enhancing their performance. But for this, one will need a huge amount of training data that has more recently become available to researchers.

Painter Recognition

In the initial stages of automated digital art analysis, the painter (author) recognition was more popular. The reason lies with the database availability. In that period each group of researchers collected manually from Internet a set of images; to keep the work in a reasonable amount, they would search for specific artists and downloaded images of works created by them. Therefore, databases were naturally ordered with respect to author in the period when images were described by handcrafted features and analytically simple classifier followed.

Into this direction, we can nominate the work of Keren et al. [14], that used the cosine transform for extracting texture features that are further classified by a

Naive Bayes Classifier for identifying several artists. Li and Wang [15] considered that relevant description lied in the frequency domain and coupled bidimensional Multiresolution Hidden Markov Models with Gabor wavelet features to classify 5 Chinese ink painters. Widjaja et al. [16] identified four painters using both color and texture descriptors. Khan et al. [17] blend shape and color information using a more elaborated scheme based on a Bag of Words to recognize 10 painters from 400 images.

With respect to these works, several observations can be made:

- databases were limited to hundreds of images and several (up to 10) classes. This was due to the limited availability of data, since major museums didn't start to publicly share images of the works and the amount of works authored by certain artists is more limited than the equivalent for a genre.
- major directions in describing images have been established in the form of color and shape. For color the preferred description was based on statistics gathered in the spatial domain, while for shapes a frequency-based set of descriptors was the major option.
- a painter is significantly more consistent and conservative with respect to variations in his works than a School of Art or a genre. Therefore, artist recognition is easier, and this is facilitated by the fact that abstraction level is consistent over a class.
- Thus, this can be seen as the start of automatic art analysis and soon the researchers recognized the fact that the problems became too simple and returned findings are not sufficient, so they sought harder problems.

Artistic Movement Classification

Throughout the course of civilization, the trajectories of humanity and art have remained intertwined. Across the centuries, we have witnessed magnificent artistic movements brought forth by exceptional artists who have expressed their visions through various mediums and aesthetic approaches, guided by distinct philosophies and principles. Nowadays, we have the privilege of appreciating a diverse range of art styles, particularly paintings.

Artistic expressions encompass a wide spectrum of styles, spanning from subtle variations to striking, readily discernible differences. Style can be used to describe the unique elements, methods, or techniques of an artist's individual works, but it is also used to describe the artistic movement or school to which an artist is aligned. This association may arise from active participation in a specific group or from categorization by art historians. This second meaning is the one that annotated datasets used for automatic classification of art refer to. While in this case simple, one hot label categorizations can sometimes be limiting (because certain paintings can have influences from different styles) it can also serve to unify different artistic expressions under collective sets. Table 9.1 displays some of the art movements (found in existing public databases) along with their respective characteristics.

Classical methods employ feature descriptors spanning various categories for artistic movement classification. For instance, in discerning between Impressionism

Table 9.1 Art movements (styles) found in public databases with their approximate historic periods and some characteristics

Art Movement	Period (aprox)	Characteristics [18]
Byzantinism	330–1450	Religious, devotional, angular contours, flat colors, aura
Renaissance	1300–1620	Linear and atmospheric perspective, dark
Baroque	1590–1760	Dramatic, over-exaggeration, allegory, strong colors, high contrast
Rococo	1720–1780	Decorative, brighter, ludic, carefree
Romanticism	1790–1850	Rebellion, emotionally charged, sentimental, shadow, and light effects
Realism	1840–1870	Real life depictions, anti–bourgeois, harsh, social critique
Impressionism	1850–1900	Physical sensation, movement, intense colors, no distinct contours, light effect
Post-Impressionism	1886–1905	Meaningful forms, structure, strong edges, abstract forms, emotions
Expressionism	1890–1940	Strong colors, abstract, violent brushworks, search
Symbolism	1850–1900	Feelings, emotion, passion, dream imagery
Fauvism	1905–1908	Wild color contrasts, unnatural, simplified composition, impulsive lines
Cubism	1905–1940	Geometric shapes, confusing perspective, fragmentation, rejection of rules
Surrealism	1920–1945	Irrational juxtaposition, dream world, subconscious, taboos
Abstract art	1910–now	Geometric, not objective, simplified compositions
Naive art	1890–1950	Childlike simplicity, erroneous perspective, ethnographic patterns, frankness
Pop art	1950–1969	Imagery from popular culture, irony, uniform blocks of color and clear contours

and previous artistic movements, a key distinction lies in the brushwork and texture. Ancient pottery and Orthodox iconoclasm exhibit color palettes with a limited number of colors due to their antiquity. Additionally, to differentiate between styles like Realism and Surrealism, a comprehensive understanding of the painting's content is crucial and using global descriptors becomes imperative.

Initially, attempts to categorize art based on artistic movements relied on limited datasets and a small range of styles. For instance, the system proposed by Gunsel et al. [19] was designed and tested on a database containing 290 paintings from 5 artistic movements. They introduced six basic features derived from grayscale images, and the recognition process was assessed using various classifiers such as kNN, K-Means, and Support Vector Machines (SVMs). As bigger datasets were collected, more complex solutions could be developed. Arora and Elgammal [20]

used a dataset containing almost 5000 paintings to discriminate between 7 artistic movements using low level as well as semantic level features.

Condorovici et al. [21] tackled the issue from a perceptual standpoint, constructing descriptors designed to be closely aligned with human perception. These descriptors encapsulated significant categories of perceptual attributes like brightness, color, shape, texture, and contours. They introduced a new descriptor called Dominant Color Volume and used the gestalt (shape) theory to derive an anchoring complex image decomposition, to describe different areas of the painting. Florea and Gieseke [22] used an adapted learning framework (using boosted ensembles of Support Vector Machines) that is fed with complementary feature extraction that primarily utilize the Color Structure Descriptor and respectively histogram of topographical features for texture evaluation.

Karayev et al. [1] employed Convolutional Neural Networks (CNN) to classify 25 genres, outperforming hand-tuned descriptors in a large-scale dataset. Yet, it's worth noting that the input dimension was also derived from traditional features. Tan et al. [23] introduced their pre-trained CNN and visualized the extracted features to demonstrate the high complexity of the classification task. Lecoutre et al. [24] delved into the utilization of a deep residual neural network (ResNet) that has been pre-trained and highlighted that a deeper retraining process is necessary to achieve improved performance.

Classifying fine art collections presents a more formidable challenge compared to recognizing objects like dogs or cats, or even analyzing human faces, because a comprehensive understanding of the art domain, including its history, is essential for more intricate classifications. This is particularly true for artworks like Abstract and Illustration paintings, which are non-representational and non-figurative in nature [23]. Recognizing such pieces may require a degree of imagination, thus being more difficult for a machine. As can be seen in Table 9.1, the features of different art movements are discernible in the colors, the textures, and contours, as well as the theme of the painting, the placement of its different parts, the emotion it evokes. Consequently, categorizing the art movement can be broken down into more manageable tasks, like identifying the type of scene or recognizing objects and their positions. These are also areas of investigation within automated art analysis.

A technical observation is that although the performance gradually increased overtime despite evaluation on larger and larger databases, it remained lower than similar approaches dealing with natural photographs. A couple of reasons add to this conclusion: first, the domain of natural photographs is virtually unlimited, as always one can go and make additional photos, while databases of art are limited due to aesthetic requirement for a painting to be considered valuable. Another reason is that highly praised works of art break previously established barriers, showing creativity and imagination. The rules put down to describe an artistic movement are features and ideas that can be found in many, but not all works of art associated with that movement. Furthermore, sometimes categorization into a specific movement of a work is very difficult even for experts; from a machine learning perspective, this means that the labels are noisy. All these reasons add up and limit the achievable automatic recognition rate.

Genre Recognition

One interesting annotation available in some datasets is the painting's genre which denotes the central subject of the work of art such as portrait, seascape, historic battle, religious or mythical art, symbolic, flower painting, still life, wildlife etc. One can argue that the task of genre recognition is like the recognition of scenes in photographs. This task is considered more challenging than a simple object detection task because it involves interpreting the composition of a scene, which can comprise multiple objects arranged coherently. Different research like [25–27] employed convolutional networks to identify scenes in photographs from various datasets. Yet in the case of paintings, one must consider the fact that some degree of abstraction can be present due to the style of the painting. The issue of how style impacts the representation of real objects was tackled by Hall et al. [28]. They experimented with an approach to train multiple classifiers with different feature sets. In each case, the classifier was trained on a database of photographs and then tested directly on paintings. Their goal was to use deep learning to address the challenge of cross-representation. They labeled this challenge as a cross-depiction problem, which is understandably complex, given the substantial alterations in visual information representation when employing an abstract style.

Building on this notion, Crowley and Zisserman tested the ability of convolutional networks to detect objects depicted in paintings, with training conducted on real-world data. Their conclusion was that the network can accomplish this task effectively, provided that the style being approached is a realistic one [29].

Tan et al. [23] illustrated the features extracted from the trained CNN by visualizing the neuron responses. By analyzing them they observed that paintings belonging to the same genre don't necessarily have matching low to high level descriptors. This is not the case when analyzing normal photographs where the features extracted from images from the same class (e.g. faces) show similarities. Their conclusion was that art classification is more challenging.

In the study by Florea et al. [8], the authors delved into the human-interpretable factors that prevent CNNs from comprehending painting genres. Starting from the idea that deep networks detect objects and based on their presence they recognize scenes [30], they experimented by dividing the dataset in train and test partitions based on the styles of the paintings. More precisely some styles were left only on the test dataset. They showed that, by doing this, the recognition rate for the scene type (genre) decreased significantly, thus the abstraction given by the style has an important part in the recognition process. The same conclusion is reached by analyzing the recognition of the genre in relation to the art movements. The more abstract the style of the painting is, the more improbable is for the network to correctly recognize the genre. Superior recognition rate is achieved for older styles (up to Post-Impressionism) that don't use a lot of abstraction, and portrait scenes in a traditional and realistic manner. But art movements like Surrealism or Cubism that are further away from reality give worse results when recognizing the type of scene.

A difficulty that arises when working with content strongly influenced by the artistic style of the authors lies, as stated before, in the scarcity of available images,

in contrast to the abundance of "consumer" photos. One potential approach to tackle this situation could involve employing style transfer techniques. Style transfer entails the process of applying a secondary style to the domain of the initial one (this will be further detailed in a later section of this chapter).

Badea et al. [31] applied domain transfer techniques to gain insights into the internal representation and structure of the painting clusters. By examining various domain transfer methods, they assessed the potential in enhancing recognition rates and enabling the network to surpass abstraction constraints. In this way they intended to make the CNN learn from diverse image types belonging to the same scene category. This endeavor involved annotating photographs based on scene type in relation to genre and applying diverse style transfer methods to a substantial corpus of photographs. Intuitively the distinction between artistic images and photography lies in their respective styles. Different experiments have been made by using techniques of style transfer to "paint" consumer photographs as well as artistic photographs annotated by genre. The assumption made was that the composition of artistic photographs would be more likely similar to the ones of the paintings, whereas consumer photographs can have any composition (presence and placement of objects in the scene). But their experiments indicated that, although the result of the style transfer methods is visually pleasing to the human eye, it does not correctly replicate the artistic movement of the painting and it does not help the CNN get better results. Because certain criteria must be met for a piece to be recognized as a work of art, which includes a notable level of artistic originality compared to previous works, the domain of paintings is comparatively less populated than that of regular images. When faced with the task of enhancing the performance, CNNs prefer handling novel pieces of art when it is exposed to a larger variety of artworks during its training phase. In this aspect, CNNs share a resemblance with human experts, as those with expertise in art don't refine their skills by scrutinizing regular images.

Visual Saliency Estimation

Visual saliency refers to a scene's capacity to capture the focus of various individuals on specific objects within that scene. In separate psychological experiments, Zeki [32] and Ramachandran and Herstein [33] revealed that the essence of comprehending art lies in discerning its perceptual mechanisms, rather than dissecting its aesthetic attributes.

Analyzing saliency maps has demonstrated its efficacy in producing consistent aesthetic assessments for real-world, natural images [34]. This concept subsequently evolved into a metric for gauging the complexity of artistic compositions [35]. Notably, within paintings, there exists a profound correlation between the saliency map (i.e., focal points or gaze fixations) and the emotions evoked by the artwork, as demonstrated by Yanulevskaya et al. [36].

In the context of the fixation of one's gaze on an artistic painting, Locher et al. [37] discovered that within the initial two seconds, art viewers engage with the entire composition, grasping its 'core'—that is, comprehending the entirety simultaneously, regardless of the visual intricacy of the scene [38]. This is the case no matter what the artistic style of the painting is. It is only after this initial exploratory phase that viewers

tend to zero in on more nuanced details. Furthermore, during this subsequent period, research has demonstrated the significance of bottom-up saliency in influencing eye movement patterns [39]. To sum up, extensive studies have delved into gaze patterns and behaviors exhibited by individuals when perusing art. However, the utilization of saliency in characterizing image content has been mostly overlooked.

Automated Aesthetic Appraisal

The initial observation is that human masters' artworks are nearly unanimously appreciated. Therefore, even if aesthetic judgment is a subjective matter and it is very hard to reach strong consensus, it has been shown to establish a universal aesthetic measure. The effort is noticeable in multiple domains. The basic one is in the psychological field, where for instance Mastandrea et al. [40] hinted that appraisal, beyond conscious cognitive tasks, is based on automatic (in the sense of subconscious) processes, thus there are reasons for a universal measure.

In the domain of computer vision, the process of building aesthetic measures for artworks is derived from the broader work of seeking such a value for natural photographs. For a more detailed view on directions, solutions, and results, we kindly refer the reader to the work of Anwar et al. [41]. The authors conclude that there is still work to do and, given the previously mentioned differences between the domain of natural images and respectively artworks, we can reasonably argue that there is even more work to do for appraising artworks.

For instance, Berezhnoy et al. [42] extracted full and partial image descriptors for classification of oil paintings into 'high-quality' and 'low-quality', based on photography-deduced rules of composition (e.g., rule of thirds, color harmony). Hu et al. [43] referred to color composition and evaluated color harmony to generate aesthetic measures. In the evolution of the field, as we come closer to the present moment, more complex measures have been proposed. Guo et al. [44] constructed an annotated database with visual complexity (that has been determined by saliency map) and tried to learn this with a machine learning solution; further, the automated prediction is combined with a balancing measure.

More recent solutions made use of the deep convolutional networks power. Zheng [45], while working in artistic graphic design, constructed an artificial database, obtained the human evaluation, and asked the Visual Memory Network to learn the association.

Overall, in this direction, one will note that results are at a lower stage of evolution compared to other tasks associated with digital art. Since there is no unanimous agreement over aesthetic measures in natural photography domain, there isn't either in the visual art. More relevant approaches are in the psychological domain where there is an interest in finding the cognitive process associated with aesthetic judgment. In the computer vision domain, the current dominant solution is to build a database, annotate it with aesthetic values and ask a deep network to learn the association; the limitation in this approach comes from the volume of annotated data available.

9.3 Automated Art Generation

The integration of artificial intelligence in art analysis has opened the potential for employing computer vision algorithms to create art. Even the most advanced current solutions, that are actively utilized and have some works recognized as genuine art, propose generating numerous potential outputs and then choosing only the most meritorious ones as being possible artificial art.

Overall, the effort to generate synthetic art can be separated in five phases:

1. Artistic transfer with methods not involving machine (deep) learning.
2. Classical artificial painting synthesis aimed at using a wide set of packages carefully engineered to produce images that resemble artistic works. This phase preceded the usage of deep learning and quite often was restricted to specific groups driven by enthusiasm toward art.
3. Neural style transfer (NST) developed on findings that an image fed through a deep convolutional network is decomposed into content (subject) and style. From this moment, most solutions were built around deep learning frameworks.
4. Adversarial neural style transfer where the technique of NST is combined with adversarial generative models to synthesize images with artistic content.
5. Latent diffusion models which are developed from text to speech synthesis processes.

In the next subsections we are going to take each one at a time and detail them to provide a better overview. However, some preliminaries must be discussed first. These works aim at creating art and one characteristic of art is creativity. Therefore, we are going to summarize some ideas about creativity.

9.3.1 Creativity

Similar to artificial intelligence, there are multiple definitions of creativity that may not necessarily align completely. Drawing inspiration from the widely adopted Turing test which is the most widely used definition of an intelligent agent, there is a broadly used definition of creativity, expressed by Lovelace [46]: An artificial agent denoted by *A*, that has been designed by C, passes the Lovelace test if and only if:

(1) *A* outputs *o*.
(2) *A*'s outputting *o* is not the result of a random hardware error, but rather the result of processes *A*. These processes need to be repeatable.
(3) C (or someone who knows what C knows and has C's resources) cannot explain how *A* produced *o* by appeal to *A*'s architecture, knowledge base and core functions.

Obviously, this test has limitations, such as the subjectivity definition of "cannot explain". Therefore, subsequent works, such as the Ritchie test [47] proposed variants

and complementary measures to define a more complete test. However as is the case in many other scenarios, even if arguable and subject to critique, the original version remained the most popular [48] and thus we are not going to delve further into details.

9.3.2 Artistic Transfer

These attempts originate from the color transfer algorithms. Color transfer (also named color mapping) methods aim to recompute the color palette off a subject image by finding a transfer function (often named mapping) between that image and a reference image. A more detailed perspective on the theoretical formulation, results and applications can be found in the work of Finlayson et al. [49].

For the moment let us mention that the first significant result is in the work of Reinhard et al. [50]. In this solution, the colors u, taken from the source image I_s, are first represented in a perceptual space, and, next, are adjusted, based on the tones from the reference image I_r, according to a linear model:

$$g(u) = au + b$$

The adjustment is on each chosen color plane independently. This linear mapping is defined by two constants, namely a and b, which are chosen such that the mean and the variance from the source image to be precisely the same as the ones from the reference image. This initial approach had shortcomings and was further amended for a more effective transfer [49]. While color transfer had many applications, we are interested here in those that aim at introducing an artistic effect.

In video productions, in order to achieve the desired effect, artists must slowly and painstakingly adjust the color palette of an initial record, which is also known as color grading. Into this direction, Bonneel et al. [51] introduced an example-based video color grading approach, relying on the color transfer method, to map the palette of a source video sequence to a target one. After a first step replicating Reinhard's solution, for reduction of artifacts, a differential geometry-based interpolation model is used to smooth changes. In the last step, the keyframes with best representation of the interpolated transformation curve are determined. Similarly, in the realm of creatively employing color transfer, Lee et al. [52] took a different approach. Instead of employing a specific reference image for each subject image, they developed a universal function in a preprocessing phase. This function was then utilized to calculate transfer parameters for new reference images. Also suggesting artistic effects, the adaptive method by Rabin et al. [53] uses mathematical constraints to derive a more elaborate mapping.

However, the color transfer methods, as their name states, transfer only color; implicitly this means that the content is that of the original subject image. Generally, if the original image does not have artistic content, the color transfer method does not have the power to add it. They are capable only of enhancing upper existing artistic tint. Visual examples of the mentioned methods can be seen in Fig. 9.2.

Fig. 9.2 Examples of color transfer methods where the solution seeks to augment the artistic view of the original image. The original image is on the top row, the reference image is in the middle row and the resulting image is in the lower row. One can notice that if the original image was not art, neither is the result

Recognizing the constraints of color transfer techniques in generating artistic content, alternative solutions have emerged to focus on transferring the artistic essence. The principle of transfer in this case is like the one used by Reinhard et al. to transfer color: match statistics over the appropriate descriptor space. While color transfer methods operate within the descriptor space of colors, in the case of so-called "style transfer", the descriptor space pertains to edges. To achieve a better definition of edges, images have been decomposed in Laplacian pyramids such was the case of Sunkavalli et al. [54] or Aubry et al. [55]. After these two transfer methods were established, it became evident that there was potential for combining them. For example, Arbelot et al. [56] integrated these approaches, striving to find transformations that would maximize what they referred to as 'expressiveness' aiming to evoke artistic flavors.

Into more detail, the Laplacian method assumes that the images are represented as a Laplacian pyramid with several levels. On every level, the style transfer solution is completed using a gradient transfer. Specifically, at each pixel, **p**, in each level of the pyramid, considering a neighborhood **q**, the set of gradients for the two images is denoted by $\nabla S_{\mathbf{p},\mathbf{q}}$ (for the subject image) and respectively for the reference image by $\nabla R_{\mathbf{p},\mathbf{q}}$. The transfer is implemented by iteratively correcting the current local point S(**p**):

$$S_n(p) = r(S_{n-1}(p));$$

$$r(i) = g + sign(i - g)t(|i - g|);$$

$$\mathrm{t}(i) = \mathrm{CD}F^{\{-1\}}_{\nabla R(p)}\left(CDF_{[\nabla S(p)](p)}\right)$$

where the CDF is the cumulative density function (cumulative histogram) computed on the image, r(•) is the transfer mapping function, while $S_1(\mathbf{p})$ is the initial (i.e. at iteration 1) local pixel of the subject image and $S_n(\mathbf{p})$ is the value of the pixel from the same position at iteration n. The mapping function is computed iteratively to avoid the artifacts introduced by the discontinuities originating in the approximation of the cumulative density function to local cumulative histogram. The process usually converges in about 10 iterations.

These so-called style transfer methods compensate for the lack of artistic content from color transfer methods, but, at the end, they also need an original image with artistic content to transfer with. In other words, they do not create anything, they simply transfer. Visual examples can be seen in Fig. 9.3.

9.3.3 Classical Synthetic Painting Generation

Attempts to use computer vision techniques to generate art have existed from earlier times. In this direction we mention the work of Baker and Seltzer [57] which iteratively evolved a simple drawing into a sketch. The procedure involves starting with a random group of lines and using mutations and moving operation in a genetic evolutionary algorithm to end up with a meaningful drawing. The result, while occasionally had some naturalism, lacks the consistency of an art drawing.

A further development into this direction is the so-called non-realistic rendering [58], which had the purpose to develop techniques that generate images in a nonrealistic manner and ultimately to combine them with graphical rendering to create computer generated art. A key development in this direction was the project called the Painting Fool (formerly available at thepaintingfool.com), which intrinsically is a software set of packages that was designed to work as an artist [59]. The project has been developed over a long period of time, with an assumed goal of constructing algorithms and software code describable as artistic or creative, rather than simply returning images that only appeared as being painted by a person. In a sense, the project anticipated the recent development by incorporating various AI techniques including, but not limited to natural language processing, optimization, evolutionary search, design grammar and machine learning [59].

Among these earlier attempts, the usage of evolutionary computing (most often genetic algorithms) was particularly appealing. The idea to start with a raw shape and iteratively evolve into art attracted multiple researchers [60]. Since art, at least the most popular styles, now lacks rigor (in the sense of deterministic symmetry, structure), the underlying process required the inclusion of steps based on random

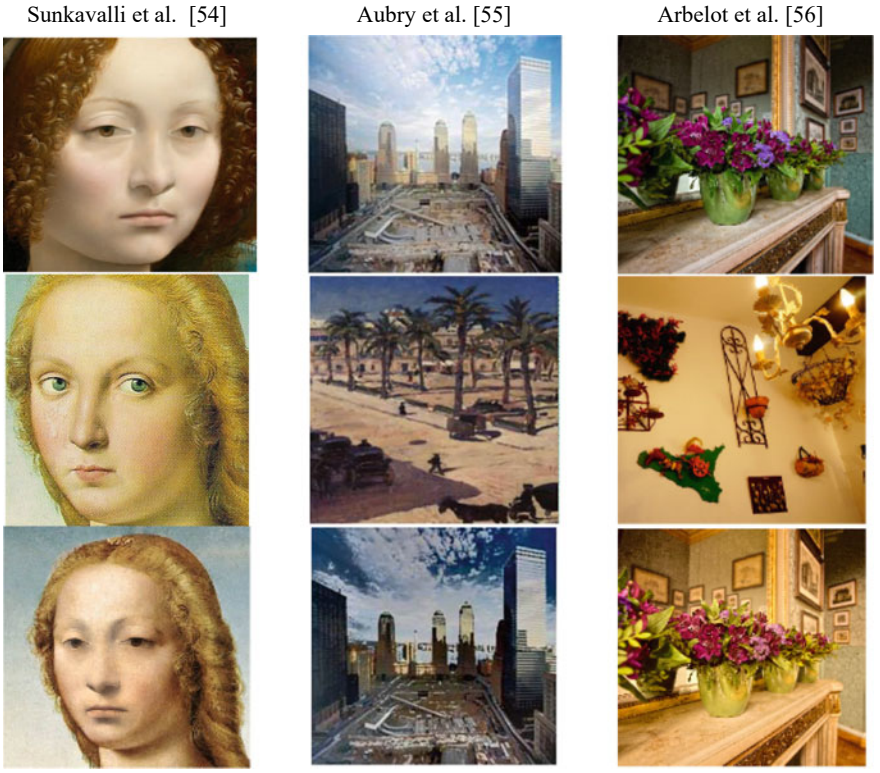


Fig. 9.3 Visual exemplification of style transfer methods—the content from the source image (top row) is either inserted and the focus is on removing artifacts, or specific construction details such as edginess are transferred from the source image into the destination image (middle row). However, this is not artistic generation, but mere artistic replication, or artistic augmentation

decisions, in order to introduce some chaos. The natural solution at that moment was provided by genetic algorithms. Yet, by understanding that synthetic creativity has its own limitations, often the generative process was complemented by either learning from a master painter works, or by mapping a style (defined as edginess and color palette) on a natural scene as in the case of Seifi et al. [61].

