Interreg
Danube Region

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Danube DNA

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Analysis of smart specialization strategies in each Danube country, mapping of particular digital readiness levels by country and industry sector along the Danube Region

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Analysis of the smart specialization strategies across the Danube region

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List of abbreviations

BiH	Bosnia and Herzegovina
ICT	Information and Communication Technology
IoT	Internet of Things
JRC	Joint Research Centre
NUTS	Nomenclature of Territorial Units for Statistics
NGO	Non-Governmental Organization
RIS3	Regional Innovation Strategy for Smart Specialization
SBR	South Bohemia Region of Czech Republic
S3	Smart Specialization Strategies
S4	Slovenian Smart Specialization Strategy
S5	Slovenian Sustainable Smart Specialization Strategy
SBR	South Bohemian Region
SMEs	Small and Medium Enterprises
SRIPs	Strategic Development and Innovation Partnerships
STP	Science and Technology Park
4S	Smart Specialization Strategy Serbia

1. The S3 strategy and its objectives

The Smart Specialization Strategy (S3) emerged as a strategic response to the challenges confronting innovation policy design and implementation within the European context, particularly the growing disparity between core and peripheral regions. The strategy seeks to integrate research and innovation into regional development agendas, with the overarching goal of identifying and capitalizing on competitive advantages within European regions. This emphasis on leveraging regional strengths aims to facilitate sustainable economic transformation, with a particular focus on the transition towards green and digital economies.

Since its promotion by the European Commission in 2010, the S3 has been underscored by a multi-level approach, targeting specific geographical locations to drive economic, social, and environmental change. By concentrating resources and efforts on priority areas for innovation, the strategy aims to enhance regional productivity, competitiveness, and convergence. This approach not only fosters regional specialization but also encourages the formation of industrial clusters capable of excelling in transnational value chains and exploiting cross-regional synergies.

Central to the S3 strategy is the concept of "playing to strengths" which emphasizes the identification of a region's unique competitive advantages, whether they be specific industries, research expertise, or natural resources. Stakeholder collaboration lies at the heart of this process, with active involvement from businesses, universities, research institutions, and public authorities essential for aligning priorities and fostering knowledge sharing.

Key to the successful implementation of S3 are several enabling conditions, including specialization-diversification, cooperation, and knowledge transfer. Post-2020, the European

Commission has stressed the importance of adapting S3 to diverse regional needs, broadening innovation, strengthening cooperation, and reinforcing monitoring and evaluation processes. Effective implementation requires selective and customized policy strategies, enhanced institutional capacity, revised incentive schemes, and support for interregional cooperation.

A variety of policy instruments are employed in S3 implementation, ranging from support for research, development, and innovation projects to education and training programs. These instruments aim to advance industrial modernization, collaboration, entrepreneurial discovery, and strategic priority setting. By aligning with EU funding priorities, S3 strategies ensure access to crucial financial resources necessary for implementation.

In conclusion, the S3 strategy represents a concerted effort to drive sustainable economic development across EU regions by leveraging regional strengths and fostering innovation. Through stakeholder collaboration, selective policy interventions, and alignment with EU funding, the strategy seeks to address regional disparities and promote economic convergence while advancing the transition towards green and digital economies.

2. National perspectives on the S3

This section explores the diverse national perspectives surrounding the implementation of the S3 within the countries part of the Danube DNA project funded by the Interreg Danube Program. Following the detailed input provided by the project partners (PPs) on national and sectoral perspectives on S3 in their own countries, this report provides an assessment on how the S3 framework has been embraced and adapted to the distinctive socio-economic national context, aiming to mitigate regional disparities and drive innovation-led growth. The focus in this synthesis report is on approaches, achievements, and obstacles encountered by nations in aligning with the overarching objectives of the S3 strategy. Moreover, an assessment is made of the current digital readiness levels of these nations, and their potential for future advancements in innovation and economic growth is uncovered.

2.1 Austria

Austria's digital transformation strategy is anchored in its Digitalization Master Plan, which lays out a comprehensive framework to strengthen the economy, improve citizens' quality of life, and promote digital sovereignty. The government is investing heavily in technologies like artificial intelligence, automation, and cybersecurity [1]. Small and medium-sized enterprises (SMEs) play a significant role, supported through programs like KMU.DIGITAL and Digital Innovation Hubs. Austria is also prioritizing digital education, sustainable agriculture, and healthcare, with the "Artificial Intelligence Mission Austria 2030" strategy further enhancing its position as a leader in AI adoption [2]. Styria, a key province, embodies the S3 principles through its "Economic Strategy Styria 2030," which integrates innovation, sustainability, and digital transformation.

2.1.1 National and sectoral strategic goals for digitalization

The Austrian government envisions a comprehensive digital transformation through its Digitalization Master Plan. The three main goals are improving digital sovereignty, bolstering the economy and labor market, and enhancing citizens' quality of life. The plan emphasizes securing digital infrastructure, promoting digital skills, and creating a safe, trustworthy online environment [1].

Economic development is at the core, with particular emphasis on supporting SMEs and expanding Austria's global competitiveness in digital technologies. Programs like KMU.DIGITAL encourage SMEs to implement cybersecurity and automation measures. Public administration aims to digitize its services, making them more accessible to businesses and citizens. Similarly, healthcare, mobility, and education will see digital enhancements, from telemedicine and personalized health management to e-learning platforms and intelligent traffic management [2].

The Austrian "Artificial Intelligence Mission Austria 2030 (AIM AT 2030)" strategy aims to develop a robust AI ecosystem that aligns with European values and human rights principles.

This strategy seeks to make Austria a research and innovation hub while mitigating AI risks and protecting citizen rights [3].

2.1.2 The S3 agenda and takeaways from implementation

The S3 strategy is encapsulated in Styria's "Economic Strategy Styria 2030," which guides the province's economic development. The plan emphasizes innovation, skills development, sustainable economic activity, internationalization, and comprehensive digital transformation. Styria is known for its strengths in automotive engineering, machinery, and healthcare. These are seen as foundational sectors that should leverage Industry 4.0, automation, and AI to maintain global competitiveness [4].

To ensure the S3 strategy's success, Styria emphasizes stakeholder engagement, regularly monitoring progress, and aligning its goals with national priorities. It creates mission maps to visualize operational goals, strengthens evidence-based policy information systems, and encourages active dialogues with partners. The focus remains on practical measures that promote exports, regional economic balance, and sustainable growth.

2.1.3 Regional perspectives

The S3 strategy, outlined in the Styria 2030 Economic Strategy, sets long-term economic goals for the Austrian province up to 2030. Key focus areas include promoting innovation through research and startup support, securing skilled labor with a focus on digital skills, and advocating for sustainable economic activities like renewable energy and emission reduction. The strategy also emphasizes internationalization by expanding exports, regional development through targeted support for rural and urban areas, and comprehensive digital transformation to enhance efficiency and create new business opportunities. These initiatives aim to strengthen the competitiveness and sustainability of Styria's economy by 2030 [4].

2.1.4 Sectoral priorities

Styria's economic strategy in Austria exemplifies the S3 approach by aligning local strengths with key priorities. The region's long-standing automotive and mobility industry uses digitalization to optimize production, innovate mobility solutions, and enhance competitiveness. Mechanical and plant engineering sectors focus on Industry 4.0 and automation to develop advanced machinery and improve production processes. In response to an aging population and increasing healthcare demands, the health and medical technology sector is adopting telemedicine, AI diagnostics, and personalized healthcare. The tourism and leisure industry, a significant part of Styria's economy, leverages digital marketing, customer engagement, and data analytics to improve visitor experiences. The information and communication technology (ICT) sector drives digitalization across other industries, fostering an ecosystem where innovation and startups can flourish. Styria's strong research and development capabilities, supported by close ties between universities and local industries, help address challenges like skilled labor shortages and data security, while also creating opportunities for sustainable growth [4].

2.1.5 Challenges and opportunities

Key challenges facing digital transformation include a skilled labor shortage, where training and education are needed to equip workers with the latest digital skills. Cybersecurity and data protection remain critical, especially as sensitive data are increasingly digitized and automated. The transition to digital technologies requires significant investment, and SMEs may struggle to secure the necessary funding.

On the other hand, digitalization opens vast opportunities. It fosters innovation and strengthens companies' global competitiveness by developing new business models and markets. Production and logistics can become more efficient, saving costs and streamlining processes. Data analytics and AI can help personalize customer experiences and create sustainable growth. Digitalization also aligns with environmental goals by improving resource use and reducing emissions.

