A research on innovative skills and best practices to enhance HE students employability, flexibility and transversal capabilities and develop effective digital workbased approaches

Case of Bulgaria

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Digital Transformation, Industry 4.0 and Human Resources Management: Innovative skills to enhance HE students' employability, flexibility and transversal capabilities

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STATISTICS AND ECONOMIC INDICATORS ON DIGITALISATION AND DIGITAL SKILLS

Bulgaria score in composite indexes and indicators relevant to digitalization and Industry 4.0 readiness

Digital Economy and Society Index

Since 2014, the European Commission's Digital Economy and Society Index (DESI) summarises indicators on Europe's digital performance. Four dimensions are being assessed: human capital, connectivity, integration of digital technology, and digital public services. According to the DESI 2021 reports (based on data from 2020), Bulgaria's overall ranking in the EU context is very low, equal to that of Greece and higher only than that of Romania. Regarding the digital skills of the population, Bulgaria's level is the lowest in the EU. Only 29% of the population aged 16 to 74 is digitally literate - a poor result against an EU average of 56%. Only 11% of the population have above basic digital skills, also a poor result that is just a third of the EU average. The only positive result is that 28% of all ICT specialists are women, a score that is very high compared to other EU countries. In the area of Connectivity, Bulgaria scores lower than the EU average in terms of both fixed and mobile broadband take-up. 5G readiness is also lower than the EU average. The examination of enterprises' ability to integrate digital technology shows mixed results. According to this index, the use of Artificial Intelligence is higher than the EU average; this assessment, however, contradicts Eurostat data where Artificial Intelligence use in Bulgarian enterprises is lower than the EU average[i]. Bulgaria scores low on enterprise engagement in e-commerce (the result is around half the EU average). In the area of digital public services, the score is below the EU average for citizens but above the EU average for enterprises due to an active national strategy in that regard (European Commission, 2021).

Digital Transformation Scoreboard

In 2018, Bulgaria scored low in the European Commission's Digital Transformation Scoreboard. The scoreboard provides a comparative assessment of the factors supporting digital transformation in the EU countries. The Digital Transformation Enablers' Index assesses five categories of enablers (digital infrastructure, investment and access to finance, supply and demand of digital skills, e-leadership and entrepreneurial culture). The Digital Technology Integration Index assesses the effects of digital transformation, namely to what extent companies are using digital technologies (enterprises that have an ERP, enterprises using RFID technologies as part of production and service delivery process, enterprises using two or more social media,

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enterprises sending invoices in an agreed standard format which allows their automatic processing, enterprises that buy at least one cloud computing services, SMEs selling online, SMEs' total turnover from e-commerce, SMEs that carried out electronics sales to other EU countries). The scoreboard focuses on 9 technologies – big data and data analytics, cybersecurity solutions, social media, robotics and automation, 3D printing, mobile services, cloud technologies, Internet of Things, Artificial Intelligence.

Bulgaria's score on the Digital Technology Integration Index is 22.5, compared to an EU average of 37.3. Similarly, Bulgaria scores 33.8 on the Digital Transformation Enablers' Index compared to an EU average of 49.2 (European Commission 2018). It is found to be among the EU's least digitally aware countries, with little ongoing discussion of key technologies such as cybersecurity, blockchain, Artificial Intelligence, Robotics or 5G. On the positive side, Bulgaria is assessed to have a positive entrepreneurial culture and boasts a good score on ICT start-ups, higher than the EU average (a score of 67, compared to an EU average of 43). All in all, the Scoreboard concludes that while Bulgaria performs well in the field of entrepreneurial culture and ICT start-ups, it performs poorly in the field of investments, digital infrastructure, e-leadership, supply and demand of digital skills, and digital transformation.

Roland Berger Industry 4.0 Readiness Index

The Industry 4.0 Readiness Index developed by Roland Berger (2014) is based on two sets of indicators:

1. *Industrial excellence,* which bundles together indicators related to the sophistication of the production process, the degree of automation, the workforce readiness and innovation intensity
2. *Value network,* which bundles together indicators related to high value added, industry openness, innovation network and Internet sophistication.

Bulgaria has the lowest score compared to all other EU countries included in the study. Based also on the share of manufacturing in GDP, it is included in the cluster of „hesitators", together with Poland, Slovakia, Italy, Spain, Portugal, Estonia and Croatia. While the index was calculated back in 2014, it stands to reason that Bulgaria's position has not improved relatively to the position of the other countries.

Readiness for the Future of Production Index

Bulgaria scores relatively low in the European context according to the Readiness for the Future of Production Index, which measures the factors that enable the successful adoption of emerging technologies in production (WEF, 2018). The index is based on comparing the countries' structure of production (complexity and scale), and 6 drivers of production – 1) innovation and technology, 2) human capital and skills, 3) regulation and governance (institutional framework), 4) natural resources and sustainability, 5) global economy, trade and investment, and

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6) demand environment. Out of 100 countries in the world, Bulgaria scores 36th on Technology and Innovation and 30th place on Sustainable Resources, but occupies only 52nd place on Human Capital and Skills, 55th place on Institutional Framework, 51st place on Global Trade & Investment and 60th place on Demand Environment. The country's score is fairly reasonable with respect to share of manufacturing in employment, share of venture capital relative to the economy and to some extent economic complexity. However, very low scores stand out in the areas related to human capital and skills, and in particular with respect to Availability of scientists and engineers (80th place in the world), Digital skills of the population (72nd place), Capacity to attract and retain talent (88th place), On-the-job training (90th place).

The scores on Technology and Innovation are less than satisfactory, too, especially in the European context. The country's performance on indicators such as firm-level technology absorption, impact of ICTs on new services and products, company investment in emerging technology and companies embracing disruptive ideas are less than would be expected for a EU member state.

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Driver: Technology & Innovation 0-10 (best)	36	4.8
Technology Platform 0-10 (best)	44	6.4
2.01 Mobile-cellular telephone subscriptions /100 pop.	41	127.2
2.02 LTE mobile network coverage % population	50	86.8
2.03 Internet users % pop.	58	59.8
2.04 FDI and technology transfer 1-7 (best)	43	4.7
2.05 Firm-level technology absorption 1-7 (best)	57	4.5
2.06 Impact of ICTs on new services and products 1-7 (best)	51	4.7
2.07 Cybersecurity commitment 0–1 (best)	45	0.6
Ability to Innovate 0-10 (best)	35	3.1
2.08 State of cluster development 1-7 (best)	60	3.7
2.09 Company investment in emerging technology 1–7 (best)	45	3.7
2.10 Gov't procurement of advanced technology products 1-7 (best)	50	3.3
2.11 Companies embracing disruptive ideas 1-7 (best)	65	3.4
2.12 Multi-stakeholder collaboration 1-7 (best)	65	3.5
2.13 R&D expenditures % GDP	39	1.0
2.14 Scientific and technical publications Number per Billion PPP$ GDP	43	15.3
2.15 Patent applications applications/million pop.	40	3.86
2.16 Venture capital deal volume US$ millions	47	3,171.9
2.17 Venture capital deal volume per size of economy US$/GDP	18	59.7

Source: WEF, 2018, pp. 80-81.

Portulans Institute Network Readiness Index

The Network Readiness Index (NRI) developed by the Portulans Institute is a global index on the application and impact of ICTs in economies around the world. The 2021 Portulans Institute report maps the network-based readiness of 130 economies based on their performances in four different pillars: Technology, People, Governance, and Impact. The index is composed of 60 variables.

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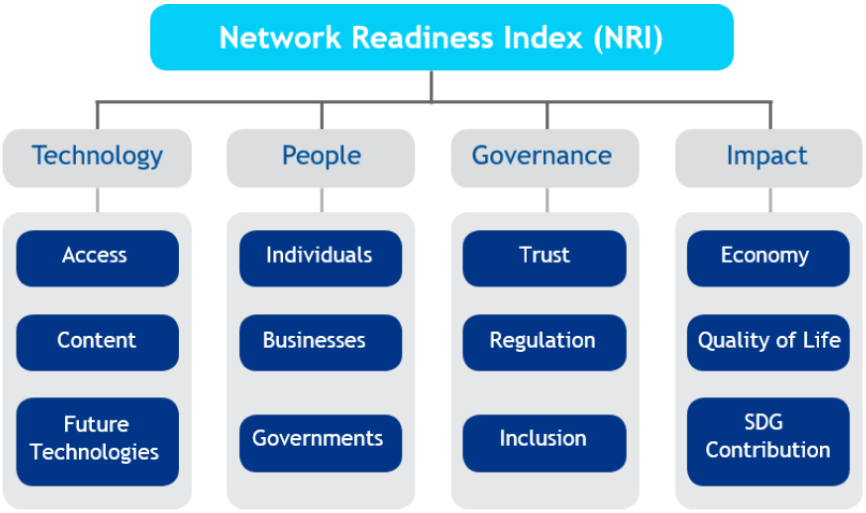

Of the 4 pillars, the Technology pillar is the most important one for the purpose of our study. Unfortunately, this is where Bulgaria scores rather low, ranking 56 out of all 130 countries. In the sub-pillar Future Technologies (adoption of emerging technologies, investment in emerging technologies, robot density and computer software spending), it performs even worse and ranks 78. Bulgaria lags behind the Europe region in all Pillars (Portulans Institute, 2021).

Other studies

According to a 2017-2018 survey of 367 Bulgarian enterprises, covering all geographical regions and most of the traditional sectors (Nikolova-Alexieva and Mihova, 2019), 5% of the Bulgarian small and medium-sized companies lack any digitalization. The majority of the companies (68%) are at the early stage of digitalization and only provide digital information but have no active interaction with customers online. Only around 20% of the companies are involved in e-engagement, including e-commerce, two-way communication with customers online, and e-business processes. 6% of the companies are in the integral stage of digitalization, with fully digitalized internal processes, customer relations and value-chain relations. Only 1% of all companies can be characterizes as having the highest degree of digitalization (Nikolova-Alexieva and Mihova, 2019, p. 262). Even though we believe some major improvements have been observed in the period after 2019, these 2018 results clearly show that Bulgarian industry does not utilize the potential of digitalization to a satisfactory extent.

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Bulgaria's score in composite indexes and indicators relevant to innovation and talent development

European Innovation Scoreboard

The European Innovation Scoreboard 2021 classifies Bulgaria in the group of "emerging innovators" with an overall index amounting to just 44.5% of the EU average for the same year. There has been some gradual improvement over the last few years (around 7% compared to the 2014 baseline), but even this upward trend does not live up to the potential shown by the EU as a whole, where the average improvement has been 12.5% over the same period. The best performance is recorded in:

- Digitalization, but the result is only due to better performance on the broadband penetration indicator
- Intellectual assets, due to good performance in the trademark applications and industrial design applications indicators
- Environmental sustainability, due to the environment-related technologies indicator, where Bulgaria scores over 80% of the EU average for the same year.

Yet Bulgaria's performance on the other digitalization-related indicator – People with above basic overall digital skills – is overall dismal, assessed at just 9% of the EU average (https://ec.europa.eu/docsroom/documents/45907/attachments/1/translations/en/renditions/native).

Global Innovation Index

According to the results in the 2021 Global Innovation Index of the World Intellectual Property Organization (Global Innovation Index, 2021), Bulgaria showcases a positive trend and reaches 35th position out of 132 countries (up from 37th compared to 2020). More specifically, it reaches 27st position on knowledge and technology outputs and 36th position on infrastructure.

In 2020, enterprises have provided 36% of the Research and Development (R&D) funds in Bulgaria, but over 90% of them have been spent within the enterprise sector itself, mostly on in-house research and development. Technology transfer is much less common. Only 6% of business (R&D) spending is targeted at scientific organizations and universities. In the same year, the public sector has provided 25% of all R&D funds. Around 85% of these funds have been spent within the public sector and 12% have been spent in higher education institutions. Much of the public-sector research is not sufficiently applicable to the economy and society or does not receive market realization. Public institutions and universities are not active in start-up and spin-off activities or technology transfer (despite the formal existence of Transfer of Technology Offices). There has been no clear connection between funding for universities/research organizations and the quality and applicability of the research they

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produce. This latter problem is being addressed by the government with recent policy measures.

According to both the Global Innovation Index 2021 and the IMD World Talent Ranking 2020 (https://www.imd.org/centers/world-competitiveness-center/rankings/world-talent-competitiveness/), Bulgaria struggles with deficiencies concerning human capital for research activities. It ranks very low in Europe in areas such as factors enabling talent, and ability to attract, grow and retain talent.

Digital skills

In Bulgaria the level of digital skills of the population and the workforce is very low by European standards. Based on 2021 Eurostat data, only 31% of individuals have at least basic digital skills; in the EU-27 the average share is 54%. The individuals with above basic digital skills in Bulgaria are only 8%, compared to an EU-27 average of 26%. This stalls the economy, hinders industrial transformation, reduces Bulgarian companies' competitiveness in the digital world and hinders the development of e-government. In Bulgaria, only around 17% of the population interacts electronically with the government, one of the lowest score in the EU (Hallward-Driemeier et al., 2020, p. 133). There is a clear relationship between digital skills and age in Bulgaria, which is directly related also to productivity. More than 80% of the younger people consciously use the internet and digital devices, while this is not true of the older population. The digital inequalities between age groups are likely to also influence jobs and employment (Kostov et al., 2021, p.7). The share of graduates in tertiary education in science, mathematics, computing, engineering, manufacturing and construction per 1000 of population aged 20 – 29 stands at 14.3%, making Bulgaria one the countries with the lowest such share in the EU. According to the OECD's PISA survey from 2018, Bulgarian students were the worst performer in science and the second to worst in mathematics in the EU-27. The survey found out that 47% and 44% of the 15-year olds in Bulgaria underperformed in science and mathematics respectively. The corresponding OECD-average percentages are 22% and 24% respectively (OECD, 2018).

Shortages of skilled ICT staff are a continuous issue for the business sector in Bulgaria and impede competitiveness. Around 40% of the Bulgarian companies report shortage of ICT personnel (Stefanov et al., 2021, p.54). On the positive side, the number of ICT experts in Bulgaria is growing, as is the share of ICT experts in employment.

Bulgaria ranks 46th in the Global Talent Competitiveness Index, which compares 125 economies in terms of human capital and its contribution to national competitiveness. This score is very low in the European context. As regards the enabling factors for talent, the country scores low on technology utilization and professional management, and not very high on investment in emerging technologies. The score is generally low in terms of attracting and developing talent, and higher on the indicators concerning mid-level skills and high-level skills and innovation output. Bulgaria scores 95th in the global pool in terms of availability of

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scientists and engineers. On the positive side, the country has been improving its position since 2019 (Lanvin and Monteiro, 2021).