9.3.4 Neural Style Transfer

The original neural style transfer has been proposed in the seminal work of Gatys et al. [62]. In this work, the authors demonstrated the power of deep neural networks (CNNs) in producing images with an artistic flavor by separating and reassembling image content and style. The decomposition is achieved by extracting representations of the image through different layers of a deep convolutional network. This overall

process of using deep networks to represent a content image in different styles, extracted from a style reference image, is known as Neural Style Transfer (NST). It is gathering broad popularity and a multitude of approaches have been proposed to improve or extend the original algorithm.

From a taxonomy point of view, the neural style transfer method comes from a group of algorithms that use the image representation within the deep neural networks and iterative optimization to reconstruct images. The original idea was proposed by Mahendran and Vedaldi [63]. The algorithm assumes a given CNN representation, then starting from random noise, modifies the CNN weights using stochastic gradient descent such that the mentioned CNN forms a representation which minimizes a mean square error with respect to the desired one.

In continuation of this class of methods, the neural style algorithm [62] is initialized with a white noise image, **X**, which is altered to match the superimposed statistics, thus also departing from minimization of a simple means square error. The global loss function used in the neural style transfer method is a convex combination between the content loss function and, respectively, the style matching loss term. In this method, the content matching is for the subject image, **S**, while the resulting generated image is **X**. Considering the activations F^l_{ip} (P^l_{ip}) of the ith filter on the lth layer at position **p** in a deep network representation of **S** (and respectively **X**), the loss function dedicated to content is:

$$L_{content}(S, X, l) = \frac{1}{2} \sum_{i,j} \left(F^l_{ip} - P^l_{ip} \right)^2$$

To emphasize and control the correlations between activations (of the two representations), the algorithm uses the Gram matrix. More precisely, $\mathbf{G_{ip}}$ is computed as the inner product between the vector (from matrix) representation of the ith and pth activation maps of the lth layer:

$$G^l_{ip} = \sum_k F^l_{ik} F^l_{pk}$$

In the Gram matrix-based definition, the responsibility of preserving each layer contribution is emphasized. The lth layer contains N_l feature maps of size M_1. Therefore, if one considers **R**, the Gram representations, along the style source image **X**, A^l and G^l can be found by maximization via gradient ascent. Thus, the term contributing from a specific layer is:

$$E_l = \frac{1}{4N_l^2 M_l^2} \sum_{i,j} \left(G^l_{ip} - A^l_{ip} \right)^2$$

Overall, the total style loss is:

$$L_{style}(A, X) = \sum_{l=0}^{L} w_l E_l$$

The linear combination of the mentioned terms forms the total loss function:

$$aL_{total}(X, S, R) = \alpha L_{content}(S, X) + \beta L_{style}(A, X)$$

where α and β are empirically determined weights.

Given the dramatic visual impact and the consequent popularity of the initial method, the researchers started to investigate into more detail the neural style transfer algorithm. One perspective that drew interest was the mathematical explanation of the derivation. Into this direction, Li et al. [64] showed that, in fact, the maximization of the Gram matrix representation in the style transfer process is mathematically equivalent with the minimization the Maximum Mean Discrepancy (MMD) approximated within the second order polynomial kernel; therefore it represents another version of matching the feature distributions. Therefore, it still falls into the same category of transfer methods that aim to match statistics over some carefully selected representation of the image. We recall that Maximum Mean Discrepancy (MMD) is a test statistic for the two-sample testing problem, where acceptance or rejection decisions are made for a null hypothesis [65]. This means that a minimum MMD asks that the two distributions (which, in our case, are that of the image **X** and of the reference images: for style **S** and for content **R**) to be similar enough (i.e. within a statistical relevance limit). In fact, the work of Li et al. [64] shows implicitly that the neural style transfer follows the original principle introduced for transfer methods by Reinhard et al. [50], but with the major difference that the feature representation is not color, but it is extracted from the activation of a specified layer from a convolutional neural network. There are certain additional differences, such as the fact that neural style transfer approximates the matching error, showed by Li et al. to be developed into polynomial extension up to 2nd order only. The exact solution would be by inverting and composing the Cumulative Density Functions (CDF) of the multidimensional descriptors.

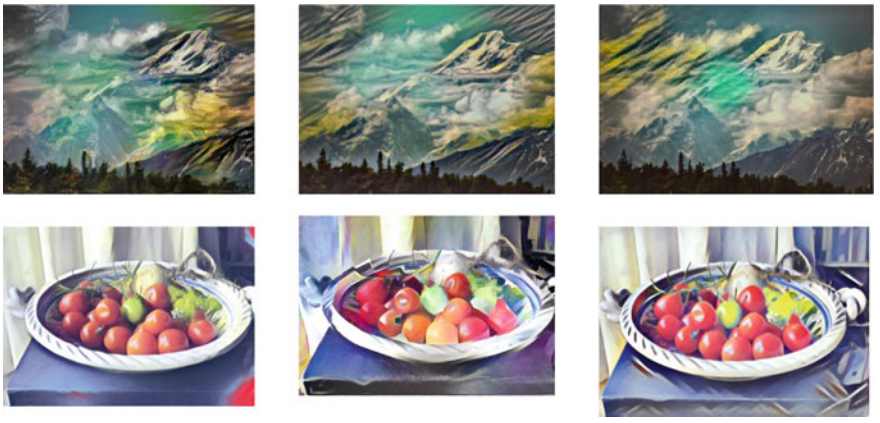
Given that the process has limitations, several improvements have been proposed. In dealing with the Gram-based algorithm, one will soon find out that it can become instable during optimization and hyperparameters which require manual tuning have a significant impact. The activations maps lead to approximately the same Gram matrix irrespective of their mean and variance. To compensate for this fact, one introduced an additional histogram loss, which requires a more precise optimization, but also a more complete and pure approach to the transfer by matching the idea behind the statistics. They also proposed a solution for automatic parameter tuning, in such a manner that it will prevent gradients from getting extreme values.

It also has been noted that NST introduces certain artefacts. To avoid breaking the coherence of fine structures in the style transfer, Li et al. [66] incorporated supplementary constraints upon low-level descriptors in the pixel space, in the form of a Laplacian loss. This loss is given as the squared Euclidean distance between the

responses of a Laplacian filter applied on the content image and the stylized result, thus adding parts of the idea from the Laplacian transfer.

The standard neural style transfer process is, in fact, an image optimization method, in the sense that it starts with an image having random values for pixels and iterates (changes pixels values) until the image matches certain statistics [67]. Thus, the process is slow and overall resource-consuming, especially when the reconstructed image has large resolution. Once the iteration process was broken into smaller parts and an analysis of the change with respect to duration was made, it turned out that most of the image was computed in the first steps; yet this reduction of complexity and time consumption was limited [68]. Therefore, alternative solutions have been proposed in the form of so-called Model-Optimization-Based Offline Image Reconstruction [69]. Several methods [70, 71] have been proposed that essentially pre-train a feed-forward network to move the computational excess in the training phase. At testing stage, the stylization process can be simply done in the forward pass of the network, thus accelerating the image reconstruction process significantly. The drawback of these methods is that for each style reference image (i.e., painting), a new network needs to be trained, while the original NST algorithm could have been applied for any new style image. Some examples of results obtained with various solutions of neural style transfer can be seen in Fig. 9.4.

Now the real question is how well does NST (and variants) work? At the time of appearance, they certainly had the "WOW!" factor and it led the people to the idea that they can help them create paintings like Van Gogh or other great art masters. However, a more precise evaluation found that there are limitations. Efforts were continuously put into developing and refining the style transfer based on these concepts. One direction was to refine the standard NST algorithm aiming to better imitate certain artistic styles. Badea et al. [68] analyzed multiple transfers and found that colorful styles with medium abstractization are easily transferred in this manner. While NST



Gatys et al. [62] Johnson et al. [71]: Ulyanov et al. [70]:

Fig. 9.4 Examples of images obtain by NST with three different solutions

Fig. 9.5 Example of three images produced with three alternatives of NST, out of which none looks particularly artistic

does not impose a specific limitation on the types of styles that can be transferred, it exhibits strengths and weaknesses in handling certain stylistic elements. For instance, all NST solutions, either working on image level or at style level, perform well in generating irregular style characteristics. However, when confronted with styles featuring regular elements like low-poly and pixelated styles, NST tends to yield distorted and irregular outcomes [67]. Figure 9.5 presents some examples of images produced with NTS-like methods that are not particularly artistic.

Another limitation appears when the NST uses images which are not photographed to demonstrate the transfer capacity. For instance, if sketches or cartoons are used as input content, the stylization is ineffective and not even a network recognizes the output as non-realistic photo. Furthermore, in a holistic qualitative test, where the purpose is to recognize the scene from a painting adding to original training set images which have natural content and style following a NST process had little to negative impact over a deep CNN trained accordingly.

In conclusion, we may say that the NST algorithm produces pleasant images, indicating that it is possible to recreate masterpieces from art, but it also still contains many more limitations such as artifacts, lack of quality in the output, lack of style, etc.

9.3.5 Art Synthesis with Generative Adversarial Models

We recall that generative adversarial networks (GAN) are unsupervised machine learning systems imagined to synthetize data given a certain distribution. Going into more detail, they are built as a loosely organized cycle, with a pair of models being trained: (1) a generative model G which receives as input a vector of random numbers and returns data that matches the probability density function of a given training set and (2) a discriminative model D that seeks to determine if the generator produced data is synthetic or comes indeed from the given training set. The two models are arranged in a two-player, thief-policeman-like game where the generator G seeks to increase the likelihood that the discriminative model D makes a mistake, while

D seeks to distinguish better the synthetic from the true data. In the most popular embodiment both G and D are built with artificial neurons more likely in the form of deep neural networks. Therefore, G seeks to maximize the entropy (i.e., confusion), while D aims to minimize it, thus producing a min–max structure. The general loss of a GAN is:

$$min_G max_D V(D; G) = \mathrm{E}_{\mathbf{x}\sim p_{\text{data}}(\mathbf{X})}\left[\log D(\mathbf{X})\right] + \mathrm{E}_{\mathbf{z}\sim p(\mathbf{z})}[\log(1 - D(G(\mathbf{z}))]$$

where original training data is **X**, while initial random data is **Z**; G(**z**) is the generated data.

Since neural style transfer was already popular once the GAN models started to become stable and they were usable to generate new data, a combination between style transfer and generative models appeared in a progressive form [72]. The following steps are taken to build this new model:

1. The generator has as input a latent code, but it can also be neglected and initialized from a learned constant.
2. Given an input latent code **z**, the generator, which implements a non-linear association, maps the latent input space **Z** into **W**, f: **Z** → **W**, by generating **w**.
3. Following the mapping, the generator learns the affine transformation which associates **w** to styles y_S. y_B; the latter controls the normalization of the generator G.
4. The used normalization procedure is standard translation to 0 mean and 1 variance. Next y_S is used as scaling constant and y_B as bias.
5. The generator gets white noise as input. The noise is uncorrelated and has been generated within a single channel of images. Synthesis layers are fed with dedicated noise.
6. The so-built noise image is transmitted to all feature maps and an additional convolution follows.

While in the original work [72] the method was used to produce realistic images, subsequent application showed that it can be used to generate nonrealistic ones with art like flavors. Examples produced with StyleGAN may be seen in Fig. 9.6.

In the initial form, GANs were unconditional, in the sense that they assumed that all data was valid, being in a single category and therefore synthesized data must fall in the same unique category. Obviously, in many problems, data has class labels and therefore conditional GAN (C-GAN) appeared. C-GANs are asked to produce data from a specific class, therefore the generated image is conditioned by an input class label. To implement this task, the C-GAN relies on a loss function, that structures the differences between input and generated images. In conditional GAN, the generator assumes a segmentation type of network (e.g. U-Net), while the discriminator borrows from a PatchGAN architecture in the sense that it penalizes differences in local structures (“patches”). The method is shown to prefer images with medium patches [73].

Fig. 9.6 Images generated with original StyleGAN (top row), the conditional form (middle row) and with cycleGAN (bottom row)

Another direction to approach the problem of neural style transfer using GANs is to rely on the so-called cycleGAN [74]. The latter was specifically designed to transfer an image into another one. The architecture consists of two generators: one generative network (G_S) for generating images for the first domain (Domain-S), while the second generative network (G_T) is used for producing images for the second domain (Domain-T), thus closing the cycle. The two generators are trained to be inverses of each other $G_T(G_S(\mathbf{x})) = \mathbf{x}$.

In the case of synthesizing images with artistic nuances, the source domain is made of photograph, while the target domain is made of an artistic painting. The outcome image is retrieved in the middle of the cycling process as it should be a combination between the subject of the photograph and the style of the painting. A significant limitation in this approach is that creativity requires injection of some randomness; unfortunately, the only source to inject randomness in the cycleGAN is through images. Therefore, some approaches were built specifically to address this limitation. A notable approach using cycleGAN is Artsy-GAN [75]; they proposed a set of changes to increase the perceived creativity of a resulting image:

1. Adding a perceptual loss to the reconstructing loss in order to move the general solution towards art.
2. Relying on a sub-sampling on the chrominance channels. This had the effect of improving precision and reducing size.
3. Adding noise to the generator input to increase randomness and thus creativity.

Overall neural style transfer allowed artistic strokes on photo images, but the content was still in direct relation with the input photo. Adding a GAN into the process allowed changes of the subject of the image and slight modification of the style imported from the style reference image. Thus, we may conclude that GAN based artistic image synthesis is an advancement with respect to previous developments. However, as is the case with general art value, it's rare and is also in the eye of the beholder.

9.3.6 Latent Diffusion Models

Text to Image Synthesis

Probably the current most advanced models that are aiming to generate creative art are the latent diffusion models, also known as stable diffusion. They are a development of text to image generators which is the opposite of the image captioning solutions.

Image captioning aims to build solutions that, starting from an input image, aims to provide rich text as description. They can also be seen as a development from image classification, where, given an image, the classifier returns a unique word which is the label of the dominant object in that image. Image captioning assumes the recognition of various objects within the input image, discerning either the spatial relationships between them, or identifying a specific action linked to one of the objects and putting together all these keywords in a phrase that has meaning and grammar consistency. The later part has been borrowed from natural language processing and in the early phases required a recurrent network which often implies long term short memory blocks. Very recently the natural language processing part was approached with the so-called transformers.

In parallel, conditional generative adversarial networks are used in many applications to synthetize objects from a specific class. The development from synthetized images based on one word description to synthesized images based on a caption (rich text) was seen as natural evolution [76]. These methods accrued compelling progress in the last years with respect to diversit, visual realism and semantic alignment. The core of the model is based on a GAN and has also a branch to address the natural language processing part.

The proposed solution of text to image was introduced by Reed et al. [77]. They implemented conditions on the generation process which received as condition a complete sentence embedding that has been extracted from a pre-trained text encoder. The discriminator was tasked to differentiate between real, original and respectively synthesized image-text pairs. Hence, the natural extension of a C-GAN came in

replacing the conditioning on a class label, y with a text embedding, ϕ. Suitable loss function forced both the generator and discriminator to match the realism of the image with text description.

In a development of the same problem, where noticeable artifacts were thought to be eliminated by decomposing the problem into smaller sub-problems, some solutions propose decomposing the image into style and content. For instance, Lao et al. [78] defined the style using a vector of random values and respectively content by selecting random text embedding from the latent space using an unsupervised process. In this solution, another encoder receives real images and predicts the style and content (modeled as latent variables), which are the further foundation for generating an image. The encoder and the decoder are constrained by a specific term in the loss function to be consistent with one another. Obviously by inputting appropriate images one can inject artistic style into synthesized images, therefore opening synthetic art creation. However, this kind of solution did not have enough time to mature because the latent diffusion models appeared, and they produce much better performances.

Diffusion Models

In the very recent period, several image generative models appeared as commercial applications. They are built upon text to image synthesis and one specific aspect is that they have been trained on extremely large databases. Out of them several appeared directly as a solution, and public knowledge is restricted to marketing text, while the so-called stable diffusion is based on an academic work, which is that of latent diffusion models [79].

From a technical perspective, stable diffusion is an incremental and engineering-based process over previous contributions. The method is composed of semantic compression and perceptual compression; a contribution with tangible results is to separate tasks and train the model distinctly and to follow with an aggregation based on carefully selected parameter values. Parameter selection is a distinct engineering effort that was further coupled with conditioning mechanisms. Beyond that, the architectures are classical with visual transformer as a unit for synthesis and diffusion models.

The images produced by this diffusion model are noted by their realism (which, in this context, refers to the artefact free nature and not to the artistic style). While the method has been developed mainly to generate photograph like images, it can also be used to create art-like pictures, as the public interface explicitly supports a wide variety of artistic styles. Several examples of images produced with stable diffusion are showed in Fig. 9.7.

If one wishes to summarize the solutions proposed to synthetize art-like images, he will note the continuous effort from different perspectives, practical or theoretical. Significant efforts were directed towards understanding art, decomposing it into disjoint components (such as style and content) and formulating mathematical concepts that model the nominated components. On the practical side one can note a continuous evolution measured with respect to the lower bound: that the resulting images are less and less bad. On the upper bound, synthetic art is similar with what

"landscape" "men" "old" + "art style-cubist"

"beach" "landscape" "night" + "art style-hyperrealism"

"beach" "landscape" "night" + art style-impressionism

"fear" "dark" + "art style-pointillism"

"abstract" "landscape" + "art style-renaissance"

"painting" "young" "woman" "with" "fruit" "basket" "in" "old" "town" + "art style-expressionist

Fig. 9.7 Examples of images that mimic specific artistic styles that have been created with stable diffusion

people produce: many drive to paint an artistic feature, but very few actually succeed. The major difference between humanity and artificial intelligence is the speed and the volume that they can produce: even the fastest painter needs a couple of minutes to draw a sketch and maybe an hour to put some colors on an image, while a stable diffusion based algorithm requires around 100 s to deliver the output.

A significant overall preference of human observers for art created by humans against art created by AI was noted by Bellaiche et al. [80]. In this work two studies were designed to explicitly evaluate the preferences of human observers of art. Both studies consistently indicated human created art as the winner. The authors suggested several reasons. One direction refers to the perception of creativity where the human observer preferred over cognition and production. The core idea here is that artworks reflect a profound human experience, while AI synthetized works are superficial from this perspective. The second idea that has been concluded by the test is that human value effort: in humanly generated artworks there are small clues and details which suggest effort; in contrast, in AI works, there is an indefinite suggestion of ease and velocity of production.

While it has been argued that the quality of human masters is significantly higher than the best works that an AI can deliver, the rebuttal to this idea relates to the bias introduced by the ease of production: people are both impressed by, for instance, the quality of Van Gogh works, as well as his struggles during life to produce them, both mentally and material. In contrast, when the AI produces an outstanding work, because there is a fantastic ease in doing it, people will tend not to consider it; a master like Van Gogh, if he disliked the end painting, he destroyed it, and poor works were never shown. An AI must show all the works and puts the pressure on the critics to select outstanding images from trivial ones.

There is also another effect that AI has on the world of art: the AI learns and replicates previous works, and further combines learned features with random seeding being creative at the end of the process which is explicitly based on luck. It is also able to produce huge amounts of works. If a young artist wishes to become known and appreciated, he has to be truly creative and distinguish himself from all the patterns that are repeated by AI processes. Thus, we would argue that now, due to AI, it is harder to become a good and famous painter.

9.4 Conclusions

This chapter aims to summarize several results that would write down small pieces of information that put together would answer the question: "are computers able to understand art?". Like any philosophical question there is no definite answer. The gathered results point towards a negative answer. The computers are not (yet) able to identify accurately the genre, the scene, to precisely locate objects in an image. If understanding has the meaning of structural understanding the answer is "not really": there have been efforts, but there is still path ahead.

Researchers in computer vision and machine learning became even more ambitious: they built computer programs to create art. While, in general, computer-generated art is significantly less appreciated than human artworks, it is not without value. There do exist museums and expositions that are well appreciated, that show only artificial art.

Furthermore, in the process of generating and understanding art, even if the final goal has not been reached yet, several intermediary results have significant value. There have been efforts in understanding art perception, decomposing art in features that have meaning from a computer vision perspective, that also led to interesting facts about human masters' cognitive process. The ease of generating artificial art makes it more popular and thus images of artworks penetrated different social groups; in many cases those people were interested in the original human work and thus art became more popular.

Probably the most striking conclusion is that computer vision and machine learning involvement into visual art changed for good the way that this domain progresses.

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Chapter 10
Challenges and Opportunities in Occupational Health and Safety Digitalization

Roland Iosif Moraru

Abstract The digitalization of the economy and society opens up an unsuspected field of possibilities for the occupational health and safety domain. By digitalization, we should understand not only digital technologies as such, but the uses they allow and their possible uses on individuals, organizations and businesses. Going digital improves the efficiency of the company's operational processes, so we must seek to digitalize to be competitive. The interaction between humans and machines, the resort to Big Data, control and interface tasks, and the resolution of network problems, are now part of the working conditions. The importance of digitalization was even more felt following the "COVID-19" pandemic of 2020. One of the biggest impacts for companies was that employees could no longer go at their place of work, or in a greatly reduced way. This meant that they now had to work online from home and independently, which was made possible thanks to digitalization. The World Health Organization has defined occupational health as being the overall physical/mental and/or social state of well-being of employees taken into consideration by employers, and not just the absence of illness or disability. Safety, on the other hand, is characterized by a work environment fairly protected from certain or potential risks that can injure workers. There is an occupational health and safety risk management process that takes place in three phases. First the workplace hazards are identified. Then, those underlying the risk are defined and assessed. Finally, there are appropriate controls for hazards. Risk management is partially but essentially based on the analysis of several declarative elements which must conduct towards the implementation of improvement/prevention/protection strategies and measures. The multiple origins of the contributing factors make the analysis complex and needs to be structured to be effective. This is a basic reason for which digital technology becomes a valuable supporting tool. Moving to a digital age and integrating digital technology within a company represents a challenge from which advantages can arise, improving the quality of employment and work, or disadvantages that can lead to psychosocial risks. In this evolutionary and dynamic context, the chapter aims

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L-I. Cioca et al. (eds.), *Digital Transformation*, Intelligent Systems Reference Library 253, https://doi.org/10.1007/978-3-031-55952-5_10

to detect and systematize both the current challenges of the world of work, from a safety perspective, and the answers that the acceleration of digitization processes can provide in order to adapt solutions to minimize occupational risks to the new trends that manifests themselves globally.

Keywords Digitalization · Circular economy · Occupational health and safety (OHS) · Human factors · Emerging risk · Artificial intelligence · Risk management · Psychosocial risk

10.1 Introduction

The European Union is nowadays committed to achieving its vision directed towards long-lasting sustainability by pursuing two of his basic processes of change envisaged: realizing the ambitious goal related toclimate neutrality, meanwhile implementing a circular economy. Also, EU is trying to take steps towards the future with quite a intimately linked policy agenda, developing "*a Europe fit for the digital age, empowering people with a new generation of technologies*"), a special effort to "*support the circular economy*" [1]. In addition, the New Industrial European Strategy, launched in March 2020, highlighted the role of the European industries should accomplish in such a process. At the present, anyway, just a few number of organizations are actively targeting, implementing and pursuing smarter strategies to increase circularity in economic activities (production, manufacturing, transportation, services etc.) and networking the plans of digital evolution on medium and longer time horizon, because they are lacking enough guidance on how best to use digital technologies to maximize sustainable resources production and consumption [2]. Some primary considerations linked to change induced through digitalization are highlighted in Leka (2021) [3].