2.2 Bosnia and Herzegovina

Bosnia and Herzegovina (BiH) is focusing on aligning its national development goals with the UN's Sustainable Development Goals (SDGs), aiming for smart economic growth, social cohesion, infrastructure development, environmental sustainability, good governance, poverty reduction, and human capital development. The country emphasizes digital transformation across all sectors to drive economic growth, enhance competitiveness, and improve public services. Despite the strategic planning, challenges such as complex governance structures, limited resources, and the need for enhanced digital infrastructure persist. However, BiH recognizes the opportunities digitalization presents in traditional sectors and aims to leverage these for broader economic and social benefits.

2.2.1 National and sectoral strategic goals for digitalization

Bosnia and Herzegovina aims to integrate digital technologies across all aspects of society and the economy to foster economic stability, reduce poverty, and improve governance and public services. The national development strategy focuses on accelerating the digital transformation to boost productivity, efficiency, and innovation. This includes significant investments in ICT infrastructure development like broadband networks and future technologies such as 5G and 6G, alongside enhancing digital skills and education to prepare the workforce for the digital economy. The strategy also emphasizes fostering a culture of innovation and entrepreneurship, particularly within the ICT sector, and ensuring robust cybersecurity measures to protect digital advancements.

2.2.2 The S3 agenda and takeaways from implementation

Bosnia and Herzegovina is still in the early stages of formulating and adopting S3. Current efforts are directed towards setting up a working group and defining the strategic sectors that will drive economic development. The process involves extensive stakeholder engagement and aligns with European Union frameworks, aiming to pinpoint areas where

BiH can leverage its unique strengths and competitive advantages. Although implementation challenges such as governance complexity and resource limitations exist, the S3 initiative is seen as crucial for fostering innovation and technological adoption.

2.2.3 Regional perspectives

BiH's complex political structure results in varying degrees of S3-related activities across different regions. Entities like Republic of Srpska and the Federation of Bosnia and Herzegovina have begun exploring and implementing regional innovation strategies that identify and prioritize sectors for development based on local strengths. These efforts are complemented by local initiatives that seek to leverage specific regional advantages for economic growth and development. Regional strategies focus on enhancing innovation capacities and fostering economic diversification with a strong emphasis on digitalization and technological advancement.

2.2.4 Sectoral priorities

Strategic sectors such as ICT, automotive, energy, and agriculture are central to BiH's S3. The choice of these sectors is strategic, aiming to harness specific regional strengths and meet global demand trends. For instance, the ICT sector is seen as a catalyst for modernization across other sectors, while the energy sector's focus on renewables aligns with global sustainability goals. Similarly, the traditional agricultural sector's transformation through digital technologies could lead to significant efficiency gains and output increases, helping to stabilize rural economies and improve food security.

2.2.5 Challenges and opportunities

The main challenges in digitalizing these sectors include addressing the existing skills gap, updating legal systems, ensuring robust cybersecurity, and overcoming the digital divide that affects equitable access to technology. However, the opportunities digitalization presents include enhanced efficiency and productivity, innovation in products and services, better access to global markets, sustainable development, and improved quality of life for citizens.

BiH's approach to digitalization and the S3 framework, although at an early stage, shows a clear pathway towards integrating modern technologies to foster economic growth and social improvement. The country's efforts to develop a comprehensive strategy that includes digital transformation as a core component demonstrate its commitment to achieving long-term sustainability and competitiveness.

2.3 Bulgaria

Bulgaria's National Development Programme "BULGARIA 2030" emphasizes accelerated economic development, demographic upswing, and reducing inequalities, with a strong focus on digitalization and technological upgrading across various sectors. The country is strategizing to transition its economy towards knowledge-based and smart growth sectors, including high-tech and ICT-driven industries. By improving digital infrastructure and fostering innovation, Bulgaria aims to enhance competitiveness and ensure sustainable growth. The strategic initiatives are geared towards modernizing traditional industries and capitalizing on advancements in areas like AI, clean technologies, and efficient public services.

2.3.1 National and sectoral strategic goals for digitalization

Bulgaria has defined clear strategic goals to incorporate digitalization across all sectors of its economy. The primary focus is on developing a robust digital infrastructure that supports both current and future technological needs. Key initiatives include enhancing the quality of education to produce a workforce skilled in digital technologies, boosting scientific research and infrastructure to foster innovation, and digitizing the manufacturing sector to increase productivity and efficiency. Additional emphasis is placed on environmental sustainability through digital solutions that optimize resource use and promote clean technologies, aligning with global green transition goals. The overarching aim is to create a digitally adept society where both citizens and businesses can thrive in a modern, connected Bulgaria.

2.3.2 The S3 agenda and takeaways from implementation

Bulgaria's Innovation Strategy for S3 for 2021-2027 targets the enhancement of the nation's innovative capabilities by focusing on sectors where Bulgaria shows strong capacity and competitive advantages. The strategy seeks to elevate the country's status to that of a moderate innovator by 2027, improving the business environment through technological upgrades and fostering a dynamic innovation ecosystem. By facilitating cooperation among educational institutions, research centers, and businesses, the strategy aims to accelerate the commercialization of research and drive the creation of high-value products and services.

2.3.3 Regional perspectives

Bulgaria's S3 implementation recognizes the diverse potential of various regions by tailoring initiatives to regional strengths and opportunities. This decentralized approach ensures that regional programs align with local economic landscapes and capitalize on unique regional assets. For instance, regions with a strong presence in information technology might focus more on advancing ICT capabilities, while areas with a rich agricultural heritage might emphasize biotechnological innovations in farming. This targeted approach helps to maximize the impact of S3, promoting balanced regional development and mitigating the risk of economic disparities between different areas of the country.

2.3.4 Sectoral priorities

The strategic sectors identified in Bulgaria’s S3 include ICT, mechatronics, biotechnology, and the creative industries. These sectors are selected for their potential to significantly impact economic development through technological advancement and innovation. For example, the ICT sector is expected to drive digital transformation across all other sectors, while mechatronics will enhance manufacturing processes through automation and smart technologies. Biotechnology is targeted for its potential to revolutionize healthcare and agriculture, and the creative industries are seen as key to enriching cultural heritage and boosting tourism through digital engagement.

2.3.5 Challenges and opportunities

Digitalization efforts in Bulgaria face challenges such as the need for substantial investment in technological infrastructure, bridging the significant digital skills gap, and integrating digital solutions across all economic sectors. However, these challenges are accompanied by substantial opportunities. Digital transformation could significantly enhance operational efficiencies, foster product and service innovation, and open up new markets for Bulgarian enterprises. Moreover, improving public sector digital services can lead to more transparent and responsive governance.

2.4 Croatia

Croatia's strategic goals for digitalization and the implementation of S3 focus on leveraging digital technologies to enhance economic growth, competitiveness, and sustainable development. Key sectors targeted include ICT, advanced manufacturing, agriculture, renewable energy, and tourism. The national strategy emphasizes innovation, stakeholder collaboration, and effective use of EU funds to support research and development. Challenges such as institutional capacity, resource constraints, and the digital skills gap must be addressed to realize these goals.

2.4.1 National and sectoral strategic goals for digitalization

Croatia aims to transform its economy through comprehensive digitalization strategies that span multiple sectors. Key insights include efforts in tourism, where digitalization focuses on enhancing visitor experiences through online booking platforms, mobile apps, and digital marketing strategies to attract international tourists. In ICT, Croatia invests in digital infrastructure, promotes digital skills, and fosters innovation to position itself as a regional technology hub. The agriculture sector leverages digital technologies such as precision agriculture, IoT sensors, and farm management software to optimize production, reduce resource use, and improve market access, supporting sustainable agricultural development. Emphasizing environmental sustainability, Croatia prioritizes renewable energy, aiming to reduce dependency on fossil fuels and promote green energy solutions. In advanced manufacturing, Croatia utilizes digital technologies like additive manufacturing, robotics, and

automation to drive efficiency and innovation, focusing on high-tech industries such as automotive, aerospace, and electronics.