Statistical data

Statistical data, as presented in the tables below and additionally in Annex I, indicates that despite good basic economic indicators, such as the share of industry and the ICT sector in GDP, Bulgaria lags behind other EU countries in almost all enterprise-level indicators pertinent to digitalization and Industry 4.0. Overall, Bulgarian enterprises are not taking up new digital technologies and innovative business models as fast as enterprises in most other EU countries. For some indicators, the performance of Bulgarian enterprises is far below the EU average. This includes basic indicators such as digital intensity of enterprises and innovation potential. Performance is also rather poor in the area of e-commerce, use of cloud computing, and cybersecurity. The raw data thus confirms the information derived from composite indexes presented above.

Note on source: The statistical data below is derived from the Eurostat database.

Basic economic indicators pertinent to Industry 4.0 readiness

Indicator	Year when data is provided	Bulgaria	EU-27
Percentage of industry in GDP	2020	17.7%	17.5%
R&D spending (as % of GDP)	2020	0.85%	2.32%
Percentage of the ICT sector in GDP	2019	6.62%	4.89%
Percentage of innovative industrial enterprises in the overall number of enterprises	2018	35.3%	53.1%
SMEs with at least a basic level of digital intensity (% of enterprises)	2020	33%	60%

Notes:

The industrial sector in Bulgaria is dominated by the manufacturing sub-sectors (metallurgical, chemical, and machine building). However, the most dynamic sectors are textile, pharmaceutical

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products, cosmetic products, mobile communications and the software industry (Kostov et al, 2021, p.10).

In 2020, R&D expenditure as a share of Bulgarian GDP was only 0.85% (as compared to an EU-27 average level of 2.32%). 40% of all R&D expenditure was financed from foreign sources. Within the public sector and the higher education sector, 90% of the R&D spending is used to cover regular costs such as salaries, renovations and consumables, while only 10% is invested into specific research projects. Risk financing is just 0.018% of GDP, and most financing opportunities are concentrated in Sofia and the ICT sector. Business expenditure on R&D is growing faster than public expenditure but, at a level of 0.56% of GDP, it is still below the EU-average of 1.46% of GDP (Draft Programme "Research, Innovation and Digitalization for Smart Transformation" 2021-2027, 2022, p. 5).

Basic enterprise indicators pertinent to electronic information sharing

Indicator	Year when data is provided	Bulgaria	EU-27
Electronic information sharing (% of enterprises)	2019	23%	36%
Enterprises that use ERP software package to share information between different functional areas (% of enterprises)	2021	22%	38%
Enterprises using software solutions like Customer Relationship Management (CRM) (% of enterprises)	2021	17%	35%

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Basic enterprise indicators pertinent to e-commerce

Indicator	Year when data is provided	Bulgaria	EU-27
SMEs selling online (% of enterprises)	2020	8%	17%
e-Commerce turnover (% of SME turnover)	2020	3%	12%
Enterprises sending e-invoices in a standard structure suitable for automatic processing (% of enterprises)	2020	10%	32%

Basic enterprise indicators pertinent to Industry 4.0 technologies – Internet of Things

Indicator	Year when data is provided	Bulgaria	EU-27
Enterprises using interconnected devices or systems that can be monitored or remotely controlled via the internet (% of enterprises)	2021	15%	29%
Enterprises using two or more Internet of Things devices or systems (% of enterprises)	2020	5%	7%
Enterprises using Internet of Things devices for premises' security (% of enterprises)	2021	11%	21%
Enterprises using Internet of Things devices for production processes (% of enterprises)	2021	3%	5%

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Enterprises using Internet of Things devices for logistics management (% of enterprises)	2021	4%	6%

Basic enterprise indicators pertinent to Industry 4.0 technologies – Artificial Intelligence (AI)

Indicator	Year when data is provided	Bulgaria	EU-27
Enterprises using AI (% of enterprises)	2020	5%	7%
Enterprises using AI technologies for machine learning (e.g. deep learning) (% of enterprises)	2021	1%	3%
Enterprises using AI technologies for automating different workflows or assisting in decision making (% of enterprises)	2021	2%	3%
Enterprises using AI technologies for marketing or sales (% of enterprises)	2021	1%	2%
Enterprises using AI technologies for production processes (% of enterprises)	2021	1%	2%
Enterprises using AI technologies for organisation of business administration processes (% of enterprises)	2021	1%	2%
Enterprises using AI technologies for management of enterprises (% of enterprises)	2021	0%	1%
Enterprises using AI technologies for logistics (% of enterprises)	2021	0%	1%

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Enterprises using at least one of the AI technologies: AI_TTM, AI_TSR, AI_TNLG, AI_TIR, AI_TML, AI_TPA, AI_TAR (% of enterprises)	2021	3%	8%

Basic enterprise indicators pertinent to Industry 4.0 technologies – Cloud Computing

Indicator	Year when data is provided	Bulgaria	EU-27
Enterprises buying cloud computing services used over the Internet (% of enterprises)	2021	13%	41%

Basic enterprise indicators pertinent to Industry 4.0 technologies – Big Data

Indicator	Year when data is provided	Bulgaria	EU-27
Enterprises analysing big data internally from any data source (% of enterprises)	2020	6%	13%
Enterprises analysing big data internally from any data source or externally (% of enterprises)	2020	6%	14%
Enterprises having another enterprise or organisation perform big data analysis for them (% of enterprises)	2020	1%	3%

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Enterprises purchasing (access to) any big data (% of enterprises)	2020	0%	1%
Enterprises analysing big data from smart devices or sensors (% of enterprises)	2020	2%	3%
Enterprises analysing big data from geolocation of portable devices (% of enterprises)	2020	4%	7%
Enterprises analysing big data generated from social media (% of enterprises)	2020	2%	7%
Enterprises analysing big data internally using machine learning (% of enterprises)	2020	1%	2%

Basic enterprise indicators pertinent to Industry 4.0 technologies – 3D Printing

Indicator	Year when data is provided	Bulgaria	EU-27
Enterprises using 3D printing (% of enterprises)	2020	3%	5%
Enterprises using own 3D printers (% of enterprises)	2020	1%	3%
Enterprises using 3D printing services provided by other enterprises (% of enterprises)	2020	2%	3%

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Basic enterprise indicators pertinent to Industry 4.0 technologies – Automation

Indicator	Year when data is provided	Bulgaria	EU-27
Enterprises using service robots (% of enterprises)	2020	2%	2%
Enterprises using industrial robots (% of enterprises)	2020	4%	5%
Enterprises using industrial or service robots (% of enterprises)	2020	6%	7%

Basic enterprise indicators pertinent to Industry 4.0 technologies – Cybersecurity

Indicator	Year when data is provided	Bulgaria	EU-27
Enterprises that experienced at least once problems due to an ICT related security incident (unavailability of ICT services, destruction or corruption of data, disclosure of confidential data) (% of enterprises)	2019	16%	13%
Enterprises having insurance against ICT security incidents (% of enterprises)	2019	3%	20%

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Variations across enterprise size and region

In Bulgaria, digitalization and the innovations related to Industry 4.0 are much more widespread in big companies than in small ones. According to experts, companies owned by international corporations are also more likely to be digitalized.

Indicator	10-49 employees	50 - 249 employees	Over 250 employees
Enterprises with internet access	95.4%	99.3%	100%
Enterprises using paid cloud computing services	10%	22.6%	44.6%
Enterprises performing big data analysis	5%	10.7%	21.4%
Enterprises using ERP software	17.1%	40.1%	65.2%
Enterprises using CRM software	14.3%	27.9%	34.8%
Enterprises sending e-invoices suitable for automated processing	8.9%	13.8%	24.2%
Percentage of innovative enterprises in the overall number of enterprises 2018	24.2%	46.8%	76.1%

Source: Bulgarian National Statistical Institute, data for 2021 (https://nsi.bg/en/content/2841/ict-usage-enterprises; https://www.nsi.bg/en/content/2712/innovation-active-enterprises-share-all-enterprises)

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There is also great divergence between the Industry 4.0 readiness of different regions in Bulgaria. Yugozapaden region (the region in and around Sofia) has great potential in augmented reality (top 10 of all European regions), cybersecurity, additive manufacturing and autonomous vehicles (Hallward-Driemeier et al., 2020, p. 193). In the Sofia region there is a large concentration of companies in the mechatronics and ICT sectors. The demand side – the users of mechatronics and ICT products, as well as various intermediaries, are also located in Sofia. In the subsector of computer programming, 87% of the revenue of the entire sector is concentrated in Sofia, as well as 80% of the jobs, and 91% of the added value. A similar disproportion is observed in other subsectors, such as: Information Service Activities (81% of the sector revenues are in Sofia), Manufacture of Computer, Electronic and Optical Products (67% of the sector revenues are in Sofia), Scientific R&D (92% of the sector revenues are in Sofia) (Stefanov et al., 2021, p.57).

Main barriers to digitalization in Bulgarian SMEs

According to experts and current studies, some of the main barriers to digitalization in Bulgarian SMEs are:

- Low level of investment in the development of industry, both in terms of financial and human resources. Resource mobilisation is dependent on financial assistance from the EU
- Suboptimal coordination and use of the different EU level instruments
- Low levels of R&D spending overall, and especially in the public sector.
- Low levels of patenting and publication activity, indicating that Bulgaria is relying on imported technology
- Insufficient awareness and knowledge about high-tech solutions
- Insufficient financial resources for the purchase of technology and digital solutions
- Insufficient capacity to invest in research and innovation activities for the creation of the necessary technology
- Shortages of highly qualified ICT staff and difficulties in training existing staff to use high-tech solutions, especially in smaller towns (Kostov et al., 2021, p. 8)
- Low levels of digital skills across the population
- Adoption of some elements of Industry 4.0 but overlooking other steps in automation and digitalization, which makes the process suboptimal and does not allow the companies to capitalize on all potential gains in productivity and competitiveness.
- Suboptimal interaction and coordination between the national and regional authorities

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- Suboptimal collaboration between the public authorities, the business sector and other stakeholders affected by industrial transformation
- Small domestic market for ICT and mechatronics services and products, especially for the more advanced ones. The public sector is also not acting as a driver for innovative services and products in the ICT and mechatronics sectors. Export markets are not fully used due to the lack of integrated public-private market intelligence services and instruments (Kostov et al., 2021, p. 95)
- Weak connection with international networks and value chains; insufficient Foreign Direct Investment flows to the mechatronics and ICT business, which prevents upward movement on the value-added chain
- While the export orientation of the ICT and mechatronics companies is an advantage, there is no specific market niche where Bulgarian enterprises emerge as competitive.

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NATIONAL STRATEGIC PLANNING AND REGULATORY DOCUMENTS

Policy context and strategic documents

In the 2014-2020 period, the Bulgarian government developed several strategic plans relevant to the digitalization of Bulgaria's economy and industry. These documents were relatively effective in kick-starting important reforms and support measures and shaping a pro-digitalization policy context:

- National Broadband Development Strategy 2012 – 2015
  https://www.mtitc.government.bg/upload/docs/AktualiziranaStrategia.pdf
- Connect Bulgaria: National Broadband Infrastructure Plan for Next Generation Access 2014
  https://www.mtitc.government.bg/upload/docs/2014-07/BG_NGA_PLAN_ENG.pdf
- Digital Bulgaria 2015 Programme and Action Plan
  https://www.mtc.government.bg/en/category/85/national-programme-digital-bulgaria-2015
- Updated policy in the field of electronic communications 2015 – 2018
- Innovation strategy for smart specialization 2014 – 2020
  https://www.mi.government.bg/files/useruploads/files/innovations/ris3_26.10.2015_en.pdf
- E-Governance Development Strategy 2014 – 2020
  https://www.mtc.government.bg/sites/default/files/uploads/pdf/e_governance_strategy.pdf
- Concept for promoting the education of software specialists 2015
  https://www.strategy.bg/FileHandler.ashx?fileId=6315
- National Cybersecurity Strategy: Cyber Resilient Bulgaria 2020
  https://www.strategy.bg/StrategicDocuments/View.aspx?lang=bg-BG&Id=1120
- National Strategy for Small and Medium-sized Enterprises 2014 – 2020
  https://www.mi.government.bg/files/useruploads/files/national_strategy_sba_2014-2020-veren.doc
- Concept for Digital Transformation of the Bulgarian Industry (Industry 4.0) 2017 – 2030
  https://www.mi.government.bg/bg/themes/koncepciya-za-cifrova-transformaciya-na-balgarskata-industriya-industriya-4-0-1862-468.html
- Draft Industry 4.0 Strategy 2018

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https://www.bia-bg.com/uploads/files/events/Industry_4.0/Strategy_Industry%204.0_draft_30%20March%202018.pdf

More recently, many of these documents have been updated and some new ones have been adopted with the objective to further shape the state of digitalisation in the course of industrial transition. The documents are in general harmony with, and faithfully reflect, current EU priorities and policies:

- National Program "Digital Bulgaria 2025" https://www.mtc.government.bg/sites/default/files/uploads/it/09-12-2019_programa_-cifrova_bulgariya_2025.pdf
- Connected Bulgaria: Updated National Broadband Infrastructure Pan for Next Generation Access 2020 https://www.mtc.government.bg/sites/default/files/updatedngaplanconnectedbulgaria.pdf
- National Development Programme Bulgaria 2030 https://www.minfin.bg/upload/46720/National%2BDevelopment%2BProgramme%2BBULGARIA%2B2030.pdf
- Draft Partnership Agreement for Bulgaria 2021 – 2027 https://ec.europa.eu/info/publications/partnership-agreement-bulgaria-2021-2027_en; https://www.eufunds.bg/bg/node/4825
- Updated Innovation Strategy for Smart Specialisation 2021 – 2027 Under elaboration, draft available from https://www.strategy.bg/FileHandler.ashx?fileId=29718
- National Strategy for the Development of Scientific Research 2017 – 2030 https://www.strategy.bg/FileHandler.ashx?fileId=9594
- National Strategy for SMEs 2021 – 2027 https://www.mi.government.bg/files/useruploads/files/MSP/SME_strategy.doc
- Digital Transformation of Bulgaria for the period 2020 – 2030 https://www.mtc.government.bg/sites/default/files/digitaltransformationofbulgariafortheperiod2020-2030f.pdf
- Concept for the Development of Artificial Intelligence in Bulgaria until 2030 https://www.mtc.government.bg/en/category/157/concept-development-artificial-intelligence-bulgaria-until-2030
- Updated National Cybersecurity Strategy: Cyber Resilient Bulgaria 2023 https://www.strategy.bg/FileHandler.ashx?fileId=24215
- The Digital Bulgaria 2025 Programme and its Roadmap

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https://www.mtc.government.bg/en/category/85/national-program-digital-bulgaria-2025-and-road-map-its-implementation-are-adopted-cm-decision-no73005-12-2019

https://www.mtc.government.bg/bg/category/85/nacionalna-programa-cifrova-bulgariya-2025-i-putna-karta-kum-neya-sa-prieti-s-rms-no-730-ot-5-dekemvri-2019-godina

The policy context created by these different but interconnected strategies is presented in detail below.

