Awareness and Development of Industry 4.0: Case of Latvia

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Abstract

Industry 4.0 technologies are rapidly penetrating manufacturing and social spheres, causing irreversible changes in the procedural and organizational structures of individual organizations and society. To cope successfully with current and future changes, countries must create the necessary preconditions, which include political will expressed in legislative initiatives and strategic plans, public awareness of new technologies, modernization of the educational process and active research activities directed towards the creation of innovative solutions based on Industry 4.0 technologies. This paper presents the results of desk research made to understand the current situation of awareness and development of Industry 4.0 in Latvia. It covers aspects related to statistics and economic indicators of digitalization level, national strategic planning and policy documents, educational events and projects relevant in the context of Industry 4.0. Moreover, the paper summarizes knowledge and skills that should be purposefully developed to support the successful introduction of Industry 4.0 into the economics and the industrial competitiveness of the country.

Keywords

Industry 4.0, Digitalization, Digital Skills, Advanced Technologies

1. Introduction

Use only styles embedded in the document. For paragraph, use Normal. Paragraph text. Paragraph text. Paragraph text. Paragraph text. Paragraph text. Paragraph text. Paragraph text. Paragraph text. Industry 4.0, also referred to as the fourth industrial revolution, is a new but fast-penetrating term in political, industrial, and educational discourse. It is associated with the introduction of automation and intelligent technologies into manufacturing and social processes and changing of usual business models or ways of performing certain tasks. The nine pillars of Industry 4.0 include big data, autonomous robots, simulation, horizontal and vertical system integration, Internet of Things (IoT), cloud computing, additive manufacturing, augmented reality, and cyber security [1]. Authors of [2] have gathered evidence that Industry 4.0 also known as smart manufacturing can be a source of increase of productivity, reduced maintenance costs, shortened downtime by identifying early non-conformities, faster manufacturing value-added growth, energy saving, reduced amount of waste, it can create more jobs than it would replace, and other positive tendencies. Industry 4.0 aims to increase the competitiveness of industries, companies, and even countries through increased efficiency, real-time optimization, improved service, and faster responsiveness to customer needs.

According to [2], the main industries engaged in Industry 4.0 in Latvia are telecommunications, electronics, logistics, smart mobility, and biotechnology and some of the key networks involved in the Industry 4.0 innovation ecosystem are IT Cluster, Latvian Information and Communication Technology Association (LIKTA), European Digital Innovation Hubs (EDIH), and Annual 5G Techritory – Europe's Leading 5G Ecosystem Forum. Companies from the IT, electronics and telecommunications sectors actively engage in digitalization, automation, robotization, and data-driven analysis of business processes. They offer a range of services and solutions in data analytics and visualization, intelligent

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automation, cybersecurity, IoT, cloud computing, artificial intelligence and augmented reality for enterprises of different sizes and industrial fields. The most powerful player definitely is LMT, a mobile telecommunications operator and market leader in Latvia [3]. The enterprise participates actively in projects directed towards developing and introducing technologies of Industry 4.0 and collaborates with government, industrial and academic institutions. It is also involved in explanatory activities regarding Industry 4.0, its influence, and requirements. Enterprises in the metalworking industry are greatly supported by the Association of Mechanical Engineering and Metalworking Industries of Latvia which organizes educational and experience exchange events actively participates in projects related to Industry 4.0 and has also developed training materials in the Latvian language for the implementation of Industry 4.0 in the metalworking industry.

The changes associated with the implementation of Industry 4.0 require changes in the educational context: new students must acquire knowledge and skills necessary for successful professional activity in the new realities, while those who already have got their degrees must have the opportunity for reskilling. This is reflected in the introduction of a new concept "Education 4.0" that emphasizes the need for digital transformation in the educational field in order to provide students with the necessary technical skills.

The goal of the research presented in this paper was to identify the current state of awareness and development of Industry 4.0 in Latvia and to find out what skills and knowledge are demanded to meet the challenges. The following aspects were addressed:

- national support for the concept in terms of policy and strategic planning documents;
- raising the general level of awareness of the concept through educational campaigns and events;
- scientific advancements in the country through the creation of solutions in the field of Industry 4.0;
- integration of the concept into the study process of higher education institutions.

The research applied a desk research method by analyzing online information sources published between 2017 and 2022 in a systematic way. The following information sources were identified as being of interest for the current research:

- websites of companies, higher education institutions, government institutions, and projects;
- Latvian strategic planning documents and legal framework;
- articles in the media;
- project reports;
- books;
- scientific publications.

The search of information sources was performed both on Google and in scientific databases such as IEEE Xplore, Science Direct, SCOPUS, and Web of Science. The paper's authors used the combination of the terms “Industry 4.0” and “Latvia” as the main keywords for searching information sources. However, terms combinations that cover the main pillars of Industry 4.0 (IoT and Latvia, cloud computing and Latvia, robotics and Latvia, big data and Latvia, augmented reality and Latvia, cyber security and Latvia, additive/advanced manufacturing and Latvia) were also used to extend search results.

The structure of the paper is as follows. Section 2 describes Latvian statistics and economic indicators related to the level of digitalization and digital skills. Section 3 presents national strategic planning and policy documents relevant to the promotion of Industry 4.0. Section 4 provides an insight into raising the level of awareness about Industry 4.0 through educational events. Section 5 summarizes international and local scientific and educational projects that are related to Industry 4.0 and involve representatives of Latvia. Section 6 discusses the integration of the concept Industry 4.0 into higher education. Section 7 addresses the skills and knowledge demanded by the field. Finally, conclusions are given at the end of the paper.