By creating multiple possibilities for work organization, digitization offers new and valuable opportunities for prevention. All forms of work are concerned, whether they are mainly intellectual or mainly physical activities.

The challenge is to take advantage of the full range of possibilities and find solutions adapted to the specific needs of each company. In his new forecasting cycle, the European Agency for Safety and Health at Work (EU-OSHA) uses macroscenarios in order to explore the consequences of implementing a circular economy on OHS.

providing a brief insight at the implications of the scenarios in relation to digitalization and OHS [4].

Since 2020, both the digitalization vector development and AI applications worldwide use have gained an obvious and quasi—exponential impetus induced by the SARS-COV 2 pandemic crisis and the requirement to adapt to ever new and challenging work environments and tools for an ever increasing number of employees. Extensive teleworking/enhanced learning and use of online tools for communication and networking purposes have become priorities of our days.

10.2 Potential OHS Implications Resulting from Digitalization

For the mentioned European project, four different circular economy scenarios have been developed, all of which were grounded on the same set of key factors. Different realistic future assumptionswere assumed for each key factor and grouped—in a logical manner—together with the help of software to create consistent scenarios. The obtained result consist in several scenarios that represent a range of different possible outcomes for actions/events in the near future. Therefore, the assumed digitalization levels for 2040 ranges between scenarios, giving as further results various effects/implications. Figure 10.1 shows the four EU-OSHA different scenarios, which look at the future of the circular economy over a time lapse up to 2040. A brief description lists the characteristics of every scenario, followed by some of the most important OSH implications resulting from digitalization in the circular economy [5].

The emergence of Key Enabling Technologies such as, the Internet of Things, algorithms, digital work platforms, artificial intelligence (AI), Big Data, collaborative robotics (Fig. 10.2) and the significant increase in the population working remotely creates opportunities, but also emerging challenges and hazards related to OHS [7, 8].

Based on its "Foresight Study on Digitalization and OSH", EU-OSHA was conducting a research project on "*OSH Overview*" (2020–2023) to supply detailed information for policies, prevention measures and good practices on the challenges and opportunities of digitalization in the context OSH. The project was focused on the next vectors of interest [5]:

i. ***AI—Based Technologies and Advanced Robotics***

Advanced robotics and technologies/systems based on AI are changing at a fast pace the way people's work is designed/performed.

These systems, which are either embedded (e.g. robotics) or non-embedded (e.g. smart apps), are capable of taking actions, with a certain level of autonomous behavior (Fig. 10.3).

This evolution detains the capacity to exert significant and major positive implications and relevant effects, not only for business productivity/effectivenes, but also for OHS. As an example, employees can be replaced from risky working environments, while the working tasks/jobs can be optimized.

Such systems can execute high-hazard tasks or monotonous tasks, which are generally related to several classic and/or emerging OHS risks, leaving to workers to perform primarily only low-level hazard jobs and productive—or even creative—tasks. Robotics allows us to avoid dangerous situations for workers and to improve the quality of work and improve employees wellbeing transferring to faster, accurate and not tiring equipments, the monotounous/repetitive tasks. Cobots—for example—are able to facilitate access to work for various individuals which are at a certain moment excluded, for example, assisting disabled people or older workers at work. The increasing rate of smart mobile bots at the workplace could generate the risk

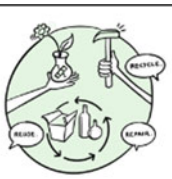	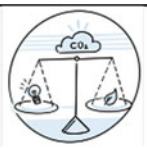		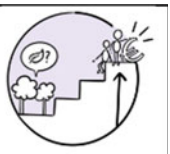
EVOLUTION: The economy of the 2040s — fully circular and inclusive	***TRANSFORMATION: Carbon neutrality – the dangerous kind***	***EXPLOITATION: Staying afloat – amid economic and environmental crises***	***FRAGMENTATION: Regional circularities — with European divisions***
In 2040, the best-selling products are those that are cradle to cradle and "net-positive" in terms of social and environmental sustainability. Reuse takes precedence over replacement, environmental and safety considerations dominate decision-making.	The year 2040 marks the achievement of carbon neutrality in Europe. But as environmental outcomes were prioritized above all else, this often came at the expense of job quality and working conditions, with workers widely dispersed and often lonely.	In 2040, the biggest concern for many is just having a job, not what the job entails. Most people focus on keeping things afloat, so much else is not taken into account - not the environment, social rights or the quality of jobs.	In 2040, everyone knows that contract workers are well looked after, but substandard workers are not. The environment is not a priority either, circularity being mostly regional.
Potential implications for OSH in 2040 resulting from digitalization in the Circular Economy			
- Physical risks are reduced in all industries, but psychosocial risks are increasing (e.g. due to work in isolation, due to performance pressure) due to increased digitization and automation in the circular economy. - Existing databases for all materials and products reduce hazards in repair, reuse and recycling.	Decentralized deployment/placement of workers makes OHS supervision and monitoring much more difficult. -Mobile work means workers are more likely to work in unsafe environments. -Rapid introduction of new materials means documentation is insufficient, exposing workers to unknown hazards.	- Workers lack the necessary skills to migrate or find a job, which increases the likelihood of employment with low OHS standards. -The preponderance of work on digital platforms means that responsibility for OHS is unclear, mental health risks are increasing and there is insufficient protection for self-employed and contingent/migrant workers	-Workers displaced by new technologies are pushed into the informal economy with very low OHS standards - At the regional level, digitization is very uneven, which makes it difficult to share OSH-relevant information.

Fig. 10.1 General presentation of the EU-OSHA scenarios and the possible OSH consequences induced by digitalization. *Source* adapted from EU-OSHA, European Risk Observatory Report (2018)

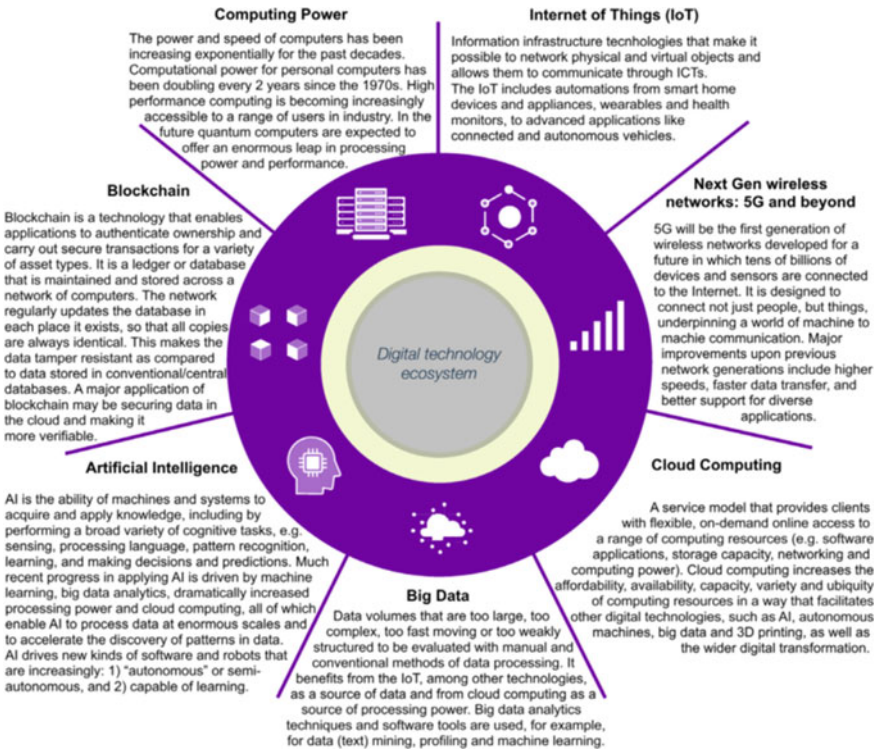

Fig. 10.2 Key Enabling Technologies: An ecosystem of interdependent digital technologies, forerunner of opportunities and challenges in OHS. *Source* adapted from OECD, 2019, and Voss et al. (2019)

Fig. 10.3 Advanced robotics: performing specific physical/cognitive tasks

of injuries, since undesired events may occur from direct interaction with cobots or with the machines/equipments they use. Even if intelligent robots are learning continuously, they can—nevertheless—behave unexpectedly, even if they submit to their design efforts to consider all possible scenarios. Workers who have to maintain the rythm and the level of work of an intelligent cobot could be subjected to high pressure associated with performance.

ii. **Managing Workers with the Support of Artificial Intelligence**

AI and digital technologies have given rise to new forms of worker management. Unlike previous forms of management that rely heavily on human supervisors, managing workers using AI refers to new systems and tools that collect real-time data about worker behaviors from various sources to inform management and to support automated or semi-automated decisions based on algorithms or more advanced forms of AI. More and more technologies are used mobile, portable or built-in digital monitoring (in clothes or on the body) to monitor workers in real time. Work is increasingly monitored and coordinated by algorithms and AI based on volumes big data, productivity tracking data workers, location, vital signs, indicators of stress, microfacial expressions and even tone analysis and of feelings. Research in this area identifies and debates the opportunities these new systems offer for AI-based management, as they can support decisions aimed at improving OHS in the workplace, when they are built and implemented transparently and workers are informed and consulted. Invasive monitoring enabled by technologies of AI-assisted digital monitoring can have an impact negative, especially on the mental health of workers. Workers may feel that they will lose control over content, pace and work schedule, as well and on the performance of work tasks, that I cannot interact socially or take a break when they want and that their privacy is invaded. For example, the use data to reward, penalize or even to exclude workers could create insecurity and stress. To prevent this, it is important to ensure transparency in the collection and use of this data. The research also maps and debates the legal, regulatory, ethical and privacy challenges and risks and concerns for OHS, particularly in relation to the psychosocial risk factors that these new forms of monitoring also give rise to and managing workers.

iii. **Work on Digital Platforms**

Work on digital platforms is any type of paid work performed through or on an online platform. Researches carried out in the area of working on platforms are targeted towards:

- analyzing and debating the opportunities, challenges and hazards encountered in platform working;
- charting the categories of work on the platforms as well as the related hazards and opportunities;
- highlighting and proposing policies to prevent OHS hazards for workers on online platforms;
- generating and developing brand new and feasible practical tools for prevention in the field of OSH.

The state-of-the-art body of research work related to occupational injuries and illnesses occurred on digital platforms already has emphasized the impact of poor working conditions, connected directly with low incomes, irregular working hours, lack of autonomy and control, job insecurity, non-conventional workplaces and lack of collective representation on the physical/psychological health and well-being of involved employees.

The main risks identified in different types of activities carried out through digital platforms are exemplified in Table 10.1.

Table 10.1 Occupational risks for selected examples of work in digital platforms

Type of activity	Physical risks	Psychosocial risks
Parcel delivery	Ergonomic risks, related to physical overload or repetitive manual tasks Road accidents (vehicles, bicycles Slips, trips and falls Violence at work Exposure to extreme weather temperatures Exposure to hazardous substances or biological materials	Excessive workload Working hours Isolation Bullying, verbal abuse, harassment…
Manual workers (locksmiths, electricians, plumbers, etc.. who receive work through platforms) ***(Handiwork)***	Exposure to hazardous substances (lead, asbestos, etc.) Working in awkward positions or performing awkward manual tasks, increasing the risk of AMS Lifting heavy or awkward objects Exposure to electricity, extreme temperatures or noise Working at height Slips, trips and falls Working with various tools	Excessive workload Working hours Isolation Bullying, verbal abuse, harassment…
Online content review	Ergonomic problems, due to improper workstation setup, including the visual display unit, keyboard, desk, and chair Prolonged sitting and sedentary behavior Excessive screen time	Exposure to violence, crime, abuse and illegal content while working Isolation Excessive workload and time pressure
Remote programming	Ergonomic problems, due to improper workstation setup, including the visual display unit, keyboard, desk, and chair Prolonged sitting and sedentary behavior Excessive screen time	Isolation Excessive workload and time pressure

iv. **Intelligent Digital Systems**

New monitoring systems for worker safety and health are being developed, for example smartphone applications, wearable devices, mobile monitoring cameras or drones, smart glasses, ICT-based applications and smart personal protective equipment to monitor and improve OHS. They can be used, for example, to monitor the physiological or mental state of workers, such as stress level, fatigue, alertness and heart rate, as well as posture and body movements, to monitor the location of workers in hazardous areas, to train workers or alert workers' managers or even emergency services. In addition to the opportunities for OHS, there are also concerns, for example related to data privacy, ownership issues, effectiveness and standardization. EU-OSHA studies assess their implications, looking at new types of monitoring systems (technologies), their use (e.g. supporting OHS compliance, effective enforcement or training), as well as OHS challenges and opportunities associated with their implementation and design. An overview of workplace resources is also provided (eg codes of good practice, company-wide policies, recommendations, guidance, protocols and training).

v. **Remote Work**

A basic distinction should be made between "***working from home***", which refers to teleworking at home [9], and "***working at home***", which describes the performance of work "*using the home as a place of work and production without ICT*".

10.3 Risk Control Through the Use of Artificial Intelligence

Organizations are rapidly growing the level of implementation in their own systems of variably advanced layers of AI in work management mechanisms, for setting working schedules and output targets, in designing/assigning tasks to their employees, as well as in hiring, performance evaluation and dismissal [10].

Artificial intelligence is increasingly becoming an essential tool for monitoring potentially dangerous situations when it is too difficult to do so with a human operator.

Among the most famous and frequently used in the workplace are: chatbot in call centers and platform applications that enable so-called "*Gig Work*" (a person who works temporarily in the service sector as an independent entrepreneur or freelancer).

AI can monitor a multitude of work contexts and operational parameters: from inappropriate human reliability to the condition of plant equipment, from the risks associated with the location where the worker is located to his state of health. Data is collected from sensors placed in the work environment and on the worker's equipment (overalls, helmets, wristbands, etc.). By monitoring health indicators such as heart rate and skin temperature, sensors can alert workplace managers to employees who are starting to show signs of potential physical problems.

Advance in AI and Machine Learning has ***important advantages*** over a human:

- *It works rapidly;*
- *It works continuously 24/7;*
- *It is able toperform working tasks/jobs in high noise levels, noxious and dynamically changing work environmental conditions and layouts.*

All these, in turn, are making AI an unvaluable assistant for a security officer/manager. Is AI able to render an industrial project safer? Certainly! It can highly enhance the increase of the safety culture level from pathological to proactive and support the manager decision—making processes by highlighting the supporting information needed in a dynamic approach of occupational risks effective management.

a. **Reduces Human Errors**

It is well-known that human factors are exerting a vital role and a major proportion in workplace accident genesis processes and models, with fatigue, lack of attention, diminished level of concentration, difficulties in focusing attention on the job execution and psychosocial risk easily being important co-factors in the initiation and development of undesired event occurrences. So a major AI advantage is its lack of ability to become distracted, burned-out, rusty or out-of-focus. This genuinely means that AI security can reduce the effects of human error in the workplace. One example is the system launched in 2018, AI-SAFE [11].

If an employee is not properly equipped, AI-SAFE is issuing and sending alert signals and automatically diminishis the access.

b. **Takes on and Performs Dangerous or Demanding Tasks**

Robots incorporating AI are increasingly becoming more mobile and intelligent/collaborative, removing human operators from dangerous locations and boosting the resilience, accuracy, rapiduty and operational safety. Drones can replace human operators in evaluating and researchimg/investigating hazardous locations, and gathering/reporting back relevant information and data. In this regard, robotics effectively can substitute human operators in performing sfaety-threatening activities. For example, the use of drones is increasing in the construction industry.

Industrial exoskeletons take on tasks characterized by high physical demands. Their goal is intended to increase, amplify or strengthen the effectiveness/performance of a worker's arms and shoulders, but also of the lower back and upper extremity. Although it is still unclear to what extent they are used, exoskeletons have already proven useful in certain. Environments. It must also be taken into account that this kind of assistance devices has a significant potential to induce some unexpectd maybe new OH&S hazards.

Both ***Virtual Reality*** (VR) and ***Augmented Reality*** (AR) are able to offer the important benefit of taking out some employees from risky working locations, because they are likely to be implemented, for example, to help in certain maintenance activities in heavy duty environmental conditions and also for immersive training. Nevertheless, one shoul not forget that devices based both on VR and AR can also represent a source of hazard through various aspects which can favour the

occurrence of implicitly acting risk factors such as: disorientation in space and time, motion sickness related health issues, eyestrain consequences, distraction form the working task, information overload and risk of misinterpretation which could trigger an accidental scenario.

c. **Monitor Workplace Harassment**

In 2019, it has been predicted that the use of AI to identify occupational harassment will become quite extensive in more the most advanced and developed states of the world. AI will be able analyse and emphasize occupational bullying/harassment through the intermediate of natural language processing.

Artificial Intelligence will be able and will perform continuous scanning of work office e-mail messages for inadequate and/or intriguing phrases, then generating and sending specific and directed alerts. By analyzing data/information, AI will be able to uncover payment inequities/gaps and arbitrary/unequal promotions. Supported by dedicated systems of voice recognition, AI will also be able to identify and point who is talking the most in briefings/meetings. It is presently already clear and obvious that an equal, well-balanced and diverse workforce is likely to bring for any economic organization major and clear economic advantages, in terms of involvment, committment and participation in decision-making processes aimed at enlarging the profitability of the considered organization.

However, workers can experience the feeling that they are losing control on the rythm, scheduling and even content of their working task. Resorting to the use of such acquired data to/information in order to stimulate/reward, sanction/penalize or even fire/exclude employees has an obvious capacity to generate and develop the perception of lack of safety, job insatisfaction and to stimulate anxiety and work-related psychological risk (distress at work).

In order to mitigate this kind of unwanted occurrence, it is paramount to provide a minimal level of organizational honesty and transparency regarding the gathering and valorization of such sensitive information/data. New categories of intelligent monitoring tools also offer opportunities to improve basic OSH oversight, support risk-based prevention and protection programs (meant to be realistic, feasible and implemented in fact) and increase inspection effectiveness [12].

d. **Monitor the Location of the Worker**

Wearable technology, devices that are weared by their user (worker) in the proximity of the skin, where they are exerting the role of detecting, analyzing and transmitting data concerning, for example, bodily signals allowing real-time feedback to the worker. Tech Togs, wearable technology or fashion electronics are pieces of clothing and accessories that incorporate advanced electronic and computer technologies. While wearable technology is not technically AI, advances in the industry are bringing AI into this technological fabric. The main functions of such industrial garments include:

- Tracking the location of the worker;
- Monitoring vital parameters of the human body;

- Giving risk alerts/alarms in the working environment;
- Sending in real-time useful information to remotely-located workers;
- Reducing the risk of musculo-skeletal disorders;
- Improving staff awareness/induction/training.

Figure 10.3 shows a simple model of vest and helmet detection using ***You Only Look Once (YOLO)***, a set of object recognition techniques designed for real-time image analysis with low latency requirements [13].

e. **Automation of the Workplace**

Employing large—scale automation processes, the human workforce can be re-located into tasks/jobs/activities that are requiring a larger use of soft skills, such as cooperation, particpation, involvment, collaboration, communication and –very important, through the lenses of creativity—problem solving.

On the other hand, on the negative side of the picture, working task automation can be clearly related with more sedentary/repetitive work. Working tasks automation is –on the other hand—able to generate cognition/cognitive overload and/or boredom/rustiness, performance pressure, work intensification and the manifestation of certain hazards such as feelings of isolation and lack of interaction with other persons, which—in turn—can exert a negative impact on the teamwork.

10.4 Challenges, Opportunities and Threats Related to Digitalization in OHS Context

10.4.1 Evolutionary Foundations: The Transition from I1.0 to I4.0 of Working Activities and OSH

In the present, it is almost compulsory to pay attention to consider the emergence of ***new and increasing risks resulting directly or implicitly from digitalization, quasi-generalised connectivity and the practical extended application in real world***.

This changing situation generates increasingly new forms of manifestation of the so—called emerging occupational risks [14].

Among the areas that will be explored by OHS in the future are those that correspond to the modifications in not so much considering the humans who will be replaced, but how to redesign digitally transformed vith a vue to optimize, improve, and maintain available creativity in organizations by designing cross-generational, cross-cultural operational areas and work systems that are people—friendly and—as much that it is envisageable—protected from human error.

In this regard a digitalization evolutions process is required for addressing related drawbacks and/or challenges and valuing the related opportunities (Fig. 10.4) [15].

In such an evolving context, OHS 4.0 through its element of digital transformation connected thoroughly to the notion of cyber-physical system, cognitive computing,

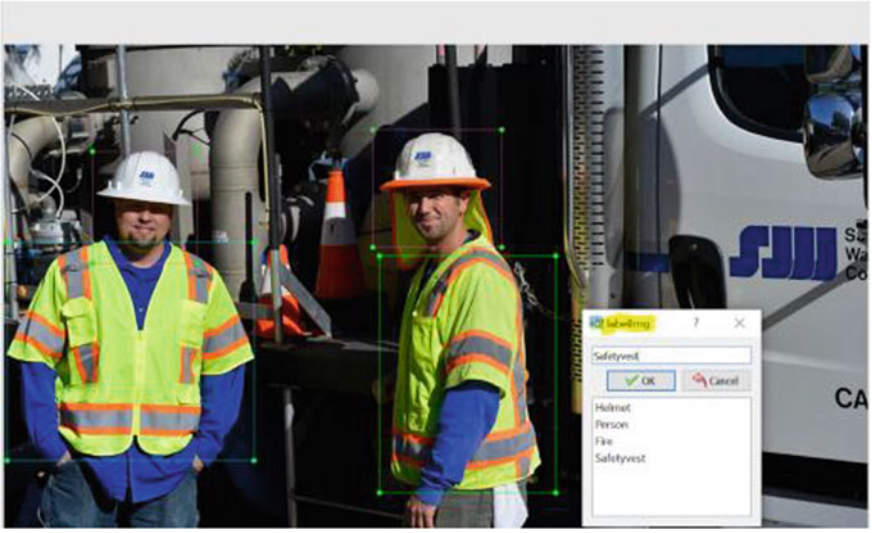

Fig. 10.4 AI—based YOLO detection model. *Source* Redmon et al. (2016)

virtualization, and Key Enabling Technologies, are having the capability adrress the major challenges faced.

This paragraph aims to present the results of a study [16] that attempted to give some synthetic answers to some of the following actual questions:

i. Digital transformation and intelligence/smartization are likely to facilitate a smooth evolution from OHS 4.0 to 5.0 and its implementation in an holistic manner?
ii. Are we able to develop new models of working systems and processes organization and cultural change from OHS 4.0 to OHS 5.0 in VUCA environments?
iii. Can it be established a functional correlation of the OHS 4.0 to 5.0 evolution to the Sustainable Development Goals by innovation and excellence?
iv. Occupational safety and health is a preventive activity, in it's nature—related to the performance of economical activity, aimed to produce/manufacture products/services in safe and sound conditions for the employees directly involved in the process.
v. As the knowledge of OHS and its risk identification and control mechanisms, measures, techniques, tools, strategies and processes are concerned, it is compulsory to take into account the multidimensionality of any working process/system/activity at a historical moment.

Figure 10.5 highlits the main key elements from "*Activity Theory*" as an evolutionary entirety.