Policy in support of Industry 4.0

The 2018 Industry 4.0 Strategy outlines the following priority areas of intervention:

(1) Strengthening the links between science and industry and facilitating the participation of Bulgaria in European and international programs, initiatives and networks related to Industry 4.0

(2) Achieving higher technological sophistication of the Bulgarian economy by introducing standards, ensuring the security of smart production systems, taking up innovative business models, building a broadband infrastructure for industry, improving the business environment and the regulatory framework, and improving resource and energy efficiency

(3) Building human, scientific, organizational and institutional capacity through changing outdated organization and structures of work and promoting digital skills at all levels of education and training, including on-the-job training, retraining and lifelong learning

Among some of the measures proposed for supporting Industry 4.0 in Bulgaria are:

- Attracting relevant Foreign Direct Investment through government initiatives. Current investment promotion policies focus on industrial sectors such as mechanical engineering, electronics and electrical engineering, automotive sector, production of medical equipment and medicines, production of optical products, ICT, scientific and research activity, technological and industrial parks
- Tax relief
- Financial guarantees thought the Bulgarian Development Bank
- Risk capital funds
- Innovation vouchers through the National Innovation Fund
- Funding for relevant projects through the National Innovation Fund
- Infrastructure such as test laboratories, clusters, research and innovation infrastructure, establishment of Digital Innovation Centres. Digital Innovation Centres are planned as key elements of a support ecosystem for the digitalization of industry, with specific focus on supporting small and medium-sized enterprises (SMEs).

In general, the government's policy for promoting Industry 4.0 focuses on:

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- Institutional support for the development of Industry 4.0 and creating synergies between existing policies, programs, strategies and support measures
- Educational and scientific initiatives to build institutional and organizational capacity for Industry 4.0
- Supporting the creation of pilot projects and demonstration models.

In addition to this overarching strategy, the Bulgarian government has developed strategic documents focusing on specific areas of technology pertinent to Industry 4.0, such as cybersecurity and Artificial Intelligence.

The national strategy for cybersecurity was updated in 2021. While it is mostly focused on national security, some of the priorities and identified interventions concern also industry, both in terms of maximizing the contribution of industry to the development of cybersecurity solutions, and in terms of industrial cybersecurity. The strategy includes a multitude of priorities and broadly defined aspirations, many of which are, as of now, not translated into concrete realistic plans of action. All in all, however, it manages to outline the key areas and actions that will likely become a focus of government interventions in the future. Among those that are relevant to industry are:

- Improving the legal and regulatory frameworks
- Improving the security of internet environments
- Strengthening European cooperation in the cybersecurity area and introducing a EU framework (and a national system) for cybersecurity certification of IT products, services and processes
- Improving network and information systems security - accelerating the transfer and adoption of good practices and technologies; implementation of modern tools and platforms for identifying and responding to incidents and security breaches; carrying out analysis, tests and simulations, and pilot and test projects at the initiative and with the resources of industry; increasing investments in network and information systems security; improving the knowledge and skills of specialists in network and information systems security
- Addressing emerging cybersecurity issues in digital processes and spheres such as e-commerce, internet payment gateways, financial services, e-payments and digital currencies, e-healthcare and insurance, social networks, search engines, cloud services and applications, online media, etc.
- Implementation of enterprise-level standards for information security and cybersecurity suitable for SMEs
- Improving awareness of cybersecurity and building a cyber culture in enterprises, with a focus on SMEs
- Including SMEs in information sharing and prevention networks

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- Introducing measures to ensure the reliability, accessibility and security of open data
- Building skills, competences, capacity and momentum for research and innovation in the field of cybersecurity, including through new initiatives and through technology parks, centers of excellence and centers of competence
- Implementing programs for the technological development of industry that incorporate systems and solutions designed to ensure cybersecurity and protection
- Supporting industry through testing for cyber security breaches, and through simulation environments for checking and increasing resistance to attacks and breaches
- Establishing of a mechanism for sharing resources, capacity and skills between the private, public and academic sectors
- Engaging the major ICT companies and multinational technology companies in the process of developing a National Cybersecurity System, in increasing the security of the Internet space, and in supporting SMEs and national and international centers of competence.

The Concept for the development of Artificial Intelligence (AI) in Bulgaria until 2030 charts the vision and the policy priorities for the development and use of AI in Bulgaria. It prioritizes the development of modern and reliable communications and scientific infrastructure, availability and access to open data, data sharing architectures, interoperability of available public data, and introduction of AI-based innovation in key sectors. The concept recognizes the need to improve knowledge, skills and research, innovation and technology transfer capacity. Finally, setting up the necessary regulatory framework for the development and implementation of reliable and ethical AI technologies is recognized as a precondition for further innovation in the AI sector, along with raising awareness and building trust in society. Interestingly, with the exception of the information technology industry (software industry), the industry sector is not mentioned as a priority sector for the development of AI.

Some of the specific proposed measures are:

- Organizing and integrating available infrastructure
- Organizing experts for the accumulation of large data sets in priority areas to help define formats, structures, standardization approaches and interoperability of data sets
- Creating incentives for organizations to share data
- Providing freely accessible data for AI applications and high-tech AI platforms
- Constructing digital information hubs in the field of AI and robotics, co-financed by the European programme "Digital Europe"
- Creating a Bulgarian Research Programme for AI and robotics

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- Involving Bulgarian teams in pan-European networks in artificial intelligence, robotics and digitalization, and otherwise enhancing the cooperation between Bulgarian and EU researchers
- Cooperation between education, research and AI professionals in developing joint AI training
- Focusing on the development of education (at all levels) that can provide digital skills specific to the creation and application of AI
- Supporting the transfer of knowledge from science to business via incubators and the creation of start-ups in universities and research organizations
- Enabling the development of research capacity in industry by funding innovative in-house laboratories in companies.

Innovation support policy

Innovation support policy includes support for Industry 4.0. The current framework focuses on:

- Human capital and scientific research, which is focused on improving the digital skills of the population, as well as on enhancing education and training in Information Technology and Informatics. In order to improve the quality of the workforce, Bulgaria carried out a number of educational reforms and increased the intake of students in professional areas related to Mathematics, Informatics and Computer Sciences, and Communication and Computer Technology. At the end of 2015, the Government developed a Concept for Supporting the Education of Software Specialists. A Strategy for the Effective Application of ICTs in Education and Science until 2020 was also adopted
- Bulgaria's innovation strategy for smart specialization prioritizes Mechatronics, Informatics and ICTs. *Informatics and ICT* and *Mechatronics and Clean Technologies* were priority thematic areas in the Innovation Strategy for Smart Specialization 2014 – 2020. The thematic area *Informatics and ICT* will be a priority in the new Innovation Strategy for Smart Specialization 2021 – 2027. New measures to foster the digitalisation of enterprises through Industry 4.0 will be introduced. It is envisaged that there will be integrated projects for financing innovation in enterprises, which will combine both priority thematic areas - *Informatics and ICT* and *Mechatronics and Clean Technologies*.

  In the 2021 – 2027 Innovation Strategy for Smart Specialisation, the following new approaches are expected:

  - Implementation of Industry 4.0 technologies, business models and processes, and an overall digital transformation of Bulgarian SMEs

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- A much stronger regional dimension, including more focused regional strategies for smart specialization that will pick up just two of the four national thematic priorities.
- Establishment of an Agency for Research and Innovation at the Council of Ministers, tasked with integrating national Research & Innovation policies and exploiting synergies between initiatives and projects funded by the EU. In the future, the agency is also expected to run a new Operational Programme on Smart Transformation. The said program should support: (i) increasing the quality and capacity of the science and innovation system; and (ii) digitalisation of public services.
- Progress with technological upgrade support outside Sofia and outside the IT sector

Development policies

Objectives and measures related to Industry 4.0 and digitalization are included in the broader developmental policies of the country. The *National Development Program Bulgaria 2030* outlines the current vision and the overall goals of development policies in Bulgaria. It provides the overarching perspective for the development of the country in the next decade and will likely guide the utilization of the resources from the next Multiannual Financial Framework 2021 – 2027 and the Recovery Package. The program generally aims to accelerate Bulgaria's economic development through specialisation in products and industries with high technological and research intensity. The basic indicators of success are reaching the EU-average in the Digital Economy and Society Index (DESI) and a 15% share of high-tech exports in total exports.

The *Innovative and Intelligent Bulgaria* development axis aims at an economy based on knowledge, smart growth and a high-tech industrial base. This is the basis of the current policy in support of Industry 4.0. The key priority is to stimulate the process of digitalisation of the real economy. Specifically, efforts will be targeted at strengthening the link between science and industry and developing Industry 4.0.

This axis also foresees interventions at all levels of the education system and the system for qualification and retraining. The interventions are geared towards overcoming the low level of digital competences of the population (with a specific focus on young people, the unemployed, and the economically inactive and disadvantaged groups). A key tool is the partnership with the private sector.

In the field of science and scientific infrastructure, it is planned to (further) develop Centres of Excellence, Competence Centres and Regional Innovation Centres, to raise the standards of research institutions, to modernise R&D equipment, to encourage stronger cooperation between higher education institutions, research institutes and businesses, and to build capacity and develop human resources in the R&D system. This priority includes the objective to improve Bulgaria's performance in the European Innovation Scoreboard by achieving the

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label "Moderate innovator".

The three priorities – (1) education and skills, (2) science and scientific infrastructure, and (3) smart industry – are rightly addressed together in pursuit of a broader objective and it may be expected that the approach will initiate a coherent policy in support of Industry 4.0 in Bulgaria. It is positive that the Ministry of Economy has developed a draft detailed strategy on the Smart Industry with fairly adequate objectives and planned measures.

Objective	Measures
Digitalization of the economy	Support the development, implementation and use of e-commerce tools, management information systems, and information security systems
	Training for enterprises in the field of digital technologies, information security, e-commerce
	Support for the introduction and implementation of Industry 4.0 technologies, products, processes and standards and business models. The technologies that will be supported include physical computing, Internet of Things, 3D printing and prototyping, Big Data, cloud computing, augmented reality, Artificial Intelligence, cybersecurity systems, machine learning, robotics.
	Creation of a fund to finance Bulgarian Artificial Intelligence and Industry 4.0 projects and provision of national financing for project proposals under the "Horizon 2020" and "Horizon Europe" programs that have received a Stamp of Excellence but have not received EU funding
	Establishment and financing of a centre for testing Industry 4.0 technologies
	Information campaigns to raise awareness about Industry 4.0

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	Further development of Sofia Tech Park as a platform for providing specialized services in support of the automation and digital transformation of the industry
Technological intensity and innovation ecosystem	Support for the development of innovation-friendly institutional ecosystems and innovation capacity in enterprises, including in SMEs.
	Support for the development of innovations in enterprises, including in SMEs
	Development of a high-tech industrial base
	Promoting specialization in products and services characterised by high technological intensity and innovativeness
	Strengthening the links between business and science and promoting R&D
	Development of regional innovation ecosystems through regional innovation strategies for smart specialization
	Widening the network of innovation centers and creating new ones, including innovation clusters, Centers for Competence, Centers for Excellence, Digital Innovation Hubs, Regional Innovation Centers, Centers for approbation of new technologies, etc.
	There will be state support for the establishment of Digital Innovation Centers (Hubs) (partly funded by the "Digital Europe" program) to provide businesses with access to technological expertise and experimental facilities. Recently, 17 candidates for European Digital Innovation Hubs under the Digital Europe program were selected. They are geographically located in the six regions of

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Bulgaria. The selection is in line with the regional specialisation plans set out in Bulgaria's innovation strategy for smart specialisation

Support for technological modernization and implementation of innovations – priority beneficiaries are the start-ups in the high- and medium-tech industries or the sector of knowledge intensive services

Support for entrepreneurship and start-ups through financial instruments, guarantees, risk finance, microfinancing and access to infrastructure – priority beneficiaries are the start-ups in the high- and medium-tech industries or the sector of knowledge intensive services

Support for the development of a strong entrepreneurship ecosystem including technological parks, business incubators, venture funds, business angels, crowdfunding platforms, shared spaces, etc.

Support for the internationalization of the innovation process in enterprises, in particular by promoting the participation of enterprises in international projects and supporting exports and foreign market access for enterprises

In the *Connected and Integrated Bulgaria* development axis, it is foreseen to improve the country's digital connectivity through the establishment of modern and secure digital infrastructure as a basis for offering more services through digital management and collaboration. Cybersecurity is also acknowledged as a prerequisite for the effective functioning of digital infrastructure. The priority focuses on improving access to high-speed internet and the introduction of 5G mobile networks.

The other development axes in the *National Development Program Bulgaria 2030* are unrelated to Industry 4.0 and less related to digitalization.

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Policy in support of SMEs

The National Strategy for SMEs 2014 – 2020 is aimed at providing adequate government support for SMEs (specifically innovative SMEs) and at encouraging entrepreneurship. Digitalization and Industry 4.0 are directly addressed in several priority areas that were outlined in this strategy, including those related to more efficient public administration, skills and innovation, and environmental protection. An adequate strategy towards SMEs can encourage Industry 4.0 by supporting: (i) technological transfer and links between business, education, technological parks and the public sector; (ii) R&D in SMEs; (iii) e-commerce; (iv) e-education; (v) SMEs' access to ICTs.