2. Indicators on digitalization and digital skills

In general, Latvia has the advanced coverage of high-speed internet and, as a result, almost all enterprises and most householders have access to the Internet [4]. At the same time, Latvia ranked 20th among the 27 EU countries (below the EU average) in terms of digital skills at all levels, from basic

skills to advanced levels, in 2021 [5]. Although an increasing number of Latvians engage in online activities, Latvia's level of digital skills is one of the lowest in the EU [6]. Only 43% of the population aged from 16 to 74 have at least basic digital skills, versus the EU average of 56% [5]. According to [6], the lack of digital skills is identified as a factor hindering the introduction of innovations. Improving the digital skills of the population is a precondition for creating and ensuring an environment conducive to digitalization, improving business productivity, and promoting Latvia's progress and investment in new digital technologies [7]. Also, regions have an unused potential for broadband optical internet access, providing a reliable and fast digital infrastructure for enterprises and remote working possibilities for employees [8].

In terms of the integration of digital technologies in companies, Latvia ranks 23rd among EU countries, which is still rather below the EU average level. The share of SMEs with at least a basic level of digital technologies is 42%, while the EU average is 60% [5]. The proportion of companies that acquire cloud services is 18%, only 9% use big data and 19% use social media to popularize their activities [5]. Latvian enterprises have to adapt to the reality of Industry 4.0 and should be able to integrate these new technologies [9]. Currently, greater efforts are needed to promote the use of digital technologies in small businesses. At present, Latvia is focusing on improving digital skills, but there is a lack of a policy to expand the use of digital technologies in small companies, as well as a strategy for the digitalization of the private sector [10].

Significant factors limiting the international competitiveness of Latvian companies are administrative burdens (e.g., labor taxes), general business costs (e.g., electricity costs, real estate taxes, etc.), and incompleteness of laws and regulations that govern the employment relationship [11].

3. National strategic plans, policy documents, and support programs

One of the priorities of the Ministry of Economics of the Republic of Latvia is to improve the business environment. The vision of the Ministry is to create an excellent business environment and move towards an innovative economic model [12]. Therefore, for further work on the improvement of the business environment, five priority directions of action have been defined and digitalization of public services and industry (Industry 4.0) is one of them [12]. Digital transformation as a fundamental principle of Latvia's economic development is included in a number of state government planning

documents for the next policy development period 2021-2027 [13], for example, the National Development Plan of Latvia 2021-2027, National Industrial Policy Guidelines 2021-2027, Digital Transformation Guidelines for 2021-2027, Guidelines for Science, Technology Development and Innovation 2021-2027 and other binding strategies and guidelines, e.g., Research and Innovation strategy for Smart specialization of Latvia, Implementation strategy of Platform "Industry 4.0", Cyber Security Strategy, Guidelines for the Development of Education for 2021-2027 "Future Skills for the Future Society".

In general, innovations do not play a large role in Latvian companies, however, Latvia is taking steps to increase the number of companies involved in innovations through regional and ERDF-funded programs. During the analysis of information sources (e.g., [10, 13]), it was identified that Latvia has introduced different support programmes and initiatives that allow companies, government and local municipalities, business startups, public research organizations, merchants, and others to get funding for digitalization and innovation introduction initiatives. Financial support is provided through the National Recovery and Resilience Plan, Innovation Motivation Programme, Business Incubators,

Start-up support programmes, Innovation vouchers and support for attraction of highly qualified specialists, Support for science result commercialization, International competitiveness development, Support for staff training, Norwegian Financial Mechanism, Acceleration funds and other programs [14, 15, 16].

Law on aid for the activities of start-up companies has initiated several aid programmes to attract highly qualified employees, reduce taxes, and introduce fixed payments [17]. In addition, subsidies and loans are available to business start-ups in rural areas to promote digital innovation or the development of new products and services in the agricultural, rural, and fisheries sectors [5]. Latvia continues to use the Competence Centre and other complementary programmes such as the technology transfer programme to promote innovation in SMEs [13]. Other support initiatives aimed at the digitalization of

enterprises include training programmes intended for the acquisition of knowledge and skills related to digital technologies and innovation [5]. The Ministry of Environmental Protection and Regional Development and the Ministry of Economics have also approved two Digital Innovation Hubs (Latvian IT Cluster and Digital Accelerator of Latvia) [5] that focus on the digital transformation of enterprises and R&D and innovative digital solutions. Latvian Investment and Development Agency plays an important role in the management of the most available support programmes for entrepreneurs [8]. It manages Technology Transfer Programme, the Innovation Motivation Programme, and the Business Incubators Programme, as well as supports foreign direct investment [15]. There are also three digital innovation centers in Latvia, which act as centers of digital excellence and single digital transformation contact points [13].

4. Educational events related to Industry 4.0

Even though information on possible Industry 4.0 educational events for 2017-2021 is incomplete and includes only those events, information about which is available on the web, it can be concluded that opportunities for training in new technologies and developing an understanding of digitalization processes are extensive. They include:

- short, one-time local and international events (seminars, forums, conference sections, etc.) like the conference „Getting Ready for INDUSTRIE 4.0: Transformations Needed" (2017) [18], II European-Latvian Forum "Industrial revolution 4.0: Digital Economics, Data protection and Compliance Best-Practice" [19], Section "Industry 4.0: Opportunities and Challenges" of the 78th International Scientific Conference of University of Latvia (2019) [20];
- recurring exhibitions of technological achievements like Business Technology Exhibition and Conference RIGA COMM [21] or International Exhibition "Tech Industry" [22];
- long-term training programs within the framework of ERAF and ESF projects, like Training of ICT professionals for promotion of innovation and development of the industry (2016-2019) [23], Training of small and micro entrepreneurs for the development of innovations and digital technologies in Latvia (2016-2023) [24], Training for ICT professionals (2020-2023) [25], Improvement of professional competence of employed persons (2017-2023) [26].

