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The Present and Future of a Digital Montenegro: Analysis of C-ITS, Agriculture, and Healthcare

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Abstract: The digitization and general industrial development of Montenegro is a great challenge for engineering and science due to its special characteristics. As the accession of Montenegro to the European Union has been an ongoing agenda for over a decade now, and the accession of the country is expected by 2025, adapting the interconnectivity and smart automation of Industry 4.0 plays an essential role in reducing the current gap between Montenegro and EU member states. In this paper, we investigate the present and potential future digitization efforts in the fields of Cooperative Intelligent Transport Systems (C-ITS), agriculture, and healthcare in Montenegro. Our work takes into consideration the characteristics of the country and analyzes the considerations and implications regarding the deployment of state-of-the-art technologies in the investigated fields.

Keywords: cooperative intelligent transportation systems (C-ITS); digital agriculture; smart farming; digital health; eHealth/mHealth

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Citation: Kara, P.A.; Ognjanovic, I.; Maindorfer, I.; Mantas, J.; Wippelhauser, A.; Šendelj, R.; Laković, L.; Roganović, M.; Reich, C.; Simon, A.; et al. The Present and Future of a Digital Montenegro: Analysis of C-ITS, Agriculture, and Healthcare. *Eng* **2023**, *4*, 341–366. https://doi.org/10.3390/eng4010021

Academic Editor: Antonio Gil Bravo

Received: 31 December 2022
Revised: 21 January 2023
Accepted: 25 January 2023
Published: 29 January 2023

1. Introduction

Humanity has come a long way since the dawn of the Industrial Revolution in the 1760s. Today, we embrace the Fourth Industrial Revolution—commonly known as Industry 4.0—which fundamentally builds on the extensive interconnectivity of smart systems. Together, they create complete smart ecosystems. However, these ecosystems are not limited to the modern urban areas of smart cities but also extend to rural areas in the form of smart agriculture.

The concept of Industry 4.0 encompasses numerous technologies and fields of practical utilization, ultimately affecting a vast portion of our everyday lives. Its basic ideology [1–3] is built around interconnectivity and smart automation, and its terminology was made widespread and popular by Klaus Martin Schwab [4], the founder of the World Economic Forum (WEF). Some argue that Industry 4.0 is the new German ideology [5], while others already point toward Industry 5.0 [6–9], or deny its existence in the first place [10] ("there is no such phenomenon as a Fourth

Industrial Revolution"). It can be approached from the associated changes in industrial capitalism [11]—or rather, "post-capitalism" [12–14], considering work and education in a post-work era, or transhumanism [15–17], focusing on the significant potential increases in life expectancy and cognitive capabilities; however, in the scope of this article, we focus on technology.

Among others, these technological fields include transportation, agriculture, and healthcare. Advanced transportation solutions not only improve the safety and efficiency of personal vehicles [18,19] but also significantly affect public transportation [20], emergency services (e.g., ambulance [21]), the transportation of goods [22], and many more. Additionally, such transformation of the transportation ecosystem may have an immensely positive impact on the environment (e.g., reduction of harmful emissions and more efficient usage of available resources) [23]. Regarding agriculture, the demand for consumable substances is expected to rise parallel with the rapid growth of Earth's population [24], which, at the time of writing this paper, is already above 8 billion; yet, at the same time, various factors (e.g., climate change) limit the adequate areas for producing food [25]. Therefore, efficiency in agriculture is more vital than ever [26]. Finally, the importance of healthcare must never be underestimated, as it is one of the keys to the quality and length of human life [27,28].

The digital transformation of these fields happens all over the face of the Earth. Of course, the pace at which such forms of transformation occur may vary greatly between the different regions of the world [29–31]. It is not only influenced by technological readiness and economic support but by the challenges imposed by regional characteristics as well.