One of the key strategic goals set in the updated National Strategy for SMEs 2021 – 2027 is to promote SME specialization in high-tech and medium-tech industries and in knowledge intensive services, while also reducing existing regional disparities. The proposed areas of interventions are focused on digitalization and skills. Efforts will be targeted at:

- Promoting the digital transformation of SMEs, including by supporting e-commerce, cybersecurity and data storage applications, CRM systems, ERP systems, automation and robots, digital technologies in industrial production
- Reducing the energy intensity of industrial SMEs through technologies and software for the management of production processes
- Encouraging SMEs to provide digital skills training for their employees, and to get actively engaged with vocational education and training, in particular dual education and on-the-job training in STEM-related professions
- Development of web-based platforms and tools for education and training for SME professionals

Policy in support of digital transformation

Bulgaria's strategy for digital transformation for the period 2020 – 2030 (published 2020) identifies the following operational priorities:

- Deployment of secure digital infrastructure, with a focus on improving access to high-speed connectivity via broadband internet access and mobile connectivity, including 5G. The strategy focuses on investment in infrastructure, as well as ensuring cybersecurity, simplifying regulation and reducing the costs for business. The ambition is to ensure by 2030 gigabit connectivity of schools, transport centers, major public service providers and digitally intensive enterprises. Further efforts will be aimed at building an efficient cloud infrastructure, as well as infrastructure for data sharing and artificial intelligence
- Cybersecurity, with a focus on improving cybersecurity training and raising awareness about cybersecurity

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- Unlocking the potential of the digital economy, with a focus on encouraging enterprises to take advantage of digital technologies such as Internet of Things, big data, robotics, Artificial Intelligence, blockchain, 3D printing, etc.; financially supporting high-risk innovative start-ups, in both their initial stages and in the scaling stages; digitalization in specific economic sectors such as agriculture, transport, energy, healthcare, finances, culture; digitalization in the area of environmental protection, the circular economy and low-carbon, resource-efficient solutions; promoting and enabling digital governance and the use of open data, digital solutions and interoperable models for data sharing in public administration and the public services
- Access to adequate technological knowledge and digital skills, with the following focus areas:
    - Promoting research and innovation, based on close university-business cooperation, continuing support for, and the development of new, research centers of excellence and centers of competence, participation in collaborative research funded by the EU (e.g. the Horizon program), funding market-oriented applied research in the field of digital technologies, and supporting innovative enterprises in the ICT and other innovative industrial sectors
    - Education and training - provision and maintenance of high-speed and secure basic internet connectivity and cloud-based services, infrastructure and platforms, to enable the digital provision of education, digital governance and network interaction. The strategy mentions also use of big data, augmented and virtual reality, and Artificial Intelligence in education but is not very specific as to the concrete applications. The same is true about the issue of cybersecurity of educational systems and networks. The development of the digitals skills of the participants in the education process, and especially pedagogical staff, is another priority in this part of the strategy.
    - Adaptation of the labor market – measures to provide an effective lifelong education and training system in order to help the workforce adapt, retrain and acquire new skills and knowledge in the digital field. The strategy also recognizes the need for special measures to improve the training of highly qualified ICT specialists, especially within the system of higher and secondary vocational education, through modernization of programs, training of teachers, and appropriate material base. The role of employers and labour market intermediaries in providing non-formal training is also acknowledged

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The Digital Bulgaria 2025 Programme and its Roadmap mirror the above priorities. They plan modernization and widespread introduction of smart IT solutions in all spheres of the economy. The priority areas include development and accessibility of digital networks and services, enhancement of digital competence and skills, a secure cyber ecosystem, Internet governance, a new regulatory framework for electronic communications and digitalization of Bulgarian industrial sectors.

Policy in support of education, training and learning

The Strategic framework for the development of education, training and learning 2021 – 2030 outlines a number of measures in support of digital education:

It is foreseen to purchase computer hardware, with priority given to schools that have not recently received equipment and schools with ICT profiles. The 2016 Pre-School and School Education Act introduced computer programming in the curricula of primary school, starting for 3rd and 4th grades. Additional measures are taken with regard to developing the digital skills of employees. Since 2021, an initiative financed by the European Social Fund and the national budget has focused on developing and testing digital skills profiles for key professions in different economic sectors, and on developing sectoral qualifications frameworks for digital skills development. Young unemployed people are targeted in an initiative of the Ministry of Labour and Social Policy which organises free training courses in digital competences. A 2021-2027 digital competences training program is also launched for all age groups including the elderly and disadvantaged people. The initiative receives EU funding under Operational Programme Human Resources Development (2021-2027).

Digital literacy is a priority in EU funding for the 2021 – 2027 programming period and the available support is expected to benefit more than 670,000 people. Government initiatives are complemented by the efforts of the Digital National Alliance in Bulgaria, whose Memorandum has been signed by key stakeholders such as the Bulgarian Academy of Science, leading Bulgarian universities, the Bulgarian Association of Information Technologies, the Bulgarian Association of Software Companies, the ICT Cluster, and various companies, start-ups and NGOs. The Alliance supports the building of a smart digitized Bulgarian economy.

In 2016, the profession Software Developer was included in the list of professions in Vocational Education and Training in Bulgaria. The government also signed collaboration agreements with relevant business associations to deliver software development training for students, including through a National Program "Training for IT Career".

ICT and Mechatronics are identified as priority areas for R&D in Bulgaria. In 2017, a National Strategy for the Development of Scientific Research in Bulgaria 2017 – 2030 was approved and a National Roadmap for Scientific Infrastructure has been developed and updated (https://www.mon.bg/upload/4012/Roadmap_2017_BG.pdf). The strategy aims at modernizing research and supporting the development of new technologies. Ensuring stronger links between education and business is also recognized as a priority.

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A major drawback in the implementation of an effective research and innovation strategy is the unbalanced regional distribution of scientific organizations, universities and successful industrial centers. To address this drawback, policy plans foresee the gradual development of scientific research in the regions, namely through the establishment of regional scientific research centers in the priority areas for smart specialization.

Key support programs

EU-funded operational programmes provide most of the funding for R&D in Bulgaria, including that earmarked for supporting digitalization and Industry 4.0.

Past support programs

Operational Programme *Competitiveness* 2007 – 2014 primarily funded the technological upgrading of Bulgarian companies. A science component existed within the Operational Programme *Human Resources* in the same time period.

In the 2014 – 2020 period, digitalization and Industry 4.0 were mostly supported by Operational Programme *Innovation and Competitiveness* (OPIC) and Operational Programme *Science and Education for Smart Growth* (OPSESG), managed by the Ministry of Economy and the Ministry of Education and Science respectively. The total funding was EUR 1.05 million and 2,131 companies benefited from it.

OPIC and OPSESG funded new technologies in four thematic areas of Bulgaria's first Research and Innovation Smart Specialization Strategy (RIS3):

- Mechatronics and Clean Technologies (around 38% of the funding)
- Informatics and Information and Communication Technologies (26% of the funding)
- Healthy Living and Biotechnology Industries (22% of the funding)
- New Technologies in Creative and Recreational Industries (14% of the funding).

Two RIS3 horizontal priorities - mainstreaming of digital technologies (further digitalisation of industry) and development of resource effective technologies – could also be used to obtain funding for Industry 4.0.

Examples from the 2014 – 2020 programming period include:

OPIC provided funding amounting to EUR 320.8 million for 469 beneficiary companies in the Mechatronics sector (894 projects). These beneficiaries were in the sectors of manufacturing of machinery and equipment (163 beneficiaries), electrical equipment (63 beneficiaries) and computers (52 beneficiaries), ICT (108 beneficiaries), scientific research (33 beneficiaries) (Kostov et al., 2021, p.45).

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OPIC and OPSESG funding also focused on intermediary bodies and collaboration between business and research. Among the major projects was the completion of the Sofia Tech Park (funded by OPIC), the creation of 10 Centres of Competence and 4 Centres of Excellence, funded under OPSESG (for a total of 348 million BGN), and two Centres of Excellence, funded by Horizon 2020 and co-funded by OPSESG.

With the exception of one Centre of Competence, all others are in the Mechatronics, clean tech and ICT sectors. The centres merge the expertise of 59 institutes, universities, research organizations and business organisations. They were expected to raise the market relevance of scientific research, build capacity for research and innovation, build scientific infrastructure and contribute toward the establishment of new enterprises. The Strategic Evaluation of the Centres of Competence and Centres of Excellence (2021) concludes that the Centres have not managed to develop research and innovation programs that are sufficiently industry or market specific, and that technology transfer activity is still limited. A specific challenge is the lack of technology transfer knowledge and skills, as well as adequate strategies for IP exploitation. The Evaluation recommends that government policy should not just provide funding for the Centres but intervene to support a strong Research & Innovation ecosystem through capacity building targeted at academia-industry collaboration and technology transfer.

Some 650 Bulgarian organizations have received around EUR 156 million funding from Horizon 2020, which is only 0.26% of the EU's total (Draft Programme "Research, Innovation and Digitalization for Smart Transformation" 2021-2027, 2022, p. 12). Among the most substantial projects is Sofia's new Big Data Center of Excellence. Some projects focused on big data, robots and advanced computing are led by Bulgarian universities and research institutes.

In addition to EU funding, Bulgaria provides funding for R&D from the national budget. Most of it is in the form of direct subsidies to public research institutions such as the Bulgarian Academy of Sciences. Competitive national funding for R&D is not substantial and is allocated through two instruments: the National Science Fund, which funds only research organisations, and the National Innovation Fund, which funds businesses. The National Innovation Fund follows the RIS3 priorities. Since 2005, the Fund has financed over 500 projects for around BGN 100 million.

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Current support programs

National Recovery and Resilience Plan

The Plan (2020), which falls under the NextGenerationEU temporary recovery instrument of the EU, has 4 pillars, two of which are relevant to digital transformation and Industry 4.0. The table below provides more details based on the preliminary plans:

Pillar	Components	Key interventions	Projects
Innovative Bulgaria	Education and skills	Reforms at all levels in education Creating a national STEM environment for skills of tomorrow (building a comprehensive educational STEM environment in Bulgarian schools) Trainings for digital skills and building a national online platform for adult learning	***STEM Centres and Innovations in Education (2021-2025)*** - Building a comprehensive educational STEM environment in Bulgarian schools - Creating a National STEM Center and regional STEM Centres - Creating STEM Centres in 2,240 schools, featuring STEM laboratories and learning spaces *Total budget: BGN 480 million EU funding, BGN 96 million national co-funding* ***Trainings for digital skills and building a national online platform for adult learning (2021-2026)*** - Free and accessible training for unemployed and employed persons – basic and medium level of skills

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		- Building national online platform for adult learning *Total budget: BGN 322 million EU funding, BGN 57.5 million national co-funding*
Research and innovation	Implementing a common policy for development of research, innovation and technologies in view of improving economic and social development of the country Programme for accelerating economic recovery and transformation through science and innovation	***Programme to accelerate economic recovery and transformation through science and innovation (2021-2026)*** - implementation of project proposals from innovative SMEs that have received „Seal of Excellence" in European Innovation Council competitions, and project proposals under the "Widening Participation" element of the "Horizon Europe" program for strengthening the research and innovation capacity of the Bulgarian higher education institutions and research organizations - creating and piloting a national model for development of research universities and a network of such universities in Bulgaria

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		Total budget: BGN 366.5 million EU funding, BGN 34.5 million national co-funding
		Enhancing the innovation capacity of the Bulgarian Academy of Sciences in the field of green and digital technologies (2021-2026)
		- Infrastructure improvements
		- Development of innovation products and technologies
		- Acquisition and development of new technologies
		- Development of human capital
		- Improving the pool of experts
		Total budget: BGN 46.5 million EU funding, BGN 5.5 million national co-funding
Smart industry (Industry 4.0)	- Updating the strategic framework for the industrial sector (reform)	***Programme for public support for development of industrial parks and improvement of their infrastructural connectivity (2021-2026)***
	- Building a mechanism to attract industrial investments	- Development of infrastructure of industrial parks
		- Measures to attract and retain strategic investors

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and develop industrial ecosystems (reform) - Programme for public support for the development of industrial parks and improvement of their infrastructural connectivity (investment) - Economic transformation programme (investment)	*Total budget: BGN 216.5 million EU funding, BGN 420 million private funding* ***Economic transformation programme*** The program provides targeted support to SMEs in areas slowing down the transformation to a digital, low-carbon and resource-efficient economy. The following funds are relevant to Industry 4.0 - Fund 1 - "Growth and Innovation" (BGN 731 million EU financing and BGN 826 million private funds): a) providing support for technological modernization through the purchase of technological equipment, with a special emphasis on digitalization; b) grants for ICT and cybersecurity solutions – support for solutions for the initial stages of digitalisation (Computerisation and Connectivity) and cybersecurity solutions; c) support for innovations, with special emphasis on the areas of ICT, industrial automation, Artificial Intelligence, robotics, blockchain,

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			fintech, cybersecurity, quantum technologies, biotechnologies, etc. - Fund 3 - "Climate Neutrality and Digital Transformation" (BGN 59 million EU financing and BGN 59 million private funds): supports infrastructure projects, including digital infrastructure (ICTs, optical infrastructure, data centers, 5G, etc.)
Connected Bulgaria	Digital connectivity	- Development and implementation of an effective policy and regulatory framework - Efficient use of the radio frequency spectrum - Creating a favourable investment environment - Large-scale deployment of digital infrastructure	***Large-scale deployment of digital infrastructure (2021-2025)*** - building of symmetric gigabit access networks throughout the country *Total budget: BGN 527 million EU financing, 105.5 million national co-financing*

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Research, Innovation and Digitalization for Smart Transformation Program 2021-2027

The total funding planned to be made available is EUR 1,095,010,854, of which EUR 864,290,000 European funding and EUR 209,500,853 national co-financing.

The Research, Innovation and Digitalization for Smart Transformation Program (2022) seeks to boost research and innovation, with the ultimate aims of helping Bulgaria achieve the status of moderate innovator and supporting a more intensive use of digital technologies in the economy and society. The program complements the National Recovery and Resilience Plan and national instruments – National Innovation Fund and Bulgaria National Science Fund. Specific measures and objectives are implementing various synergies with other key support programs.

The program addresses the following challenges:

- Low levels of public and private investment in research and development resulting in a relatively low innovation capacity of the economy
- Outdated and inadequate regulatory framework which fails to cover all innovation processes, develop an efficient national policy on funding R&D, create better conditions for the participation of business in scientific research, and properly regulate transfer of technology and intellectual property
- Insufficient efforts to build and maintain capacity for cutting-edge research. This is largely due to deficiencies in the area of human capital for research and innovation
- Limited and inefficient cooperation between scientific organizations, higher education institutions and business, resulting in low levels of transfer of technology and knowledge
- Insufficient level of internationalization of the research ecosystem
- Weak innovation activity of enterprises
- Continuing regional disparities in scientific output and innovation
- Low level of investment into e-government which results in low level of digitalization of the economy
- Universities in Bulgaria are lagging behind in the implementation of modern systems of management and control

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In relation to these identified weaknesses, the program plans the following priority areas and measures:

Priority area	Measures / interventions
Sustainable development of the capacity for research and innovation	Developing Centers of Competence and Centers of Excellence created during the last programing period Supporting key other research and innovation infrastructures and infrastructure projects Supporting partnerships between Centers of Competence and Centers of Excellence and other research organizations and SMEs – the main purpose is to motivate business to use the innovation capacity of research organisations. The support targets SMEs in the thematic areas for smart specialization, including Mechatronics and ICTs Developing innovation capacity at regional level through the creation of Regional Innovation Centers, innovation infrastructure within industrial parks and pilot collaboration initiatives involving business, research organizations and academia. These Centres will be tasked with supporting the links between business and science at regional level in the priority areas for smart specialization, including Mechatronics, clean tech and digitalisation. The plan is to create at least one centre for each thematic priority in each of the six planning regions in Bulgaria. The Centres are expected to counterbalance the concentration of innovative companies and research in the region in and around the capital and to thus nurture regional innovation systems

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	Developing a unified information platform for scientific research and innovation
	Developing conditions for sharing and managing research data according to FAIR principles and introducing open science as a standard practice in research
	Improving the visibility of scientific research results
Transfer of technologies and knowledge	Developing a national model of knowledge and technology transfer
	Programs for collaboration and transfer of technology
	Mobility programs between industry, research organizations and universities
	Developing innovation clusters
	Supporting technology- intensive and knowledge-intensive spin-offs
	Developing industrial start-up systems aimed at large-scale research and innovation
	Creating European Digital Innovation Hubs
	Building capacity for property rights protection and use
European integration and internationalization of research and innovation	Financing of projects that have received a Seal of Excellence from the European Innovation Council, the European Research Council, or Maria Curie Actions
	Increasing the participation of Bulgarian scientific organizations, universities and SMEs in the EU Horizon Program through scientific, innovation and administrative capacity building (participation in European partnerships, cooperation with the European Institute of Innovation and Technology, additional financing for projects under certain actions in the Horizon Program)

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	Exploiting synergies with other programs and instruments
	Developing skills and a platform for smart specialization, industrial transition and entrepreneurship, bringing together highly qualified training organizations and experts
Using data as key social capital	Creating a data management framework and building interoperable data spaces
	Building a smart data-driven management platform
	Development of data processing and technological tools for depersonalization of sensitive data
	Capacity building for competent authorities and promotion of data sharing - streamlining the process of requesting and providing data
	Development of cross-border services for the use and sharing of data and integration in cloud infrastructures at the European level
	Organization of large-scale campaigns, events and initiatives to develop specific digital skills to create and use digital services and products, share data and reuse public data to create innovation and added value for the economy and society
Cybersecurity	Building a collaborative environment to promote and enhance trust and cooperation between cybersecurity partners at the national level.
	Building the capacity of the National Competent Authorities (NCAs) and their sectoral teams to respond to computer security incidents
	Building a cyber-secure environment for vulnerable public and business organizations through centralized monitoring and protection

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Building a system for cyber protection of shared information resources

Competitiveness and Innovation in Enterprises Program 2021-2027

The Competitiveness and Innovation in Enterprises Program (2022) aims at promoting smart and sustainable growth of the Bulgarian economy, as well as industrial and digital transformation. It responds to EU-level policies aimed at innovative and smart economic transition and a greener, low-carbon Europe. The program addresses the insufficient development of high-tech and high to medium-tech industries and knowledge-intensive services in Bulgaria. It provides targeted support for these sectors and also tackles the issue of regional disparities.