The most recent revolution is called the "*Fourth Industrial Revolution*" (since 2012) [17] and its "flow" towards Industry 5.0 (so far) is characterized by the ***digital transition*** of organizations using:

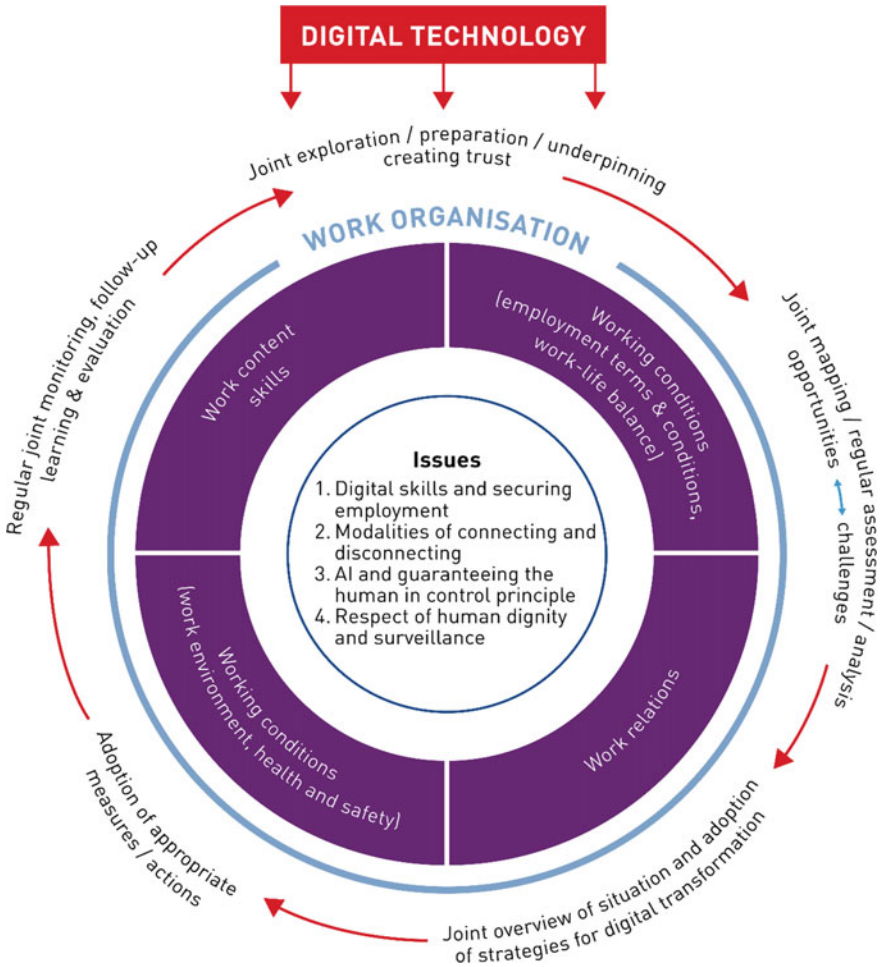

Fig. 10.5 Addressing challenges and maximizing opportunities: digitalization partnership process. *Source* European Social Partners (2020)

- machine—with—machine collaboration;
- relational interdependence;
- digital activators, (e.g. cobots and virtualization);
- working in machine-with—machine collaboration;
- scientific and technical/technological innovations;
- new forms of work organization related or not to globalization;
- integrating professional challenges with personal life demands;
- skills, knowledge, rules cahnge pace and volatility etc.

The concept was introduced and explained by the German government in the speech of Angela Merkel in the European Parliament [18], in which she defined

Industry 4.0 as: "*The digital transformation of the entire sphere of industrial production through the fusion of digital technology and the Internet with conventional technologies in industry*".

Assessing anticipatory, prevention, protection and other control measures involves the need to develop new models, always when and where the available ones are not properly useful, are inadequate or ineffective, mainly due to the fact that they are based on and around traditional/classic risks approaches.

10.4.2 The Human Factor and Industry 4.0

Menaces to today's cyber-physical systems are basically generated by human actions and human –related factors. In Industry 4.0, dangerous human errors (mistakes, omissions, errors of comission, violations, routine errors) can be the immediate causes of an undesired event, leading to various types and magnitude of consequences (delivery delays, occupational illnesses, reputation and company image losses, product errors, additional costs or even major industrial accidents) [19].

The accelerated implementation of technologies specific for Industry 4.0 (metadata analysis, robots/cobots, IoT, Artificial Intelligence, cyber-physical systems, etc.) has made systems more reliable, but the operator's problem-solving skills are diminished. In additionthe human operator has lesser and limited chances of interfering with the process.

Angelopoulou et al. (2020) stated that there are requirements for the user interface, which derive from the fact that various categories of automation technical elements that are requiring adequate mapping is constantly increasing. As a result, the sophistication of the device with which the employee/worker must "struggle" is also increasing [19].

Presently, a lot of the literature references discusses "Operator 4.0", as being the nextgen operator, physically and—even—mentally enhanced, which also with the support of sensors and other kind of relevant technical capabilities, evolved to become faster, more accurate, and increasingly skilled (Madonna et al., 2019) [20].

Some basic bonds seen through the lenses of the complexity degree, between the evolution of industry 4.0 and the operator are shown in Fig. 10.6.

Romero et al. (2016) have emphasized several typologies of operator 4.0 which are schematiclly depicted in Fig. 10.7 [21].

Industry 4.0 approaches the materialization and use of innovative interventions which changes current production cycles, updating them for continuous improvement [19].

However, given that integration adaptability cannot progress only through the acquisition of new and more refined technologies, managers shouldprovide a working/organizational climate that encourages worker representatives to constantly search for new and creative answers to fulfill their working tasks and complete entirely and effectively their work and to stay updated with the latest and more

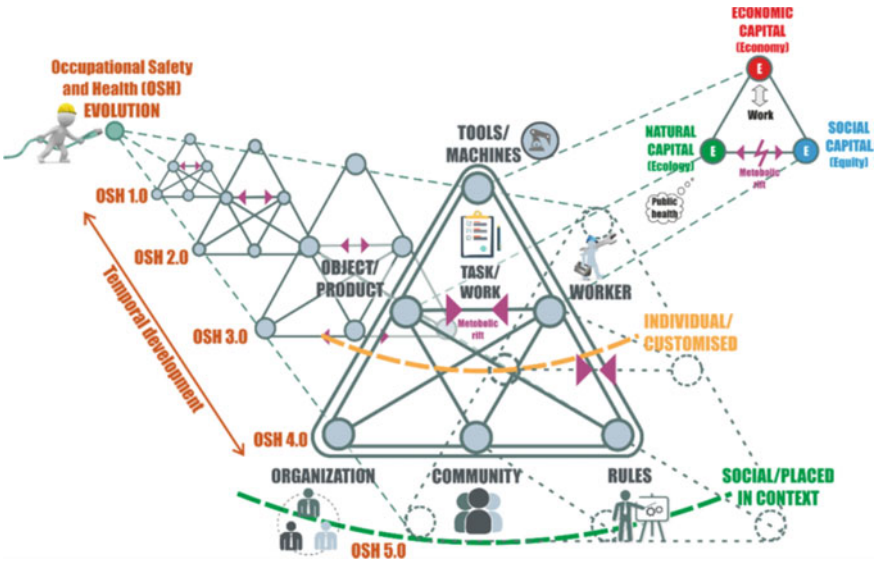

Fig. 10.6 The evolution of the work activity model. *Source* adapted from Ávila-Gutiérrez et al. (2022)

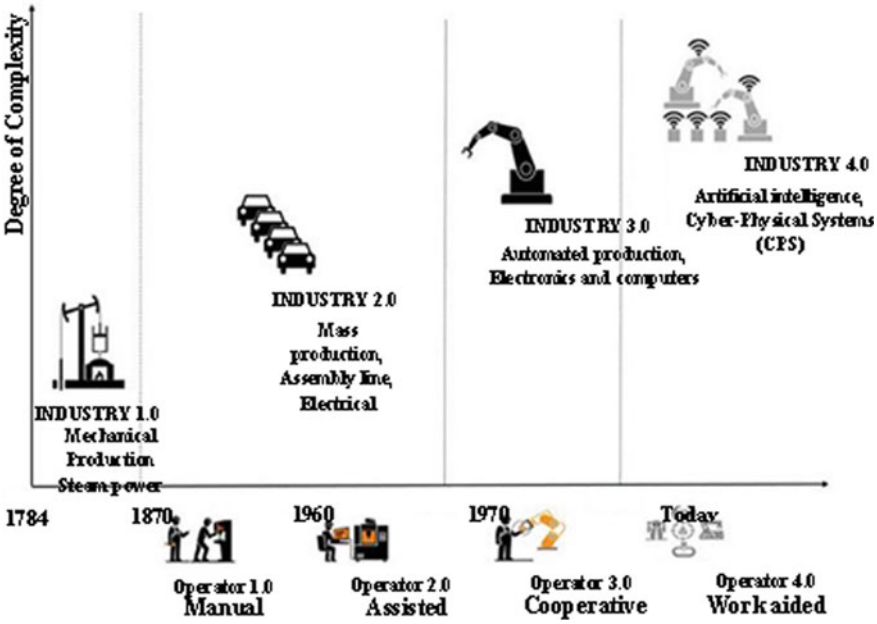

Fig. 10.7 The evolution of the human operator up to Industry 4.0. *Source* Adapted from Madonna et al. (2022)

important information from their evolutionary perspective on-the-job they are performing.

One of the ways to anticipate the probabilities of human error is the modeling and simulation model, so hazardous actions and other types of human errors could be proximate reasons for an accident in Industry 4.0, causing transport delays, scraps, excessive costs or even work accidents. In fact, the evolution of Industry 4.0 generates quite relevant challenges for the human operator, which could generate a higher the number of omission and/or commission operational errors. Madonna et al. (2019) have drawn defined a "*cognitive framework*" represented in Fig. 10.8 to give expression to the compulsory and acute emergency of the reuirement to develop realistic scenarios highlighting various possible combinations between different digital technologies and the human operator, in order to anticipate the likelihood and severity of impacts in various hazardous undesired developments [20].

Fig. 10.8 Operator 4.0 typologies. *Source* Adapted from Romero et al. (2016)

10.4.3 Emerging Occupational Risks and Digitalization

The world –in general—and the world of work, specifically, does not remain static for any organization. The companies that have processes prepared to respond to change and are disposing of effective systems for the Management of Change are generally more resilient than organiztions not disposing of such effective systems in place and related procedures. The risk management world is—and should—constantly evolving and adapting to change.

Some managers are really asking nowadays, at least in Romania—why emerging risks need to be managed, and why they shoul be managed differently than "*classic*" risks. It is valid that the risk management process detailed in ISO31000: 2018 remains valid for the management of emerging risks [22].

Emerging OHS risks really have several specific features that are rendering them different with respect to the traditionally encountered risks. The particular features of emerging risk are described in Table 10.2, using the example and reference of the SARS- COV-2 pandemic crisis.

Table 10.2 Characteristics of an emerging risk. Example based on the SARS—COV-2 pandemic

Characteristic	Notes and examples
Ajnbigitom	Risk itself is difficult to define ***Covid-19:*** Experts have admitted that a pandemic is possible, but could not describe before the event, how it will happen
Chaotic	Emerging risks are constantly changing. ***Covid-19:*** As our risk and understanding develop, the way governments manage the Covid-19 crisis has shifted around lockdowns, face masks and social distancing, creating a chaotic economy and social environment
Complex	Emerging risks can affect a large number of factors simultaneously ***Covid-19:*** The effect of the pandemic on economies may lead to recession, amplifying the impact of falling incomes and unemployment
Variable time horizon	Emerging risks sometimes seem far away, but the time horizon can change very quickly ***Covid-19:*** A pandemic seemed far away to many, then Covid- 19 spread from continent to continent in a relatively short period of time
Uncertainly	The lack of knowledge about what will become an emerging risk and how it will evolve makes it difficult to manage with a reasonable degree of certainty ***Covid-19:*** Pandemic risk is a prime example of uncertainty leading many to ignore the risk, despite experts warning for decades that the risk existed
Uncontrollable	Emerging risks are often external to the organization and therefore outside its direct control, so the need is to adapt and respond rather than control ***Covid-19:*** Organizations had to adapt their work practices and work environment to survive
Volatile	Significant changes in risk in a short period. Using the 2020 ***Covid-19*** pandemic as an example: In Romania during the summer months life was relatively "normal", while in November we had to go back to quarantine

Emerging OHS risks are likely to manifest and impact fast, but they also may never appear. In general, one can distinguish three types of emerging risks [23]:

"A new risk in a known context": Risk is generated in the outer environment and have an impact on the current activities of the organization. As an example, we know that the legislation/regulations regarding the organization's processes will be submitted to mchanges in the close future.
"A known risk in a new context": the way a risk is managed should be submitted to change if it enters a different activity domain. As an example, the organization already works with chemical agents and want to innitiate the use of certain chemical agents in a new technological process, in larger quantities, in a production facility in another country, with other workers.
"A new risk in a new context": The risk that was not considered before because the risk it did not manifested within the company.

What organizations can do is to enhance and facilitate risk management by redistributing accountability to the adequate decision levels within the organization [24].

It is, not infrequently, impossible to quantify with a reasonable degree of certainty the probabilities and impacts for emerging risks. The specific "ambiguity" characteristic makes it difficult to make timely decisions. Emerging risks are characterized by a series of common characteristics, globally depicted in Fig. 10.9.

The term "emerging risk" has a rather ambiguous character in general, but it has the advantage of allowing a distinction to be made from the traditional risks that are

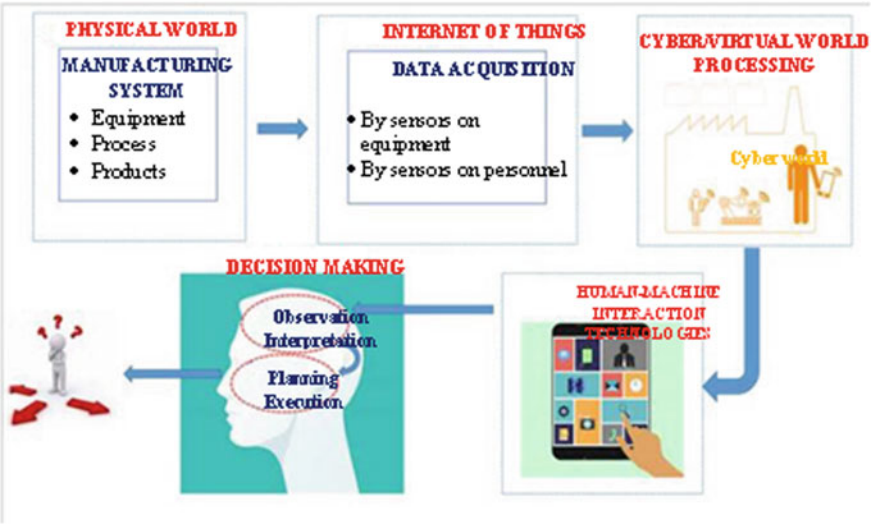

Fig. 10.9 The worker's cognitive framework in the introduction/generalization process of Industry 4.0. *Source* Adapted from Madonna et al. (2019)

currently maintained. In order to make a distinction as clear as possible, EU-OSHA approached in a first phase how to define emerging physical risks [25].

According to the EU-OSHA Risk Observatory (2009), an "***emerging OSH risk***" is any risk that is both ***new*** and ***growing*** [26].

Thus, the emerging physical risks highlighted by the European Agency in Bilbao focus mainly on the following aspects:

- lack and/or insufficiency of physical activity;
- combined exposure to MSDS and occupational stress;
- the increasing complexity of new technologies (e.g. digitalization);
- multifactorial risks;
- increased vulnerability of workers at lower decision levels;
- thermal discomfort;
- exposure to ultraviolet radiation, vibrations, uncomfortable working positions.

Within the general picture of emerging global risks (Fig. 10.10), attention is directed on lesser—known risks, which are interpreted as emerging, even if some of them were also previously present. Digitalization also offers the possibility of entrusting monotonous transport tasks to driverless systems, and of having certain parts of highly demanding tasks carried out by collaborative robots. In addition, care must be taken by means of a sensor system and suitable control software to avoid any collision between man and robot (Fig. (10.11).

In the absence of having a precise idea of our professional future, managers, employees, social partners, and prevention professionals are aware of the challenges

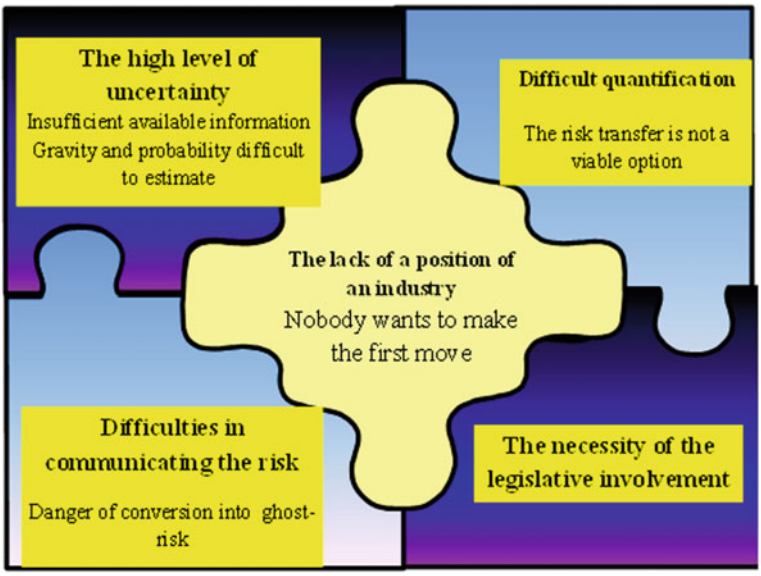

Fig. 10.10 Common elements characteristic of emerging risks

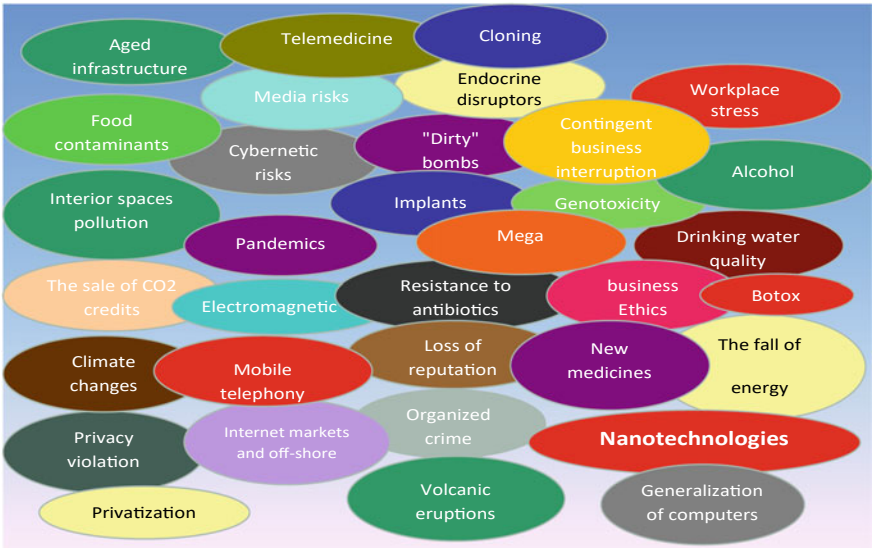

Fig. 10.11 The complex landscape of emerging risks

of tomorrow and the measures to be taken quickly to anticipate and support these transformations.Already, experts are committed to companies and their employees to search new ways to improve the Quality of Life at work. They can as such:

- carry out a diagnosis of the situation in order to detect possible problems;
- set up a psychological support cell;
- organize workshops and conferences to raise staff awareness;
- train referents on the central themes of psychosocial risks;
- advise on the procedures and management system of the OHS.

In addition, the various stakeholders must think about developing ethical charters, in particular concerning data protection and other sensitive aspects generated by digitalization. Software and mobile app developers, for their part, are required to design interfaces and systems that facilitate interactions between machines and humans and offer them the most pleasant user experience possible.

Finally, the upskilling of workers must be taken with the utmost seriousness and urgency. Summarizing and referring to the synthesis carried out by Degryse in 2016 [27], we can summarize the basic opportunities and menaces related to digitalisation in accordance with Table 10.3.

Table 10.3 Main opportunities/threats related to digitalisation: an OHS perspective (*Source* adapted from Degryse 2016)

Opportunities	Threats
New jobs (computer engineers and scientists, cybersecurity officers, network experts, maintenance etc.)	Destruction of medium and low-skilled jobs (automation and computerisation)
More agile work organisation; **new forms of more flexible and more autonomous work**	Intensification of "anytime, anywhere" work; "always-on culture"; "hyper-connectivity": blurring of the boundary between private life and working life leading to **stress and burnout**
Abolition of repetitive, low-skill and routine tasks, reduction/elimination of hazardous work. Improvement of occupational safety and health	Loss of control by workers over their own expertise, know-how and free will
Better ergonomics, help in performance of heavy or complex tasks	Digital, management, policing of workers, **risk of mutual loss of trust between employees and management**
New forms of collaboration and cooperation among workers	De-personalization of work, loss of face-to-face interaction, erosion of social skills at work
Return of industries and new smart factories—and jobs—to their regions of country of origin)	Precarisation of jobs and of employment relationships, dependence on "data masters"
Working time reduction	Weakening of collective action and industrial relations
Possibilities of social emancipation due to a new concept of "work" and change of economic model based on peer-to-peer relations (where all participants/actors are equal) and common goods	Skills and training/labour demand mismatch
	Exacerbation of inequalities (as regards skills and competences, "core" cs. "peripheral" jobs and positions, etc.)
	Wage level stagnation or decline due to an increase in highly flexible employment relationships
	"Digital Taylorism" and emergence of a class of digital workplace-based workers (crowd sourcing); world competition among workers for all jobs not requiring face-to-face contact

10.5 Conclusions

Industry 4.0 wants to be a connected factory where all the stakeholders are interconnected with each other and with the internal server which contains all the industrial documentation they will need. The construction of an improved risk mitigation approach can only be done effectively if it is shared by all, within the company.

However, if a plethora of diagnostic analysis and audit tools exist in almost all large companies, it is clear that they are often technical and at the service of a few insiders. Pooling them, making them uniform and permanently available makes it possible to integrate all of the company's employees in this digital transformation process. This is the whole point of using a computerized and accessible online solution for steering the OHS policy. Since the Covid-19 crisis, digitalization has accelerated in all companies. It aims to improve their productivity and agility, and consequently, to increase their competitiveness.

It remains that this transformation has multiple consequences on the organization of work:

- the emergence of new categories of employment;
- the implementation of new processes;
- redefining individual or team roles and tasks;
- the acquisition of additional skills;
- changing the pace of work.

Understanding and acceptance of these often rapid technological and organizational changes by workers requires their active participation in their implementation. The employer must therefore solicit employees, their representatives and their managers from the reflection phase in order to identify their problems and define the characteristics of the solutions adapted to their real needs. This involvement continues during the implementation of the digitalization strategy, up to training and familiarization with the new tools deployed. Otherwise, the risk is to generate frustrations, errors, an increase in the mental load and an increased difficulty in disconnecting and separating private and professional life. This results in a drop in performance that is detrimental to the motivation and professional well-being of employees.

The benefits of digitization are numerous. Here are a few: (i) Centralization, pooling and securing of information; (ii) Simplification of access to data (with management of specific access rights); (iii) A reduction of all the administrative part thanks to the dematerialization of documents and procedures; (iv) Responsiveness in monitoring actions; (v) Support at all times for operators, regardless of the distance, thanks to real-time notifications, videoconferencing tools opening up the possibility of remote audits and even the possibility of electronically signing documents; (vi) Dashboards and performance indicators provide in a few clicks, at all levels of the company, from general management to middle management, including human resources and financial services, the data they need to manage the business.

Below are some benefits that the **implementation of a digital solution in the field of OHS** can have:

a. ***Save time and resources, increasing productivity***: OHS administrative and reporting tasks sometimes take up more than 50% of work time. Moreover, the applications can offer the possibility of immediate access from the mobile phone, when the situation calls for it. In an industrial environment in full digital transformation, the digitization of work instructions is essential to allow companies to motivate their teams, improve safety at work and above all boost operational

excellence. Digitizing work instructions should, however, be seen as a necessary investment that yields many benefits to the business.

b. ***Reduce costs in the field of OHS***: cost reduction will occur both by increasing the productivity and efficiency of OHS processes, but also by effectively focusing measures to prevent unwanted events, costs related to non-conformities or incidents, as well as by significantly reducing costs with existing support processes where such an application is not implemented. Moreover, if the application can be used on a large scale, it can significantly reduce transport costs, due to the possibility of expanding the number of users at the level of any region.
c. ***Consolidates and improves reporting processes***: as a rule, such applications can be customized so that various reports can be obtained, depending on the need, being at the same time a perfect tool for carrying out internal audit.
d. ***Increases the transparency of the company in the field of OHS***: it is not new that more and more beneficiaries request concrete, verifiable information about OSH performance. Such an application can ensure both transparency at the internal level and the efficiency of decisions at the highest level, as well as transparency and ease of communication in the face of various requests on the OSH line of the beneficiaries. Moreover, such applications should implicitly include setting alerts and warning key people about certain responsibilities, tasks or deadlines for the performance of certain actions.
e. ***The information is at hand and easy to access from anywhere***: (most applications are also designed for accessing directly from the mobile phone). Instead of moving OHS managers into the field, data recording can be available to anyone, as long as it can be accessed from a mobile phone. Also, many applications do not need a permanent connection to the Internet, being able to record data on the terminal in the field, and when possible, update their information in the common database.
f. ***Continually help improve the company's OHS performance***: As most applications allow real-time OHS reporting, performance improvement can be tracked shortly after implementation. In addition, performance improvement will be able to start immediately, given the streamlining of non-conformance governance processes and tracking of prevention plans.
g. ***Connects employees and increases their level of trust***: this can be observed directly proportional to the size of the company, but what is certain is that such applications allow a mature process of communication, delegation, collaboration and joint monitoring of the implementation of the proposed actions, times decided.
h. ***Standardize OHS processes and fully centralize information***: Conventionally, OHS information is found in countless forms, processes, procedures. Such an application has an essential role in gathering this data in one place, managing outdated information and preventing employees from using outdated processes or procedures.
i. ***Quantify and help reduce the level of occupational risk***: risk assessment methods, impact assessments, prevention plans and how to keep them are very different, which is why in conventional systems it can be extremely difficult to

get an accurate and fair picture of risk level. Such applications create the possibility of dynamic risk assessments, so that hazards or non-conformities can be proactively identified, and prevention and improvement plans can be pursued uniformly and systematically.