In this paper, we analyze the present presence and the potential future of digitization efforts in the fields of transportation, agriculture, and healthcare in the country of Montenegro. Montenegro is a particularly interesting target of analysis in the context of Industry 4.0, both due to its rather unique natural characteristics (e.g., intensely rugged terrains) and its rapidly developing modern history. After all, the Montenegro we have on the world's map today was formed via the independence referendum of 2006, and since 2008, the accession of Montenegro to the European Union has been in progress. This latter fact comes with strict requirements and the need for compliance with regulations, but also means development aid in various forms, such as funding mechanisms (e.g., Instrument for Pre-Accession Assistance). Additionally, assistive programs and projects have been created to support the digitization of the country. One such program is the Digital Entrepreneurial Nest and Industry 4.0 in Montenegro, also known as DigNest [32]. A great number of the authors of this paper are contributing members of the DigNest project.

The rationale of this paper is to contribute to the driving forces of Montenegrin digitization. The comprehensive analyses and thorough assessments of this work aim to provide expert insights and know-how support regarding the investigated fields, and to assist paving the next steps toward short-term and long-term goals. In the scientific literature, there are already published works about the different aspects of the current state and the advancement of Montenegro. Most of these case studies focus on specialized topics of development. Digital transformation as a whole is addressed by Golubović et al. [33]. Beyond the challenges and the opportunities, the authors also draw conclusions regarding the new mindset in the Montenegrin organizational culture, education, customer satisfaction, and other social impacts. Transformation is viewed through the necessities mandated by the pandemic of the recent years. The work of Melović et al. [34] narrows down the focus of digital transformation to digital marketing and electronic business in Montenegro. The large-scale research encompassed a survey, in which data were collected from 172 companies. The authors conclude that "the more a company relies on the use of digital marketing in its business, the more significant its impact on promotion and brand positioning". In the areas of transportation, the Montenegrin railway is studied by Bošković et al. [35], Jakovljevic et al. [36], and Bramo and Llaci [37] on the topic of sustainability, bridge rehabilitation, and its connection to

Albanian agribusiness. Maritime transportation is a highly relevant field of research in Montenegro due to the country's geography. The works of Nikčević and Škurić [38], Kapidani and Kočan [39], and Hasaj et al. [40] also address sustainability, and similarly focus on cross-border cooperation. Agriculture is investigated by the works of Rajović and Bulatović [41,42], Ćorić and Popović [43], and Radonjić and Hrnčić [44]. Apart from sustainability and e-agriculture, the impact of non-native pests, which can be a major issue in Montenegro for various plants and crops (e.g., olives [45] and raspberries [46]), is also studied. Regarding healthcare-related works, Ivanović and Raković [47] performed a Montenegrin case study for the country's e-health card information system, while Safet [48] dealt with questions of management, and Mantas et al. [49] focused on modern healthcare education. The technological trends of Montenegrin manufacturing are reviewed by Vujanović [50], and Boban et al. [51] studied the competitiveness of homemade consumables. Labović et al. [52] studied food safety in Montenegrin restaurants and other food service establishments, Rajović and Bulatović [53] investigated plant- and animal-based food production, and Martinovic and Mirecki [54] analyzed their connection to health in the country. Tourism is addressed by the works of Jaksic-Stojanovic et al. [55], Moric et al. [56,57], and Bigović [58], highlighting sports, cultural and rural tourism, and its seasonality.

The methodology of this work was based on various pillars. First of all, the authors consulted with numerous Montenegrin authorities, organizations, and institutions, including the Chamber of Economy of Montenegro (https://www.privrednakomora.me/en (accessed on 21 January 2023)); the Ministry of Agriculture, Forestry and Water Management (https://www.gov.me/mpsv (accessed on 21 January 2023)); Montenegro Ministry of Health (https://www.gov.me/mzd (accessed on 21 January 2023)); Clinical Centre of Montenegro (https://kccg.me/ (accessed on 21 January 2023)); Mljekara Lazine, Montenegro (https://mljekaralazine.me/ (accessed on 21 January 2023)); the University of Montenegro (https://www.ucg.ac.me/ (accessed on 21 January 2023)); and the University of Donja Gorica, Montenegro (https://www.udg.edu.me/ (accessed on 21 January 2023)). The authors of this work also investigated the Montenegrin state of the respective fields in the scope of the DigNest project. Additionally, the recent regional advances were studied from published scientific works, as well as from technological, industrial, and economic reports.