In relation to these identified weaknesses, the program plans the following objectives and interventions that relate to Industry 4.0:

Objective	Interventions
Exploiting the benefits of digitization for citizens, companies and governments	Supporting the introduction of Industry 4.0 technologies in enterprises according to RAMI 4 standards
	Supporting investments aimed at introducing digital technologies, software, digital applications and implementing appropriate cybersecurity and data privacy processes in SMEs
	Creation of a module/tool for measuring the level of digitization of enterprises
	Support for digitization of SMEs and restructuring of work processes and flows
Building capacity for research, innovation and the introduction of advanced technologies	Support for the development of innovations in enterprises
	Support for the implementation of innovations in enterprises
	Internationalization of the innovation process in enterprises by attracting foreign researchers, with a focus on enterprises in the growth stage

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	Support for the creation of innovative start-up enterprises, preferably with main activity in the medium to high-tech industries and knowledge-intensive services
	Support for claiming and protecting industrial property in enterprises
Strengthening the growth and competitiveness of SMEs, including through productive investments	Support for production investments in enterprises with growth potential or according to the regional development potential
	Encouraging entrepreneurial activity – support for the establishment and growth of start-up enterprises
	Support for the development of the entrepreneurial ecosystem, internationalization and attracting foreign investments
	Support for growth and competitiveness of SMEs within new/existing industrial parks

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EDUCATIONAL EVENTS RELATED TO INDUSTRY 4.0

Educational events related to Industry 4.0 in Bulgaria are mostly academic conferences and events organized by business, for business. While there are undoubtedly some events organized in the frame of EU-funded projects, too, most of them do not have a pronounced educational value. Rather, they mostly raise awareness about Industry 4.0, mobilize stakeholders or provide information about project results. One notable example of an EU-funded event is the 2017 conference *Industry 4.0 – Digitization and prospects for the growth of the Bulgarian economy* which was organized in Sofia Tech Park by the Bulgarian Small and Medium Enterprises Promotion Agency and was targeted at representatives of SMEs. Another such example is the 2022 High-Tech Summit for the Black Sea, which is financed under the Horizon 2020 program.

Examples of mostly academic events focused on Industry 4.0 topics are:

- The annual DIGILIENCE conference focused on cyber information sharing and situational awareness, Artificial Intelligence for cybersecurity, policies and solutions for security and resilience of Industry 4.0 and critical infrastructures. The conference was first held in 2019 and was organized by the Institute of Information and Communication Technologies at the Bulgarian Academy of Sciences. In 2020 it was hosted by Nikola Vaptsarov Naval Academy in Varna and in 2021 by the National Military University "Vasil Levski" in Veliko Tarnovo. The 2022 DIGILIENCE conference will be held in Plovdiv
- The annual international scientific conferences *Industry 4.0 and High Technologies, Business, Society*, organized by the Scientific Technical Union of Mechanical Engineering in collaboration with a number of leading Bulgarian research institutions and universities. As of 2022, the conference is in its 7th edition
- The 2022 international applied science conference "The Circular Economy in the Context of the Relationship Industry 4.0 – Society 5.0"
- The 2017 international scientific conference *Industry 4.0* organized by two of the leading universities in Bulgaria – Sofia University "St. Kliment Ohridski" and the University of National and World Economy
- Industry 4.0 has been discussed in conferences focused on education in Bulgaria. An example is the 2018 *The Future of Education Conference*, which was jointly organized by the America for Bulgaria Foundation and the European Commission in Bulgaria, in partnership with the Ministry of Education and Science. The conference included a special panel *Unlocking the Potential of Vocational Education in the Age of Technology, Preparing Students for Industry 4.0*

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- GATE *Big Data and Artificial Intelligence* forum, organized by GATE Institute Bulgaria and the Chalmers University of Technology, Sweden
- The 7th IEEE International Conference "Big Data, Knowledge and Control Systems Engineering" (BdKCSE'2021) organized by John Atanasoff Union of Automatics and Informatics

Examples of events organized by business are:

- The annual International Technical Fair, organized in the frame of the prestigious International Fair in Plovdiv – the event provides special attention to Industry 4.0 in recent years. It allows companies to present their products and establish business contacts
- Annual business forum *Industry 4.0*, which has been held in Plovdiv since 2017
- Annual Global Tech Summit which brings together high-tech firms
- Global Conference Women in Tech Sofia 2022
- 2017 Sofia AI Summit, organized by hacker.works
- 2022 Webit Impact Forum, focused on innovations and technologies and organized in Sofia Tech Park
- A number of other relevant events organized in Sofia Tech Park

Bulgaria has also hosted some major regional events that bring together policy makers, scientists and business, e.g. the Fourth Regional Cybersecurity Forum for Europe and the Commonwealth of Independent States in 2020, the Fourth Regional Cybersecurity and Cyber Crime Forum for South East Europe in 2017, the Regional Cybersecurity forum InfoSec SEE (for the Balkans) 2022.

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INTERNATIONAL AND LOCAL PROJECTS ON INDUSTRY 4.0

Bulgaria has been involved in a relatively high number of international EU-funded projects focused on Industry 4.0.

Bulgarian organizations are not particularly active in the EU's Horizon Program and other high-level research programs as compared to organizations from other EU countries. However, a few of them have been involved in EU-funded research projects relevant to Industry 4.0. These projects are briefly presented below:

- ACTPHAST4.0 (Accelerating Photonics Innovation for SMEs: A One Stop-Shop-Incubator) --- creates a photonics innovation incubator to cater to the needs of SMEs in in the context of Industry 4.0 in which photonics technologies are a key enabler
- BEYOND4.0 (Inclusive Futures for Europe BEYOND the impacts of Industrie 4.0 and Digital Disruption) --- examines the impact of the new technologies and Industry 4.0 developments on the future of jobs, business models and welfare
- DiManD (Digital Manufacturing and Design Training Network) --- designs and implements an integrated programme in the area of intelligent informatics-driven manufacturing that should provide the benchmark for training future Industry 4.0 practitioners
- MIND4MACHINES: Manufacturing Industry's Novel Digitalisation Value Chains for Connecting Machines with People, Process and Technology --- focuses on solutions for new cross-sector interconnections and digitalisation value chains combining manufacturing and novel, disruptive solutions in ICT (hardware, software, services and connectivity, Big Data, Cloud Computing, Artificial Intelligence, Blockchain, IoT and Cybersecurity)
- ECHO: European network of Cybersecurity centres and competence Hub for innovation and Operations --- seeks to improve the proactive cyber defence of the EU, through effective and efficient multi-sector collaboration
- 5G-INDUCE: Open cooperative 5G experimentation platforms for the industrial sector NetApps --- develops an open, ETSI network functions virtualisation-compatible, 5G orchestration platform for the deployment of advanced 5G network applications in the Industry 4.0 service deployment environment
- RAINBOW: An Open, Trusted Fog Computing Platform Facilitating the Deployment, Orchestration and Management of Scalable, Heterogeneous and Secure IoT Services and Cross-Cloud Apps --- develops an open and secured fog computing platform that

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will advance the management of extensible, diverse and safe IoT services and cross-cloud applications.

All the projects mentioned above can be explored at https://cordis.europa.eu/.

Some notable projects funded under Interreg focus on improving regional-level policy and enhancing the capacity of regions to support digital transformation and industrial innovation. Under the DIGITAL REGIONS project (Regional policies adopting Industry 4.0 for their Digital Transformation) eight regions engage in policy cooperation with the objective to adapt innovation policies in order to support the transformation of their manufacturing sectors and their transition to Industry 4.0. The CARPE DIGEM project (Catalysing Regions in Peripheral and Emerging Europe towards Digital Innovation Ecosystems) is focused on collaborative development of policy instruments promoting inclusive digital innovation ecosystems and services. The DEVISE project (Digital tech SMEs at the service of Regional Smart Specialisation Strategies) involves 9 regions in efforts to unlock and exploit the potential of digital tech SMEs to boost the competitiveness of other SMEs in sectors included in Regional Smart Specialisation Strategies. The SKILLS+ project (Supporting knowledge capacity in ICT among SME to engage in growth and innovation) is focused on improving SME competitiveness policies through public policies promoting ICTs. In the INNOBRIDGE project (Bridging the innovation gap through converting R&D results into commercial success in a more effective and efficient way) the consortium engages in sharing good practices to empower regional economies to exploit their own Research and Development results by effective commercialization (More about the above 5 projects can be found at https://projects2014-2020.interregeurope.eu/). The DIGITRANS project (Digital Transformation in the Danube Region) addresses the need for new business models in view of the increasing digitisation of business processes. The SMART FACTORY HUB project (Improving RD and business policy conditions for transnational cooperation in the manufacturing industry) engages partners in efforts to improve the cooperation between research and business in the smart factory field (More about the above 2 projects can be found at http://www.interreg-danube.eu/).

Bulgarian organizations participate in many Erasmus+ projects. Such initiatives are primarily contributing to innovations in the field of education or are enabling learning mobility across borders. A great number of projects are focused on digitalization, especially the development of digital skills in the education sector. A few projects are specifically looking into Industry 4.0. Examples of projects led by Bulgarian organizations:

- Upskilling Lab 4.0: focused on developing a model, framework and tools for skills improvement of companies' staff, with a focus on modern technologies and open innovation in the area of Industry 4.0
- Apprenticeship Cluster for Industry-Ready Engineers of Tomorrow: focused on elaborating a new partnership structure between technical universities, enterprises, local authorities and social partners, specifically in the area of Mechanical Engineering

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and Mechatronics and in view of providing work-based learning and apprenticeship that responds to Industry 4.0 job demands.

- Maker schools: Enhancing Student Creativity and STEM Engagement by Integrating 3D Design and Programming into Secondary School Learning: the project develops learning materials for secondary school students in the area of 3D printing and design, including through the use of programming languages.
- Industrial Internet of Things VET Network: raises awareness about the potential and possible applications of the Internet of Things technologies, and contributes to upskilling and reskilling of company employees, professionals and VET providers.

Examples of projects with Bulgarian organizations involved as partners:

- The ICT Engineer of the 21st Century: Mastering Technical Competencies, Management Skills, and Societal Responsibilities --- develops a transnational multidisciplinary intensive study program in the field of ICT-based entrepreneurship
- Digital Transformation in Advanced Manufacturing --- designs, tests, refines and exploits an integrated curriculum in digital transformation competence for mid to high-level technicians
- INGENIOUS-Strengthening Digital Pedagogy Skills and Competencies of Educators --- focuses on developing the digital skills of VET educators
- Developing STEM Competences with Robotics --- focused on learning approaches in Robotics for younger learners
- Joint Cyber Workforce Development Initiative to Enable the European Industry to Overcome the Shortage of Cybersecurity Professionals --- a training package for manufacturing SMEs to ensure data security in the context of Industry 4.0 context and reduce the shortage of staff with cybersecurity competences
- Active Learning Community for Upskilling Technicians and Engineers --- develops a learning platform and a mobile application for the sector of Machine Building and Mechatronics, with course content and industry-relevant problems as source materials for practical assignments
- Work-based training approach in the field of Industry 4.0 for competitive European Industry: provides a training course and promotes work-based learning on the topic of Industry 4.0, with special attention to apprenticeship training, by involving social partners, companies and VET providers.

All the projects presented above can be explored further at https://erasmus-plus.ec.europa.eu/projects.

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INDUSTRY 4.0 AND HIGHER EDUCATION

Industry 4.0 is not usually directly referred to in the programs offered in higher education institutions. There are occasional papers published by Bulgarian academics, but they are mostly introductory in nature and do not suggest a strong research activity in this field in the relevant university faculties. Teaching and research capacity is obviously more developed strictly within individual technical areas making up Industry 4.0. No university offers a comprehensive program covering all aspects of Industry 4.0. In all fairness, this is not surprising and would perhaps not be the most adequate approach at the moment, at this level of development of Industry 4.0 in Bulgaria and considering the available teaching and research capacity. We believe at this stage it is important for universities to focus on providing skills and knowledge in the various study areas that are the building blocks of Industry 4.0 – Artificial Intelligence, Big Data, Internet of Things, Cybersecurity, etc. A more comprehensive approach can be taken at a later stage, when there is sufficient academic capacity.

Annex 2 of this report provides a comprehensive analysis of the Industry 4.0-relevance of all the Bachelor, Masters and Doctoral programs offered in Bulgarian Universities. The data is based on the accreditation results published by the National Evaluation and Accreditation Agency. Looking at the data, we believe several conclusions are in order:

- Almost all Universities offer programs in Computer Science, Information Systems, Informatics and ICTs. This is largely a response to the high demand for ICT specialists on the labor market and also reflects a desire of some of the less popular universities to secure candidates. This is an excellent result at first glance. There is really not much more that could be expected in terms of increasing the availability of such programs. The real issue, however, is the quality of the education offered in some of the non-technical universities. It is beyond doubt that the availability of ICT education will raise awareness of digitalization and will improve the digital skills of the new generation. However, we believe there is a great divide between the level and quality of Computer Science and Informatics education across the different universities, with the Technical Universities and the Kliment Ohridski University in Sofia offering the highest quality IT education. The extent, to which students graduating from other universities are prepared to take up challenges related to programming and the complex technologies making up the backbone of Industry 4.0, is dubious. Another issue is the relevance and applicability of the knowledge received in universities to the actual business needs and the processes and practices in the high-tech industry. Unfortunately, many students still leave the universities not prepared to work with the latest technologies or according to industry standards. While this is a common challenge for all Bulgarian universities (including the leading ones), there is again a quality divide between the main technical universities and the established universities in Sofia and the rest of the

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higher education sector. All in all, in the future Bulgaria needs to focus more on ensuring the quality of IT education than on increasing the quantity of available programs.