Furthermore, educational events are offered to academic staff and staff of state institutions and enterprises in specific industries and any working or self-employed person. In 2019, the Latvian Information and Communication Technology Association together with industrial partners started an educational campaign "Smart Latvia" to educate managers of Latvian SMEs about the latest IT solutions and encourage them to use these solutions in their business environment [27]. Furthermore, some of the events found by the authors are dedicated to Industry 4.0 and digitalization, while others focus on individual Industry 4.0 pillars such as cybersecurity, artificial intelligence and data analysis, cloud computing, and others. In the context of education, it is worth mentioning that according to [8], Ministry of Economics developed an investment plan for 2021-2027 to improve the digital skills of company employees and it is planned to divide the investments into three parts:

- Massive Open Online Courses on topics such as the basics of UX/UI, e-commerce, data analysis and visualization, database development and maintenance, programming, business intelligence system development;
- European Digital Innovation Hubs offering advanced digital skills development through training on topics such as cybersecurity, artificial intelligence and high-performance computing;
- cooperation with industry associations to support the development of digital skills of employees in areas such as online information storage, use of websites/social portals, software configuration, online sales, image, video and audio processing, presentation preparation, and others.

5. International and local projects on Industry 4.0

Analyzing local and international projects linked to Industry 4.0 and its main pillars where partners from Latvia are participating, a wide range of projects were found and 38 of them are represented in

this publication. All projects can be divided in five main categories and some of them can be categorized in more than one of these categories:

1. Projects that aim at developing some legal and regulatory framework for the further progress of Industry 4.0 and related technologies by gathering best practices [28, 29, 30], generating policies [30], formulating action plans [31, 32, 33, 34], making guidelines [35], developing standards [9, 7, 30], or issuing recommendations [29, 37];
2. Projects whose goal is to raise awareness and the level of knowledge in topics related to Industry 4.0 through free access online courses [38, 39, 40], study programs [36], demonstrators [41, 42, 43], educational events [29], training and consultations [31, 37, 44, 45, 46], tools for digitalization assessment [29, 32, 47], or a framework of necessary skills for cybersecurity specialists [48];
3. Projects that aim at developing specific technological solutions and architectures that could bring Industry 4.0 to life i.e.: various kinds of sensors and sensor networks [42, 49, 50, 51], technologies for augmented reality headset [52, 53], technologies for building [54] and testing IoT [52], computer vision-based methods for traffic analysis [52, 55] and manufacturing [52], an optoelectronic system for analysis of microbiological pollution [52], multiple robot cooperation software framework [52], methods for using computer vision and machine learning for automatization of industrial processes [52], eCMR indexing prototype [56], technologies for autonomous robots [52, 57, 58], autonomous microrobots [59], integrated and modular architecture for drones [60], communication systems for drones [60] and autonomous vehicles [34, 61], autonomous vehicles and linked technologies [61, 62];
4. Projects that strive for implementing Industry 4.0 in a particular field like: agriculture [28, 52, 57, 63, 64], food and beverage production [43], food retail [52], automotive industry [43, 65], industrial machinery [43], transportation [43];
5. Projects that create communities, clusters, and networks for promoting Industry 4.0 [30, 41, 44, 48, 64].

Most of the described projects correspond to the categories of raising awareness and knowledge (17 projects) and developing specific technical solutions (16 projects). There are few organizations from Latvia that operate as partners in several projects identified during this study: EDI – Institute of Electronics and Computer Science, LMT, and Lightspace technologies.

Out of 38 analyzed projects, 11 belonging to the 1st, 2nd and 5th of mentioned categories concentrate on Industry 4.0 as a whole while other projects focus on one or several of its pillars. There are 13 projects concerning IoT, 11 – autonomous robots, 9 – big data and analytics, 7 – cybersecurity, 4 – augmented reality, 2 – horizontal and vertical system integration, 1 – additive manufacturing, and 1 – simulation.

6. Industry 4.0 and higher education

Unfortunately, at the moment, the concept of Industry 4.0 is poorly integrated into the discourse of higher education institutions in Latvia. Both the general search on Google and specific searches on the websites of Latvian higher education institutions yield almost no results. An exception is rare references to the professional growth of academic staff through their participation in various events (like conferences and mobility programs) covering some aspects of Industry 4.0, for example, [66, 67, 68]. The only university that addresses the necessity of educational changes in the context of Industry 4.0 is the Latvia University of Life Sciences and Technologies. It emphasizes the need to modernize study programs of the Faculty of Information Technologies by including courses on Industry 4.0 and programs of other faculties by incorporating topics on Industry 4.0 in their courses [69].

An important factor that could indicate that higher education institutions are aware of the inevitable need to change their study programmes under the influence of Industry 4.0 is that, between 2017 and 2021, several higher education institutions developed new study programmes covering one or more pillars of Industry 4.0. A summary of these programs is given in Table 1 based on the register of study programmes of the Higher Education Quality Agency in Latvia [70].