2.4.2 The S3 agenda and takeaways from implementation

The implementation of S3 in Croatia involved identifying priority sectors with high innovation potential and leveraging national and EU funds to support these areas. Croatia's S3 focuses on ICT, renewable energy, tourism, and advanced manufacturing, with significant funding through national and EU programs to enhance digitalization and technological upgrading. Policies promoting collaboration and technology transfer between industry and academia have been implemented, facilitating the commercialization of research findings. Initiatives such as technology parks and innovation hubs foster an environment conducive to innovation. Increased investment in research and innovation has led to growth in patent filings, technology exports, and startup activity, reflecting Croatia's commitment to strengthening its innovation ecosystem and driving economic transformation. However, challenges such as limited institutional capacity, resource constraints, and stakeholder engagement remain. Enhancing institutional frameworks and building expertise in innovation policy are crucial for effective S3 implementation.

2.4.3 Regional perspectives

Different regions in Croatia have tailored S3 activities to their unique strengths and economic focuses. In the Istria Region, the focus is on sustainable tourism, agri-food innovation, and cultural heritage preservation. Innovation hubs support local agri-tech startups and eco-friendly tourism ventures. Zagreb County, as the capital region, promotes high-tech industries, ICT innovation, and digital services through technology parks and incubators. Split-Dalmatia County emphasizes marine and maritime industries, renewable energy, and sustainable tourism, with projects like marine research centers and renewable energy infrastructure. Osijek-Baranja County prioritizes agricultural innovation, bio-economy, and rural development, establishing agri-tech clusters and research partnerships.

2.4.4 Sectoral priorities

Croatia's S3 prioritizes several key sectors for digital transformation and economic development. In tourism, digital technologies enhance the tourism experience, streamline operations, and reach a global audience through digital marketing. In ICT, investment in infrastructure and skills development aims to position Croatia as a regional tech hub. The agriculture sector sees digital tools like IoT and precision agriculture improving productivity and sustainability. Renewable energy efforts focus on reducing fossil fuel dependency and promoting green energy, aligning with sustainability goals. Advanced manufacturing technologies drive efficiency, productivity, and innovation, supporting economic growth and competitiveness.

In summary, Croatia's strategic goals for digitalization and S3 implementation are centered on enhancing economic growth, competitiveness, and sustainability through targeted investments in key sectors. By addressing challenges and leveraging opportunities, Croatia aims to create a dynamic and innovative economy.

2.4.5 Challenges and opportunities

A primary obstacle lies in the digital skills gap, denoting the shortage of workers possessing the required technical proficiency to spearhead digital transformation endeavors. Bridging this gap necessitates substantial investments in education and training programs tailored to the demands of emerging digital industries.

Another hurdle pertains to limited access to high-speed internet and digital services, particularly in rural and underserved regions, impeding the uptake of digital technologies and constraining opportunities for economic advancement and innovation.

As reliance on digital technologies escalates, so does the risk of cyber threats and data breaches. Croatia requires robust cybersecurity measures and protocols to safeguard against such risks. Strengthening cybersecurity capabilities and fostering collaboration between the public and private sectors are pivotal in mitigating this challenge.

The Croatian Agency for SMEs and Investments underscores the significance of digitalization in fortifying the resilience and competitiveness of businesses. Through the adoption of digital technologies, companies can enhance operational efficiency, curtail expenses, and augment their competitiveness in both domestic and international markets. Furthermore, digitalization can catalyze innovation, entrepreneurship, and job creation, propelling sectoral expansion and economic resilience.

2.5 Czech Republic

The Czech Republic's approach to digitalization and smart specialization is marked by significant industrial presence and strong connections with European markets, particularly Germany. The national strategy emphasizes research, innovation, and technological advancements to maintain competitiveness in various sectors. The S3 in the Czech Republic, known as the National RIS3 Strategy, has undergone several updates to align with evolving economic and technological landscapes.

2.5.1 National and sectoral strategic goals for digitalization

The Czech Republic is a highly industrialized country, with industry contributing approximately 40% to its GDP. The economy is heavily reliant on exports, particularly to EU countries, and has a significant relationship with Germany, especially in the automotive sector. Small and medium enterprises (SMEs) are a backbone of the Czech economy, employing about 70% of the workforce [5].

In response to the Industry 4.0 initiative launched in 2012, the Czech government adopted the "Initiative Industry 4.0" in 2016, aiming to prepare the industry for digital transformation [6]. Concurrently, the "Work 4.0" initiative was launched to address future labor market trends influenced by industrial changes, along with the "Education 4.0" concept to adapt the education system to new technological demands. The Czech Republic is also part of the Digital Europe Programme, which aims to accelerate digital transformation across Europe

with a budget of EUR 7.588 billion for 2021-2027 [7]. The Ministry of Industry and Trade manages this program nationally, supporting various digital initiatives.

The national digital agenda focuses on several key areas: research, development, and innovation in the digital economy; digital readiness of various economic sectors; enhancing digital skills and education; building robust digital infrastructure; ensuring cybersecurity and trust in the digital environment; and creating supportive legislation for digital initiatives.

2.5.2 The S3 agenda and takeaways from implementation

The Smart Specialization Strategy (S3) in the Czech Republic is encapsulated in the National RIS3 Strategy, initially approved in June 2016 and subsequently updated in 2018, 2021, 2022, and 2024. The strategy outlines key areas for development, including research and innovation for business, public research and development, smart skills, and the digital agenda [8].

Challenges identified in the implementation of the S3 strategy include low added value and lower-order innovation, a weak endogenous business sector, an unsatisfactory business environment, insufficient quality and internationalization of public research, poor cooperation between research institutions and the private sector, inadequate digital infrastructure, and underutilization of digital potential by companies.

Opportunities focus on enhancing the digital economy through collaborative research, innovative competencies, and participation in EU digital initiatives. The strategy also emphasizes preparing the workforce for digital transformation and improving digital infrastructure and cybersecurity.

2.5.3 Regional perspectives

The implementation of S3 varies across regions in the Czech Republic. In the South Bohemian Region (SBR), strategic targets include improving human resources, fostering cooperation between research organizations and industry, business development, and promoting digital transformation [9]. Key economic sectors in SBR are machinery and mechatronics, electronics and IT, biotechnology, automotive, and textiles. The South Bohemian Region is

notable for its strengths in advanced manufacturing technologies, photonics, industrial biotechnology, and social sciences. Institutions like the University of South Bohemia play a crucial role in these domains.

2.5.4 Sectoral priorities

Nationally, the sectoral priorities of the S3 are defined by the structure of the Czech economy and historical industry trends. Priority sectors include advanced machinery, digital market technologies, transportation, healthcare, cultural and creative industries, sustainable agriculture, and smart cities. These sectors are prioritized due to their significant contributions to GDP, export potential, and alignment with national development goals. The focus is on maintaining global competitiveness, supporting innovative technologies, and promoting sustainable development.

2.5.5 Challenges and opportunities

Challenges associated with digitalization in strategic sectors include low levels of digital adoption among companies, insufficient investment in new technologies, inadequate digital infrastructure, and gaps in digital skills within the workforce. Opportunities include enhancing research and development in digital fields, promoting collaborative research between public institutions and private companies, leveraging EU digital initiatives to boost innovation, and developing advanced digital competencies and infrastructure to support economic growth.

In conclusion, the Czech Republic's digitalization and smart specialization strategies aim to strengthen its industrial base, enhance research and innovation, and prepare the workforce for future technological changes. The focus on strategic sectors and regional strengths highlights a comprehensive approach to maintaining economic competitiveness and promoting sustainable growth.

2.6 Germany

Germany's national development strategy, rooted in sustainability, emphasizes a balance among environmental protection, social equity, and economic prosperity [10]. The overarching goal is to maintain technological leadership and enhance national competitiveness through technological innovation, particularly in high-tech sectors such as health, mobility, and energy. The strategy is robustly aligned with digital transformation across all sectors, aiming to bridge the digital divide, foster a skilled workforce, and expand research and development to spur innovation. Key initiatives include ensuring nationwide high-speed internet access to support digital participation, adapting educational systems to provide necessary technological skills like data science and cybersecurity, and promoting STEM education alongside retraining programs for the existing workforce.

2.6.1 National and sectoral strategic goals for digitalization

Germany identifies several sectors as pivotal for its industrial and technological advancement, closely tied to its digitalization and high-tech agenda. High-tech industries, including sectors like health, mobility, and energy, are noted for their growth potential and innovation capacities [11]. The Industry 4.0 initiative focuses on the digitalization and automation of the manufacturing sector, enhancing efficiency and flexibility. Additionally, sustainability technologies that support the transition to renewable energy sources and principles of a circular economy are emphasized for their critical role in Germany's energy transition and environmental sustainability efforts. Key sectors like healthcare and mobility are also deemed crucial due to their contributions to economic and technological competitiveness, benefiting from targeted government support for innovation and advanced technology adoption.