The remainder of this paper is structured as follows: Transportation (i.e., cooperative intelligent transportation systems), agriculture (i.e., digital agriculture and smart farming), and healthcare (digital healthcare and eHealth) are discussed in Sections 2–4, respectively. Each section begins with an introduction to the field and the related concepts. This is followed by a brief overview of the current state in Montenegro and the rest of the world. Then, the involved technologies and the potential use cases are elaborated. After the relevant features and attributes of Montenegro are revised, the considerations and implications of these properties are analyzed from a technological perspective, followed by a concise summary. The analysis of transportation is detailed from all these sections in order to reflect its importance regarding the long-lasting financial and geopolitical implications of the ongoing investments, and the associated recent events. The paper is concluded in Section 5, highlighting the most important discussions of the investigated fields and the future steps toward a digital Montenegro.

2. Cooperative Intelligent Transportation Systems

2.1. Introduction and Concepts

Present transportation systems face various challenges. In the past decades, the number of traffic participants has grown significantly. The spread of just-in-time supply chains requires highly available and reliable transportation systems. Such systems' safe and economical operation is an essential building block of modern economies.

Intelligent Transportation Systems (ITS) try to solve some of the above-mentioned problems. ITS technology covers various use cases and methods in order to address current and upcoming issues. These use cases include data collection from the road network, data provisioning to the traffic participants, law enforcement with smart devices, and communication among the various traffic participants. From a road operator's perspective, ITS can use induction loop detectors, intelligent cameras, radars, or other devices to count the traffic and measure the speed or other attributes of the passing vehicles. The road operator can use this information to create long-term statistics, optimize traffic flows, oversee and control the traffic network in real-time, analyze traffic disturbances, and increase drivers' awareness via smart traffic signs or other communication technologies. ITS also covers efficient ways of toll collection. Vehicle drivers also benefit from ITS via the more-efficient road networks or the valid and up-to-date information on the roads. ITS can also reduce the load of law enforcement. For example, an intelligent camera deployed at an intersection can detect and charge violations of traffic rules. The speed cameras and radars can see violations of speed limits, whereas the weighing types of equipment built into the road surface can help to enforce the special limitations applicable to the particular road section. As we can see, ITS uses and facilitates digitalization in order to provide more efficient, safe, and sustainable transportation.

Cooperative Intelligent Transportation Systems (C-ITS) provide the next generation of ITS. In C-ITS, the vehicles and the infrastructure are equipped with communication devices. These devices offer two-way communication methods to further enhance existing, or introduce new, ITS use cases. We call this kind of communication Vehicle-to-Everything (V2X). Based on the direction of the communication, we can categorize the use cases. In Vehicle-to-Vehicle (V2V) use cases, the vehicles communicate with each other directly. Such use cases are traffic jams ahead or V2V safety services such as collision and "do not pass" warnings. In Infrastructure-to-Vehicle (I2V) use cases, the infrastructure can provide information to the vehicles; for example, it can warn the drivers about the applicable speed limit or ongoing road works. These use cases help the road operators to influence and actively increase traffic participants' awareness. In Vehicle-to-Infrastructure (V2I) use cases, vehicles can provide statistical data to the roadside infrastructure or ask for traffic sign prioritization. Vehicle-to-Network (V2N) use cases implement services such as teleoperated driving and automated valet parking.

The evolution of C-ITS splits into three phases that rely on different standards. Day 1 use cases mainly focus on awareness services where the infrastructure notifies the vehicles about speed limits, road works, traffic light status, etc. Further, vehicles share their presence and status/attribute information. Such Day 1 systems are currently deployed in various locations, e.g., under the coordination of the European C-Roads platform [59]. From the road-user point of view, the Golf VIII was the first mass-produced vehicle in Europe with V2X as a standard feature. Since then, various other models have been equipped with this technology. The currently available V2X solutions mainly support Day 1 use cases.