In the field of OSH, AI can be implemented in: training, testing, supervision, information, evaluation, decision-making, avoiding work accidents. Creating a software application that improves OSH performance by implementing an adaptive system predictive of human behavior in different contexts that identifies safety issues and provides solutions for better training, verification and supervision of workers is an objective of current research.

In an ambitious European context in terms of risk prevention in business, digital and dedicated OHS tools are essential allies for any organization wishing to gain in efficiency and performance.

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Chapter 11
Digital Transformation of the Transport Sector Towards Smart and Sustainable Mobility

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Abstract This chapter follows challenges, policies, and research directions shaping the digital transformation of the transport sector towards smart and sustainable mobility. Urban mobility, facing growing number of vehicles, increasing urbanization, and environmental concerns, actively seeks solutions through information and communication technologies. In-vehicle digitalization has recently revolutionized the automotive industry, while ongoing efforts focusing on digitally connected vehicles and smart infrastructure are laying the foundation for autonomous mobility. The USA Department of Transportation proposes a safety standard mandating vehicle-to-vehicle communications for new cars, aiming to propel the automotive industry towards communication and information technology development for enhanced safety and energy efficiency. The European Union targets carbon free road transportation by 2050, as part of European Green Deal, and plans to reduce the road fatalities to zero by 2050, as part of Vision Zero strategy. In this context, the smart and sustainable mobility concept envisions the use of state-of-the-art sensors and communication technologies toward a more efficient and safer transportation network and foresees the development of autonomous vehicles support technologies, improved route planning strategies, and electric vehicle proliferation. In this chapter, after an

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L-I. Cioca et al. (eds.), *Digital Transformation*, Intelligent Systems Reference Library 253, https://doi.org/10.1007/978-3-031-55952-5_11

introduction to policies and technologies supporting digital transformation of the transport sector, we focus on the wireless technologies for vehicle-to-everything communications, including the contributions of our research group in developing a modular hardware-software architecture and a hybrid platform of vehicular communication and information technologies for road safety and driver assistance applications. Finally, the economic and social challenges arising from the implementation of smart mobility are examined and general conclusions are drawn.

Keywords Smart mobility · Vehicular communication · Vehicle safety · Climate neutral cities

11.1 Introduction

Information and communication technologies are being adopted on a mass scale and digital innovations are fundamentally transforming today's society and economy. In particular, the transport sector is reshaped by digital transformation which paves the way towards smart and sustainable mobility. Vehicular-to-everything (V2X) communications, artificial intelligence, digital twins, big data analysis, augmented reality, internet of things, cloud and edge computing are just a few key technologies driving digital transformation in this area and providing the framework for innovative solutions to the major challenges facing the transport sector.

According to the World Health Organization, approximately 50 million people are injured annually in road accidents and more than 1 million of them lose their lives every year [1]. Moreover, road accidents represent the main cause of death among young people between the ages of 15 and 35. Negative impact on the economy of road accidents is also estimated at approximately 3% of the gross domestic product [2]. In this context, the United Nations General Assembly adopted in 2020 a resolution on improving global road safety, which aims to reduce by 50% the number of deaths and injuries globally by 2030. This target is also assumed at the level of the European Union (EU), which has the long-term strategic objective of approaching zero road deaths and serious injuries by 2050, according to the *EU Road Safety Policy Framework 2021–2030—Next steps towards "Vision Zero"*. The analysis presented by the International Forum of Carriers [3] shows that the number of deaths has decreased in the previous decade, but the global downward trend was less than 10% per decade in the group of countries included in the study, which highlights the need for major innovative actions to reach the 50% reduction proposed for this decade. In the report [4], published by the United States of America Department of Transportation, it is highlighted that road safety applications based on vehicle communications can contribute to a reduction of up to 81% of road accidents. Similar conclusions are drawn by the European Transport Policy reports [5], emphasizing connected mobility as a key transformative direction towards *Vision Zero* mission.

Within the framework of the *European Ecological Pact—Green Deal* [6], the EU has also set very ambitious targets, which aim at road transport without carbon

emissions until 2050, including an emission reduction of 55% until 2030. Such clean mobility objectives require deep innovative transformations, both in technologies and services, including connectivity and information technologies, as well as digitally facilitated services, such as car sharing / carpooling [7].

In this context, the digital transformation of the transport sector arises as a solution to simultaneously address traffic efficiency and safety. The first stage of development involves the implementation of cooperative intelligent transport solutions and dedicated systems [8, 9]. Vehicular-to-everything communications represent an essential part of these solutions, and their purpose is to involve both road and pedestrian traffic participants in a network that forms interactions and provides information of interest, as illustrated in Fig. 11.1. These communications come in various forms, such as vehicle-to-vehicle (V2V), vehicle-to-road infrastructure (V2I), infrastructure-to-pedestrian (I2P) or vehicle-to-pedestrian (V2P) communications.

The initial development of communications within the transport area was aimed at facilitating traffic monitoring and control. Currently, the focus is on driver-assistance, inter-connected cars, and their integration within an intelligent routing network. A special research interest is dedicated to generating digital twin platforms for urban or regional traffic, including real-time inputs from various cameras and sensors networks, transpositions in the virtual domain of all the traffic components, along with large-scale traffic simulation and optimization tools, as well as communication and control units for implementing optimal traffic solutions. In the near future, autonomous driving and infrastructure are expected to concentrate most of the research and development resources from this area [8–10].

Fig. 11.1 Vehicle-to-everything (V2X) is a connected mobility platform that allows vehicles to interact with their surroundings, such as other vehicles, cyclists, pedestrians, road infrastructure or mobile networks

All these current and future developments are also accompanied by important challenges, such as significant reduction of the fabrication costs, the harmonization of novel technologies, building a very large-scale support infrastructure, and mitigating high cyber-security risks. On the other hand, the emerging of sixth generation (6G) cellular communication technologies may prove disruptive to existing V2X communication technologies bringing unexpected solutions for various open problems as well as a series of new research challenges.

In the next sections of this chapter, we focus on wireless technologies for V2X communications with a special focus on the contributions of our research group in developing a modular hardware-software architecture and a hybrid platform of vehicular communication and information technologies for road safety and driver assistance applications. Finally, the economic and social challenges arising from the implementation of smart mobility are examined and general conclusions are drawn followed by the list of references.

11.2 Wireless Technologies for Vehicular-to-Everything (V2X) Communications

Various types of wireless technologies can be used for vehicular communication applications, but none of them can be currently considered as the dominant standard technology for this field. A first approach was to broadcast certain information regarding road traffic to a group of receivers within a certain coverage area by using standard analog radio communication, which was later replaced by digital audio broadcasting (DAB) communication [11]. The second development phase involved mobile cellular technologies providing bi-directional V2X communication, but the high costs of operating cellular networks and the high communication latencies made them less suitable for vehicular communications, at that time [12]. The need for alternative solutions led to wireless local area network (WLAN) approach, which offered the advantages of high data transfer rates, low latencies and low implementation and operation costs but it also came with major challenges, being strongly affected by the vehicle speed and the number of devices connected to a single cell. The WLAN approach allowed ad-hoc connections, where users establish peer-to-peer connections without the need to connect to a station-like architecture, which significantly reduces the implementation costs. As a result, the IEEE 802.11 standard for WLAN was amended to add wireless access in vehicular environments, coined as IEEE 802.11p [13], which is the basis for dedicated short-range communications (DSRC) protocol developed in the USA and intelligent transport system (ITS)—G5 protocol developed in the EU. Short-range communication approaches have also led to the development of architectures based on local central stations (called Road Side Unit—RSU), which mediate both infrastructure-vehicle communication (V2I and I2V) and vehicle-to-vehicle communication (V2V). Thus, the OBU (On-Board Unit) vehicular nodes, installed inside the vehicle, communicate with the RSU-type

units installed at the level of the road infrastructure, as well as directly to other nearby OBU units. To provide viable information for specific vehicular applications, the OBUs are equipped with global position system (GPS) modules. DSRC and ITS-G5 have found applications for various vehicular safety services, intelligent transport systems and vehicular e-payments. In this context, let us emphasize that the potential of other near field communication (NFC) technologies, such as Bluetooth [14, 15], Zigbee [16], Visible Light Communications (VLC) [17–19], have been investigated by numerous research groups worldwide for alternative vehicular short-range communication solutions, which are now at various technological readiness levels. However, DSRC / ITS-G5 is currently the sole wireless short-range vehicular technology that reached both ultimate technological and commercial readiness level and it is viable competitor for cellular technologies in V2X communication applications.

A comparative analysis presented in [20, 21] contrasts DSRC, third generation (3G) and fourth generation (4G) of broadband cellular networks technologies in a single scenario, revealing 3G inadequacy in meeting the standard requirements for cooperative intelligent transport systems (C-ITS) and emphasizing DSRC superiority to 4G in time-sensitive C-ITS applications, in addition to operational costs. However, the recent development of fifth (5G) broadband cellular networks has significantly improved the performance of C-V2X with respect to standard requirements for C-ITS. In [22, 23] this latest technology has been assessed in terms of latency, packet loss, throughput, jitter in V2V and V2I scenario and have been proven comparable to DSRC/ITS-G5 and even superior in some applications. Nevertheless, the high cellular bandwidth costs move researchers in this area towards hybrid solutions involving two or more wireless technologies mentioned above [24–26].

11.3 Hardware Architecture and Characteristics of Dedicated Short-Range Communications for V2X Applications

Dedicated Short-Range Communication (DSRC) utilizing the 5.9 GHz frequency, band and is underpinned by the IEEE 802.11p standard. Implemented in various contexts such as vehicle-to-vehicle (V2V), vehicle-to-road (V2R), vehicle-to-infrastructure (V2I), DSRC aligns with road safety requirements and is a natural candidate for V2X applications in the development of connected vehicles and autonomous vehicles. IEEE 802.11p optimizes IEEE 802.11 medium access control (MAC) and physical layer (PHY) protocols for improving communications performance in the context of high mobility characterizing vehicular communications.

For the implementation of DSRC network, the fifth generation On-Board Unit (OBU) developed by Cohda was used by our research group. Known as MK5, it is a small and low-cost OBU based on the automotive-grade RoadLINK chipset developed in collaboration with NXP Semiconductors and it is considered a leader for V2X trials [27]. The block diagram of this DSRC module is illustrated in Fig. 11.2.

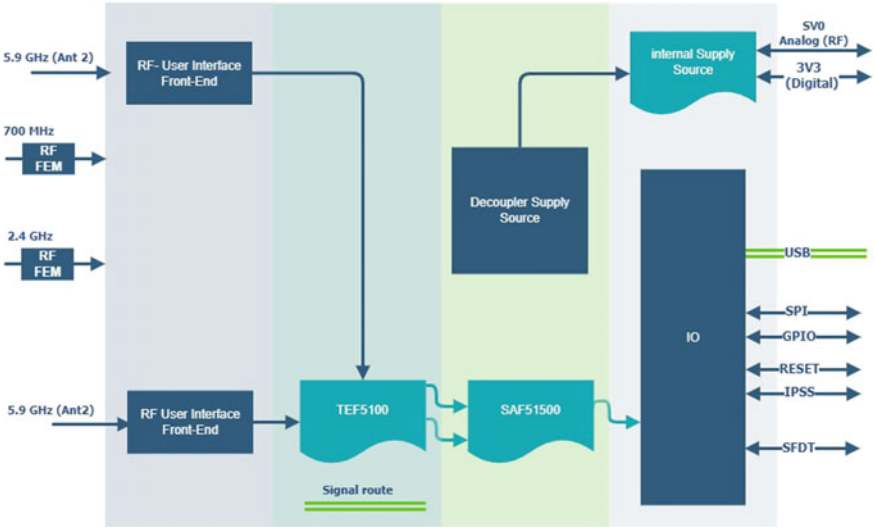

Fig. 11.2 Illustration of the architecture dedicated to DSRC communication modules based on MK5 OBU

MK5 reveals a return loss on all RF ports within the acceptable range of 0 dB, while DSRC receiver measurements, ranging from −95 to 20 dBm, demonstrated a stability of ±2 dB in various operating conditions. Employing advanced algorithms, the modular receiver processes all data, while the PHY-RF user interface enhances radio configurations. The RF subsystem can emit through separately constructed antenna-type ports for 5.9 GHz frequency bands and has additional facilities for comprehensive area coverage. The RF outputs are dedicated to communications in the 760 MHz and 2.4 GHz. In the dual-radio configuration, the module benefits from versatile PHY mobility. Receiver sensitivity uses U-Blox for antennas operating at 5.9 GHz in 10 MHz bandwidth [27]. This comprehensive framework ensures the robustness of DSRC in facilitating effective short-range communication within diverse applications [28]. Henceforth, it can be asserted that high sensitivity characterizes the reception, gauged by evaluating the input signal traversing directly through the front-facing ports. Introducing an additional antenna further refines the system, featuring a Doppler frequency of 11 Hz, having the primary role to preemptively mitigate premature synchronization of the channel. A scrutiny of the transfer characteristics and rates under ideal conditions would tend to 0, but real-world scenarios, as in high-density and mobile environments, introduce interference, as reflected in Table 11.1.

The operability of the system in diverse meteorological conditions does not significantly affect the sensitivity. Data derivation and processing through Doppler corrections is summarized in Table 11.2.

Various RF solutions can be implemented with the MK5 module, both in a single and dual environment. In a dual configuration setup, the functional PHY mobility

Table 11.1 Parameters and sensitivity characteristics that a MK5 module senses in relation to interference

Number of channels ID	Modulation and coding scheme	No multipath [dBm] 1 typical (Min)	No multipath [dBm] 2 typical (Min)	Highway Nlos [dBm] 1 typical (Min)	Highway No multipath [dBm] 2 typical (Min)
13	½ BPSK	−97	−98	−96	−95
14	¾ BPSK	−98	−97	−93	−94
11	½ QPSK	−97	−96	−89	−91
10	¾ QPSK	−98	−95	−87	−88
8	½ 64 QAM	−92	−94	−86	−86
12	¾ 32 QAM	−88	−89	−84	−83
9	½ 16 QAM	−84	−88	n/a	n/a
15	¾ 32 QAM	−82	−82	n/a	n/a

Table 11.2 Data derivation and processing through Doppler corrections

Derivation	Relative strength [dB]	Delay [ns]	Doppler frequency [Hz]
0	0	0	0
1	−4	240	679
2	−6	473	−462
3	−9	750	896

operates autonomously across each module layer, functioning on distinct radio channels. For frequencies of 760 MHz and 2.4 GHz, the RF circuit needs external clearance from the internal controller to execute set-shift operations. In the realm of Cohda PHY Mobility, the system is equipped with two antennas, facilitating seamless transmission and reception of information on the 5.9 GHz and ensuring optimal performance conditions. Regarding communication modes, the MK5 platform, illustrated in Fig. 11.3, provides the flexibility of both remote connection and interface access through the VGA port. The platform's functionality and the punctual delivery of information are also credited to the contributions of U-blox.

The Medium Access Control (MAC) layer is anchored by an ARM processor built upon an SAF5100 foundation, which enables and streamlines multiple operating modes. In this context, it can be asserted that the minimum power for transmitting to the antenna connector maintains a nominal frequency of approximately −10 dBm. On the other hand, the anticipated value for the maximum power it can transmit aligns roughly with +22 dBm. Despite inherent performance limitations in establishing the MAC protocol, particularly in the case of IEEE 802.11 where self-competition among adjacent nodes and information flow constraints can occur, the ad hoc distance vector (AODV) proves valuable to IEEE 802.11p in safeguarding messages within DSRC applications.

Fig. 11.3 Illustration regarding the hardware structure of some MK5—OBU modules, but also of the GPS-GNSS antennas

11.4 Software Architecture and Algorithms for Dedicated Short-Range Communications in V2X Applications

The structural framework and its execution are built upon several interface controller modules serving data networks, CAN modules, remote connectivity, and accessibility from mobile/portable devices. Additionally, the architecture incorporates the MK5 platform, ensuring stability in data assimilation and processing through a GNSS-GPS antenna. Information transmission adheres to the 802.11p standard, made accessible and controllable via Intelligent Transportation Systems applications, establishing connections to an external Ethernet or Wi-Fi network. Figure 11.4 depicts the fundamental elements of the concept and outlines the system configuration.

To initiate configuration and synchronization in the proposed system, a connection with the Host interface is established through the software activation of dedicated pins. Further configuration involves loading and activation of Linux Kernel modules.

It is important to delineate a flow chart highlighting the data paths as it enables the generation of a simulative model aligned with the identified issues. As depicted in Fig. 11.5, the data flow diagram serves as the foundation for practical simulation processes throughout the entire system, leveraging Cohda Wireless and the ETS Shell Framework. These elements and enhanced functionalities are pre-set to foster effective communication. The core of the software architecture relies on an executable file, ets-shell.c, with the module synchronization header incorporating other network stations sharing the same extension. The system undergoes successive iterations in

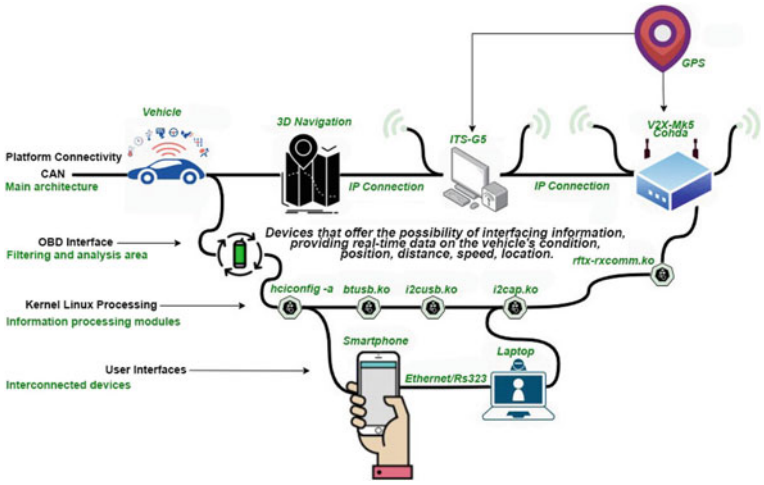

Fig. 11.4 The proposed system configuration and connectivity diagram

establishing, prioritizing, and analyzing data by initializing events within the fundamental program structure. These events are triggered through channels such as CAN, GPS, UDP, and Wi-Fi, contributing to a comprehensive understanding of the system's data dynamics.

Next, we focus on describing the algorithms for DSRC Wi-Fi initialization and transmission-reception synchronization and for defining communication channels and external GPS synchronization. We can say that each function we call is of initializer type and later it returns a descriptor of integer variable type, thus the interfaces between each module are updated and accessed. In case there is no information about the data on the CAN interface, default values are displayed. The limitation of unpredictable events is defined by iteration descriptors, and they filter the information by averaging between the Min–Max data packets, so they analyze the transfer rate, longitude, latitude, distance, the signal on emission/reception, and noise sources.

When the entire structure becomes fully operational and functional, data packets are introduced to establish the connection between the OBU and RSU modules in the proposed system. After creating the file and initializing the system, a series of queries and logs are made that prepare the directories for writing the information, and later the external GPS modules are activated, setting the arguments and conditions for each port, but also calling the MAC/IP addresses for assigning roles within the system and defining the host, as presented in Algorithm 1.

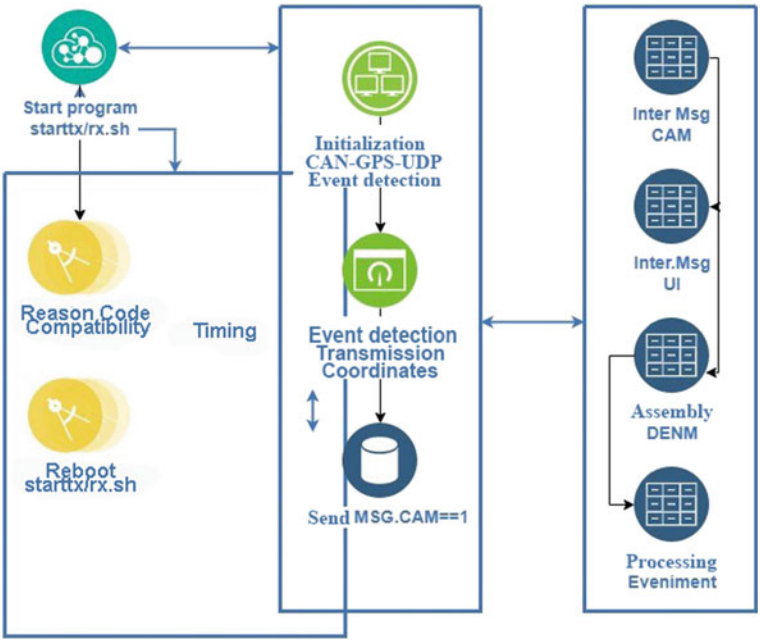

Fig. 11.5 Data prioritization diagram in MK5-based communications and iteration of the proposed data flow

Algorithm 1: Defining communication channels and external GPS synchronization, assigning the role of Host

CHANNEL_NUMBER = ${CHANNEL_NUMBER: -128}
LOG_DIRECTORY = ${LOG_DIRECTORY:-/mnt/rw/fieldtest}
LOG_FILENAME_PREFIX = ${LOG_FILENAME_PREFIX:-fieldtest_log}
EXTERNAL_GPS = ${EXTERNAL_GPS:-}
TABLE_PURGE = ${TABLE_PURGE:-22}
BROADCAST_PORT = ${BROADCAST_PORT:-43,221}
EXTRA_ARGS = ${EXTRA_ARGS:-}
SRC_MAC = $(ip addr show dev eth | awk'/ether/{print $2}')
LOG_FILE_PREFIX = ${LOG_DIRECTORY}/${LOG_FILENAME_PREFIX}
mkdir –p ${LOG_DIRECTORY}
chconfig –s –w CCH –c ${CHANNEL_NUMBER} –r a – RxMACAddr = ${SRC_MAC}
sleep 5
if [-z "$BOARD"]; then
if [-e /proc/hwversion]; then
BOARD = 'cat /proc/hwversion | cut –f 1 –d'
else
BOARD = 'hostname'
fi
fi

The initialization and pre-configuration processes can have waiting times of order of seconds, and in exceptional cases, they may reach a minute. These times differ from the connectivity and receptivity of data from GPS antennas. When we have the first set of data from the queries carried out, we can observe aspects of a statistical nature in which we identify the dynamics or the method of movement of the components in the plan. In conclusion, we obtain raw information regarding aspects of location, stability, data prioritization, and communication distances for the selected perimeter.

11.5 Practical Implementation of Simulation and Validation Results

The integration of the entire system is orchestrated through two primary components. One is tailored for the vehicle's interior, aiming to deliver information to the driver in the form of 3D navigation. This component gathers information from the vehicle via the OBD module dedicated to CAN connections and sends back other data on the central console. The navigation component features a 7-inch capacitive screen, facilitating direct communication with the driver and the external environment. It displays pertinent traffic information, distances, prioritized messages, congestion updates, and the vehicle's position, etc. Various hardware components used in our prototype, including a Raspberry Pi 0 W, SIM ports, Wi-Fi modules, Teensy 4.1 microcontrollers for data processing, and two Raspberry Pi 4 units, with a computing power of 1.5 GHz and a RAM memory of 8 GB, which makes possible real-time communication and advanced image processing. Figure 11.6 presents the structure and architecture of our prototype for sending, receiving and inter-facing communication, which is readily available for car installation and connection to the developed web interface. Regarding synchronization and function calling, a web application was created with an API that controls the entire system and works simultaneously with hardware devices. This holistic approach ensures seamless interaction and comprehensive information dissemination within and beyond the vehicle. In addition, the modularity feature allows the integration of other existing or emerging technologies, as well as the development of hybrid V2X communication systems.