At the heart of Germany’s strategic initiatives is the goal to sustain its leadership in global technological innovation, particularly within key high-tech sectors like healthcare, mobility, and energy. The national strategies are meticulously designed to ensure that Germany not only keeps pace but sets global benchmarks in technological advancements. Initiatives such as the Industry 4.0, launched as part of the High-Tech Strategy, aim to revolutionize

manufacturing through digital automation, smart technologies, and the Internet of Things (IoT), ensuring that German manufacturing remains competitive on the global stage [11].

The Digital Strategy 2025 broadens the scope of these technological aspirations to include significant improvements in digital infrastructure, promoting widespread access to high-speed internet and enhancing digital literacy and security across the population [12]. This strategy underscores the importance of creating an inclusive digital society where innovation benefits all sectors of the economy and all strata of the population.

The AI Strategy complements these goals by aiming to position Germany and Europe as leaders in ethical AI technologies. This strategy focuses on enhancing AI research, creating academic positions in AI, and fostering international collaborations, particularly in Franco-German initiatives, to harness AI for societal benefit, including environmental and workforce advancements [11].

2.6.2 The S3 agenda and takeaways from implementation

The implementation of S3 in Germany takes a unique, regionally focused approach that leverages the distinct strengths and competitive advantages of its diverse regions [12]. This strategy has enabled targeted development that aligns closely with both national objectives and local capabilities, supported by EU funding and national investments. As a result, regions have developed specialized innovation ecosystems that have contributed significantly to regional and national economic resilience and competitiveness.

The outcomes from S3 have highlighted a more efficient allocation of resources, fostering regions that are innovation leaders in specific sectors such as digital manufacturing and renewable energies. These developments have not only strengthened Germany's industrial base but have also enhanced its innovation capacity.

2.6.3 Regional perspectives

In Bavaria, for instance, the S3 strategy has been pivotal in advancing sectors that build on the region's existing strengths such as automotive and digital industries [13,14]. The region's focus on creating Digital Innovation Hubs has facilitated effective collaborations that drive forward the digital transformation agenda. Bavaria's approach illustrates how regional strategies are effectively dovetailed with national goals to push the envelope in technological advancements.

Other regions, such as North Rhine-Westphalia and Baden-Württemberg, also tailor their S3 strategies to exploit their industrial bases, emphasizing sectors like energy efficiency, the bioeconomy, and smart manufacturing solutions tailored to their specific industrial landscapes.

2.6.4 Sectoral priorities

Bavaria's strategic priorities under S3 emphasize the enhancement of its manufacturing capabilities through digital technologies and the promotion of new mobility solutions and life sciences [13,14]. The focus on these sectors is designed to leverage Bavaria's historical industrial strengths while aligning with broader global trends in technology and innovation.

This strategic focus ensures that Bavaria not only continues to lead in traditional sectors but also adapts to and capitalizes on new technological trends. The alignment of these priorities with significant investment in research and development fosters a vibrant ecosystem conducive to innovation and economic growth.

2.6.5 Challenges and opportunities

While the digital transformation presents numerous opportunities for growth and innovation across Germany's strategic sectors, it also brings challenges such as cybersecurity risks, the need for continuous upskilling of the workforce, and the integration of digital solutions in traditional industries. Nonetheless, these challenges are met with robust

strategic responses that not only mitigate risks but also enhance Germany's competitive edge globally.

Digital technologies facilitate the development of new products and services, particularly in the automotive sector, where advancements in electrification and digital services are redefining industry standards. In healthcare, digital innovations promise to revolutionize patient care and improve health outcomes, positioning Germany as a leader in digital health technologies.

2.7 Hungary

Hungary has made significant strides in digitalization and smart specialization, aiming to enhance its national and sectoral development goals. The country's strategic efforts focus on bolstering competitiveness through various economic priorities and integrating digital solutions across industries. The S3 plays a pivotal role in these initiatives, with a structured approach to implementation and continuous monitoring. Challenges remain, particularly in terms of innovation capacity and digital preparedness among SMEs, but targeted programs and supportive measures are in place to address these issues.

2.7.1 National and sectoral strategic goals for digitalization

Hungary's national development goals include advancing digitalization and technological upgrades across sectors. The country's S3 identifies eight key economic priorities: agriculture and food industry, health, digitalization of the economy, creative industry, resource-efficient economy, energy and climate, services, and cutting-edge technologies. These priorities are designed to enhance competitiveness and foster innovation across the nation.

One of the primary focuses is the digitization of the economy, which involves automating production and service processes and adopting digital business solutions. This is critical for SMEs to improve their efficiency and competitiveness. However, Hungarian SMEs face significant challenges in integrating digital solutions, which hampers their ability to compete

with Western counterparts. To address this, the National Digital Strategy has outlined several dedicated programs aimed at improving digital adoption among SMEs.

The strategy emphasizes increasing the digital supply and usage among micro, small, and medium-sized enterprises through financing programs, supporting the digital transformation of industrial SMEs, and encouraging data utilization. It also focuses on creating corporate digital experience centers and promoting fintech services to enhance online transactions. Specific initiatives include targeted programs for the agricultural sector to integrate digital tools and improve efficiency.

2.7.2 The S3 agenda and takeaways from implementation

The S3 agenda in Hungary is coordinated by the National Research, Development and Innovation Office, which oversees the planning and implementation of the National Smart Specialization Strategy. The previous S3 strategy for the 2014-2020 EU planning period laid the groundwork, and the current strategy continues to build on these foundations with a project-based approach to implementation.

The implementation of S3 involves three levels: strategic, operational, and stakeholder engagement. This structure ensures comprehensive oversight and continuous feedback from various stakeholders. The monitoring of S3 is conducted through biennial reports, although these are not publicly available.

Key outcomes of the S3 implementation include the modernization of key sectors such as metal and electronics, ICT, and environmental industries. These efforts aim to increase productivity, enhance digital infrastructure, and support the green transition. Additionally, the creative industries have benefited from initiatives to integrate design and digital technologies, which combine local traditions with modern trends.

Despite these successes, challenges persist, particularly in financing the RDI system and improving the knowledge flows within the innovation ecosystem. The underfunding of public R&D and the separation between research, education, and innovation organizations are significant barriers. To address these issues, Hungary emphasizes the importance of

enhancing the digital readiness of SMEs and fostering intersectoral connectivity through digital tools.

2.7.3 Regional perspectives

Regionally, the implementation of S3 in Hungary varies, reflecting the unique economic landscapes of different areas. For instance, the South Transdanubia region focuses on modernizing the metal and electronics industry, promoting smart manufacturing, and introducing environmentally friendly technologies. This regional approach aims to improve productivity and competitiveness.

In the ICT sector, the emphasis is on developing digital infrastructure, strengthening data analytics, and fostering innovation. Regions like Central Hungary, which hosts a significant number of ICT enterprises, face challenges due to the limited availability of EU support resources typically allocated to other regions. Therefore, regional strategies also focus on addressing these disparities and promoting digital skills development.

Environmental industry and energy sectors are prioritized for their role in supporting the green transition. Regional initiatives include harnessing renewable energy, increasing energy efficiency, and developing smart urban infrastructure. Similarly, the creative industries are targeted for their potential in adding value through innovation and digital integration.

2.7.4 Sectoral priorities

Sectoral priorities under the S3 strategy are aligned with national development goals, focusing on industries that are strategically important for Hungary's economic growth and competitiveness. The automotive industry, for example, is a significant contributor to exports and employment, with substantial investments aimed at enhancing its capacity and technological advancement.

The health sector is another priority, with efforts to strengthen R&D capacities, promote smart care developments, and increase international cooperation. Digitalization plays a crucial role here, with initiatives aimed at improving access to health services and encouraging the use of innovative diagnostic and therapeutic technologies.

The agriculture sector is targeted for digital transformation to improve efficiency and productivity. Programs supporting the integration of digital tools and data utilization are crucial for modernizing agricultural practices and enhancing the sector's competitiveness.

2.7.5 Challenges and opportunities

The digitalization of Hungary's economy presents both challenges and opportunities. One of the major challenges is the digital lag among SMEs, particularly in sectors like tourism, construction, food industry, logistics, and retail. The digital preparedness of micro-enterprises is particularly low, which hampers their ability to compete and integrate into global value chains.