- Some of the 52 accredited Higher Education Institutions in Bulgaria offer programs specialized in various areas of Industry 4.0. Out of the range of Industry 4.0 study areas, automation appears to be most widely covered in accredited programs and is available for students in almost all geographical regions. However, it is beyond doubt that great variations in quality are observed in this area, too. At the very least, the Technical Universities and the Kliment Ohridski University in Sofia are the only ones that boast relatively strong cooperation with business and well-equipped laboratories featuring industry-grade technologies and robots, which allows them to offer quality practical training and generally relevant courses. In the area of Artificial Intelligence, Big Data, Mechatronics and Robotics there are just a few programs that are unlikely to be able to meet the future demands for skills in these areas. Internet of Things is not taught as a comprehensive program as of now but is taught as a course in some universities. At first glance, there are quite a few programs on cybersecurity, but the fact is that the available academic offer is mostly focused on the national security aspects; cybersecurity is usually taught in the Military Academies or as part of the National Security professional stream. It is thus unclear if Bulgaria has the necessary educational offer to ensure specific cybersecurity and information security skills for industry, seeing as the offer in the area of information security is also not great. There are some programs on innovation management and tech entrepreneurship, which is encouraging. However, this offer needs to diversify and grow, too.

All in all, ICT has become by far the most popular discipline in secondary schools and universities but issues remain. Firstly, quality of the programs can be significantly improved. Secondly, the uptake of digitalisation in non-ICT majors remains limited, which is one of the reasons why we are not seeing fast improvement in the levels of digital literacy in the country. Importantly, the availability of programs and courses in the key technology areas of Industry 4.0 appears insufficient to meet future demands. If Bulgaria is to enact a shift toward Industry 4.0 and further develop its high-tech industries, a concerted effort involving higher education institutions and business needs to be made to ensure that the educational system has the capacity to produce a sufficient number of adequately qualified professionals. There is also room for innovation in higher education to provide training tailored to the needs of SMEs. This could be achieved through modular, blended courses delivered in specific sectors and geographical regions, with flexible timing, and with practical content.

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Outside the formal higher education sector, ICT businesses have already started developing alternative education and training institutions or have been teaming up with existing universities to provide specific training. An important facilitating factor for the development of the strong innovation-based ICT sector in Sofia City has been the establishment of several private training and education academies and other talent-developing initiatives of leading ICT companies, e.g., Musala, Telerik Academy, SoftUni, LeanPlum, etc. The new educational offers are primarily geared towards meeting the rapidly rising demand for outsourcing IT services and, considering the short duration of the programs, cannot by themselves develop deeper ICT engineering and innovation skills. However, training in these institutions is led by industry professionals and is sufficiently practical, applicable and relevant to industry standards.

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COMPANIES AND INDUSTRY 4.0

Despite the challenges in the last years, industry in Bulgaria is increasingly adopting automation solutions and investing in hi-tech equipment. Among the companies that recently made substantial investments are Alcomet (manufacturer of rolled and extruded aluminium products), Teklas-Bulgaria (manufacturer of rubber, plastic and metal products), Ewellix (producer of linear motion components and actuation solutions), Ottobock Bulgaria (prosthetics company), Extrapack (manufacturer of paper, plastic, bioplastic, woven and non-woven polypropylene bags), Rollplast (production and installation of aluminium, plastic and wooden joinery), Asarel Medet (copper extracting and processing factory), Astro Clima (manufacturer of heating, air conditioning and ventilation systems), Schneider Electric (energy management and automation), Hills (brewery).

The IT sector in Bulgaria has been expanding at a rate almost twice as high as the growth rate in the rest of the economy. During the last two decades, leading multinational ICT companies have established R&D centres in Bulgaria. Notable examples are VMWare Bulgaria, Software AG, SAP, Devexperts, Paysafe, Integrated Microelectronics, Datecs, Progress, Bosch Software Innovations Sofia, IDT Bulgaria, LeanPlum, Atscale Bulgaria, Nuvolo Technologies Bulgaria, Crayon Bulgaria. Some indigenous Bulgarian companies have also managed to stand out with innovative products and occupy specific market niches - Chaos Software, Ontotext, Interconsult Bulgaria, Mobile Systems, Software Group Bulgaria, etc. Sofia-city has seen an influx of R&D intensive multinationals in the ICT sector and creation of new start-ups, especially in FinTech, Internet of Things and data analytics (e.g. Payhawk, Connectedbin, Phyre, Sirma Medical Systems, Bizportal, ProDron Sys, Sensika Technologies, etc.).

The export of ICT and mechatronics products and services has been steadily increasing in the last decade. Bulgaria has mostly been regarded as a preferred destination for outsourcing software development, largely due to cost-effectiveness for leading US, UK and European software companies. Outsourcing capacity in the Bulgarian IT sector has been steadily growing, together with the talent pool. The main factors that make Bulgaria an attractive destination for software development outsourcing are the availability of qualified software developers working at the lowest hourly labor cost in the European Union and the geographical proximity to the European market. Additional advantages are the good working ethics, the massive adoption of agile methodology in working processes and a good level of knowledge of the English language. More than 70% of the software companies in Bulgaria use English as a working language.

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The Bulgarian domestic market for new technologies is very small. The B2B market within the mechatronics and ICT sectors is limited both within each of the sectors and between the sectors. There are some cluster organisations serving sub-sectors in ICT and mechatronics that work to the benefit of their members. These cluster organisations receive funding through the EU operational programs.

Despite the positive effects of the outsourcing boom on the expansion of the IT sector, it has tended to lead to specialization in services with less added value, and it has not really instigated a remarkable development in Industry 4.0. On the positive side, the trend for the future appears positive. Most companies are increasingly moving away from providing low-cost services with little added value toward developing products and solutions with higher added value. There has been an associated rise in patenting and publication activity in the area of technology, although Bulgaria's performance in this area remains low by European standards.

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DEMAND FOR SKILLS AND KNOWLEDGE IN THE CONTEXT OF INDUSTRY 4.0

In Bulgaria, the demand for skills and knowledge in the context of Industry 4.0 is not significantly different from the demand worldwide, especially if we adopt a future-proof approach and factor in the expected further growth in the main sectors relevant to Industry 4.0. We can thus expect an increasing demand for specialists in robotics, cybersecurity, big data management, big data analytics, data security, network engineering and cloud computing, machine learning, Internet of Things, Artificial Intelligence. The demand for software engineers, software developers, programmers and IT architects will remain high. Knowledge and skills in industrial management will need to be adapted to the new realities. Among the basic soft skills that will be needed will be adaptability and knowledge in skills for managing and working in agile environments. Innovation management skills will become increasingly applicable for a growing number of industries. Finally, tech entrepreneurship needs to be developed in terms of both skills and attitudes.

In the education sector, there will be a growing demand for specialists in transfer of technology, as well as for boundary spanners able to effectively link business, research and education within the innovation ecosystems at national, regional and local levels.

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BEST PRACTICES FOR DIGITAL TRANSFORMATION AND IMPLEMENTATION OF THE INDUSTRY 4.0 CONCEPT

1. Best practice for digital transformation and implementation of the Industry 4 concept in Bulgaria.		
1	**Best practice name**	Asarel-Medet AD and Asarel Mining and Processing Complex - X-Mine project
2	**Sector**	Copper extracting and processing factory
3	**Organization implementing/disseminating the practice**	Address: locality Asarel Panagyurishte, 4500 Bulgaria ASAREL-MEDET AD has 1,200 employees at this location and 400 more employed in subsidiaries and joint ventures. Website: www.asarel.com
4	**The goal**	By implementing new technologies and integrating Industry 4.0 elements, the company aims to improve their technological processes on different levels and across all its ventures and subsidiary structures. Moreover, such systems and technologies help the company to minimize the human mistakes, to save time for production and improve the communication and exchange of information across different structures.

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5	**Description / Focus**	This is the largest Bulgarian mining company for open pit and copper ore processing. In 2021 the company has completed the renovation process of their entire technological chain. The Asarel mine and Asarel concentrator plant for copper concentrate recovery are two of the major production workshops of the Asarel-Medet JSC Mining and Processing Complex. The modern interstructure also includes a Return Water Sector, Copper Microbiological Leaching Facility, and Cyclic Flow Conveyor Technology for mined material transportation, SX-EW Facility, Purification Stations, etc. In 2019 the company started to work on upgrading their existing ERP system, which, thanks to thousands of sensors, allows them to gather a huge flow of information which can then be literally traced via the manager's phone. The system shows, for instance, micro-cracks in the machine, long before it breaks, so that it can be replaced just in time. It also measures production in real time – what goes in and out of the factory, etc. The new ERP system is one of the main projects that take part of the digital transformation strategy of the company. The systems used is from the series SIMATIC PCS7 by Siemens - Bulgaria and allows to control the entire production process along the chain. This significantly improves the efficiency and safety on different levels as well.

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		Another digitalization process implemented by the company is the adoption of Integrated Information System that supports mine planning at the Asarel Mine. According to official announcement by the Mine Manager, Ivan Andreev published on the official website of the company this is "*A unique project on the Balkans that integrates into a common information system the drilling and blasting mining activities with a digital geological, structural and hydrogeological model of the Asarel deposit*". At Asarel-Medet, the system will encompass all processes which the Mine Engineering department and Drilling and Blasting Activities unit at the Asarel Mine are in charge of, that are: geological explorations and geological block model development of the deposit, mining activity planning and drilling and blasting works designing to reporting the mined material and assessing the wall slope and wall stabilities. The implementation of the digital system for drilling and blasting activities was completed in 2020 and now allows faster, more efficient and safe operations. Asarel-Medet is the only Bulgarian company which forms part of the large-scale research X-Mine project coordinated by VTT, Technical Research Centre in Finland. The international innovation consortium unites scientific institutes, equipment manufacturers and mining companies from various European countries. The X-Mine develops new geological exploration sensor technologies and implements digital applications for

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		deposit modelling and more efficient ore processing. As a result the company uses a sensor scanner for drill cores from specialized geological exploration, automated mineral sorting equipment and a new specialized software for result assessment and analysis. This improves ore mining and processing efficiency and has a favourable environmental protection impact according to Desislav Ivanov and Stanislava Milusheva who are part of the Mine Engineering department team at Asarel-Medet. The new sensor technologies are based on X-ray fluorescence (XRF), X-ray transmission (XRT) and 3D visualization technologies. All of them are incorporated to mineral sorting equipment as well as ore deposit modelling and mining operations planning software systems.
6	**Target groups**	The employees and staff members at Asarel-Medet AD and all its subsidiaries and joint ventures. Students who participate in the company`s summer internship program.
7	**Results / impact with a focus on:** **1. sector** **2. individuals, like students or employees**	X-Mine is a project funded under Horizon 2020 program of the European Commission. Thanks to it, the mining companies who participate in this project (including Asarel-Medet) are anticipated to achieve up to 20% reduction of their transportation costs, 7% reduction of handled waste, from 10 to 30% lower power consumption and carbon emissions reduction. The schedules envision that the products would be

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		commercialized within two years after the project completion when other companies will have access to these technologies as well. By applying new methods and technological operations, the mineral grain size, their distribution and the entire structural, geological, geochemical and mineralogical information will become known even at the geological exploration stage. As a result, the mining will become more efficient. Furthermore, the environmental impact will also be reduced because less mining waste will be generated and mining locations will be more accurately selected.
8	**What were the obstacles?**	Although the time needed for completion of all systems was not stated as an obstacle, it can be considered as one. Due to the complexity of the processes and the big infrastructure included in the projects, the completion and full integration of digital systems took few years.
9	**What innovative skills the described above best practice might have developed to enhance students' employability?**	Skills how to work and operate with ERP system by Siemens - SIMATIC PCS7 Skills for data processing and management Skills for analysing data Skills to work with specific equipment and sensor technologies

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2. Best practice for digital transformation and implementation of the Industry 4 concept in Bulgaria		
1	**Best practice name**	Plovdiv Innovation Hub & Smart Factory
2	**Sector**	Digital technologies and digital solutions
3	**Organization implementing/disseminating the practice**	The Schneider Electric Smart Factory is located in Plovdiv and occupies an area of 12,000 square meters. Address: Industrialna Str., 4201 Plovdiv https://www.se.com/bg/bg/about-us/alliances/
4	**The goal**	Schneider Electric, a leader in digital transformation of energy management and automation, opened its first Innovation Hub in the region of Eastern Europe. The Innovation Hub is a demo space that allows visitors to experience live the company's IoT technology. The facility is located in Schneider's showcase plant in Plovdiv, Bulgaria, that meets the highest internal standard of the Schneider Group for industrial production, automation and effective process management.
5	**Description / Focus**	The Smart Factory in Plovdiv manufactures 42 million circuit breakers per annum. Through them the company provides electrical distribution and protection to people from about 30 countries.

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		Nearly 70% in the manufacturing facility are fully automated and operational processes are digitalized through the company`s applications. Moreover, the team of Smart Factory continues to implement new technologies including creation of digital solutions on the spot in case the corporate tools do not offer such solutions. Productivity and efficiency are managed through data collection and visualization in user-friendly dashboards that enable quick and informed decision-making process. Maintenance is done with the help of augmented-reality-based solution that saves time and make the process completely paperless. As a result, the workforce is more empowered, and people's knowledge is constantly advancing. In 2019, the production site in Bulgaria received the highest level of industrial certification in the company – Smart Factory. It is one of the biggest and most modern plants in Europe in the digital transformation of energy management and automation systems. The enterprise became the first Smart Factory of the Schneider Electric across Eastern Europe and the second one in the whole of Europe. The Smart Factory certificate attests to the highest level of technological maturity of Schneider Electric manufacturing. The premises of the factory are managed with a BMS (Building Management System) and are equipped with a power management system. These have allowed the

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		enterprise to become the first in Bulgaria with an ISO 50001 power management standard. Maintenance of machines and facilities is carried out based on the software application Augmented Operator Advisor – an application that allows the maintenance staff to see technical information and suggestions for replacement and prophylaxis of parts visualized as an element of a snapshot of the inspected equipment. All this was achieved thanks to Schneider's IoT platform EcoStruxure. It makes possible connecting devices in various architectures depending on the scale necessary for the particular site; data management and collection, as well as work with tools for preventive and predictive maintenance. EcoStruxure consists of three main layers – connected devices, edge control and software, applications and services – and allows building of different architectures to the scale required for each site, managing and collecting data, as well as working with preventative and predictive maintenance tools.
6	**Target groups**	Businesses and companies Students and teachers People interested in Industry 4.0, digital transformation and application of new digital technologies
7	**Dissemination / implementation method**	Apart from the application of new technologies, applications and systems related to digital transformation, the Smart Factory in Plovdiv organizes

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		webinars and organized visits of the facilities. During these visits people can see in practice how new technologies are integrated and used in the production processes of the factory.
8	**Results / impact with a focus on** **1. sector** **2. individuals, like students or employees**	The achievements and new technologies used by the Smart Factory have a positive direct impact on the companies and businesses in the area, because it gives a good example how digitalization of operational processes can save resources and improve the overall performance of the company. Through the webinars and organized visits of the facilities, the factory have also direct impact on students and other people interested in Industry 4.0 and digital transformation.
9	**Sustainability**	Also, the facility gives good example how Industry 4.0 and digital transformation can foster the sustainability in operational processes.
10	**What innovative skills the described above best practice might have developed to enhance students' employability?**	Knowledge and skills related to digital transformation and creating digital ecosystem. Knowledge and skills related to industrial digitalization and smart solutions. Knowledge and skills related to building management and automation solutions.