Table 1
New Latvian study programs covering technologies related to Industry 4.0

Title	Higher Education institution	Study level	Study courses included
Cybersecurity Engineering [76]	Vidzeme University of Applied Sciences	Professional master study programme	Courses cover different aspects of cybersecurity and corresponding technologies [77]
Cyber Security Engineering [78]	Riga Technical University	Academic master study programme	Courses cover different aspects of cybersecurity and corresponding technologies
Mechatronics [79]	Vidzeme University of Applied Sciences	Professional bachelor study programme	Courses, among others, include IoT and sensor networks, robots and robot control systems, sensors and their use [77]
Robotics [80]	Transport and Telecommunication Institute	Professional bachelor study programme	Courses cover many topics related to the development of robotics systems
Smart Electronic Systems [81]	Riga Technical University	Professional bachelor study programme	Courses, among others, include IoT technologies, signal processing, smart embedded systems
Smart Technologies and Mechatronics [82]	University of Liepāja joint programme with Ventspils University of Applied Science	Professional bachelor study programme	Courses, among others, include IoT, artificial intelligence, robot control, cybersecurity, cloud computing
Virtual reality and smart technologies [83]	Vidzeme University of Applied Sciences	Professional master study programme	Courses cover topics of machine learning, 3D graphics, virtual and augmented reality, computer vision [77]
Computer Science [84]	University of Latvia	Academic bachelor study programme	Courses cover topics of embedded systems, wireless sensor networks, IoT, and robotic basics
Computer Science [85]	University of Latvia	Academic master study programme	Courses cover topics of embedded systems, wireless, sensor networks, big data
Geoinformatics [86]	University of Latvia	Professional bachelor study programme	Courses cover topics of sensors and remote sensing in various areas, e.g., agriculture, forestry, etc.

At the same time, the Transport and Telecommunication Institute advertises two study programmes that at present are not included in the previously mentioned register but can be attributed to Industry 4.0. They both provide a double degree with the University of the West England:

- Data analytics and artificial intelligence (academic master study programme) that includes courses on intelligent data processing, cybersecurity, machine learning, and data analytics [71];
- Artificial intelligence (academic bachelor study programme) that contains many courses related to developing intelligent systems and understanding the concept of artificial intelligence [72].

Furthermore, there are also two programs in Latvia offered by Riga Technical University that were developed more than ten years ago and seem relevant to the context of Industry 4.0:

- Smart Electronic Systems (professional master study programme, license year – 2009) that includes, among others, courses on signal processing systems, 5G wireless technologies, data transmission in wireless sensor networks [73];
- Intelligent Robotic Systems (academic bachelor and master study programme, license year – 2010), which mainly contains courses related to robotics [74, 75].

Separate courses addressing pillars of Industry 4.0 can also be included in other study programmes as mandatory or free electives.

7. Skills and knowledge required for Industry 4.0

It is obvious that the nature of many jobs will change due to digital innovations such as machine learning, big data, and artificial intelligence. With regard to economic trends, the demand for labor in low-skilled occupations and occupations where routine activities can be automated is expected to decline [7]. Trends show that, on average, around 14% of existing jobs could disappear as a result of automation in the next 15-20 years, but another 32% are exposed to significant changes in their job responsibilities due to automation of individual tasks [87].

In [7], it was indicated that in the period until 2027 there will be an excess of the labor force with secondary general education, basic education, and a lower level of education. In turn, a deficiency in the labor force will be observed with vocational secondary education, especially in engineering and manufacturing [7]. There is also a forecast of a shortage of highly qualified specialists in natural sciences, ICT, and engineering (the shortage in STEM fields may increase to ~14 thousand) [7].

According to forecasts, the growth of the Latvian economy will be mainly determined by the use of new technological processes, digitalization (the concept of Industry 4.0), and process optimization [7, 10]. Consequently, the fastest job growth is expected in high- and medium-high-tech sectors, such as ICT, as well as in high-skilled professions, such as managers and senior professionals [7, 10]. Future professions are primarily based on the so-called "digital" and "human" factors, namely skills in working with data, artificial intelligence, new technologies, and professional skills in technical fields, especially automation, robotics, control and programming of complex technologies [10, 11], as well as skills for successful process management and human interaction [7, 10].

Skills such as creativity, problem-solving, negotiation, critical thinking, teamwork, empathy and emotion management, intercultural communication, and the ability to adapt and lead changes will be relevant [7, 88]. Besides the collected information on knowledge and skills from the analysis of various Latvian economic indicators and documents relevant to Industry 4.0, the analysis of educational events allows concluding that knowledge and skills in the following fields are also vital:

- general understanding of Industry 4.0 (opportunities, challenges, requirements, benefits, importance);
- latest technologies for digitalization and automation (IoT, artificial intelligence and machine learning, cloud computing, data analytics, and cybersecurity).

In Latvia, employers are spending relatively little money on employee training compared to other EU countries. The share of training expenses from total labor costs in Latvian enterprises is only 0.8%, but in the EU on average – 1.7% [7]. The main obstacles to employees' growth are their inability to combine training with work schedules and insufficient support from their employers [7]. Overall, only 11% of Latvian companies provide training to their employees in ICT skills compared to the EU average (23%) [7]. Therefore, it is necessary to strengthen the cooperation between educational institutions and industry in order to improve the content of study programs and align it with the development needs of

the industry, especially by promoting the acquisition of competencies necessary for the development of Industry 4.0 [7, 11]. With the digitalization of different sectors and the emergence of new technologies and knowledge, the higher education sector should be more flexible in transferring this new knowledge and skills to the population [7]. Also, recently developed study programs in higher educational institutions indicate the need to develop skills in the fields of cybersecurity, robotics, artificial intelligence, smart technologies, and virtual/augmented reality [11].