The versatility of the proposed system has been validated through successful tests in various traffic conditions, proving V2X communication distances of more than 250 m. A stationary point and a vehicle were used, the stationary point in the case of measurements was a sign representing a private parking lot inside the university campus. The GPS-GNSS antenna was installed on it with magnetic strips and fed to a 12V source. The messages transmitted from the fixed point were informational and contained data regarding location, longitude, latitude, distance, and amount of information. For the dynamic object, a new generation vehicle was used that benefits from some safety systems as well as a navigation system that allows interconnection with other external devices. The power supply of the MK5-OBU modules was carried out at the car socket, but with a voltage filter to eliminate possible voltage

Fig. 11.6 The structure and architecture of the proposed system for sending, receiving and interfacing communication

variations that could endanger the hardware integrity of the devices. The calibration and synchronization processes of the systems entailed approximately 10 min, during which various tests were conducted. These tests involved the transfer of data for both transmission and reception, validating the requested iterations from the command line, etc. Beyond the 3D navigation integrated into the central console of the vehicle, the tested system incorporated a portable device and a Wi-Fi router. This integration served the dual purpose of facilitating information routing between the two devices in the initial stages and synchronizing Master–Slave control functions among MK5 modules. Figure 11.7 provides a visual representation of the system's components and of the starting point for the conducted measurements.

The API and the initial version of the application, designed for the portability and management of information through MK5 modules and a 3D navigation system, undergo several iterations. The primary objective of these iterations was to activate all communication interfaces and mechanisms facilitating the transmission of information via CAN and RF to other structures, leveraging CAM/DENM type messages. The utilization of. *ets-shell1/2* through.bash enables the request of the entire routing procedure for the main paths coursing through the stacks of the MK5 architecture. The data transport process establishes multiple connections in diverse directions, dynamically selecting the most suitable frequency. Whether operating on a 2.4 GHz band for medium distances or synchronizing to a 5.9 GHz frequency band in the test environment, the overarching aim is to autonomously transmit specific information.

The system identifies the position, calculates the coordinates, and analyzes the area where the vehicle is located to facilitate convenient routes. In case that the traffic density is high and the GPS signal has no coverage in that area, the *gpsfake* subsidiary functions are activated to randomize the coordinates and parse them into a file, which it will later manipulate by overwriting the information. The crucial stage, where the synchronization of emission and reception becomes paramount, involves concatenating the received data set with the emitted one and validating the connections directly linked to the MK5 central unit. Communication settings and

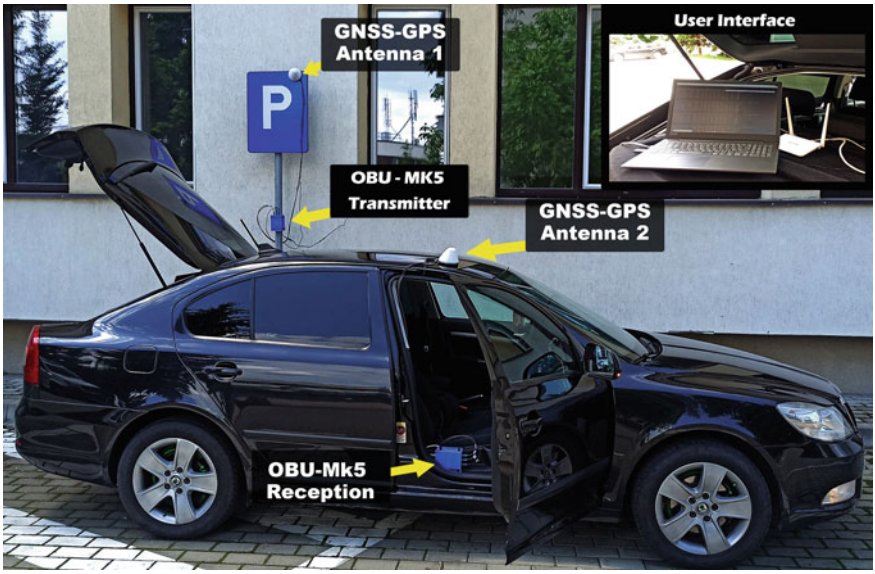

Fig. 11.7 Presentation of the external setup and exposure of the elements used, OBU-MK5 units, GPS-GNSS antennas

module prioritization occur at the ID level, initially identified with associated IP addresses. For OBU1-MK5, the address is 192.168.22.122, and for OBU2-MK5, the address is 192.168.22.123. In our initial findings, over the entire distance of approximately 250 m covered by the first experiments, the packet loss threshold stood at around 8% of the total number, resulting in an approximate loss of 125 kb. This loss is in relation to a suite of 15 data templates, each of 836 kb, an aspect that remains negligible in the context of the transmitted packets. Despite challenges posed by high mobility conditions that may obstruct packet transmission, the implemented corrections, including Doppler filters at the software algorithm level and exposure to heuristic algorithms capable of parsing relevant information, present a highly viable perspective. Notably, accuracy drops are observable with increased distance between the transmitter and the receiver, but these changes do not lead to a complete loss of data, and the threshold is consistently maintained with convenient linearity, as illustrated in Fig. 11.8.

Even if we have to maintain linearity in terms of signal, the scenarios also try to expose less positive aspects of the developed system. Thus, when the vehicle tries to penetrate the traffic barrier, where the information is periodically distorted because the large number of vehicles equipped with all kinds of interfering devices, the signal-to-noise ratio is degraded. Regarding the disturbance or noise aspect, the measurements carried out are summarized in Fig. 11.9. When attenuation factors and noise sources are present, the connection suffers data loss, but it should be mentioned that these losses are when GSM or OSM modules are interconnected. The use of progressive corrections and linear regression in the identification of factors that negatively

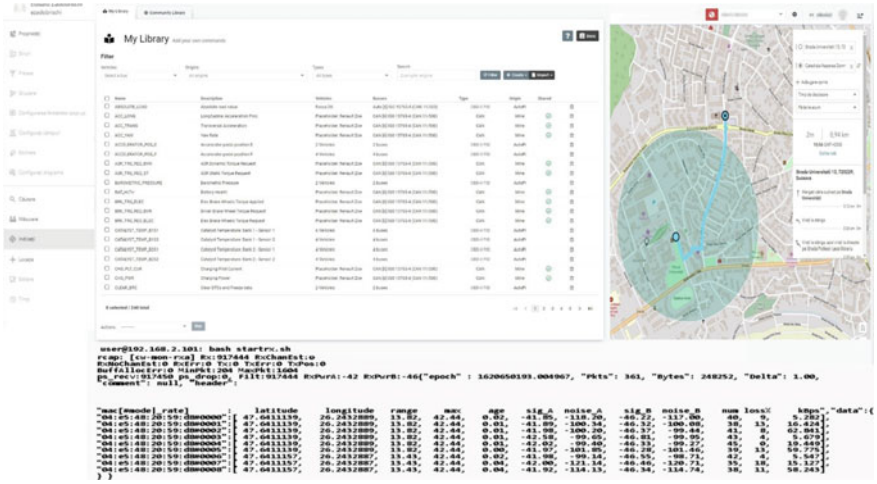

Fig. 11.8 Presentation of the web interface dedicated to communication, highlighting the characteristics, the total route followed, and listing the data received from the transmitter

influence the adaptive context is a measure to consider in possible extended scenarios. Certain aspects related to the quality of the standard in outdoor environments, to a gradual exposure with interference and high density, are clear. Thus, we can say that the transfer rate is constant for the entire duration of the realization of the scenarios and there are no problems that decline the reception of information. We mention that the current form of the system is at an incipient stage and that low to medium-level measurements have been made until this moment. The purpose of these tests was also to analyze the potential integration of facial recognition modules, voice, pedestrian detection, and interconnectivity at the level of road infrastructures. Additional information regarding our developments and applications in this area can be found in Refs. [26, 28, 29].

11.6 Economic and Social Challenges Arising from Implementation of Smart Mobility

While in the previous sections of this chapter, we focused on technical aspects involved in the digital transformation of the transport sector, with a special interest in V2X communications, in this section we examine the economic and social challenges arising from the implementation of digital transformation towards smart mobility. On the one hand, the implementation of these technologies will lead to better traffic management, improved efficiency for carriers, reduced costs, and a more efficient use of all resources [30, 31]. Both for fleets owned by companies and for regular users, the implementation of these intelligent systems would mean saving time, avoiding

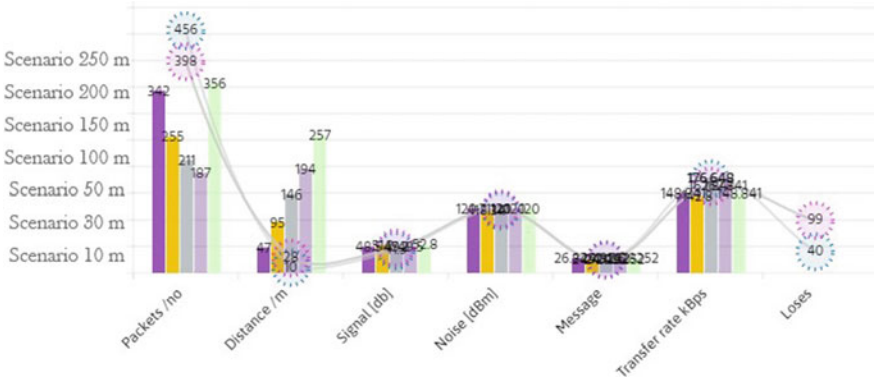

Fig. 11.9 The graphic display of the simulated scenario up to 250 m from the receivers, the presentation and interpretation of the signal, transferred data, losses, noise, distance or signal

congestion, and significantly reducing fuel consumption. In Fig. 11.10 we summarize the economic, social, and environmental benefits from implementing digital transformation in the transportation sector.

However, a societal challenge is represented by the transformation of the labor market, since this would mean a significant reduction in the number of drivers in the transport and logistics sectors, although new jobs are expected to be generated in IT, software development, and data management fields. All these equipment's will involve maintenance, revisions, and technical repairs, so technicians and engineering would need specialization in smart mobility. Being a matter of data management and protection, this transformation will increase the necessity of implementing certain cybersecurity protocols and equipment, as well as the preparation of specialists in these areas. These challenges will lead to reskilling and upskilling, adapting the current educational system to the new requirements of the new job market through new training programs and new specializations. The education systems will need to adapt quickly and prepare students for new careers directly or indirectly related to the digitalization of transport and smart mobility [32].

Another challenge will be faced by the automotive industry itself, as it will need to adapt and transition to new technologies while facing competition from new technology players and startups. In addition to the automotive industry, which will need to transform and evolve considerably, local authorities will be forced to change the urban infrastructure through a new urban design, installing 5G antennas, cameras and sensors, and advanced wireless devices. With these advantages, certain concerns will also arise for clients regarding their personal data and confidentiality, as data collection will be necessary for autonomous driving and efficient traffic management, which will give rise to justified concerns about data security and archiving [33].

Changes are expected to occur in the infrastructure and design of cities, and the urban landscape will radically change by creating special road lanes, the so-called "smart corridors" intended for intelligent cars that will integrate with public transport through multimodal hubs, leading to a resilient design that will better cope with new

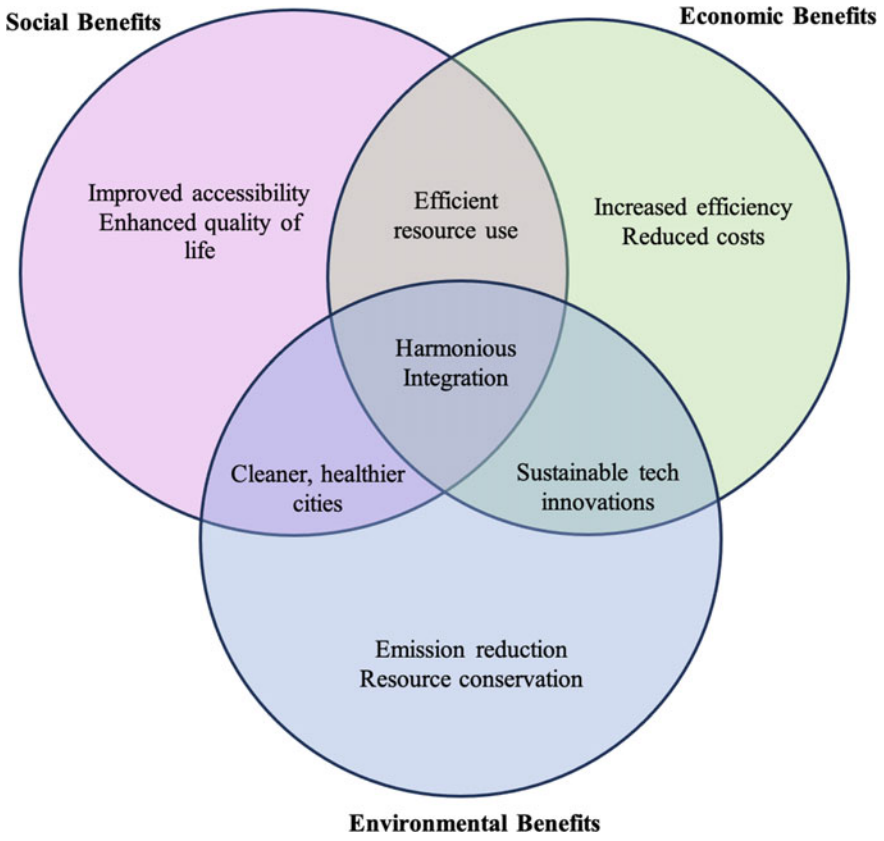

Fig. 11.10 The economic, social, and environmental benefits from implementing digital transformation in the transportation sector

climate changes. However, this new urban design will require more green space by reducing parking spaces and a more harmonious integration between smart lanes, pedestrians, and cyclists. Changes are also expected to occur in the auto insurance market as it will change the way new insurance policies are calculated, but changes will also need to be made regarding traffic legislation, in the sense that new regulations and different responsibilities will be imposed, to ensure the safety of traffic participants. All these efforts fall within the concept of sustainable development through the implementation of smart mobility, which will significantly contribute to fuel reduction, emission reduction, and thus achieving new environmental objectives.

With the implementation of these technologies, new business models related to sustainability and Mobility as a Service (MaaS) is expected to emerge [34]. MaaS represents a mix between private and public transport, with the possibility of having more efficient and personalized services. In this new context, public transport, as well as private taxi transport, will be more efficient because they will be able to better

manage their transport times, routes, and clients. At the same time, transforming cities into cities with digitized transport and smart mobility will make them more attractive for tourists as well as potential investors who would like to invest in a cleaner, accessible city with an infrastructure that does not generate additional costs. The digitalization of transport and the implementation of the smart mobility concept will improve accessibility for the elderly and for those with disabilities, facilitating their movement in cities. This means a better quality of life, as the metropolitan environment will become cleaner, more accessible, more comfortable, significantly improving the life and health of citizens, as well as their psychological status [35].

Access to efficient, flexible, and multimodal transportation will reduce the stress and frustrations associated with driving and will create a sense of independence and autonomy among the population. Real-time access to transportation options and trip scheduling will result in time savings. All of these, combined with living in a cleaner city with fewer pollutants, less congestion, and more green spaces, will lead to a state of well-being, satisfaction, and, of course, a better quality of life. The impact will be immediately felt in the educational and health sectors, as schools will be connected, with personalized routes based on the schedules of these institutions, and for the medical system, this would mean more efficient monitoring of public health and a more efficient distribution of available resources. These things are expected to the develop of a new culture, that of more efficient resource sharing and reducing dependence on personal cars, and the development of a civic culture by adjusting traffic management systems through direct feedback from citizens, to improve traffic and road safety [33]. We can underline that the digitalization of transport and smart mobility means not only the simplification and efficiency of transport but also the opening of new communication channels between authorities and citizens, which can lead to a more inclusive and responsive planning mechanism, and citizens will not only be simple users of this type of transport but also participants in its shaping.

Besides the technical, economic, and social implications, there are also certain psychological aspects that need to be highlighted. The new cars and the new method of smart mobility will undoubtedly be safer, but there will be a need to gain citizens' trust, to accept the new technologies, as according to opinion polls conducted among citizens, certain fears have been identified regarding the safety of autonomous intelligent systems. For example, the 'Pulse of Autonomous Driving' study [36] conducted by the consulting firm Ipsos in 2019 interviewed 21,000 people. It showed that 82% expressed interest about autonomous driving, but 70% also raised concerns about loss of control and 66% about technically unavoidable residual risks. In addition to personal preferences, there were also identified certain regional preferences, with drivers in congested cities being more receptive to using intelligent cars compared to those in rural areas.

In Fig. 11.11 is presented the statistical distribution of the concerns expressed by the drivers regarding autonomous vehicles, according to survey presented in [38]. We can notice that, on one hand, there is the perceived risk due to the lack of control over the vehicle, as it implies the perception of losing control and independence in traffic, and on the other hand, there is trust in technology. The perception of associated risks varies depending on the experience and confidence respondents have in technology.

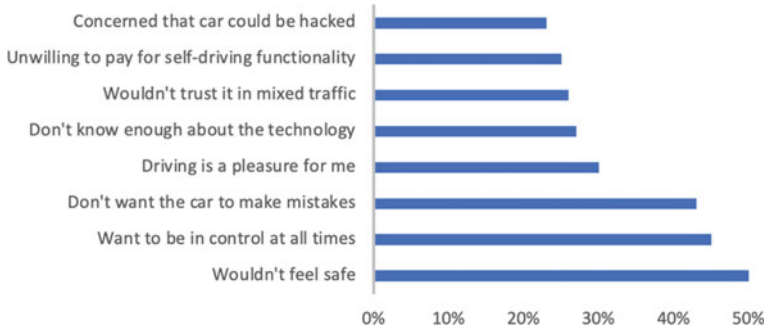

Fig. 11.11 Consumer concerns about self-driving cars. Adapted from Ref. [38]

While respondents who stated they are more familiar with technology showed greater confidence in smart cars, those less or even not at all familiar with digital technologies were more distrustful of the new technologies in the sphere of smart mobility. At the same time, traffic participants will need to adapt to new legislative norms and road safety in their interaction with smart cars, both as users and as simple pedestrians. Smart mobility will lead to more interaction with the interfaces of smart cars, which will bring certain changes in social dynamics, but at the same time will significantly reduce the anxiety and stress related to driving, will change daily routines, and participants having more time at their disposal, being able to enjoy more leisure time, travel or interaction with travel partners.

Another important psychological aspect is that traffic participants will be less frustrated because there will be a certain equity among traffic participants, there will be no more parking in prohibited places, no more speeding, and violations of traffic laws. Users who have experienced transportation with a smart car were more receptive and confident in using such a means of transport also based on the interior design of the car and the positive interaction they had with the digital interface of the car, in the sense that a more intuitive and easier interface created greater trust and less stress associated with this experience [36].

Nevertheless, smart mobility may involve a monthly subscription or certain fees for users, and the specific price will depend on the business model implemented, but there is the possibility that local authorities will get directly involved and finance the development and maintenance of the infrastructure. All these aspects and their management will make the acceptance of the implementation of these new technologies be accepted with greater or less ease.

The process of digital transformation in transportation and smart mobility will have to face challenges of an economic and financial nature, infrastructure, and public acceptance, as illustrated in Fig. 11.12.

Economic challenges manifest through the displacement of jobs, such as that of professional drivers, and the need for retraining employees in the automotive and related industries. At the same time, new start-ups in the field of intelligent mobility will need to be encouraged. Other challenges relate to the public's perception of these

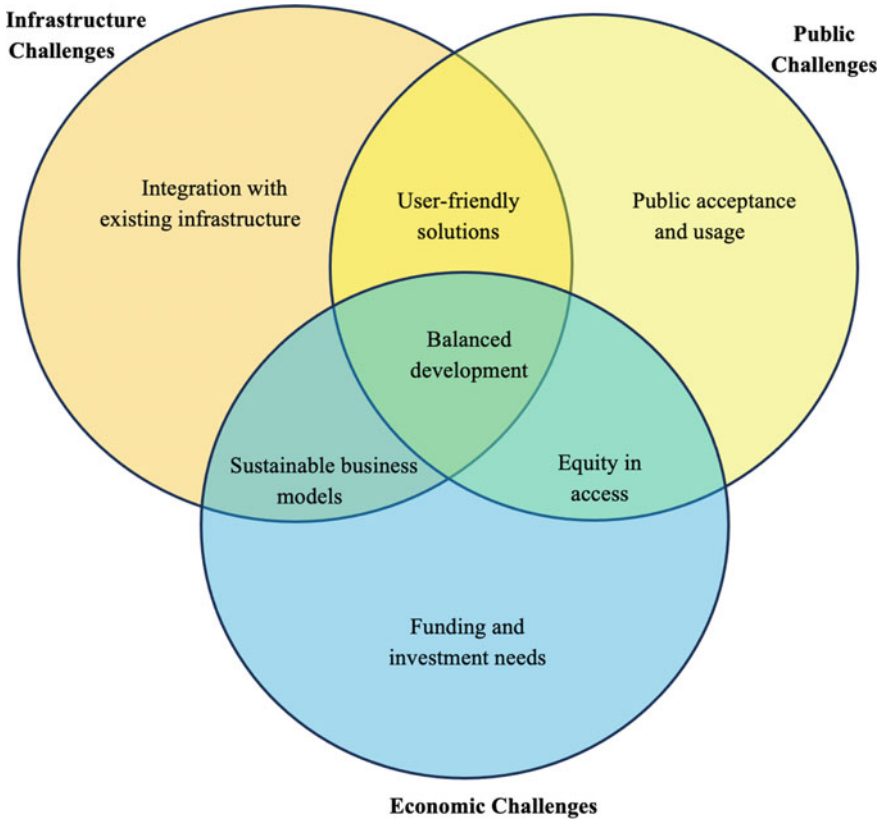

Fig. 11.12 Challenges in implementing digital transformation in the transportation sector and smart mobility

transformations, raising awareness, and involving citizens in the implementation of new projects to meet their requirements and increase the level of acceptability [37]. Equitable access to all these technologies will need to be ensured for all categories of citizens, and public transportation networks will need to be extended to be accessible to all communities and suburban areas. Local authorities will also face certain challenges, some of a financial nature, as the implementation of intelligent mobility involves the acquisition and installation of specific equipment. However, certain works on the infrastructure of cities will be required for efficient traffic management.

Implementing mobility as a service, electric transportation, and autonomous vehicle transportation require the implementation of sustainable business models that bring benefits to entrepreneurs and communities in building sustainable and climate-resilient cities. We believe that citizens need to be correctly and transparently informed about the advantages and benefits of smart mobility, to be familiarized with the concept of urban resilience, and the positive and healthy influence it would have on the environment, cities, and implicitly on their inhabitants.

11.7 Conclusions

The transport sector is currently facing profound transformations towards smart and sustainable mobility. State-of-the-art sensors and communication technologies are used for the development of a more efficient and safer transportation network paving the way for connected and autonomous vehicles. After an introduction to policies and technologies supporting digital transformation of the transport sector, we focused in this chapter on wireless technologies for vehicle-to-everything communications, including the contributions of our research group in developing a modular hardware-software architecture and a hybrid platform of vehicular communication and information technologies for road safety and driver assistance applications.