To address these challenges, the National Digital Strategy focuses on improving digital competencies and supporting the adoption of digital solutions. This includes introducing financing programs, promoting data utilization, and creating digital experience centers. These efforts are aimed at enhancing the overall digital readiness of SMEs and fostering a more innovative ecosystem.

Opportunities arising from digitalization include improved operational efficiency, enhanced competitiveness, and the potential for new business models and services. The integration of digital technologies can drive productivity gains and open up new markets for Hungarian enterprises. Additionally, fostering intersectoral connectivity and leveraging Hungary's strengths in sectors like agriculture can lead to significant advancements and economic benefits.

In conclusion, Hungary’s strategic goals for digitalization and the implementation of the S3 strategy are comprehensive and well-structured. Despite facing challenges, particularly among SMEs, targeted programs and supportive measures are in place to enhance digital adoption and drive economic growth. The regional and sectoral approaches ensure that the unique needs of different areas and industries are addressed, contributing to the overall competitiveness and innovation capacity of the country.

2.8 Montenegro

Montenegro is actively pursuing digitalization as part of its national development strategy, aligning closely with European Union methodologies and goals. The country's strategic focus on digital transformation aims to boost economic growth, enhance competitiveness, and create new job opportunities. The Smart Specialization Strategy (S3), adopted in 2019, identifies key sectors such as sustainable agriculture, energy, health tourism, and information and communication technologies (ICT) as priorities. Implementation of this strategy is supported by various policy instruments, operational programs, and the involvement of multiple stakeholders including government, industry, and academia [15].

2.8.1 National and sectoral strategic goals for digitalization

Montenegro's digitalization strategy is outlined in the Montenegro Digital Transformation Strategy 2022-2026. This strategy underscores the importance of leveraging information and communication technologies (ICTs) to improve communication speed, enhance quality of life, and facilitate more efficient services. The country aims to align with international digital transformation objectives by focusing on digital knowledge and skills, secure and sustainable infrastructure, and the digitalization of public services and businesses. This alignment is part of a broader vision to integrate into Europe's digital transformation by 2030.

Additionally, the national development goals emphasize the significance of digital transformation, especially in the wake of the COVID-19 pandemic. The National Human Development Report highlights the need for effective management of technological advancements to adapt to the rapid pace of technological development. Montenegro views ICTs as essential for economic development, aiming to expand access to modern technologies, foster a digital economy, and enhance international cooperation.

Key sectors identified as strategic for national development include sustainable agriculture, energy, sustainable and health tourism, and ICT. These sectors are targeted through various policy instruments such as grants for renewable energy sources, technology transfer services, start-up support programs, and innovation vouchers.

2.8.2 The S3 agenda and takeaways from implementation

Montenegro was the first country in the Western Balkans to adopt the Smart Specialization Strategy in 2019, aligning it with EU methodology. The S3 strategy focuses on four priority areas: sustainable agriculture and food value chain, energy and sustainable environment, sustainable and health tourism, and ICT. The implementation is supported by the Joint Research Centre (JRC) of the European Commission, which aids in developing operational programs and action plans [16].

The strategy has established a clear roadmap for fostering innovation, economic diversification, and sustainable growth. It emphasizes collaboration between government, industry, academia, and other stakeholders, known as the quadruple helix approach. This collaborative model aims to create a conducive environment for innovation and entrepreneurship.

Montenegro's innovation policy measures are outlined in the Programme for Innovation 2021-2024 and the Innovation Programme 2023-2027. These programs consolidate all national innovation support initiatives, facilitated by the Innovation Fund of Montenegro, established in 2021. The programs aim to support participation in EU and international research, development, and innovation projects.

2.8.3 Regional perspectives

Montenegro is considered a single NUTS region for the implementation of the S3 strategy, due its size. This approach ensures that the strategic objectives and activities outlined in the S3 framework are applied uniformly across the country. The strategy's priority areas—sustainable agriculture, energy, health tourism, and ICT—are supported through a national operational framework and institutional setup designed to drive innovation and development across all regions.

The S3 implementation includes initiatives to enhance research and innovation infrastructure, foster collaboration between research institutions and the private sector, and support start-up development. Regional activities are, therefore, aligned with the national

strategy, which ensures a cohesive approach to achieving the country's digitalization and economic development goals.

While the strategy is national in scope, it is crucial that regional activities are carefully aligned with the national strategy to ensure a cohesive approach to achieving Montenegro's digitalization and economic development goals. Each region's unique strengths and opportunities are considered, ensuring that regional activities complement the national objectives. This alignment guarantees that each region not only contributes to but also benefits from the overall progress.

In practical terms, this means that initiatives such as digital infrastructure development, renewable energy projects, health tourism facilities, and ICT hubs are strategically placed and developed in regions where they can have the most significant impact. By doing so, the strategy fosters balanced regional development, reducing disparities and promoting inclusive growth across Montenegro.

Moreover, the strategy includes mechanisms for continuous monitoring and evaluation to ensure that the objectives are being met and to make necessary adjustments based on regional feedback and changing circumstances. This dynamic approach allows the strategy to remain relevant and effective in addressing the evolving needs of all regions.

Overall, the S3 strategy's implementation in Montenegro as a single NUTS region exemplifies a well-coordinated and integrated approach to national and regional development. It underscores the importance of leveraging regional strengths within a unified national framework, ensuring that innovation and economic growth are distributed evenly and sustainably across the entire country.

2.8.4 Sectoral priorities

Montenegro's sectoral priorities for the S3 strategy include sustainable agriculture, energy, health tourism, and ICT. These sectors are chosen for their significant economic potential, capacity for job creation, and potential for innovation. The strategic focus on these areas is

intended to drive economic development, promote sustainability, and enhance competitiveness.

In sustainable agriculture, Montenegro aims to modernize agricultural practices, promote organic farming, and enhance agricultural productivity. The energy sector's focus is on renewable energy sources and energy efficiency, aiming to reduce the carbon footprint and increase energy independence. Health tourism is prioritized due to Montenegro's natural beauty and potential for wellness and medical tourism. The ICT sector is emphasized for its role in driving innovation, digital transformation, and economic growth.

2.8.5 Challenges and opportunities

Montenegro faces several challenges in developing and implementing its S3 strategy, including a lack of coordination among ministries, the need for greater private sector involvement, and insufficient participation from certain sectors like agriculture and education. Motivating the NGO and business sectors in specific priority areas also presents difficulties.

Despite these challenges, there are significant opportunities. Positive outcomes have been observed in strengthening the innovation ecosystem and supporting start-up development. Improvements in research and innovation infrastructure and enhanced collaboration between research institutions and the private sector are also notable. Additionally, the introduction of health tourism into normative frameworks has been a significant achievement.

Overall, Montenegro's commitment to digital transformation and the strategic implementation of the S3 framework position the country to harness the benefits of digitalization, driving sustainable economic growth and enhancing competitiveness in key sectors.

2.9 Romania

Romania's national development strategy places a strong emphasis on digital transformation, aiming to enhance the efficiency, transparency, and accessibility of public services through e-governance. The country is focused on creating a robust cybersecurity framework and ensuring equitable technology access across all societal segments. With substantial investments in broadband infrastructure, Romania seeks to provide universal high-speed internet access. This strategy aligns with the European Union's digital agenda, marking significant national investments in digital capabilities to foster economic resilience and societal well-being.

2.9.1 National and sectoral strategic goals for digitalization

Romania's comprehensive digitalization strategy underscores a broad commitment to advancing the digital economy and addressing the demands of the digital era. The focus is notably on the integration of digital technologies across public sectors and fostering digital literacy within the education system to prepare the workforce for future challenges. Special attention is also given to strengthening the digital infrastructure, which is critical for supporting high-speed internet access throughout the country, both in urban and rural areas.

The government is actively promoting the digitization of public services to enhance their accessibility and effectiveness, aiming for comprehensive interoperability of digital platforms used by public institutions. Furthermore, Romania is committed to supporting its small and medium-sized enterprises (SMEs) by integrating digital technologies to boost their innovation and competitiveness. This strategic focus is expected to propel Romania forward, leveraging digital transformation as a cornerstone for sustainable economic growth and improved societal outcomes.