Skills and knowledge necessary for the current and future workforce are largely dependent on the demand from the employers and their willingness and ability to adopt new ways of working. Three of the reviewed projects during their research conducted also studies to elicit companies' opinions regarding Industry 4.0 and intentions on digitalizing their business. In 2019, the DIGINNO project and the Women4IT project both conducted studies asking respondents about the importance of various digital technologies in their business. The sample is rather limited: the DIGINNO survey [89] had 18 respondents from Latvia while the Women4IT survey [90] gathered responses from 34 companies. Nevertheless, both surveys reveal similar tendencies: Latvian respondents of the first survey indicated automation, database, wireless, security and encryption, and cloud computing technologies as most useful, while drones, blockchain, machine learning, and augmented reality technologies were marked as less important. In the Women4IT survey, from all respondents of this survey, 76% marked mobile services, 63% cybersecurity, 62% big data and analytics, 61% cloud technologies, 57% enterprise systems, and 56% IoT as very useful for their businesses. Only 3D printing was considered less useful-marked as very important only by 22% of respondents.

Expected tendencies of the use of digital technologies in the nearest future (in 3-5 years) were studied in surveys conducted within DIGINNO [89], Woman4IT [90] as well as DigiBEST projects which conducted a survey [91] in 2020 gathering responses from 51 Latvian companies. Answers to this question in all three surveys coincide as well: companies express their intent to invest in wireless, database, automation, security and encryption, cloud computing, big data and analytics, data visualization technologies, and robotics.

During the research, several projects were found that strive to define sets of skills needed for certain areas. One of the deliverables of project ITSVET was a standard for ICT security specialists [92] which describes the knowledge and skills needed for such professionals in great detail. The standard demands professional as well as general skills. 4CHANGE project has created VET programs [93] for CNC machine operators of various qualification levels working in enterprises aligned with Industry 4.0. Cybersecurity skills framework [94] that was developed during the SPARTA project describes skills needed for various roles at the company to ensure its cybersecurity. These frameworks are intended to provide a basis for a discussion between academia, industry, policymakers, specialists, and others.

Therefore, specific skills and knowledge that will be demanded in the future from employees depend largely on company size (SME or large company) and targeted market (local or international), company's digital maturity, and strategic vision of the business. However, the general trends indicate a necessity to develop the following skills and knowledge:

- general digital competence (effective use of software and hardware, searching and evaluating the reliability of the information, etc.);
- soft skills and transversal competences (creativity, problem-solving, critical thinking, teamwork, intercultural communication, emotional intelligence, etc.);
- general knowledge of Industry 4.0 (opportunities, challenges, requirements, benefits, importance);
- awareness of and skills in using the latest technologies for digitalization and automation (IoT, artificial intelligence and machine learning, cloud computing, automation, robotics, big data analytics and cybersecurity, smart technologies and virtual/augmented reality).

8. Conclusions

Even though Latvia has been popularizing itself as one of the leading countries in terms of Internet speed and even five years ago was among the Top 10 countries worldwide [95], the digital skills of the country’s citizens are below the EU average. Latvia is also still rather below the EU average level in

terms of the integration of digital technologies in companies (e.g., cloud technologies, big data, artificial intelligence solutions, etc.).

The introduction of Industry 4.0 technologies in the main processes and daily activities of companies is unavoidable if the companies want to improve their work efficiency and remain competitive. The Latvian government must also be involved in promoting the introduction of these technologies, as they will also have an impact on the development of the Latvian economy. At present, Latvia has developed a number of strategic plans and policy documents that can help integrate and develop Industry 4.0. However, the government should not only develop a vision to create an excellent and innovative business environment and propose various strategic plans but also take measures to support the introduction of innovative solutions in companies. Despite the fact that various short-term and long-term training opportunities are provided, companies are quite reluctant to use them for the improvement of the digital skills of their employees. Therefore, cooperation between the companies and educational institutions should be encouraged and more information should be provided on the available support programmes to get funding for digitalization activities and the improvement of digital skills for employees (both basic and advanced skills). Only by improving the digital skills of the population, it is possible to create conditions for the acceptance of digital innovations, improvement of business productivity, and promotion of Latvia's progress on a global scale.

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10.References

[1] G. Erboz, How to Define Industry 4.0: The Main Pillars Of Industry 4.0, in: Proceedings of International Scientific Conference on Managerial trends in the development of enterprises in globalization era, Slovak University of Agriculture, Nitra, 2017, pp. 761-767.
[2] UNCTAD Secretariat, Issues Paper on Industry 4.0 for Inclusive Development, 2020. URL: https://unctad.org/system/files/information-document/CSTD2021-2022_Issues01_Industry4.0_en.pdf.
[3] LMT, About LMT, 2022. URL: https://bizness.lmt.lv/en/about-lmt.
[4] Official statistics portal, Use of computers and internet, 2022, URL: https://stat.gov.lv/en/statistics-themes/information-technologies/computers-and-internet.
[5] European Commission, Digital Economy and Society Index (DESI) 2021 – Latvia, 2021,URL: https://ec.europa.eu/newsroom/dae/redirection/document/80482.
[6] I. Helmane, Ceļa karte Latvijas digitālajai transformācijai (in Latvian), 2020. URL: https://lvportals.lv/norises/321428-cela-karte-latvijas-digitalajai-transformacijai-2020.
[7] Ministry of Educaton and Science of the Republic of Latvia, Izglītības attīstības pamatnostādnes 2021.-2027.gadam "Nākotnes prasmes nākotnes sabiedrībai" (in Latvian), 2020. URL: https://www.izm.gov.lv/sites/izm/files/iap2027_projekta_versija_apspriesana_160720201_2.pdf.
[8] Ekonomikas ministrija, Latvijas Ekonomikas attīstības pārskats (in Latvian), Ekonomikas ministrija, Rīga, 2021.
[9] J. Menaker, V. Ozoliņa, Latvian High-Tech Industry: Trends and Developments, Economics and Business 32 (2018) 160-171. doi: 10.2478/eb-2018-0013.
[10] OECD, Going Digital in Latvia, OECD Publishing, Paris, 2021. doi: 10.1787/8eec1828-en.
[11] Cabinet of Ministers of the Republic of Latvia, Par Nacionālās industriālās politikas pamatnostādnēm 2021.-2027. gadam (in Latvian), 2021. URL: https://likumi.lv/ta/id/321037-par-nacionalas-industrialas-politikas-pamatnostadnem20212027-gadam.
[12] Ekonomikas ministrija, Latvijas Ekonomikas attīstības pārskats (in Latvian), Ekonomikas ministrija, Rīga, 2020.