Day 2 focuses on perception sharing and advanced use cases. On Day 1, the C-ITS stations share their status/attribute information only. Contrary to this, perception sharing enables the exchange of perceived information. This overcomes a massive challenge in the C-ITS world—the penetration issue—meaning that the stakeholders are unwilling to invest in the technology due to the low number of initially deployed devices. This is mainly a chicken-and-egg problem, but several strategies exist to overcome this issue. One of them is providing governmental funding for deployment projects (such as the C-Roads project). Another C-ITS technology enabler can reward Original Equipment Manufacturers (OEMs) in various benchmarks such as Euro NCAP, which will include V2X technology in its evaluation methodology. The third possible solution for this problem is an appropriate strategy to have non-V2X-equipped users in the system. Perception-sharing technologies are based on advanced sensor infrastructures and are expected to significantly mitigate the concerns about penetration by putting unequipped vehicles on the C-ITS horizon. The standardization of Day 2 enabler V2X protocols and related message formats is currently under development.

Day 3 systems further enhance the quality and volume of the shared information in the C-ITS domain. The main goal of Day 3 is to enable the so-called cooperative driving use cases. They are expected to further enhance the safety and efficiency of traffic. Cooperative driving enables sharing the future state or the intention of the equipped vehicles. These use cases also assume some level of automation for the vehicles. Currently, the use cases are under development for Day 3 systems.

2.2. Current State in Montenegro

In the European Union, the Platform for the Deployment of Cooperative Intelligent Transportation Systems (C-ITS Platform) was created by the European Commission services (DG MOVE) in 2014 with the intention to facilitate the emergence of a shared vision across all actors involved in the C-ITS value chain. Based on the results, the EC adopted the European Strategy on Cooperative Intelligent Transport Systems in 2016 with the primary goal of helping the convergence of investments and regulatory frameworks across the EU, including the adoption of the appropriate legal structures, initiating various programs for EU-funded projects, continuing the C-ITS Platform and increasing the volume of international cooperation with other regions of the world on the aspects of C-ITS. It also involves the C-Roads platform [59], the flagship initiative of European Member States, road operators, and associated partners for testing and implementing C-ITS services with cross-border harmonization and interoperability in the main scope. Within this learning-by-doing approach, the EC gathers real-life deployment experiences through Member State pilot activities and continuous coordination with C-Roads.

Since its official launch in 2016, C-Roads proved that C-ITS has arrived into the everyday life of road users and that there are vast benefits to exploit in the near future. With the help of Europe-wide harmonization activities and relying on strategic partners, such as the CAR 2 CAR Communication Consortium (C2C-CC), ASECAP, CEDR, EU EIP, and the European Commission, C-ITS deployments reached a total of 20,000 km of road sections equipped with mature ad hoc short-range communication units (ETSI ITS-G5). Moreover, 100,000 km overall are covered with wide-area cellular communication technologies—such as 4G and 5G—and 35 cities are already actively working on their C-ITS service implementation, with more than 50 to be expected by the year 2023 [59].

The closest C-Roads Core Member states to Montenegro are Slovenia, Hungary, and Greece, while Croatia is an Associated Member of the platform [59]. In comparison, at the time of writing this paper, ITS technology in Montenegro is very much in its infancy. ITS is a part of the long-term goals of the country, according to the Transport Development Strategy until 2035 [60]. However, it is important to highlight that C-ITS is not a part of the current strategy (i.e., it is not being considered for the following 13 years). Regarding ITS, the primary considerations for enhanced traffic safety are intersections and railway crossings. In accordance with Directive 2010/40/EU [61], the installation of ITS devices for traffic signalization, highway control, and management is planned for the first-ever Montenegrin motorway and the Sozina tunnel—the longest tunnel in the country. Yet, the analysis provided by the strategy also states that "Montenegro lacks experience and appropriate structures for coordination and management of the introduction of ITS, especially in road and rail transport sectors" and that the "structure of state administration's transport sector lacks dedicated bodies for intermodality and co-modality, intelligent transport systems and interurban public transportation". Additionally, the recent case study of Prelevic [62] highlights that the lack of information-technology-related education and greater confidence in more conventional approaches contribute to the current state.

2.3. Technologies and Use Cases

C-ITS use cases and V2X communication pose several technical challenges [63,64]. The most critical ones are listed below.