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3. Best practice for digital transformation and implementation of the Industry 4 concept in Bulgaria		
1	**Best practice name**	Software University - SoftUni
2	**Sector**	Tech Education
3	**Organization implementing/disseminating the practice**	Software University – SoftUni organizes online and onsite courses and training programs. Address: Aleksandar Malinov Boulevard 78, 1799 American college, Sofia Website: https://softuni.bg/ (Bulgarian) and https://softuni.org/ (International)
4	**The goal**	SoftUni is the biggest tech education provider for business and software development in South-Eastern Europe. It offers study programs and courses in software engineering, prorgamming and other IT topics. By collabortaion with tech and IT companies and proffesionals SotUni continuously updates their study programs in order to meet the current market needs and equip threir students with relevant knowledge and competitive skills. SoftUni is a Bulgarian licensed training center under the Vocational Education and Training Act. After each successful course (with a grade equal to or higher than

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		3.00 in theory and practice), students receive a state-recognized "Vocational Training Certificate", as well as an application valid throughout the European Union.
5	**Description / Focus**	SoftUni organizes in-depth professional program in software engineering in Bulgaria, providing students with the opportunity to acquire the profession of "software engineer". The curriculum has been developed with direct participation of IT companies and experts and is based on the „learning by doing" approach. Thus, the study program includes working with the latest software technologies and learning best practices in the field of programming. In addition to the curriculum in software engineering, SoftUni organizes a number of courses on various topics in the IT and digital field such as Systems Administration, AI (artificial intelligence), Cloud, Blockchain, Cybersecurity, Robotics and many others. Although students have the possibility ot attend classes online, it is usually recoomeded for those enrolled in Programming Basics course to attend the classes physically in the SoftUni classrooms. Depending on the topic, classes have duration of 3 to 4 hours. Classes include a lecture with live demonstrations, questions and exercises in class under the mentorship of the lecturers. In most of the cases, homework tasks have to be uploaded in the automated Judge system. The same system is used also during the exams. Students are are

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		asigned with tasks that they have to solve and upload. Their assessment is done authomatically and immediatelly by Judge system, i.e. students receive a real-time feedback. Thus, the exam and evaluation processes are entirelly automated, which saves time and reduces teh risk of mistakes. Software University offers to its students to take advantage of their Career Center that was created in order to support and assist students and graduates to find a job. According to the published information in SoftUni website, the Career Center helps students to find a job within the period of 2 weeks to 2 months. Depending on the specifics of hiring processes and number of candidates in different companies this period may require longer time. In addition to the couses offered in Bulgaria, in 2019, SoftUni successfully organized trainings in Romania, Singapore, the Philippines and Poland, providing free training in programming, as well as a comprehensive software engineering curriculum. Furthermore, in 2021 it was launched the SoftUni Global initiative, which aims to provide quality learning content to those wishing to enter programming from anywhere in the world.

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6	**Target groups**	Students Professionals in IT sector who want to aquire additional knowledge and/or qualifications Young emplyees who want to build additional competences in IT sector and topics Companies and businesses who want to provide additional training to their staff members to improve their digital skills.
7	**Results / impact with a focus on** **1. sector** **2. individuals, like students or employees**	According to the information pubclished on the official website of SoftUni Global the comany acheived the following results: • 97% of graduates begin work in the IT sector • Over 15 200 graduates • Community of more than 300 000 students • More than 100 partnerships with leading companies in the IT sector • Organized and implemented trainings in more than 40 cities in Bulgaria • Created 23 000 video lessons lasting over 70 000 hours • Organized over 2 000 training sessions and over 1 500 seminars and events • Over 12 000 created projects • Over 26.6 million exercise submissions

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8	**What innovative skills (if any) the described above best practice might have developed to enhance students employability?**	Each program and course offered by SoftUni focuses on developing particular skills in certain areas. Some of these skills are in the fields of: Software engineering Programing
9	**References**	https://softuni.bg/ https://softuni.org/

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4. Best practice for digital transformation and implementation of the Industry 4 concept in your country.		
1	**Best practice name**	Technological park at the Technical University of Gabrovo.
2	**Sector**	Higher education
3	**Organization implementing/disseminating the practice**	Technical Univeristy of Gabrovo
4	**The goal**	The technology park and the laboratories that are part of it imply the implementation of scientific and applied research of scientists from the partner organizations, including for the needs of business. Moreover, the modern equipment provides opportunities for the universtity to develop and intergate sustainable and modern learning practices in the training of undergraduate and graduate students. The tecnology park provides opportunities for lecturers, postgraduates, researchers and students to work and excel their knowledge and practical skills in various aspects in the field of Industry 4.0.

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5	**Description / Focus**	Technical University - Gabrovo is an educational and scientific institution that has a modern base and manages one of the most modern technology parks in Bulgaria that was established in 2020. The Technology Park of the Technical University of Gabrovo has in total 18 laboratories of the Competence Centre "Intelligent, Mechatronic, Eco and Energy Saving Systems and Technologies", Centre of Excellence "National centre of mechatronics and clean technologies", Competence Centre "Quantum Communication, Intelligent Security and Risk Management Systems (QUASAR)" and the Centre for Competence "Digitalisation of the Economy in Big Data Environment", funded by the Operational Program Science and Education for Smart Growth, co-financed by the European Regional Development Fund. Various institutions, associations, universities, and entities partner with TU Gabrovo in the establishment of the laboratories. The Centre for Competence laboratories "Intelligent, Mechatronic, Eco - and Energy Saving Systems and Technologies" are the basis of the Technology Park of the Technical University of Gabrovo. The laboratory complex Energy saving systems and technologies for design and production of high-tech products includes 4 laboratories. At the CAD/CAM systems for design and production of high-tech products laboratory is

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		performed scientific and applied research related to the development, modelling and optimization of technological processes and new designs of cutting and combined tools. A 5-axis lathe-milling machining centre was purchased for the production of complex parts. A 3D metal printer and specialized software for additive technologies were purchased within the Laboratory Additive and Energy Saving Technologies and Equipment. Laboratory Intelligent Technologies Based on Intensive Energy Flows is implemented as a result of the partnership between the Technical University of Gabrovo and the Institute of Electronics at BAS. The laboratory performs scientific and applied research in the field of electron-beam welding and surface modification of metals and alloys for the mechatronics needs. A machine for dynamic and static tests and a semi-automatic microhardness tester have been installed at the laboratory Energy saving technologies for prolonging the life cycle and increasing operational safety. The equipment performs static or dynamic load tests according to the requirements of international standards of metallic and non-metallic materials. Two laboratories, equipped with unique equipment and specialized software are built at the laboratory complex Intelligent mechatronic systems for measurement and control. At the laboratory Intelligent mechatronic systems for measuring static and dynamic quantities can be performed measurements with

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		proven accuracy of the geometric parameters of machine-building products, study of the accuracy and calibration of measuring instruments and systems in accordance with the industry needs. X-ray diffractometry of monolithic materials and thin layers, qualitative and quantitative analysis of structural, phase and composite polycrystalline materials, as well as measurement of residual stresses in monolithic polycrystalline materials and residual austenite are performed at the laboratory Intelligent systems for studying the structure and properties of materials. Laboratory complex Intelligent energy saving systems and technologies has 6 new laboratories – Development of eco and energy saving, contactless electricity transmitters; Development of methods and tools for solving energy and infrastructure problems related to mass electric mobility; Environmental, energy saving and electromagnetically compatible lighting, LED and RES components and technologies; Energy efficient systems and technologies using heat and hydraulic energy and secondary and renewable energy sources; Electric drive and electrical equipment - contemporary energy-efficient electrical components and systems with application in the industrial sector. The laboratory complex Electronics and Sensors has 2 laboratories Microelectronic and microprocessor devices and systems and Sensors and sensor systems

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		for development of sensor elements for humidity, gases and temperature and microelectronic and microprocessor devices and systems. Within the Centre for Excellence "National Centre for Mechatronics and Clean Technologies" was built the laboratory "Accurate measurements of dynamic quantities in mechatronics", part of the laboratory complex "Robotic mechatronic technologies". This is the only laboratory in the country, which has a mechatronic system with six degrees of freedom to study dynamic characteristics, with reference properties, which will experimentally determine and study the dynamic characteristics of machines and equipment subjected to alternating mechanical effects (land vehicles, ships, and aircraft). Two laboratories are built on the territory of the Technical University of Gabrovo within the project "Quantum communication, intelligent security and risk management systems" (QUASAR). The Quantum Communication Laboratory has a CLAVIS quantum communication platform, which includes a complete quantum key sharing system (QKD system), supporting a coherent one-way protocol (COW protocol), quantum random number generators, switches and service equipment with specialized measuring equipment. The Innovative sensor technologies laboratory has specialized equipment and software for design,

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		measurement, diagnostics and analysis of sensors and electronic products. The Technology Park also includes a laboratory Digitalization of the economy in a big data environment that examines problems of the economy digitalization in a Big Data environment.
6	**Target groups**	Students and researchers of all levels and academic staff at the university Partner organisations and institutions Businesses Other organisations – public and non-governmental interested in projects and topics related to Industry 4.0 and relevant to the fields of research of the laboratories inside the Technology park.
7	**Results / impact with a focus on** **1. sector** **2. individuals, like students or employees**	The access to the laboratories and the opportunity to work with these technologies and systems allow students, researchers, and other academic staff to better understand theory and to gain practical experience. Partner institutions, organisations, and businesses develop projects related to Industry 4.0 and relevant to the fields of research of the laboratories inside the Technology park.

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8	**What innovative skills (if any) the described above best practice might have developed to enhance students employability?**	Thechnology park implements vairous projects that are entirely focues on businesses. Students and PhD students can participate in these projects as well. In this way they further develop their practical skills and knowledge in the filed of Industry 4.0. The exersices and work at the laboratories on different business-related projects equip students with more practical skills related to automation technology solutions. They gain knowledge and experience in working on specific tasks. Not only students improve their professional skills, but they also improve and develop various soft skills, such as team work, business communication, meeting deadlines, work on projects that are very improtant for becoming more successfull on labour market.
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APPENDICES

Appendix 1: Additional statistics and economic indicators on digitalisation, digital skills and Industry 4.0

Additional enterprise indicators pertinent to electronic information sharing

Indicator	Year when data is provided	Bulgaria	EU-27
Enterprises using CRM to analyse information about clients for marketing purposes (% of enterprises)	2021	11%	19%
Enterprises using CRM to capture, store and make available clients' information to other business functions (% of enterprises)	2021	15%	34%
Enterprises whose business processes are automatically linked to those of their suppliers and customers (% of enterprises)	2017	17%	18%
Enterprises using automated data exchange with other ICT systems outside the own enterprise (% of enterprises)	2012	49%	52%
Enterprises using automated data exchange for receiving orders from customers (% of enterprises)	2010	29%	26%
Enterprises using automated data exchange for sending or receiving data to / from public authorities (% of enterprises)	2012	45%	38%

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Enterprises using automated data exchange for sending or receiving transport documents (% of enterprises)	2012	16%	24%
Enterprises using automated data exchange for sending orders to suppliers (% of enterprises)	2010	13%	30%
Enterprises that share electronically information suitable for automatic processing with external business partners or on the SCM with suppliers or customers (% of enterprises)	2010	39%	51%
Enterprises that share electronically information suitable for automatic processing within the enterprise and with external business partners (% of enterprises)	2010	24%	34%
Enterprises that regularly share electronically information with customers on inventories, production plans or demand forecasts (% of enterprises)	2010	9%	9%
Enterprises using automated data exchange for sending or receiving product information (% of enterprises)	2011	31%	34%
Enterprises using automated data exchange for sending payment instructions to financial institutions (% of enterprises)	2012	24%	37%
Enterprises using automated data exchange for sending / receiving data to / from public authorities and using internet for treating an	2011	28%	22%

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administrative procedure completely electronically (% of enterprises)			
Enterprises using automated data exchange for sending / receiving data to / from public authorities and using internet for returning filled in forms (% of enterprises)	2012	43%	34%
Enterprises who share electronically information with suppliers and customers on inventory levels, production plans, demand forecasts or progress of deliveries (% of enterprises)	2012	26%	13%

Additional enterprise indicators pertinent to Industry 4.0 technologies – Internet of things

Indicator	Year when data is provided	Bulgaria	EU-27
Use smart meters, smart lamps, smart thermostats to optimise energy consumption in the enterprise's premises (% of enterprises)	2021	3%	6%
Use sensors, RFID or IP tags or internet-controlled cameras to improve customer service, monitor customers' activities or offer them a personalised shopping experience (% of enterprises)	2020	4%	5%
Use movement or maintenance sensors to track the movement of vehicles or products, to offer condition-based maintenance of vehicles (% of enterprises)	2020	6%	7%

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Use sensors or RFID tags to monitor or automate production processes, to manage logistics, to track the movement of products (% of enterprises)	2020	2%	3%

Additional enterprise indicators pertinent to Industry 4.0 technologies – Artificial Intelligence

Indicator	Year when data is provided	Bulgaria	EU-27
Enterprises with a chat service where a chatbot or a virtual agent replies to customers (% of enterprises)	2020	2%	2%
Enterprises use one AI system (of E_CHTB, E_BDAML, E_BDANL, E_RBTS) (% of enterprises)	2020	5%	6%
Enterprises use two AI systems (of E_CHTB, E_BDAML, E_BDANL, E_RBTS) (% of enterprises)	2020	0%	1%
Enterprises use AI technologies for performing analysis of written language (% of enterprises)	2021	1%	3%
Enterprises use AI technologies for converting spoken language into machine-readable format (% of enterprises)	2021	1%	2%
Enterprises use AI technologies for generating written or spoken language (% of enterprises)	2021	0%	1%
Enterprises use AI technologies for identifying objects or persons based on images (% of enterprises)	2021	1%	2%