[13] Ministry of Economics of the Republic of Latvia, Economic Development of Latvia, Ministry of Economics, Riga, 2020.
[14] Ministry of Finance of the Republic of Latvia, Recovery and Resilience facility (RRF), 2021. URL: https://www.esfondi.lv/upload/anm/atjaunos_meh_finmin_800x600-ppt-eng_short.pdf.
[15] Invertment and Development Agency of Latvia, Programmas (in Latvian), 2020. URL: https://www.liaa.gov.lv/lv/programmas.
[16] Startup Latvia, Acceleration funds, 2021, URL: https://startuplatvia.eu/acceleration-funds.
[17] Saeima, Law on Aid for the Activities of Start-up Companies, 2016. URL: https://likumi.lv/ta/en/en/id/287272-law-on-aid-for-the-activities-of-start-up-companies.
[18] MASOC, Conference Industrie 4.0 in Riga and Beyond. „Getting Ready for INDUSTRIE 4.0: Transformations Needed", 2017. URL: https://www.masoc.lv/data/pielikumi17/Industry%204.0%20in%20Riga%20and%20Beyond_provizorisk%C4%81%20programma.pdf.
[19] Institute of Economics of the Latvian Academy of Sciences, Industrial revolution 4.0: Digital Economics, Data Protection & Compliance Best-Practice, 2018. URL: https://2018.economicforum.lv/wp-content/uploads/2019/10/conference_program_en.pdf.
[20] University of Latvia, Industrija 4.0: iespējas un izaicinājumi (in Latvian), 2019. URL: https://www.bvef.lu.lv/index.php?id=69384.
[21] RIGA COMM, 2022, URL: https://rigacomm.com/en.
[22] Tech Industry, 2022, URL: http://www.techindustry.lv/.
[23] Latvian Information and communications technology association, Projekts "IKT profesionāļu apmācības inovāciju veicināšanai un nozares attīstībai" (in Latvian) 2020. URL: https://likta.lv/wp-content/uploads/2020/05/Apmacibu-izmaksas-07.2016-03.2020.pdf.
[24] Latvian Information and communications technology association, MMU projekta īstenošana (in Latvian), 2022. URL: https://likta.lv/mmu-kursi/.
[25] Latvian Information and communications technology association, IKT profesionāļu apmācības inovāciju veicināšanai un nozares attīstībai (in Latvian) 2022, URL: https://likta.lv/projekts-ikt-profesionalu-apmacibas/.
[26] State Education Development Agency of the Republic of Latvia, ESF projekts "Nodarbināto personu profesionālās kompetences pilnveide" (in Latvian), 2021. URL: https://www.macibaspieaugusajiem.lv/par-projektu?tab=collapse-82.
[27] Latvian Information and communications technology association, Par projektu "Gudra Latvija", 2022, URL: https://www.gudralatvija.lv/par.
[28] Data Driven Dairy Decision For Farmers, 4D4F Homepage, 2020. URL: https://4d4f.eu/.
[29] DIGINNO, Homepage, 2020. URL: https://www.diginnobsr.eu/.
[30] INNO INDUSTRY, Homepage, 2020. URL: https://projects2014-2020.interregeurope.eu/innoindustry/.
[31] SKILLS+, Homepage, 2020. URL: https://projects2014-2020.interregeurope.eu/skillsplus/.
[32] DigiBEST, Homepage, 2020. URL: https://projects2014-2020.interregeurope.eu/digibest/.
[33] IoTXchange, Homepage, 2022. URL: https://urbact.eu/iotxchange.
[34] AutoDrive, Homepage, 2020. URL: https://autodrive-project.eu/.
[35] INTERFRAME-LV, PROJECT INTERFRAME-LV AS A PROVIDER OF SOLUTIONS TO CURRENT PROBLEMS IN LATVIA, 2021. URL: https://www.lza.lv/en/activities/news/599-project-interframe-lv-as-a-provider-of-solutions-to-current-problems-in-latvia.
[36] ITSVET, ITSVET-project, 2019. URL: http://itsvet-project.eu/.
[37] Digital Competences Development System - DCDS, About page, 2020. URL: http://www.dcds-project.eu/about/.
[38] 4CHANGE, Homepage, 2020. URL: http://www.change4industry.eu/.
[39] European Commision, Innovative Open Education on IoT: improving higher education for European digital global competitiveness (IOT-OPEN.EU project), 2016. URL: https://erasmus-plus.ec.europa.eu/projects/search/details/2016-1-PL01-KA203-026471.
[40] BRACKET, Homepage, 2021. URL: https://bracket.erasmus.site/.
[41] European Commision, Digital Technologies, Advanced Robotics and increased Cyber-security for Agile Production in Future European Manufacturing Ecosystems (TRINITY project, 2022. URL: https://cordis.europa.eu/project/id/825196.