2.9.2 The S3 agenda and takeaways from implementation

Romania has embraced the S3 with a goal to pinpoint and cultivate key economic potential areas within each region. By engaging a wide array of stakeholders, including those from the public, private, and academic sectors, Romania aims to stimulate regional innovation and development through targeted support. The S3 strategy has identified several key sectors such as engineering, ICT, and biotechnologies, where targeted efforts are being made to enhance research and innovation capabilities.

This focus is coupled with substantial efforts to integrate digital transformation across public and private sectors, ensuring that the benefits of digital advancements are widely distributed. A significant emphasis is placed on enhancing the competitiveness of SMEs, which are seen as pivotal to the regional and national economic fabric. Through various innovative project calls and initiatives under S3, regions within Romania are increasingly focusing on digitalization and modernization, reflecting a proactive approach to regional economic development.

2.9.3 Regional perspectives

In the South-East Development Region of Romania, the application of S3 reflects a clear strategy to leverage regional strengths in high-technology and innovation to stimulate economic development and improve the quality of life. The strategy focuses on transitioning from traditional competitive bases like labor and natural resources to innovation-driven development. This shift is supported by fostering research capacities in high-tech areas that have the potential to catalyze other productive sectors.

The regional approach within the South-East includes strategic priorities such as supporting R&D organizations, promoting digital transformation, developing human capital in innovation, and applying Key Enabling Technologies across identified smart specialization areas. These cross-cutting priorities are designed to modernize the regional economy

through technology and innovation, fostering collaborative entrepreneurship and integrating into global value chains.

2.9.4 Sectoral priorities

The sectoral priorities within South-East Romania focus on several high-potential areas including engineering and shipping, the clothing industry, agri-food and biotechnologies, aquaculture and fisheries, tourism, and ICT. These sectors are chosen for their regional significance and potential for innovation-led growth. The strategy aims to enhance these sectors through targeted R&D, digital transformation, and sustainable practices, ensuring that they contribute effectively to the regional and national economic landscape.

These sectoral priorities are aligned with Romania's broader objectives of enhancing its position in the global market while ensuring sustainable development. The focus on sectors like ICT and biotechnologies not only supports industrial modernization but also plays a crucial role in the digital and ecological transition of the region.

2.9.5 Challenges and opportunities

The digital transformation of strategic sectors in Romania presents both challenges and opportunities. Key challenges include bridging the digital skills gap within the workforce, ensuring widespread access to advanced digital infrastructure, and maintaining robust cybersecurity measures. Additionally, there are challenges related to regulatory frameworks and ensuring that digitalization efforts are inclusive and equitable across all societal segments.

On the opportunity front, digitalization offers the potential to significantly enhance the efficiency and competitiveness of Romanian industries. It provides a foundation for innovation in sectors like healthcare, energy, and manufacturing, through technologies such as AI, IoT, and cloud computing. Moreover, digital tools can enable more sustainable practices across industries, contributing to Romania’s environmental goals.

2.10 Serbia

Serbia's strategic focus on digitalization and smart specialization (S3) aims to drive sustainable economic development and enhance global competitiveness. The government has implemented comprehensive strategies and action plans that prioritize digital infrastructure, innovation, and sectoral growth, with significant emphasis on ICT, creative industries, and advanced manufacturing. Challenges include aligning with EU standards, enhancing digital literacy, and fostering public-private collaboration. Opportunities lie in leveraging emerging technologies and developing regional innovation hubs.

2.10.1 National and sectoral strategic goals for digitalization

Serbia's national and sectoral strategic goals for digitalization are comprehensively outlined in various governmental plans and strategies. The Economic Reform Programme for 2023-2025 underscores digital transformation as a cornerstone for structural reform. It emphasizes developing a robust national ICT infrastructure, fostering innovative IT solutions, and supporting talent within the creative industries [17]. These initiatives aim to align Serbia's digital capabilities with European Union standards, ensuring the country remains competitive within the global market.

The adoption of the Smart Specialization Strategy (S3) for 2020-2027 marks a significant step towards building a competitive economy driven by research, development, and innovation. This strategy is reinforced by detailed Action Plans spanning 2021-2022 and 2023-2025, which lay out targeted measures across five strategic objectives. These include enhancing research and development capacities, fostering economic growth through collaborative R&D efforts, supporting innovative startups through improved education systems as well as business and administrative conditions, and advancing digital infrastructure. These measures aim to integrate Serbia more deeply into the global digital economy.

Aligned with the Western Balkans Digital Agenda, launched by the EU in 2018, Serbia's Digital Agenda encompasses broadband connectivity, cybersecurity, the digital economy, and

research and innovation [18]. Apart the abovementioned S3 for 2023-2027, this overarching framework includes several other specific strategies such as the Strategy for the Development of the Information Society and Information Security (2021-2026), the Strategy for the Development of Digital Skills (2020-2024), the Strategy for the Development of New Generation Networks until 2023, Artificial Intelligence Strategy for 2020-2025, Public Administration Reform Strategy for 2021-2030, and Electronic Administration Development Plan for 2020-2022 [19]. These documents collectively aim to position Serbia as a leader in digital innovation and infrastructure within the region.

2.10.2 The S3 agenda and takeaways from implementation

The Smart Specialization Strategy (S3) process in Serbia, initiated in 2017, represents a coordinated effort led by the Ministry of Education, Science, and Technological Development. An inter-ministerial working group was established to develop the Research and Innovation Strategy for Smart Specialization (RIS3). The adoption of the S3 strategy, dubbed in Serbia as Smart Specialization Strategy Serbia (4S), in February 2020 marked a significant milestone, aiming to enhance Serbia's regional and global competitiveness through focused research, development, and innovation efforts [20].

The implementation of the 4S strategy has been guided by Action Plans. The first Action Plan for 2021-2022 included 43 measures across five strategic goals, focusing on enhancing research and development capacities, fostering economic growth, improving both education system and business and administrative conditions, and improving digital infrastructure. While some measures have been successfully implemented, others remain ongoing or have been extended into the 2023-2025 action plan. Key achievements include the prioritization of measures aimed at enhancing human resources, particularly among entrepreneurs, innovators and researchers, which is critical for driving innovation.

Challenges in implementing the 4S strategy have included improving digital infrastructure, silo-less inter-governmental initiatives and communication, increasing stakeholder participation, and tech startup funding constraints. Despite these challenges, significant opportunities have emerged, particularly in the adoption of emerging technologies such as

AI, IoT, and blockchain, as well as in reaching critical mass in the digital growth community, exemplified by Serbia's three main Science and Technology Parks (STPs). The stated technologies are already being applied in various sectors, including telecommunications and banking, demonstrating Serbia's potential for significant advancements in digital innovation and infrastructure.

2.10.3 Regional perspectives

Serbia's approach to regional S3 implementation is multifaceted, aiming to promote balanced regional development and enhance local innovation capacities. Key to this approach is the promotion of abovementioned three STPs as digital innovation hotspots, strategically located in the northern, central (Belgrade), and southeastern regions. These parks are designed to serve as hubs for research, development, and innovation, supporting local startups and established businesses alike.

Additionally, the government has established a network of regional startup innovation centers to bolster local and regional innovation potential. As of 2020, numerous startup centers have been set up across Serbia, providing essential infrastructure and support for regional innovation activities. These centers aim to become self-sustaining, fostering a vibrant ecosystem for startups and innovative businesses. The development of optical broadband networks in rural areas is another significant measure aimed at improving connectivity and supporting regional development, ensuring that even remote areas can participate in the digital economy.

The regional innovation ecosystem is further strengthened through continuous dialogue and collaboration among public administration, business, and research sectors. This collaborative approach is crucial for tailoring 4S strategies to regional needs and ensuring the successful implementation of innovation-driven economic activities. By fostering strong regional innovation ecosystems, Serbia aims to leverage local strengths and opportunities to drive national economic growth.

2.10.4 Sectoral priorities

Smart Specialization Strategy Serbia (4S) identifies four priority areas for digitalization and technological upgrading, leveraging local R&D expertise and aiming to commercialize innovations to enhance Serbia's competitive advantage. These priority areas are Food for the Future, Information and Communication Technologies (ICT), Future Machines and Manufacturing Systems, and Creative Industries.

In the Food for the Future sector, the focus is on high-tech agriculture, value-added food production, and sustainable agricultural practices. This involves the integration of digital technologies to enhance productivity and sustainability in the agricultural sector. The Information and Communication Technologies (ICT) sector emphasizes key areas such as big data analytics, cloud computing, the Internet of Things (IoT), software development, and embedded systems. These areas are critical for driving digital innovation and supporting the growth of the digital economy.