The endeavor to implement an integrated system within the car's passenger compartment, manifested as a portable navigation system installed on the central console, emerged as both a challenge and a necessity. This undertaking involved the implementation and testing of a platform founded on the 802.11p—DSRC standard, utilizing an MK5 system developed by Cohda Wireless. The resulting device exhibited a hybrid architecture designed to transmit prioritized messages via two modalities, namely CAM and DENM, these directives originating from a (virtual) Roadside Unit. Information underwent filtration from a central station, traversing from On-Board Unit 1 to On-Board Unit 2. The Linux operating system served as the dedicated platform for this application, residing within the in-vehicle navigation system. The system operated within the frequency bands of 700 MHz, 2.4 GHz, and 5.9 GHz. The implementation spanned diverse environments, specifically tailored to underscore deficiencies arising from interference in relation to the 802.11p—DSRC standard. The messages employed adhered to nomenclature dedicated to cause identifications in the realm of road safety. Demonstrably, utilizing this architecture and the MK5 system, critical messages transmitted via CAM and DENM protocols could effectively reach their destination, even in dynamic environments fraught with obstacles or interference. User interaction with the interface was facilitated through an LCD touchscreen display. To mitigate the impact on driving style, audio notifications were implemented to convey the degree and complexity of situational information. Software modules and architectures were developed to analyze the external environment, prioritizing information based on its significance. Consequently, drivers gained the ability to observe objects and pedestrians in potentially perilous situations but also to communicate potential accident-causing scenarios. The versatility of the proposed system has been validated through successful tests in various traffic conditions, proving V2X communication distances of more than 250 m.

Finally, the economic and social benefits and challenges arising from the implementation of smart mobility were examined. The improvement of traffic management and the reduction in the number of accidents, fuel savings and the positive impact on the environments, career opportunities for new specializations and professions and development of new industries, increased accessibility and improved quality of life were the main analyzed benefits. The displacement of jobs, such as that of professional drivers, and the need for retraining employees in the automotive and related

industries, and the financial resources needed for adapting the city and road infrastructure were some of the economic challenges addressed. The public's perception of these transformations, equitable access to all these technologies, the need for a new culture, including resource sharing, and a new type of interaction and communication, both among citizens and between citizens and authorities, were pointed out as the main social challenges.

Acknowledgements This work is supported by NetZeRoCities Competence Center, funded by European Union—NextGenerationEU and Romanian Government, under National Recovery and Resilience Plan for Romania, contract no. 760007/30.12.2022 with Romanian Ministry Of Research, Innovation and Digitalisation, through specific research project P4—Smart Mobility and Infrastructure.

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Chapter 12
Data-Driven Decision Making: Application of People Analytics in Human Resource Management

Živilė Stankevičiūtė

Abstract Recently, the field of human resource management (HRM) has undergone a significant transformation due to the impact of technological advances and increasing relevance of business analytics. Organizations worldwide are increasingly applying people analytics, which enables making more rational, objective and effective decisions about people based on the analysis of data. People analytics has a huge potential while dealing with unpredictable challenges organizations and their employees are facing today. On the one hand, people analytics can reveal the efficiency, effectiveness, and impact of the HRM function, especially emphasizing the strategic partnership role of human resource (HR) professionals. On the other hand, people analytics changes the way organizations identify, manage, develop and control their workforce. The term "people analytics" refers to a novel, evidence-based and data-driven approach to manage workforce. The focus is very much placed on workforce planning, recruitment and selection, development and training, and employee performance while analyzing data to establish causal relationships or other insights and accordingly drive actions by influencing the key decisions. However, applying people analytics involves numerous challenges revealing that not all organizations are on the same maturity level. Although previous research provides some theoretical insights regarding the implications of people analytics in HRM, empirical studies dealing with organizational examples and readiness to create business value through people analytics are nonetheless lacking. The chapter aims to reveal how people analytics is applied in the HRM field. While doing this, a qualitative research was conducted including 12 interviews with HR professionals from different organizations operating in various industries. The results revealed that organizations mainly used only descriptive analytics and the focus was more on HR metrics. In most cases, the decisions about workforce planning or employee remuneration were data-based. However, analytics was less used in employee selection and recruitment, and training and development areas. Not rare were the cases, when intuition of HR professionals or line managers drove the decisions. This chapter has strong practical implications

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L-I. Cioca et al. (eds.), *Digital Transformation*, Intelligent Systems Reference Library 253, https://doi.org/10.1007/978-3-031-55952-5_12

seeing that the results can encourage organizations to rely more on people analytics to optimize the HRM function and add value to organizational success and employee well-being. In addition, the results draw attention to the potential challenges of people analytics organizations should take into considerations.

Keywords People analytics · Data-driven decision-making · Human resource management · Data · Evidence-based approach · Technological advances

12.1 Introduction

As a result of unpredictable, constant and dynamic changes, the patterns of organizations' operation have been undergoing significant changes. The transformations also apply to employment aspects such as work space and time (flexible—anywhere/anytime), work relations (on demand work—gig work, freelancing), content of work (augmentation and new rules), and allocation and organization of work (agile, participative, algorithmic) [1]. Correspondingly, the human resource management (HRM) function alters and evolves as a field [2] embracing enormous opportunities the new technologies can bring [3] and relying on the growing relevance of business analytics, as a strategic organizational capability [4]. Business analytics implies extensive use of increasing amounts of data, statistical and quantitative analysis of these data, explanatory and predictive models, and finally fact-based management to drive various decisions and initiatives, such as predicting consumer behavior or better management of traffic networks [5]. Following the examples in marketing or finance domains, HRM is taking strides to combine people's intuition, beliefs, and experience with the new trend of data analytics [6–9]. As a result, an innovative practice called people analytics has emerged [4, 10–13]. Although with different perspectives (and labels), generally, people analytics refers to "the analysis of employee and workforce data to reveal insights and provide recommendations to improve business outcomes" [14] (p.5).

People analytics aims to enhance not only the efficiency of the core HRM functions, such as workforce planning, selection and recruitment, training and development, and performance management [15, 16], but also seeks to optimize the employees performance and contribute to building a successful organization [17]. Predicting appropriate hires, promoters and attrition, defining the most effective ways of employee collaboration while working remotely, or finding and developing knowledge stars, or making connection between employee behavior and customer satisfaction [15] serve as examples of people analytics aimed at addressing diverse organizational challenges. As employee and workforce data can help answer topical managerial questions or solve pressing business issues, or move towards solving wicked problems, people analytics has been described as a "future value driver in HRM" [18], "critical to any organization's success" [19], "a game changer for the future of HR" [20]. This notwithstanding, these high hopes will remain empty promises if the organizations do not actually adopt people analytics, in other words,

if they demonstrate the lack of readiness to generate business value by practicing people analytics [18, 21].

The literature and empirical evidence are somewhat controversial as regards the organizations' situation in adoption of people analytic. The first stream of scholars argues that organizations worldwide are increasingly deploying people analytics [16]. For instance, more than a half (52%) of European companies reported that they used people analytics when making both strategic and operational decisions. On the contrary, the second stream posits that organizations struggle to adopt people analytics arguing that the pace of adoption of people analytics is very low and falls short of expectations [19, 22, 23]. For instance, in 2019, KPMG conducted a study and surveyed more than 1,200 human resource (HR) executives globally. The survey findings suggested that the vast majority—70%—of the respondents acknowledged the necessity for workforce transformation; however, only 37% of those surveyed felt "very confident" that HR were actually capable of transforming and progressing while invoking such important skill as analytics. More importantly, only one fifth of the respondents believed analytics would be among the main HR initiatives over the next few years and only 12% indicated analytics as an issue the highest-level managers should be concerned with [24]. More recently, the HR Research Institute, based on a survey, announced that only 29% of HR professionals said they were good or very good at making positive changes based on people analytics, although another 35% rated themselves as "moderate" in this area. Accordingly, a third were poor or very poor at making positive changes based on people analytics [25]. Finally, a Gartner, Inc. survey of 105 HR leaders demonstrated that just 5% of companies have implemented generative AI in HRM [26].

There are no doubts that over the last few years, the volume of literature on people analytics has grown rapidly [2, 4, 17, 27, 28]. It focuses mainly on people analytics conceptualization and the way it operates [6, 22], how it should be implemented [18, 29], and the main opportunities, barriers and challenges of people analytics [4, 16, 17]. Thus, the literature tries to cover the way the people analytics can help the organizations to create business value [8] or not to become a management fad [6]. Despite that, the literature of people analytics is still in the early stages [16]. Moreover, there is a lack of empirical quantitative studies examining how people analytics is applied in HRM and how it could help organizations and HR professionals in making decisions [16, 18]. This chapter is designed seeking to narrow this gap down.

The chapter aims to reveal the way people analytics is applied in the HRM field. More specifically, the chapter aims to answer the following research questions:

RQ1. How is people analytics described by HR professionals? What does people analytics mean for HR professionals?

RQ2. What opportunities and value people analytics brings to organization, HR professional and employees?

RQ3 What are the main challenges in applying people analytics?

RQ4 How is people analytics applied in different HRM functions: workforce planning, selection and recruitment, training and development, performance appraisal, and remuneration.

While doing this, a qualitative research was conducted including 12 interviews with HR professionals from different organizations operating in various industries in Lithuania.

The chapter contributes to the scientific literature in several ways. First, it responds to the call in the literature [16] and provides empirical insight based on the qualitative study tackling the approach of HR professionals. Second, by mapping the field, the chapter expands the available knowledge about people analytics adoption in different functions of HRM, for instance in recruitment or performance management. Third, as the volume of data available to analyze and predict employees' behaviors will continue to grow exponentially [30], the chapter contributes to the growing body of the literature on value of people analytics, opportunities provided, and possible challenges, which need to be considered.

The chapter is organized along the following lines: theoretical background, methodology, results and discussion including practical implications and limitations, and conclusions.

12.2 Theoretical Background

Conceptualization of people analytics. Advancing technologies and new sources of structured and unstructured data make radical changes in all organizational functions, including allowing for better analysis of the complexity in workforce-related decision-making [9]. These transformations cause debates on both business practitioner and scientific level giving different labels to the process aimed to analyze HRM activities for making better decisions on the people side of business [31, 32], such as human resource analytics, workforce analytics, talent analytics or human capital analytics [4, 22]. However, people analytics and human resource analytics have recently become the most common terms [10].

Thus, people analytics is a relatively new concept [9], although analytics in HRM has been around for years [22]. For instance, the notion of measurement in human resources was expressed by Kaufman (2014) [33] and by Lawler et al. (2004) [34] arguing that people analytics opens a powerful way for the HRM function to add crucial value to their organizations. As such, business and researchers communities believe that people analytics is well positioned to alter the way organizations identify, manage, develop and control their employees [16, 30, 35]. Despite such enthusiasm, people analytics has become somewhat of a buzzword [32]; it means different things to different people [27] with some authors referring to it as merely a "management fad" [6]. Table 12.1 presents some of definitions retrieved from the literature.

Although the huge diversity of definitions is provided in the scientific literature (for the full overview of them see Margherita (2022) [4] and Falletta and Combs (2021) [27]), all of them have several things in common.

Table 12.1 Definitions of people analytics

Source	Definition
Falletta and Combs (2021) [27]	"HR analytics is a proactive and systematic process for ethically gathering, analyzing, communicating and using evidence-based HR research and analytical insights to help organizations achieve their strategic objective" (p. 54)
Bassi et al. (2011) [31]	"an evidence-based approach for making better decisions on the people side of the business; it consists of an array of tools and technologies, ranging from simple reporting of HR metrics all the way up to predictive modeling" (p. 16)
Marler and Boudreau (2017) [22]	"A HR practice enabled by information technology that uses descriptive, visual, and statistical analyses of data related to HR processes, human capital, organizational performance, and external economic benchmarks to establish business impact and enable data-driven decision-making" (p. 15)
Tursunbayeva et al. (2018) [10]	"People Analytics is an area of HRM practice, research and innovation concerned with the use of information technologies, descriptive and predictive data analytics and visualization tools for generating actionable insights about workforce dynamics, human capital, and individual and team performance that can be used strategically to optimize organizational effectiveness, efficiency and outcomes, and improve employee experience" (p. 231)
Huselid (2018) [35]	"the processes involved with understanding, quantifying, managing, and improving the role of talent in the execution of strategy and the creation of value. It includes not only a focus on metrics (e.g., what do we need to measure about our workforce?), but also analytics (e.g., how do we manage and improve the metrics we deem to be critical for business success?)" (p. 680)
Van den Heuvel and Bondarouk (2017) [13]	"systematic identification and quantification of the people-drivers of business outcomes, with the purpose of making better decisions" (p. 160)

First, people analytics is an evidence-based approach to people-related decision-making. The core idea of the mentioned approach is that good-quality decisions should be based on a combination of two things, namely of critical thinking and the best available evidence [36]. Evidence-based practice is about making decisions when the best available evidence from numerous sources are used. Such use of the evidence should reflect three characteristics, namely conscientiousness, explicitness and judiciousness. Decisions are to be made through six types of activities: asking (raising questions which reflect the problem), acquiring (systematically finding the proof), appraising (critically evaluating the credibility and pertinence of the evidence), aggregating (referring to the process of weighing and putting together the evidence), applying (integrating the evidence into the process of making informed decisions) and finally assessing (appraising the result of the adopted decision) [36]. Thus, people analytics as an evidence-based approach creates great possibilities for personal and professional growth [37], and makes organizations more transparent and productive [11].

Second, people analytics involves using information technology (IT) to collect, manipulate, visualize and report data. Recent advancements in IT, such as human resource information systems (HRISs), machine learning (ML) and artificial intelligence (AI), have provided human resource professionals the opportunity to collect data and extract some insights from them [38, 39]. For instance, the use of technologies makes it feasible to analyze intricate performance data, screen potential employees, develop tailored training recommendations, enable intelligent scheduling, or demonstrate how employee satisfaction or remuneration is linked to the value of an employee in a particular organization [40, 41]. More recently, AI technology enriched HRM processes, including predicting the likelihood of a candidate's success in the organization [42]. As the AI use is constantly growing with the potential to enhance the people-related decision-making process, ongoing disputes started capturing the ethics dimension [43]. This notwithstanding, it seems that most organizations struggling with high-quality IT infrastructure have outdated or unsophisticated technology, despite the fact that it is critical for people analytics to deliver promises [8, 38].

Third, people analytics adopts systematic methods of analysis and visualization of data. Already at the beginning of people analytics, a core distinction was made between analytics and metrics, arguing that people analytics involves more sophisticated analysis of data and "people analytics" should be separated from "HR metrics" [22, 34]. Here, two aspects could be underlined. The first one refers to data, as organizations focus on several challenges in this field, namely high volume of data generated both internally and externally, high velocity in terms of data generation and decision-making, data quality ("garbage in, garbage out"), and high variety of data, e.g. videos, images, text, audio [5, 44, 45]. The second one refers to the maturity of people analytics, as it is obvious that most organizations are grappling with the transition from basic operational reporting to more advanced forms of analytics [16]. As such, three analytics maturity levels can be derived based on to organizations' analytical capacity and focus [4]. Descriptive analytics aims to examine what occurred in the past and how this influences the present situation, by answering the questions related to *what happened, why did it happen, and what is happening* [4, 16]. The core idea is to characterize the present state of an organizational situation in a manner that highlights developments, patterns, and exceptions [44]. Predictive analytics refers to explanatory patterns from past or present events to forecast future organizations' development by answering the questions *what will happen* and why in the future [4, 16]. Thus, future possibilities or early warning signals are presented. Finally, prescriptive analytics, as the most sophisticated type of analytics, aims at suggesting the best decision options in order to take advantage while answering the questions such *as what should I do and why* [4, 46]. Drawing upon the findings, the previous literature demonstrated the consensus on people analytics' low maturity [16].

Forth, people analytics serves the need of executives and other top decision makers. People analytics allows, in case of human resource professional having strong analytical competencies, to communicate the results of sophisticated models

to decision makers in terms of "telling a story" beyond numbers or numerical values [47]. This, in turn, leads to clear decisions made avoiding intuition.

Fifth, people analytics is about supporting people-related decisions. These decisions might be in various areas and related to being hired or dismissed, being promoted or demoted, being included in training or coaching programs, etc.

Sixth, people analytics is about the impact of HRM decisions on business and performance outcome. Once again, two aspects are highly relevant. Initially, people analytics reshapes the profession of HRM professionals [17, 32] requiring news skills or even skills sets in business acumen, consulting, human resources, work psychology, data science and communication field [14]. Next, people analytics enhances HRM as a field and makes HRM of strategic significance [2]. This makes changes in organizational landscape, as for long years human resource professionals have experienced difficulties establishing themselves as equal contributors to organizational outcomes, facing trust issues particularly in their relations with decision-makers on organizational level [48].

Summing up, the mentioned six characteristics taken together allow stating that people analytics can be portrayed as an innovation as it is new, designed to influence employee attitudes and behavior [22, 49] and refers to evidence-based and data-driven approach to people management.

Opportunities and Challenges of People Analytics

The literature abounds with promises of people analytics. One of them affirms that people analytics is supposed to replace gut feeling decisions with data-based decision-making, and supplement intuition-based choices with objectivity [6, 17]. Another one speaks about better horizontal and vertical alignment of HRM functions. The next two are about better integration of human resources within strategic planning function and enhanced illustration of cause-and-effect relationships between HRM and organizational results [2]. Ultimately, increased credibility within the HRM field is among the promises [2]. These promises are built on at least two assumptions [2]. Firstly, decision-making based on algorithms is often considered more reliable, more objective and less error-prone than human decision-making [16, 50]. Secondly, people analytics is believed to predict future human behavior through historical data analysis [16, 45].

Thus, as people analytics holds significant promises, the literature accordingly focuses on the opportunities presented by it [51]. Quite recently, Giermindl et al. (2022) proposed business-oriented and employee-oriented benefits [16]. Turning to business level, it is assumed that people analytics can generate feasible insights into all stages of the employee life cycle, namely attraction, recruitment, onboarding, development, retention, and separation [52]. These insights, in turn, lead to improved operational and strategic organizational performance. For instance, predictive analytics might identify the mix of benefits which would help retain the employees [2]. Turning to the benefits for employees, they include health benefits, development opportunities to extend the experience, job satisfaction, and other benefits in field of employee well-being [16].

In addition to the gains, there are also challenges. The starting point undoubtedly involves the commitment and understanding of top leaders about the value that people analytics can provide, all the while cultivating a data-driven culture [21]. Technical barriers seem to be often encountered in practice as current IT applications are mainly designed to support only data reporting [18]. Additionally, lack of data quality and proper data raises the concern of data reliability [18, 53] which may lead to misleading conclusions as in the case of Amazon [51]. Moreover, some human resource professionals lack the analytical capabilities as well as the strategic perception how people contribute to the success of a particular organization [9, 29]. This challenge also relates to a low level of cooperation between different departments while sharing data and analytical insights, seeing that, for instance, data from Finance or Production department are crucial to deliver observations in terms of people development, remuneration, and product quality [16]. Finally, some skepticism and doubts exist where people can be reduced to numbers and metrics [29] and about the use of employee data in an ethically legitimate way [41, 43].

Overall, studies highlight the promises and opportunities of people analytics in the whole employee life cycle, while challenges are related to human, data and technical barriers while putting analytics strategy in place.

People analytics in particular HRM functions. People analytics aims to assist organizations in comprehending their staff and particular employees by enhancing the accessibility, interpretability, and actionability of data related to employee attributes, behavior, or performance [10]. Asking strategically important questions and presenting answers in a logical structure that demonstrates the link between input and output is at the core of people analytics. From the HRM perspective, people analytics might provide insights for various areas, from workforce planning to dismissal management. In case of sourcing, acquisition, and hiring, technologies allow speeding up the review of resumes, enabling them to be sorted and prioritized, with the most promising and the candidates for best suitable organization on top [51]. Analytics can predict needs of organization and based on them, employees can be trained by using the most cost-effective way [42]. Moreover, people analytics might enhance skills acquisition by observing how employees react to various training materials and by customizing delivery methods to align with their preferred learning styles [51]. As regards performance appraisal, analytics makes it simpler to collect data from internal and external sources about employee performance [42] leading to continuous monitoring, feedback, coaching, and transparency [51]. Finally, identifying what causes employee dissatisfaction and unhappiness might reduce employee replacement costs.

Thus, people analytics has the potential to reveal causes, define situations and predict future attitudes or behaviors of workforce. This might be used by HR professionals as a tool for proposing the decisions aimed at better employee well-being and higher organizational performance.

12.2.1 Methodology

Research context. The context of the study is Lithuania, which has already earned its name in the IT sector [54] and digitalization is seen on political and business levels as key to economic growth [55]. Lithuania is the second cyber-safest country in the world [56]. Moreover, in the general study of the digital quality of life, in 2022, Lithuania got an index of 0.7 and took the thirteenth place in the world [56]. Furthermore, in the country, the internet quality is even 22% ahead of the global average [56]. Thus, these evidence of technological advances together with the growing demand of candidates for job analytics positions in Lithuanian companies were behind the choice to analyze the way people analytics is applied in the HRM function in organizations operating in Lithuania.

Data collection. Having the aim of this chapter in mind, qualitative research was used in the form of semi-structured interviews based on open-ended questions. The advantages of the semi-structured interview are as follows: it is both versatile and flexible; it ensures reciprocity between the interviewer and participant; finally, it allows asking follow-up questions based on participants' answers with the aim to gain a rich understanding of the phenomenon analyzed [57].

In this study, HR professionals, who hold HR manager or HR business partner positions were interviewed. The informants were reached via LinkedIn and other social media or by contacting the professional networks.

In research that employs semi-structured interviews, the sample size is often determined by the number of participants interviewed until "data saturation" is achieved [58, 59]. Saturation refers to the point at which the data collection process no longer offers any new or relevant data. In the literature, three methods are proposed to justify the sample size [60]. This chapter follows the first method, which suggests citing recommendations by qualitative methodologists [60]. According to Hennink and Kaiser (2022) [59], data saturation can be achieved even with a small sample, such as 9–17 interviews. In this study, data saturation was deemed to be reached after twelve interviews. All participants were females. The duration of working as an HR manager in particular organizations ranged from less than 1 year to 18 years. The interview data are explained in Table 12.2.

Based on the existing literature review, during interviews, four areas of focus were covered, such as perception and definition of people analytics, application of analytics in different HRM functions; opportunities the people analytics provides, and, finally, the core challenge while employing people analytics. The interview guide was prepared in advance covering the mentioned topics. Interviews were organized at the convenience of informants taking part in the research in terms of both place and time, and conducted in the Lithuanian language. During the interviews the participants were encouraged to express their opinions freely. All interviews were audio recorded. Additionally, notes were taken. They lasted from 24 to 55 min. Confidentiality and anonymity were guaranteed concerning both the individuals and organizations at which they are employed.

Table 12.2 Interview data

No of informants	Main areas of activities of the organization	Organization size (criterion—number of employees)*	Interview duration
I1	Employment search, employment. Personnel selection	Big	45:13
I2	Energetics, automation, wholesale	Medium	55:37
I3	Metal processing	Medium	40:19
I4	Furniture manufacturing; Wholesale	Big	48:37
I5	Food production	Medium	32:16
I6	Retail sales	Big	44:04
I7	Chemical industry; Agriculture	Big	32:12
I8	Food production	Medium	38:42
I9	Hotels	Medium	24:30
I10	Metal processing	Medium	25:57
I11	Logistics services	Medium	35:14
I12	Furniture manufacturing	Medium	41:27

* Very small—up to 10 employees, small—up to 50 employees; medium—up to 250 employees; big—more than 250 employees

Data analysis. The interviews were recorded and transcribed. The data obtained during the interviews were processed by interpreting, systematizing, analyzing, and categorizing the responses.

12.2.2 Results and Discussion

This chapter aimed at revealing how people analytics is applied in HRM. The results and discussion are further provided based on four research questions presented in the introduction.

RQ1. The description of term "people analytics". The prevailing notion conveyed during the interviews supported the idea that people analytics was an integral part of HRM. Although analytics is attracting interest "*when I hear the term HR analytics, first of all I think, it's great that we can talk about it*" (I8), it is still an emerging concept and "*analytics is not discussed in the personnel departments of all organizations*" (I12). As such, people analytics is treated by informants as HRM innovation supporting the view expressed by Marler and Boudreau (2017) [22].

As it is seen from Table 12.3, HR professionals associate the term "people analytics" with several aspects. Firstly, the association was made with data, numbers and metrics, which provide an assistance in decision-making. Secondly, people analytics is supposed to reveal the value the employees add to overall organizational performance, Thirdly, analytics enables evaluating the usefulness of processes. Fourthly, it is about future-oriented approach while predicting. Finally, people analytics refers to a management fad.