[42] VIZTA, Homepage, 2021. URL: https://cordis.europa.eu/project/id/826600.
[43] AI4DI, About page, 2021. URL: https://ai4di.eu/.
[44] Swedish Institute, i4.0 Baltics Homepage, 2016. URL: https://si.se/en/projects-granted-funding/i4-0-baltics-developing-industrial-4-0-competence-centres-and-network-in-estonia-latvia-and-lithuania/
[45] WOMEN4IT, Homepage, 2017. URL: https://women4it.eu/.
[46] INforM, Homepage, 2019. URL: https://interreg-baltic.eu/project/inform/.
[47] DINNOCAP, Homepage, 2022. URL: https://www.dinnocapbsr.eu/.
[48] SPARTA, Homepage, 2022. URL: https://www.sparta.eu/.
[49] European Commision, Intelligent Motion Control Platform for Smart Mechatronic Systems (I-MECH project), 2022. URL: https://cordis.europa.eu/project/id/737453.
[50] Institute of Electronics and Computer Science, Industrial inertial wireless sensor (IIWS), 2020. URL: https://www.edi.lv/en/projects/industrial-inertial-wireless-sensor/.
[51] Institute of Electronics and Computer Science, Industrial inertial wireless sensor (IIWS) part 2, 2022. URL: https://www.edi.lv/en/projects/industrial-inertial-wireless-sensor-iiws-part-2/.
[52] Competence Centre of Electrical and Optical Equipment Production Sector of Latvia, LEOPC Projects (in Latvian), URL: https://www.leopc.lv/projekti/.
[53] Lightspace Technologies, NGEAR 3D, 2022. URL: https://lightspace3d.com/ngear-3d/.
[54] ENACT, Homepage, 2022, URL: https://www.enact-project.eu/.
[55] Real-time AI urban video analytics Homepage, 2021. URL: https://innovations.lmt.lv/projects/real-time-ai-urban-video-analytics/.
[56] DIGINNO-Proto, Homepage, 2020. URL: https://www.diginnobsr.eu/diginno-proto.
[57] Institute of Electronics and Computer Science, Development of a robotic weed management equipment (RONIN), 2020. URL: https://www.edi.lv/en/projects/development-of-a-robotic-weed-management-equipment-ronin.
[58] European Commision, Intelligent Motion Control under Industry 4.E (IMOCO4.E project), 2021. URL: https://cordis.europa.eu/project/id/101007311.
[59] Institute of Electronics and Computer Science, RoVam Development of microrobot based on visual recognition and machine learning for manipulation of individual living cells (RoVam), 2021, URL: https://www.edi.lv/en/projects/development-of-microrobot-based-on-visual-recognition-and-machine-learning-for-manipulation-of-individual-living-cells-rovam/.
[60] COMP4DRONES, Homepage, 2022. URL: https://www.comp4drones.eu/.
[61] AI4CSM, Automotive Intelligence 4 Connected Shared Mobility, 2021. URL: https://ai4csm.automotive.oth-aw.de/.
[62] European Commision, Programmable Systems for Intelligence in Automobiles (PRYSTINE project), 2018. URL: https://cordis.europa.eu/project/id/783190.
[63] European Commision, Aggregate Farming in the Cloud (AFarCloud project), 2018. URL: https://cordis.europa.eu/project/id/783221.
[64] Latvian IT Cluster, AUMENTA, 2020, URL: https://www.itbaltic.com/single-post/aumenta.
[65] 3Ccar, Homepage, 2021. URL: https://3ccar.automotive.oth-aw.de/.
[66] I. Vasermane, LiepU pētnieki paplašina kontaktu tīklu, piedaloties konferencēs, forumos un tīklošanās pasākumos (in Latvian), 2019. URL: https://www.liepu.lv/lv/jaunumi/3530/liepu-petnieki-paplasina-kontaktu-tiklu-piedaloties-konferences-forumos-un-tiklosanas-pasakumos.
[67] Rēzeknes Tehnoloģiju akadēmija, Erasmus+ programma sniedz iespēju pilnveidoties (in Latvian), 2019. URL: https://2021.rta.lv/aktualitates/1967/.
[68] Vidzeme University of Applied Sciences, Vidzeme University of Applied Sciences Organizes Scientific Conference. 2021. URL: https://va.lv/en/news-events/news/vidzeme-university-applied-sciences-organizes-scientific-conference.
[69] B. Rivža, P. Rivža, 4.industriālā revolūcija: digitālā ekonomika un LLU studiju procesa izaicinājumi (in Latvian), 2019. URL: https://www.llu.lv/sites/default/files/2019-01/AK_2019_B_P_Rivza.pdf.
[70] Higher Education Quality Agency, Study Programmes, 2022. URL: https://eplatforma.aika.lv/index.php?r=site%2Fprogram%2Flist&StudyDirection=17&AccreditationStatus=accreditated.