The Future Machines and Manufacturing Systems sector focuses on the development of special-purpose machines, smart control systems, eco-friendly combustion devices, and smart environmental solutions. This sector aims to advance Serbia's manufacturing capabilities through the integration of advanced technologies and innovative solutions. The Creative Industries sector encompasses creative digital audiovisual production, the video game industry, and smart packaging solutions. This sector leverages Serbia's rich cultural heritage and creative talent to drive economic growth and innovation.

2.10.5 Challenges and opportunities

The implementation of digitalization in Serbia's strategic sectors presents several challenges and opportunities. The overall key challenges include enhancing digital literacy across different demographics, bridging the urban-rural digital divide, and improving fixed-broadband connectivity. These challenges are critical as they impact the overall inclusivity and effectiveness of digitalization efforts. Additionally, there are concerns about competition-related issues in infrastructure sharing and last-mile service provision, which need to be addressed to ensure fair and efficient digital services. Specific challenges for the

Food for Future sector include different types of long-term testing, certification of traditional products, low technology transfer from R&D focused on waste reduction, renewable energy, eco-friendly packaging, as well as producers' mistrust of domestic innovations. Specific challenges for the ICT sector include procurement of state-of-the-art technology for training and education facilities in this field, establishing new R&D and business parks for ICT business and start-ups, limited soft business skills and know-how at start-ups and companies. Specific challenges for the Future Machines and Manufacturing systems sector are related to improvement of cooperation between companies with R&D organizations, out-migrations of highly educated staff and inability to retain talent. Specific challenges for the sector of Creative Industries assume creative firm's hardware and software capabilities, poor awareness of and application for EU funds, under-utilized R&D initiatives.

Despite these challenges, there are significant opportunities for Serbia in the digitalization of strategic sectors. The adoption of emerging technologies such as AI, IoT, and blockchain presents vast potential for innovation and economic growth. The government's commitment to AI development, reflected in the Strategy for the Development of AI (2020-2025), highlights the potential for significant advancements in digital infrastructure and innovation [21]. Moreover, Serbia's well-developed digital connectivity infrastructure, coupled with ongoing improvements, positions the country favorably for future digital growth. Expected effects for the Food for Future sector is added value increased in the food production chain. Expected effects for the field of ICT is the domestic ICT market developed. Expected effect in the field of Future Machines and Manufacturing systems is related to enhanced R&D capacities of the business sector through cooperation of science and economy, and the improvement of capabilities for developing general and special-purpose machines. Finally, expected effects for the field of Creative Industries assume strengthening creative industries though the focus on hardware and software improvement, and involvement of R&D and intellectual property protection.

In summary, Serbia's strategic focus on digitalization and the implementation of the S3 strategy are designed to foster sustainable economic growth and enhance global competitiveness. While challenges remain, particularly in the areas of infrastructure and

digital literacy, the country's proactive approach and commitment to innovation provide a robust foundation for future development. By leveraging its strengths and addressing its challenges, Serbia is well-positioned to achieve its strategic goals in digitalization and smart specialization.

2.11 Slovakia

Slovakia is strategically positioning itself to transition into a digitally driven, innovative, and ecologically sustainable country. Through its comprehensive Framework Strategy for the Digital Transformation of Slovakia 2030, the nation aspires to integrate advanced digital technologies into all sectors, transforming the way its citizens and businesses operate and enhancing public administration and infrastructure management.

2.11.1 National and sectoral strategic goals for digitalization

Slovakia's digital transformation strategy is ambitious, targeting the integration of artificial intelligence, the Internet of Things (IoT), 5G, big data, blockchain, and supercomputing into the national economy. These technologies are expected to act as catalysts for economic growth and enhanced competitiveness. The government aims to simplify citizens' daily lives and support entrepreneurs by reducing administrative burdens and providing strategic incentives, promoting an efficient and inclusive digital economy.

This strategy is aligned with global digital trends and tailored to meet Slovakia's specific needs. It seeks to ensure that all citizens benefit from digital advancements, thereby fostering social inclusion and sustainable development. Key to this strategy is the development of human capital and infrastructure, supported by a regulatory framework conducive to digital innovation. Slovakia’s commitment to digital transformation is further reinforced by the EU's new financial frameworks and programs, which prioritize the development of the digital economy, reflecting the recommendations of international bodies like the OECD and the UN.

2.11.2 The S3 agenda and takeaways from implementation

Slovakia's implementation of the Smart Specialization Strategy (S3) reflects a national commitment to integrating cutting-edge technology across various sectors to foster economic growth and resilience. The strategy has facilitated partnerships between public sectors, industries, and the academic community, focusing on transforming and strengthening industry through technological advancements.

The Action Plan for Smart Industry underlines this approach, aiming to digitize the industrial base, from SMEs to large enterprises. It has established initiatives to enhance digital competencies, reduce regulatory burdens, and foster innovation through better connections between academia and industry. This plan not only supports the direct digitalization of industry but also prepares the workforce through education reforms and partnerships with technical universities and scientific parks.

2.11.3 Regional perspectives

Smart specialization in Slovakia is tailored to regional strengths and opportunities, with strategic initiatives adapted to local economic conditions. For example, regions with strong automotive or IT sectors focus on developing these industries through targeted S3 activities, thereby increasing their innovation capacity and economic output.

The connection between regional industries and educational institutions is particularly important, as it enhances students' skills and integrates them into the local economy. These connections are crucial for fostering an innovative and entrepreneurial environment in the regions, which is essential for sustainable regional development.

Within Slovakia, some regions are actively engaged in implementing S3. These activities often focus on supporting innovation, research, and development, which are key elements of the smart specialization strategy. Regions can invest in creating an innovation ecosystem, promoting collaboration between businesses, research organizations, and public

institutions, and supporting the development of specific industries or technological areas where they have significant potential.

Western Slovakia, particularly the Bratislava and Trnava regions, is the most economically developed area of Slovakia. The strengths of this region include the automotive industry, information technology, and educational and research institutions. Central Slovakia, including the Banská Bystrica and Žilina regions, focuses on the engineering and wood processing industries, tourism, research, and education. Eastern Slovakia, specifically the Prešov and Košice regions, faces the greatest economic challenges but also has unique strengths such as the IT sector, industrial production, tourism, and cultural heritage.

The main challenges for the regions of Slovakia are as follows:

- Infrastructure: Eastern and some parts of Central Slovakia need significant investments in infrastructure to improve their connectivity and accessibility.
- Education and skills: Strengthening the connection between educational institutions and local industry is key to improving workforce quality and reducing unemployment.
- Digitalization and innovation: All of Slovakia, especially the less developed regions, needs support in the areas of digitalization and innovation, which will lead to more balanced economic growth and increased competitiveness.

2.11.4 Sectoral priorities

Strategically, Slovakia has focused on sectors that are either traditional strengths or emerging fields with high growth potential. The action plans developed for these sectors aim to enhance their technological capabilities and make them more competitive both domestically and internationally.

The strategic focus includes supporting new technologies and applications that bolster domestic industries and export potential, connecting established companies with innovative startups and academic institutions, and ensuring the development of a skilled workforce capable of meeting the demands of a digitized industry.

The priority sectors are as follows:

- Automotive industry: This is a traditionally strong sector and one of the most significant drivers of the Slovak economy.
- Advanced manufacturing: Including precision engineering and high value-added production. Manufacturing has historically been one of the key pillars for Slovakia's development.
- Biotechnology: An emerging sector with high growth potential, particularly in healthcare and agriculture.
- Information technology: A dynamically developing sector with great potential for innovation and digitalization.
- Tourism: Given Slovakia's rich cultural heritage and natural beauty, this sector has significant potential for development and attracting tourists.

2.11.5 Challenges and opportunities

The main challenges include adapting the workforce to new technologies, ensuring cybersecurity, and extending digital infrastructure across all regions, including rural areas. Moreover, the need for a cohesive regulatory framework and effective public-private partnerships are crucial for the successful implementation of digital strategies.

However, the opportunities are vast. Digitalization can lead to significant improvements in productivity and efficiency across sectors, foster innovation, and create new business models and opportunities for growth. Additionally, Slovakia’s strategic focus on sectors like IT and biotechnology not only aligns with global trends but also positions the country to be a leader in these fields.