Based on the data, it might be said that organizations differ in terms of their thinking related to people analytics. Most of the interviewees associated analytics solely with the HR metrics they traditionally reported, concentrating exclusively on the HR function itself e.g., employee turnover, average age of employees, absence rate or voluntary employee turnover. These metrics reflect the administrative role of HR professionals, which was dominating for quite a long time [61, 62] and focus only on evaluating what the HRM function does [4]. Only a few interviewees expressed the concern about narrow understanding of people analytics and connected it to more sophisticated mathematical models, allowing to demonstrate impact of people on business outcomes: "*The attrition, the time to hire, satisfaction numbers, headcount numbers—these ones are the main ones, which we are actually using, yes. But I wouldn't say that it is a decision-making. Yes, at some point. Yes, we use, but more*

Table 12.3 The associations of people analytics provided by informants

No. of informant	Conceptualization of construct
I1	People analytics refers to "the benefit, the value added an employee might bring or it could also be associated with the way the human potential is utilized in the company"
I2	"It is a fancy and buzzing word"; "the prediction of the future"
I3	"Generally, it associated with calculations, statistics that is used to make the decisions. Decision-making using various calculation methods."
I4	"For me, this is about the tool that helps making the decisions"
I5	"A part of the personnel process"; "assistance in business decision-making": "to date, is probably already a kind of a trend"
I6	"This deals with numbers. Numbers and statistics, what the number show."
I7	"we do calculations"
I8	"I see certain numbers"; "I know what can be measures to understand the temperature, culture of personnel etc."
I9	People analytics is associated with "some indicators. Some data are collected for the company to help it strategize and optimize the operations."
I10	"About certain indicators, numbers, how to assess processes or certain parameters, or different elements of personnel management"
I11	"Essentially, it is about numbers"
I12	"How to make the decisions easier with the help of numbers"

for the, let's say, not for the prediction of the future, but rather to make an analysis what has happened. Yes, to analyze the past, but not the future" (I2).

Different opinions expressed during interviews reflect different stages of maturity of people analytics in organizations. As noted by Bassi (2011) [31], people analytics can be considered both as systematical reporting on an array of HR metrics or more sophisticated solutions based on questions "What will happen and why?" or "What should be done?". Moreover, it is not unusual for the terms metrics and HR analytics to be used interchangeably [13]. The recent literature argues for the distinction between the two terms, as metrics do not provide a sound insight into why something occurred, what explains differences in outcomes, or what the likelihood is that an event will reoccur in the future [13]. This maturity question is related very much to the decision-making culture. One of the interviewees shared the opinion that "*In some of the companies < … > when proposing something, you have to base it on certain data. You cannot just say, look, here it seems to me that we should introduced an additional new benefit, just because it would be nice. No, you have to do an assessment beforehand, perhaps there was an employee survey and they told something, evaluated, < … > perhaps some market research data.*" (I5). Accordingly, it is possible that organizations engage in and promote several types of decision-making culture, namely data-driven culture, intuition-driven culture, when "*I feel that this is the case*" (I3), or even only profit-driven culture, when "*result of the company's activities is the main analytics that dictates things*" (I7).

It also became obvious in the interviews that organizations linked the need for analytics with the size in terms of employee number of the organization, as "*we do not have any indicators, but not because we do not need them; simply the people could be counted on fingers of one hand and identified*" (I5). Additionally, the work specific and loyalty of employees are treated as factors limiting analytics adoption: "*when < … > it is a narrow fields and people have been working here for quite some time, so we do not have the need for that analytics daily"* (I3). Business development, on the contrary, is seen as a boosting factor: "*indeed, as the company grows, analytics will become necessary*" (I3). Moreover, at this time, some organizations are already convinced that "*I would say, we have sufficient analytics < … > we do have a lot of data and in different cross-sections*" (I4).

Summing up, the research results are in line with previous studies where lower levels of advanced people analytics were found [9] calling to go beyond the standard reporting and rely more on data-driven decision-making culture.

RQ2. Opportunities and value people analytics brings to the organization, HR professionals, and employees. The most common opportunities and value referred to in the interviews were the following: a tool for decision-making; a tool to assess the current situation; enabler of better communication; a means to get a complex picture of the situation; allows establishing the value of HR professionals; creating better employee well-being. They will be described further.

A tool for decision-making. This opportunity was mentioned by a high number of informants emphasizing slightly different aspects, as helping to deal with ambiguity

and sensitivity "*numbers help decide when you deal with sensitive or unclear information*" (I3) or enabling to address tendencies, because analytics makes it possible to answer "*what to do with the trends we see in the indicators. If we see the increase of turnover, we analyze the causes deeper. If we see an increase of sickness incidents, for instance, in a certain division, then we undertake cause analysis and work with that*" (I10). Moreover, the need to switch from emotions to rationality was underlined: "*I think sometimes as human beings we do everything based on emotions. So, analytics can help to be more precise and constructive in our decisions, even to support the opinion, to support the predictions, let's say for the future"* (I2).

Tool to assess the current situation. People analytics allows getting an understanding of "*what is going on in the organization*" (I10). For instance, "*if we have the NPS score of employees, then it will show us how the employees rate the company*" (I6).

Enabler of better communication. During research it was found that HR professionals faced challenges when providing information or explaining employees some delicate or even quite simple aspects of their work cycle. Thus, people analytics allows "*providing people with data*" (I7) and respectively "*explaining more clearly and simply*" (I7), as shown by this example: "*For example, a person comes to inquire about their salary and ask why they are paid so little. You then realize that they are not aware of certain things, like, for example that they have additional pension insurance. Finally, that they asked for a part of their salary to be paid as advance, but they do not consider it as salary*" (I7). In the case above, communication as well people analytics haves an educational function because "*they it written in black on white, and then the understanding and vision expand a little*" (I7).

Means to get a complex picture of the situation. One of the informants shared the opinion that people analytics was "*an additional tool and source of information for < … > simply seeing the wider picture of the situation*" (I5). Another informant broadened the understanding of what the wider picture meant claiming that it was worth to "*to compare both, with competitors and with Lithuanian data*" (I7). Finally, people analytics was compared to the car dashboard making it possible to know "*where I go, how I drive and the fuel consumption" (I8).*

Allows establishing the value of HR professionals. As it was mentioned before, HR professionals used to struggle with aligning their work with the organization's strategic direction [63] and establishing themselves as equal contributors to organizational outcomes [48]. People analytics can make break the ice seeing that it "*confers broader understanding where my value is, what I do, where I am; you know, that I could influence one or another more substantial change*" (I8).

Creating better employee well-being. The interviewees underlined that people analytics might be used for "*improving the working conditions of employees*" (I1) and for establishing higher employee engagement that leads "*to lower turnover*" (I9), or simply "*making the organization the best place to work*" (I12).

In general, organizations are familiar with the opportunities and value people analytics might generate on all three levels, namely organizational, HRM function, and employee. Although the value is perceived, there are still some unanswered questions regarding perception versus reality. Some of these questions could be

answered by exploring concrete cases of people analytics used for decision-making in particular organizations. Thus, during interviews the informants were invited to share specific cases where decisions were made based on analytics (see Table 12.4).

As it is seen from Table 12.4, HR professionals described concrete steps mainly in the renumeration field. Other examples are related to communication, dismissal or employee engagement. Still, it is obvious, that only in several cases statistical techniques were used in the analysis of data to gain some preliminary understanding of the linkages. Incidentally, such findings corresponded to the study made in nine Finnish companies [9]. Summing up, the call is to move toward more predictive and prescriptive analytics.

RQ3. Main challenges in applying people analytics. Based on data, the challenges were summarized in four areas, namely: data quality; HR information systems; necessity of analytical skills; and the analytical mindset of top-level managers.

Data quality. The quality of data was the prevailing topic the interviewees were deeply concerned about. Different aspects of quality were discussed, including data accuracy, considering that: "*if we make a mistake in the initial stage of data input, this means the statistics and insights derived from it will be erroneous*" (I6) and the fact that usually, data are spread across different IT systems making access really challenging with potential mistakes as a result of human input. Moreover, data structuration is not of lesser importance, as: "*we have everything, but we don't actually have a good solution how to get those data in an order and really make it usable for us" (I2)*. The expected concerns were not surprising as they are well described in the previous literature concluding that HR analytics results definitely depended on the quality of the input material [23].

HR information systems. The quantity of data is constantly increasing and based on the interviews one of the issues refers to getting value from these data. Seeing that data is "the new oil" [30], organizations are concerned with succeeding while using this oil. IT systems help; however, it is obvious that not all organizations are equipped with the right IT tools, "*which could help perform the analytics*" (I11), while "*there are some tasks remaining to do manually*" (I10). Thus, even in today's technology-driven working environment, organizations seem not willing, seeing no value, are not capable, or have no resources for technologies.

Necessity of analytical skills. The interviewees mainly spoke about the necessity of analytical skills in general terms only, not diving into deeper meanings. Despite that, one of them argued that "*the competence of the specialists themselves and the ability to analyze the data, to read and present them and to understand the analytics in general*" (I5) are highly relevant.

The analytical mindset of top-level managers. During interviews the wish was expressed that "*directors and managers should see the picture after opening the personnel analytics and seeing the numbers. Not numbers, but rather a picture. They do the analysis very easily, the way, let us say, the analysts do*" (I8). If the stated desire is too ambitious, the alternative suggestion implies treating people analytics on the same level as "*profit or loss statement and compliance with the budget*" (I5). Thus, analytical mindset reflects the top management maturity and it seems that HR

Table 12.4 Specific cases implemented when people analytics was adopted for decision-making

No. of informant	Specific cases implemented
I1	"Our company monitors their results; we speak about order fulfillment, hence, the indicator of orders is very important. For example, generally, we check how quickly they are able to collect certain items. If the employee is quick, they always remain and we establish certain motivation systems to enable the employees to earn a [decent] salary.. Indeed, there are some employees who earn a bigger salary as a result of their pace and motivation."
I2	"I think it's maybe better in the remuneration area. < … > . So, this is when the data really helps, so we can see where we are and we are able to adjust. Let's say we think [our offering] is too low, then we should offer more. If we got information regarding inflation and our banks are suggesting that X inflation next year, we can at least budget and take it into account in the future. So, I think remuneration [area] is the one which really uses the data, which I'm happy about."
I3	"Salary represents a quite large part of the product cost. For example, we refused orders and let the leased employees go because it was not cost-efficient to keep them; their labor was too expensive. We made the decision to better refuse the orders because we were incurring loss."
I4	"Let us present the example, when people talked about communication. Communication is also one of the terms that is sometimes is turned into a scapegoat, when something is not clear, the person says that communication is lacking. However, when you delve deeper, what specifically is lacking, would you like to get more letters? Would you like the manager to explain? Something else? Then, when you delve deeper, it becomes apparent. < … > Then we created several focus groups and what do you think? < … > We just got the answers that we did not have a uniform or, let's say, balanced communication system as to where the organization was going, what is results were, what changes were occurring and all the way down to the employee level, what their functions and responsibilities were, because regular changes result in a kind of imbalance. Thus, we created a communication plan."
I5	"Change of salary is one of them. I used to experience a situation where out specialists used to be rather intensely headhunted by other companies." "Introduction and impact of additional measures was once again justified by indicators, such as employee turnover"
I6	"There were even dismissals. I will state this very simply. If an employee does not attain the targets, they are not selling anything at all. This can be seen whether after the trial period or not. The employee had been working for six months, but in the sample among his colleagues, he was at the lowest position. Naturally, you have to say goodbye to such employee while clearly giving the reason: after all, you have not attained any result, whereas your colleagues have."
I7	"The main ones are probably related to salary."
I8	"We monitor the NPS, i.e. employee engagement, < … > , and then we draw up a kind of an action plan."
I9	–

(continued)

Table 12.4 (continued)

No. of informant	Specific cases implemented
I10	"We analyze the turnover on a quarterly basis. To this, we add the level of salary most often indicated as the cause of leaving, the time after which employees leave and considering such data, for example, we make the decisions concerning actions required. Let's say, a couple of years ago, there was a situation when after the trial period more people left, so, in the middle of the trial period we introduced an interview with the personnel specialist about how the employee was doing, what situations were envisaged, maybe they were being giving too little information etc. We saw from their feedback that often, employees were leaving just because they were not provided some information and you could have actually helped, they could have been prevented from leaving, had the response been timely. So, after this, the situation changed."
I11	"We do have zero alcohol tolerance. < … > Through communication, the appropriate attitude is being formed about non-tolerance at the company and this allowed reducing the number of incidents."
I12	–

professionals are applying for support seeking to create business value by adopting data-driven decisions.

Summing up, the challenges HR professionals revealed portray the technological side (IT, data) and the human side (skills, mindset) of people analytics complexity.

RQ4. The adoption of analytics in different HRM functions. During the interviews the adoption in the following HRM functions were discussed: workforce planning, recruitment and selection; performance appraisal; training and development; renumeration management.

Workforce planning implies the process of balancing labor supply (skills) against the demand (numbers needed) [64]. Tursunbayeva et al. (2019) [51] claim that beyond simply profiling the current workforce, people analytics enables anticipating and planning the HR needs for organization's future in a more agile way.

Turning to interview data, is seem that organizations typically implement annual business planning, and the same applies to workforce. However, it was mentioned that "*for the last few years, annual planning has in essence not been working, seeing that it does not fulfil the needs of the organization*" (I4) and due to the company's growth, it is moving to quarterly planning.

For workforce planning, organizations use several types of data. The first type includes business data and development. For instance, "*if these are increasing sales volumes, new directions of activities, new sales channels, creation and development of new products, < … > production lines are expanded, automated or modernized, then the need changes in one direction or another*" (I5). As such, "looking at the business forecast, we anticipate the number of employees we will require and their competencies" (I4). Second, in some manufacturing companies, planning is related to the number of machines available and their working hours, i.e. shifts. Moreover,

tendencies in labor markets are monitored: "*to date, we probably have situations when the positions difficult to fill are located in our divisions in the regions; then you need to see what factories are being built and created, what positions their offer and salaries. To what degree you are competitive. And perhaps [comparing] not just salaries, but additional benefits also*" (I7). Finally, human factor is sometimes considered, as "*too much overtime, huge workload, which could lead to burnout, might be a hint that we really need an additional person*" (I2).

One interviewee shared a slightly more sophisticated approach as organization has a five year strategy with some updates and planning is based on three criteria, namely: "*the orders we plan to get < … > Then we assess the turnover and the people who might possibly retire*" (I10).

Summing up, organizations are engaged in "hard" (numbers) and "soft" (skills) workforce planning [64]; however, they do not use any advanced analytics models.

Recruitment and selection. Recruitment implies the process of finding and engaging the people in the organizational needs, meanwhile selection refers to making decisions, which candidates should be employed [64]. In the light of labor force shortage, finding and hiring employees, who fit to the organizational requirements, culture, and values is the most difficult task for the HR professionals [42]. Literature describes the use of predictive analysis, when logistic regression or other parametric models that predict recruitment probability of success, satisfaction and person-job fit can be used [7]. However, during the interviews it was revealed that organizations did not apply any predictive analysis regarding probability of potential employees' success; moreover, they did not use any IT help to speed the review of resumes either. It was revealed that the process was rather typical, without relying on technologies and algorithms. For sourcing candidates, the organizations considered classical digital courses, mainly job boards, social media, corporate websites, and traditional sources such as recruitment agencies, recruitment portals, educational and training institution, public employment office or help of current employees, initiating such actions as "*bring your friend to the team. A bonus is paid if a person comes, stays throughout the trial period and then stays in the company*" (I7). However, the interviewees applied certain criteria for making the choice between sources: (a) the likelihood that it produces good candidates: "*for workers we use one ad portal, for managers—another, because the portals specialize*" (I3); (b) the speed of producing the pool of potential candidates: "*this month, we organized an experiment with those two platforms < … > , and noticed that one of them gets more reviews and we get more applicants. < … > actually, within a week, five people come to the interview*" (I9); (c) the costs compared to value received, for instance: "*we engage recruitment agencies for external help, which, again, triggers additional costs to hire. Yes. But at the same time, sometimes it works because of the local market knowledge, better understanding of it*" (I2). The interviewees reported that they calculated the probability of success when using different sources, however it was noted that "*one time one source works, another time—another*" (I8).

From the HR metrics perspective, some organizations determine the desired time to fill a vacancy: *"when the flow of selections was bigger, we had for ourselves a*

certain indicator of time, within which we would like to complete the selection. For worker positions, it is 2–3 weeks, up to 4 weeks. For specialist positions, it is 1–2 months" (I4). While others perform real calculations: "*when we start the selection until the moment when we employ someone, so, we start calculating this period*" (I8) with the potential to use the metrics to enhance the effectiveness of recruitment and selection.

Summing up, ir can be concluded that organizations, while collecting and processing data from candidates, do not apply analytics to predict whether or not a given candidate will be a good fit for a given job and particular organization.

Performance appraisal. Performance appraisal refers to joint analysis of an employee's performance against agreed objectives, and, importantly, the mapping out for future improvements in performance [65]. Literature lists several possibilities for analytics: (a) it makes it simpler to collect, retrieve and document various types of data related to performance from various resources, which can be internal or external; (b) it allows to evaluate performance in terms of both outcome and behavior; (c) it reduces biases; (d) it makes the appraisal process more accurate and reliable [42].

Based on the interviews, it appears that in all organizations, an employee performance management was in place where "*goals, linked to business, are set following annual formal appraisal < … >, however day-to-day feedback is our usual practice*" (I12). The organizations use various types of date to that goals have been achieved. The most common data source in manufacturing refers to the systems, where "*the person scan their data, scan the label and start manufacturing. We see how much time it takes to produce; everything is well visualized. Full recording*" (I3). Actually, these data serve not only as evidence for KPIs achievement, but also as a communication tool for workers to explain and justify why their and their colleague's salaries differ. However, some shift managers in manufacturing rely more on their experience, as: "*foremen say that they do not need our system; they check and hear by the sound of machines who is a fast worker*" (I3).

Drawing upon interview data, it can be underlined that organizations utilize the appraisal results, indicating that they incorporate these results into their decision-making processes. For instance, "*this is the basis for a career review*" (I8). Similarly, performance results, employee development, and career paths can be linked, as: "*actually, next to the annual goals form there is a separate development form. < … > for each employee, the development plans should be drawn up—what they should learn within the year. Then we notice that certain people have the potential to grow more; this should be included in the plans or projects, or some knowledge acquisition should be planned to help them move forward*". As a drawback, organizations do not follow the recommendations provided in the literature regarding the elimination of unconscious bias and preventing the managers from being unfair during the appraisal process [51].

Summing up, it could be concluded that organization are applying HR metrics more in performance appraisal, focusing on "what happened", but the solutions based on predictive models and "what-if" scenarios are missing.

Training and development. Knowledge, abilities, and skills of employees are seen as crucial in achieving overall goals of the organization in a sustainable manner [66].

People analytics might have several implications for employee training and development. First, it can predict the needs of the organization, which helps making the right decisions on new skills and accordingly the employees can be trained in the most cost-effective way as well as in the way which suits their learning styles the best [42, 51]. Second, people analytics measures the effectiveness and efficiency of various training programs, assessing the level of skills enhanced, the impact of training on employee motivation, satisfaction, retention, and performance, and the influ-ence on the employee career path [42]. Thus, analytics in training and development might create a complete picture including finance (money spent on training), time (hours spent on training) and changes, in terms of performance, employee attitudes, behavior, and career.

Turning to interviews data, it seems that employee development is on the organizations' agenda; it conveys the huge importance it is given as well as the overall satisfaction with it: "happy that employees care about their competencies" (I12). Thus, the organizations provide employees with possibilities to increase their skills in internal or external trainings, and different learning methods are used. It seems that internal online trainings are booming, as: "we have an online learning platform where you can learn soft skills" (I2).

However, turning to analytics in this field, it seems that organizations do not use the potential and opportunities that analytics provides. What they do in fact is only calculating or just planning to calculate some HR metrics related to training expenses and hours: "we calculate the training expenses, hours per person, but the training expenses are allocated to divisions only" (I12). None of the organizations measured how much it gained from its investment in training.

The need for training is usually determined by strategy, objectives, and priorities of organizations: *"if one of our strategic goals is, for example, the customer service standard < … > , then we plan for it, that the next year we will have trainings on customer service standards*" (I6). Moreover, some trainings are obligatory: "*for certain employees, trainings are obligatory, like sales trainings, because they are associated with the knowledge about their market, customer attraction, building of potential relationships*" (I5). The complexity regarding training was well described by one of the interviewee, stating: '*I would say from the learning perspective right now, it's rather about the budgeting exercise. < … > . We can take a look how much money was spent last year and then forecast something for the future according to that. Or maybe we should keep in mind next year the kind of skills we would like [the people to acquire]. Then we take a look at the providers and what the cost would be and then offer ideas to the budget owners.*" (I2).

Summing up, it seems that organizations understand the value training brigs to them; however, right now, they are not capable of demonstrating that value and using analytics for complex decisions regarding prediction of the skills employees need or how to use the skills in the most effective way.

Renumeration management. Analytics can be used to recommend some monetary/non-monetary rewards and other compensation packages for employees [42]. As it was already mentioned (see RQ1), organizations use some data-driven decisions for determining employee salaries and other financial benefits.

The initial source for making the decisions regarding salaries is the situation in labor market, as it is important: "*what happens on the market both in terms of employment and salaries; let us say, how easy it is to attract the talents and how the salaries grow*" (I10). The second source implies financial capacity of organization itself: "*this means how much we can or in certain cases cannot afford to raise the salary*"(I10). The third source refers to actions of the competitors, as "*we take part in the annual salary survey*" (I8). Additionally, in many cases, the strategic importance of job position determines the decision, for example, "*if we see that this is a critical position and to retain it, we have to pay more, then we pay more*" (I5).

Finally, it can be concluded that organizations use data for deciding on employee salaries; however, they do not focus on the way the remuneration impacts employee attitudes and behavior.

Practical implications. This chapter has several practical implications. First, if people analytics is to be used to sustain business, then it should be treated as a strategic organizational capability. The situation when top managers do not care about HR metrics and data-driven insights like in the case reported by one interviewee: "*I love numbers; in many cases, I do the calculations for myself; I just say that as nobody requires me to do it and do not tell me what they would like—I do the analytics purely for myself*" (I3) is not acceptable any more. Top managers should grow in analytical mindset and exhibit a higher level of maturity while defining what they should track to ensure that particular actions give them the desired financial, behavioral or other results. Second, the chapter raises awareness about possibilities and value of people analytics. The organizations are invited to rethink their HRM processes and tailor their IT systems in order to optimize the HRM function. Third, the organizations should estimate the challenges they may face in terms of data quality and quantity. Investments in IT infrastructure and avoiding the "garbage in" scenario while capturing data are key to successes in people analytics.

Fourth, as people's analytical skills belong to the top skills of today, organizations are encouraged to make sufficient investments in training and development of employees, in particular HR professionals, letting them to feel confident with traditional and new types of data and allowing them after using the analytical models to tell the story how the use of human resources made changes in performance. Finally, organizations are encouraged to deal more with predictive and prescriptive analytics while making decisions regarding workforce planning, recruitment and selection, and performance appraisal. The good practices of more advanced organizations could serve as examples where and how to start.

The chapter has **several limitations**, which need to be addressed in further research. The first one deals with the nature of the research sample. The organizations analyzed were from various industries and different in size. As the context matters, further research could focus on a particular industry or particular size of

organizations, analyzing small, medium, or big companies. Second, the chapter limited its focus to three HRM functions, namely workforce planning, recruitment and selection, and performance appraisal. Further studies might demonstrate how people analytics is applied in their areas, such as onboarding, training and development or employee relations management. Finally, the study does not include ethical and privacy concerns as a result of people analytics and this might be yet another future research topic.

12.3 Conclusions

The aim of the chapter was to reveal how people analytics, which broadly refers to the use of a data-driven approach to address the employee-related decisions, is applied in HRM field. Technological advances and increasing importance of business analytics create an ecosystem for people analytics, which can really drive the organizations both strategically and operationally as data-based decision-making allows dealing with workforce and business complexity faster and more reliably than management intuition.

Turning to the core finding of the current research, it is evident that despite the prevailing approach that people analytics is an integral part of HRM, organizations still tend to deal more with the HR metrics and accordingly, a low level of advanced people analytics was found. The interviewees believed in the value of people analytics as it helped to make the decisions, to assess the current situation, to better communicate within and outside the organization, to get a complex picture of the situation, to establish the value of the HR professional, and finally to enhance the employee well-being. Data quality, HR information systems issues, necessity of analytical skills, and the analytical mindset of top-level managers were mentioned as the main challenges of people analytics. The use of analytics in workforce planning, recruitment and selection, performance management, and training and development is still an emerging stage. Usually, the data-driven decisions were made regarding employee remuneration. Summing up, although literature predicts a promising future for people analytics, organizations are struggling to make it an organizational reality.

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