[71] Transport and Telecomunication Institute, Double Degree in Computer Science: Data Analytics and Artificial Intelligence, 2022. URL: https://tsi.lv/study_programmes/double-degree-in-computer-sciencedata-analytics-and-artificial-intelligence/.
[72] Transport and Telecomunication Institute, Double Degree in Computer Science: Artificial Intelligence, 2022. URL: https://tsi.lv/study_programmes/computer-sciences-double-degree-artificial-intelligence/.
[73] Riga Technical Univerity, Professional Master Study programme "Smart Electronic Systems", 2022. URL: https://stud.rtu.lv/rtu/spr_export/prog_pdf_en.176.
[74] Riga Technical Univerity, Academic Bachelor Study programme "Intelligent Robotic Systems", 2022. URL: https://stud.rtu.lv/rtu/spr_export/prog_pdf_en.57.
[75] Riga Technical Univerity, Academic Master Study programme "Intelligent Robotic Systems", 2022. URL: https://stud.rtu.lv/rtu/spr_export/prog_pdf_en.58.
[76] Vidzeme University of Applied Sciences, Professional Master's in Cybersecurity Engineering, 2022. URL: https://va.lv/en/study-here/masters-degree/cybersecurity-engineering/about-programme.
[77] Vidzeme University of Applied Sciences, Register of Study Courses, 2022. https://luis.lu.lv/pls/va/kursi.startup?l=2.
[78] Riga Technical Univerity, Study programme "Cybersecurity Engineering", 2022. URL: https://stud.rtu.lv/rtu/spr_export/prog_pdf_en.180.
[79] Vidzeme University of Applied Sciences, Mehatronika (in Latvian), 2022. URL: https://va.lv/lv/studijas/bakalaurs/mehatronika/par-programmu.
[80] Transport and Telecomunication Institute, Robotics, 2022. URL: https://tsi.lv/study_programmes/robotics/.
[81] Riga Technical Univerity, Professional Bachelor Study programme "Smart Electronic Systems", 2022. URL: https://stud.rtu.lv/rtu/spr_export/prog_pdf_en.189.
[82] Liepaja University, Viedās tehnoloģijas un mehatronika (in Latvian), 2022. URL: https://www.liepu.lv/lv/1267/viedas-tehnologijas-unmehatronika.
[83] Vidzeme University of Applied Sciences, Virtual Reality and Smart Technologies, 2022. URL: https://va.lv/en/study-here/masters-degree/virtual-reality-and-smart-technologies/about-programme.
[84] University of Latvia, Computer Science (bachelor), 2022, URL: https://www.lu.lv/en/studies/study-process/courses/programme-search/?tx_lustudycatalogue_pi1%5Baction%5D=detail&tx_lustudycatalogue_pi1%5Bcontroller%5D=Course&tx_lustudycatalogue_pi1%5Bprogram%5D=22302&cHash=57a784130508c781448b604e764294be.
[85] University of Latvia, Computer Science (master), 2022, URL: https://www.lu.lv/en/studies/study-process/courses/programme-search/?tx_lustudycatalogue_pi1%5Baction%5D=detail&tx_lustudycatalogue_pi1%5Bcontroller%5D=Course&tx_lustudycatalogue_pi1%5Bprogram%5D=22303&cHash=e688b51cbb423173e23b5d5123c96138.
[86] University of Latvia, Geoinformatics, 2022, URL: https://www.lu.lv/en/studies/study-process/courses/programme-search/?tx_lustudycatalogue_pi1%5Baction%5D=detail&tx_lustudycatalogue_pi1%5Bcontroller%5D=Course&tx_lustudycatalogue_pi1%5Bprogram%5D=21125&cHash=7d8c678f75c9dd35f21720961a931ae0.
[87] OECD, OECD Employment Outlook 2019: The Future of Work, OECD Publishing, Paris, 2019. doi: 10.1787/9ee00155-en.
[88] Latvijas reitingi, Vai mileniāļi ir gatavi nākamajai industriālajai revolūcijai? (in Latvian), 2019. URL: https://www.reitingi.lv/lv/news/darbs/127299-vai-mileniali-ir-gatavi-nakamajai-industrialajai-revolucijai.html.
[89] CMI/ Aalborg University, DIGINNO BUSINESS NEEDS ASSESSMENT, 2019. URL: https://www.diginnobsr.eu/_files/ugd/8cf6e6_f7e58cec3422452d8d0b3eaf99656cee.pdf.
[90] WOMEN4IT, Study: Needs Assessment at European and National Levels, 2019. URL: https://women4it.eu/wp-content/uploads/2019/09/2.1-Needs-Assessment-updated.pdf.

[91] J. Kovalska, DigiBEST Regional Study on the State of Digital Transformation and its Impact on the Regional Businesses in Latvia, 2021. URL: https://projects2014-2020.interregeurope.eu/fileadmin/user_upload/tx_tevprojects/library/file_1638609246.pdf.
[92] ITSVET, Informācijas sistēmu drošības speciālista profesijas standarts (in Latvian), 2020. URL: https://likta.lv/wp-content/uploads/2020/01/Inform%C4%81cijas-sist%C4%93mu-dro%C5%A1%C4%ABbas-speci%C4%81lista-profesijas-standarts.pdf.
[93] 4CHANGE, Industry 4.0 CHALLENGE: Empowering Metalworkers For Smart Factories Of The Future (4CHANGE). Apprenticeship training plans, 2019. URL: http://www.change4industry.eu/uploads/Docs/doc1500/1581550605_4change-cnc-operator-training-program-2020.docx.
[94] E. Piesarskas, SPARTA. D9.1 Cybersecurity skills framework, 2020. URL: https://www.sparta.eu/assets/deliverables/SPARTA-D9.1-Cybersecurity-skills-framework-PU-M12.pdf.
[95] Fastmetrics, Internet Speeds by Country (Mbps), 2020. URL: https://www.fastmetrics.com/internet-connection-speed-by-country.php.