2.12 Slovenia

Slovenia's commitment to smart specialization and digital transformation is articulated through its ambitious strategy known as the Slovenian Sustainable Smart Specialization Strategy (S5). This strategy is aimed at fostering a green, digital, and knowledge-based transformation across various sectors of the economy, aligning with broader European goals [22].

2.12.1 National and sectoral strategic goals for digitalization

Slovenia's smart specialization strategy, known under the abbreviations S4 (Slovenian Smart Specialization Strategy) and the updated S5, reflects its commitment to aligning with European directives aimed at fostering a digital and green society. S5 is the Slovenian Sustainable Smart Specialization Strategy, which builds upon the previous period's foundations to drive an "innovative, low-carbon, digital, and knowledge-based transformation of the economy and society." [22].

This strategy is supported by a robust framework involving the Quadruple Helix model, which facilitates cooperation among businesses, research institutions, the government, and civil society. Strategic Development and Innovation Partnerships (SRIPs) are a pivotal element of this model, directing the entrepreneurial discovery process and stimulating economic areas vital to Slovenia's future in the 2021-2027 program period [22].

The purpose of the Slovene S5 strategy is to accelerate the development of competitive products and services and, with the accelerated introduction of Horizontal Network of Information and Communication Technologies (HOM ICT) and key enabling technologies (KETs), to contribute to an accelerated green (and digital) transition in priority areas where Slovenia shows developmental comparative advantage, or where it achieves a critical mass of competences. As such, S5 emphasizes sustainability as a core component, positioning it alongside digital transformation as essential for achieving long-term productivity growth and economic resilience. This strategic orientation is seen as crucial not only for environmental

sustainability but also for enhancing overall life quality and economic stability across Slovenia.

2.12.2 The S3 agenda and takeaways from implementation

The implementation of the S3 strategy, now evolved into S5, has been instrumental in guiding Slovenia's economic transformation. Strategic Development and Innovation Partnerships (SRIPs) play a critical role in this process, serving as the main platforms for collaborative economic and innovation activities [22]. These partnerships focus on areas identified as having high growth potential and strategic importance, such as health, smart cities and communities, and sustainable energy.

The renewed focus under S5 includes a stronger emphasis on environmental sustainability, aligning with the European Green Deal and Slovenia’s commitment to reducing greenhouse gas emissions and achieving climate neutrality by 2050. The strategy supports the development of new skills and public finance to promote a digital-innovative transformation.

2.12.3 Regional perspectives

S5's regional implementation underscores the importance of localized strategies that cater to specific industrial strengths and technological capacities. Each region in Slovenia is encouraged to develop tailored approaches that leverage their unique resources and capabilities, fostering regional economic growth while contributing to national goals.

For example, the Pomurje region, with its focus on metal processing, tourism, and the food industry, integrates smart specialization strategies that emphasize digital transformation and sustainability.

2.12.4 Sectoral priorities

Slovenia has identified several strategic sectors for digitalization and technological upgrading, reflecting a diverse and forward-looking economic agenda. Key sectors include:

(1) smart cities and communities (which include health; energy and other supply; mobility, transport and logistics; security; quality of urban living in the smart city ecosystem), health and medicine, sustainable food production, and advanced materials; (2) horizontal network of information and communication technologies (ranging from IoT, cyber security, AI, or geolocation and time services); (3) smart buildings and home with a wooden chain; (4) networks for the transition to the circular economy (ranging from sustainable energy, biomass and alternative raw materials, green technologies and processes, circular business models, secondary raw materials); (5) sustainable food production (such as expanding food supply, optimizing supply chains, ensuring quality of raw materials); (6) sustainable tourism; (7) factory futures (such as robotics, smart factories, advanced materials and sensors, modern production technologies); (8) health-medicine; (9) mobility; (10) materials as final products (such aluminum, steel and special alloys, multicomponent smart materials, functional coatings and advanced binders for metals).

Each sector is expected to integrate digital technologies to enhance competitiveness and innovation capacity. For instance, in the health sector, the focus is on digital healthcare solutions that enhance patient care through smart devices and telehealth services. The energy sector is adopting smart grid technologies to promote sustainable energy management. Similarly, the manufacturing sector is increasingly focused on developing smart factories equipped with AI and robotics, transforming traditional production methods to meet future demands. The focus on smart industries, such as the Factory of the Future, highlights Slovenia's commitment to adopting cutting-edge manufacturing technologies, robotics, and artificial intelligence.

2.12.5 Challenges and opportunities

The industrial transformation and further economic and social development of Slovenia require improvements in the scientific research and innovation ecosystem and the provision of more coordinated, stable, and integrated investments in research, development and innovation, digital transformation, and an improvement in the competitiveness of SMEs and in knowledge and skills for smart specialization.

The challenges of digital transformation are multifaceted, involving the integration of new technologies, cybersecurity, data protection, and ensuring equitable access across all societal segments. However, these challenges are matched by significant opportunities to enhance productivity, foster innovation, and open new markets.

The strategic deployment of digital technologies across sectors like healthcare, energy, and manufacturing is expected to drive significant economic benefits, promoting a more sustainable, efficient, and competitive Slovenian economy. By focusing on digital and sustainable transformation, Slovenia aims to position itself as a leader in smart specialization within Europe, aligning its economic development with contemporary global trends and environmental needs.

3. Conclusions

This report aims to summarize key insights on the S3 at national, regional and sectoral level, which have been provided by project partners. The report is not meant to be exhaustive in the information covered, but rather **offer a bird's eye perspective** on the focus areas and implementation status. This report is also meant to be **used as a living document by the project partners** to update the information throughout the project duration. As this is a summarized document, the detailed country reports can be found on Trello and on the Danube DNA shared drive.

Across the Danube DNA countries, there are similarities in how countries engage with the S3, but also some important differences that ultimately define the course followed in implementation. The most important differences relate, however, to the very specific regional and sectoral priorities in focus, which are closely aligned to the regional and economic comparative advantage.

The **main similarities across countries** related to the higher-level strategic goals in focus. Specifically, and not surprisingly, a focus on *digital transformation* is common across all countries, highlighting the universal drive towards enhancing digital capabilities and integrating advanced technologies. Also, all countries emphasize *strengthening innovation,*

with a strong focus on research and development, indicating a collective effort to foster technological advancement and economic competitiveness. Sustainability is particularly emphasized in across countries (with a higher or lower emphasis) reflecting a growing concern for *sustainable development and green technologies*. Lastly, some countries, such as Czech Republic, Hungary, Croatia, Serbia (but also others) stress the importance of *strengthening economic competitiveness*. To improve competitiveness, important gaps need to be addressed in economic, technological, and know-how performance. For instance, to ensure that the goals of the S5 strategy in Slovenia are to be met by 2030, labor and material productivity need to be improved, innovation performance needs to be raised (as measured by the European Innovation Index), the share of population with tertiary education should be raised (e.g. from 46,9% in 2020 to 50% by 2030), as well as the participation of adult population in lifelong learning (e.g. from 8,4% in 2020 to 19% in 2030). All these improvements in performance and capabilities should ensure an increase in the Digital Economy and Society Index (DESI) by 2030.

Differences persist, of course, due to the need for each country to follow its own patterns of specialization and comparative advantage. For instance, Austria, Germany, Czech Republic and Hungary focus strategically on *high-tech industries and digital manufacturing* (integrating Industry 4.0 technologies into the production process), while countries such as Bosnia and Herzegovina, and Romania have a strategic focus on more *traditional sectors like engineering, shipping, and agri-food*, or Croatia and Montenegro focusing on sectors such as *agriculture and tourism*.

Overall, however, countries in the Danube DNA project region do share similar challenges and limitations in implementation. *Digital infrastructure* is, for instance, a challenge that even more economically advanced countries face under pressure to accelerate digital transformation in the industrial sector and across the society, such as Austria and Germany. *Skills shortage* is also a challenge currently faced across the entire Danube DNA region, underscoring the importance of adapting educational systems and workforce training to meet the demands of digital and technological advancements. *Funding constraints and bureaucratic hurdles* (administrative barriers) are also challenges shared across countries,

particularly emphasized in Bosnia-Herzegovina, Romania, Croatia, Montenegro for example, suggesting the high need to streamline administrative processes and to increase (public and private) investment. Lastly, *insufficient data* to assess status-quo, gaps, and progress with digitalization across sectors and firms, but also at national level, plagues all countries.

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