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Enterprises use AI technologies enabling physical movement of machines via autonomous decisions based on observation of surroundings (% of enterprises)	2021	0%	1%
Enterprises' AI technologies were developed by own employees (% of enterprises)	2021	1%	2%
Enterprises' AI technologies were commercial software or systems modified by own employees (% of enterprises)	2021	1%	2%
Enterprises' AI technologies were open-source software or systems modified by own employees (% of enterprises)	2021	1%	2%
Enterprises' AI technologies were commercial software or systems ready to use (% of enterprises)	2021	2%	4%
Enterprises' AI technologies were developed or modified by external providers (% of enterprises)	2021	1%	3%

Additional enterprise indicators pertinent to Industry 4.0 technologies – Big Data

Indicator	Year when data is provided	Bulgaria	EU-27
Analyse big data from other sources (than E_BDASDS, E_BDALOC, E_BDASM) (% of enterprises)	2020	2%	3%

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Analyse big data internally using natural language processing, natural language generation or speech recognition (% of enterprises)	2020	0%	1%
Analyse big data internally using other methods (than E_BDAML, E_BDANL) (% of enterprises)	2020	5%	5%

Additional enterprise indicators pertinent to Industry 4.0 technologies – 3D Printing

Indicator	Year when data is provided	Bulgaria	EU-27
Use 3D printing for prototypes or models for sale (% of enterprises)	2020	1%	2%
Use 3D printing for prototypes or models for internal use (% of enterprises)	2020	2%	3%
Use 3D printing for goods for sale, excluding prototypes or models (% of enterprises)	2020	0%	1%
Use 3D printing for goods to be used in the enterprise's production process, excluding prototypes or models (% of enterprises)	2020	1%	2%

Additional enterprise indicators pertinent to Industry 4.0 technologies – Automation

Indicator	Year when data is provided	Bulgaria	EU-27
Use service robots for surveillance, security or inspection tasks (% of enterprises)	2020	1%	0%

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Use service robots for transportation of people or goods (% of enterprises)	2020	0%	1%
Use service robots for cleaning or waste disposal tasks (% of enterprises)	2020	0%	1%
Use service robots for warehouse management systems (% of enterprises)	2020	0%	1%

Additional enterprise indicators pertinent to Industry 4.0 technologies – Cybersecurity

Indicator	Year when data is provided	Bulgaria	EU-27
Enterprises experienced at least once problems due to ICT security incident: unavailability of ICT services (% of enterprises)	2019	13%	10%
Enterprises experienced at least once problems due to ICT security incident: destruction or corruption of data (% of enterprises)	2019	7%	6%
Enterprises experienced at least once problems due to ICT security incident: disclosure of confidential data (% of enterprises)	2019	1%	1%

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Appendix 2: Higher Education programs relevant to Industry 4.0

Source: National Evaluation and Accreditation Agency (https://www.neaa.government.bg/)

University	Programs in areas enabling Industry 4.0 skills (Bachelor, Masters or Doctoral programs)	Programs directly related to Industry 4.0 (Bachelor, Masters or Doctoral programs)
American University in Bulgaria	Computer Science (Bachelor) Information Systems (Bachelor)	
Bourgas Free University	Software Engineering (Bachelor and Masters) Computer modelling (Bachelor) Applied Informatics (Bachelor) Business information technologies (Masters) Computer systems and technologies (Bachelor and Masters) Informatics (doctoral)	Artificial Intelligence and Robotics (Masters) Information security (Masters)
Varna Free University "Chernorizets Hrabar"	Digital Economics (Bachelor) Informatics and Computer Science (Bachelor) Digital Marketing and Web Design (Masters) Software Engineering (Masters)	Data Science (Masters) Cybersecurity (Masters)

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	Software Engineering and Management (Masters) Information systems and Technologies, Informatics and Computer Science (Doctoral)	
"St. Cyril and St. Methodius" University of Veliko Tarnovo	Informatics (Bachelor) Computer Science (Bachelor) Software Engineering (Bachelor) Information Brokering and Digital Media (Bachelor) Informatics – Information Systems (Masters) Informatics – Corporate Network Architecture (Masters) Computer Science – Applied Computer Science (Masters) Web technologies and Software Development (Masters) Informatics (Doctoral)	Informatics – Data Security (Masters)
"Georgi Benkovski" Bulgarian Air Force Academy		Electrical engineering, Electronics and Automation (Bachelor and Masters) Automated information processing and

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		management systems (Doctoral)
Naval Academy "N. Vaptsarov"	Information and Communication Technologies (Bachelor and Masters)	Cybersecurity (Bachelor and Masters) Automated information processing and management systems (Doctoral)
Higher School of Transport "Todor Kableshkov"	Communication and computer equipment and systems (Bachelor and Masters)	Network and information security (Masters)
Varna University of Management	Software systems and technologies (Bachelor)	
High College of Telecommunications and Posts	Network communication (Bachelor) Computer administration of software applications (Bachelor) Software design (Bachelor) Computer technologies (Bachelor) Mobile communications and Internet (Masters) Information Technologies (Masters)	High Tech Cybersecurity (Bachelor) Cybersecurity of communication technologies (in Bulgarian and English)
Military Academy "G. S. Rakovski"	Communication Networks and Systems (Doctoral)	Cybersecurity (Doctoral)

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European Polytechnical University	Applied Informatics (Bachelor) Management of information (Masters)	Information security (Masters) Personal data security management (Masters)
University of Economics – Varna	Informatics (Bachelor, Masters, Doctoral) Informatics and Computer Science (Bachelor) Mobile and web technologies (Bachelor and Masters) Computer Science (Masters)	
National Military University "Vasil Levski"	Communication technologies (Bachelor and Masters) Computer systems and technologies (Bachelor and Masters) Communication networks and systems (Doctoral)	Cybersecurity (Bachelor and Masters) Artificial Intelligence (Masters) Computer systems and cybersecurity (Bachelor) Automated information processing and management systems (Doctoral) Automation, information and control technology (Bachelor and Masters) Automated information processing and

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		management systems (Doctoral)
New Bulgarian University	Informatics (Bachelor and Doctoral) Information technologies (Bachelor) Network technologies (in English) (Bachelor) IT project management (Masters) Software technologies on the Internet (Masters) Telecommunications and computer technologies (Bachelor) Innovation and entrepreneurship in computer and communication technologies (Masters) Innovations and technologies in modern business (Masters) Telecommunications (Doctoral)	Knowledge mining and big data (Masters) Cybersecurity (Masters)
"Paisii Hilendarski" Plovdiv University	Informatics (Bachelor) Business Information Technologies (Bachelor) Software Technology and Design (Bachelor) Software Engineering (Bachelor) Business informatics (in English) (Masters)	Software technologies – Artificial Intelligence (Masters) Cybersecurity (Masters)

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	Software technologies - graphics and user interfaces (Masters) Software technologies - mobile systems and applications (Masters) Software technologies - software architectures and tools (Masters) Business software technologies (Masters) Software development and deployment (Masters) Computer and communication systems (Bachelor) Information and computer engineering (Bachelor and Masters) Telecommunication and information systems (Bachelor and Masters)	
"Angel Kanchev" University of Ruse	Informatics (Masters and Doctoral) Computer Science (Bachelor) Informatics and information technologies in business (Bachelor) Software Engineering (Bachelor and Masters) Technologies for digitally programmed machines (Masters)	Computer control and automation (Bachelor) Automation, information and control technology (Bachelor and Masters) Automation and mechatronics (Masters) Automation and computer systems for automation (Masters)

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	Computer technologies in Mechanical Engineering (Masters) Computer systems and technologies (Bachelor and Masters) Telecommunication systems (Bachelor and Masters) Telecommunication networks (Masters) Internet and mobile communications (Bachelor) Information and communication technologies (Bachelor) Computer systems and networks (Masters)	Automation of production (Doctoral) Automation in non-material sectors (Doctoral) Communication networks and systems (Doctoral) Automated information processing and management systems (by industry sector) (Doctoral)
Sofia University "St. Kliment Ohridski"	Informatics (Bachelor) Computer Science (Bachelor. Doctoral) Software engineering (Bachelor) Information systems (Bachelor, Masters, Doctoral) Information technologies (Doctoral) Software technologies (Doctoral) Discrete and algebraic structures (Masters) E-business and e-governance (Masters) E-business (Masters)	Embedded systems (Masters) Mechatronics and robotics (Masters) Artificial Intelligence (Masters) Protection of information in computer systems and networks (Masters) Information extraction and knowledge discovery (Masters)

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	Information technology services and projects (Masters) Distribution systems and mobile technologies (Masters) Software technologies (Masters) Technologies for knowledge and innovation (Masters) Technological entrepreneurship and innovation in information technology (Masters) Computer engineering (Bachelor) Communications and Physical Electronics (Bachelor and Masters) Wireless networks and devices (Masters) Communication and computer technology (Masters)	Data Science (Doctoral)
D. A. Tsenov Academy of Economics	Business informatics (Bachelor) Information systems and technologies in business (Masters) E-business and digital markets (Masters)	
Technical University - Varna	Computerized technologies in mechanical engineering (Bachelor and Masters) Communication and computer technologies (Bachelor and Masters)	Repair and operation of mechatronic devices (Bachelor)

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	Tech entrepreneurship and innovation (Bachelor) System programming (Doctoral) Computer systems and networks (Doctoral) Communication networks and systems (Doctoral)	Industrial and building automation (Bachelor) Automation and computer systems for information and control (Bachelor and Masters) Robotics and Mechatronics (Bachelor) Siemens PLC control technologies (Masters) Mechatronics (Masters) PLC and PC-based control technologies (Masters) Automation of production (Doctoral) Automated information processing and management systems (Doctoral)
Technical University - Gabrovo	Computer technologies in mechanical engineering (Bachelor and Masters) Computer systems and technology (Bachelor and Masters) Communication technique and technologies (Bachelor and Masters)	Mechatronics (Bachelor and Masters) Automation, information and control technology (Bachelor and Masters)

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	Mobile and satellite communications (Bachelor) Innovation and investment management in industry (Masters) Optical and quantum electronics (Doctoral) Industrial electronics (Doctoral) Computer systems and networks (Doctoral) Communication networks and systems (Doctoral)	Computer Aided Design in Industry (Bachelor and Masters) Elements and devices in automation and computer technology (Doctoral) Automation of engineering work and automated design systems (Doctoral) Automated information processing and management systems (Doctoral)
Technical University - Sofia	Informatics and software sciences (Bachelor and Masters) Informatics (Doctoral) Computer technologies in mechanical engineering (Bachelor) Telecommunications (Bachelor and Masters) Computer and Software Engineering (Bachelor and Masters) Information technologies in industry (Bachelor)	Digital industrial technologies (Bachelor and Masters) Mechatronics (Bachelor and Masters) Mechatronic systems (Bachelor and Masters) Analysis of large data sets and streams (Masters) Systems with artificial intelligence (Doctoral)

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Information technologies (Masters)

Telecommunications Engineering (Bachelor)

Computer Science and Engineering (Bachelor and Masters)

Computer systems and technologies (Bachelor and Masters)

Computer technology and applied programming (Masters)

Computer technologies in the non-material sectors (Masters)

Innovative information and communication technologies (Masters)

Innovative communication technologies and entrepreneurship (Masters)

Electronic control (Masters)

Computer Business Informatics (Masters)

Management and business information systems (Bachelor)

Devices and systems for analytical measurements and control of environments (Doctoral)

Industrial electronics (Doctoral)

Computer-aided design and technologies in mechanical engineering (Bachelor and Masters)

Automation of engineering work and automated design systems (Doctoral)

Automated information processing and management systems (Doctoral)

Bioautomatics (Doctoral)

Elements and devices of automation and computer technology (Doctoral)

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	Automation in the non-material sectors (Doctoral) System programming (Doctoral) Computer systems and networks (Doctoral) Note: some programs are available in English, German and/or French	
Trakia University	Information technologies in economics and management (Bachelor) Business informatics (Masters) Information technologies (Bachelor) Software engineering (Bachelor) Information and communication technologies in business and public administration (Masters) Information and communication technologies in business and public administration (Masters)	Automation and computer systems (Bachelor and Masters) Automation of engineering work and automated design systems (Doctoral) Automated information processing and management systems (Doctoral)
University of National and World Economy	E-government (Masters) Smart cities (Masters) Intellectual property and business (Bachelor and Masters) Business informatics and communications (Bachelor and Masters)	

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	Digital economy (Masters)
	Corporate strategies and digital transformations (Masters)
University of Library Studies and Information Technologies	Information technologies (Bachelor)
	Computer Science (Bachelor)
	Information brokering (Bachelor)
	Information systems and technologies (Masters)
	Software architectures and quality management (Masters)
	E-business and e-management (Masters)
	Information technologies and financial engineering (Masters)
	Software engineering (in Bulgarian and English) (Masters)
	Technological entrepreneurship and innovation in the information technologies sector (Masters)
	Digital technologies in the creative and leisure industries (Masters)
	Information systems and technologies, informatics and computer science (Doctoral)

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University of Food Technologies - Plovdiv	Business information technologies (Masters) Computer systems and technologies (Bachelor and Masters) Computer systems and networks (Doctoral) Communication and computer technologies (Doctoral)	Automation, information and control technology (Bachelor and Masters) Automation of production (Doctoral)
Prof. dr. Asen Zlatarov University - Bourgas	Computer systems and technologies (Bachelor and Masters) Software engineering (Bachelor) Software technologies (Masters)	Artificial Intelligence Systems (Doctoral)
University of Chemical Technology and Metallurgy	Automation and information technologies (bachelor and Masters) Information Technologies (Masters)	Automation of engineering work and automated design systems (Doctoral) Automated information processing and management systems (Doctoral) Automation of production (Doctoral)
Shumen University "Bishop Konstantin of Preslav"	Informatics and information technologies (Bachelor, Doctoral) Informatics (Doctoral)	Computer technologies for the automation of

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	Computer Informatics (Bachelor) Computer information technologies (Bachelor) Information technologies in the economy (Bachelor) Software technologies (Masters) Software engineering (Masters) Communication and information systems (Bachelor and Masters) Communication networks and systems (Doctoral)	production (Bachelor and Masters) Automated information processing and management systems (Doctoral)
Southwest University "Neofit Rilski"	Informatics (Bachelor and Masters) Information systems and technologies (Bachelor and Masters) Business informatics and econometrics (Masters) Computer systems and technologies (Bachelor and Masters) Communication technologies (Bachelor and Masters)	

[i] The DESI 2021 index measures the percentage of enterprises using at least 2 AI technologies but is based on an European enterprise survey on the use of technologies based on artificial intelligence by Ipsos and iCite. The Eurostat data appears broader in scope and more reliable.

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