- The communication parties are highly mobile. The relative speeds can easily exceed 250 km/h.
- The network topology changes frequently and rapidly.
- Message distribution has to be handled in a spatially aware way while the nodes are moving.
- The messages typically have broadcast destination addresses.
- The node density can be high. Channel contention needs to be avoided by appropriate countermeasures.
- The communication scheme has to support nomadic devices.
- ITS stations shall trust each other.
- Privacy protection methods need to be applied to avoid sensitive data collection.
- Distributed operation is favored over centralized due to the mission-critical use cases.
- Accurate absolute positioning is required.

Various standardization bodies participated in the harmonization and the conceptual and technical work in order to meet the multiple requirements and successfully address the challenges.

ISO created the CALM standard [65], which defines the architectural aspects of ITS stations. The standard introduced four horizontal and two vertical layers, in contrast with the classical 7-layer ISO OSI standard [66]. The four horizontal layers provide a simplified yet optimized architecture for C-ITS use cases, whereas the two vertical layers provide cross-layer functionalities.

The first layer among the horizontal layers is the Access layer. This layer covers physical access and media access control functionalities. The IEEE defined the 802.11p standard [67] in this layer in 2010, which was the enabler of V2X use cases. This standard was created as a modification/customization of the popular Wi-Fi standard; thus, it uses the same access control approach (CSMA/CA). The current mass production deployments (e.g., VW Golf VIII) are typically based on this standard. The successor of the 802.11p standard (802.11bd) is currently under development, aiming to feature backward compatibility, increased range and bandwidth, and various other advanced features [68]. An alternative to the Wi-Fi-based Access layer evolution path is provided by the standardization body of 3GPP, which developed cellular V2X (C-V2X) communication technologies [69], incorporating a slightly different channel access approach. Instead of CSMA/CA, 3GPP applied a so-called semi-persistent scheduling [70] to ensure the proper and efficient usage of the channel. This standard was introduced in Release 14 and was initially based on the LTE proximity services. 3GPP also works on the successor of the standard for the fifth generation of mobile cellular systems called 5G NR V2X [71]. ETSI also has standards that adopt these access layer solutions in the ETSI ITS standard family.

The second layer in the architecture is the Network and Transport layer. Here, IEEE and ETSI were the key contributors. IEEE developed the WAVE standard [72], which offers a lightweight transport protocol with single-hop broadcast support. On the other hand, ETSI standardized GeoNet [73], which enables single-hop broadcast, geographically scoped broadcast, anycast, and unicast transmission schemes. GeoNet defines algorithms to forward and distribute messages in the rapidly changing ad hoc network environment, by using geographic addressing and routing. On top of the GeoNet, ETSI defined the Basic Transport Protocol (BTP) [74] for simple multiplexing/demultiplexing of higher-layer protocols.

The third layer is the Facilities layer. This layer's standardization was handled mainly by ETSI, ISO, SAE, and CSAE. Besides others, ETSI defined CAM [75] for ITS station status/attribute information and DENM [76] for event notification exchange. ETSI adopted the IVI standard [77] from ISO, which tries to provide a digital representation of traffic signs precisely. ETSI also adopted SAE standards for signalized intersection digitalization [78]. This mutual influence between SAE and ETSI has a long history, resulting in similar message types and protocols. SAE facility messages are typically deployed in the USA, whereas ETSI focuses on Europe. CSAE typically covers Chinese standards. All the standardization bodies mentioned above consider the ITS domain very seriously and continuously work on future extensions of their outputs.

The Application layer defines and controls how the facility services should behave; thus, they are typically covered by the same standardization body as the related facility layer service. For example, ETSI has service specifications for Cooperative Awareness and other facility services. The SAE developed the J2945 standard family, which contains system requirements for the V2X services. This document defines the requirements for BSM transmission [79]. These standards are designed in a way to respect the addressed use case requirements and the communication channel peculiarities.

Besides the horizontal layers, there are two vertical layers in the ITS architecture—more precisely, the Security and the Management layers. These layers are cross-layer entities because they have interfaces to multiple horizontal layers. The Security layer needs to implement various requirements, which are different from the regular client–server-based systems. C-ITS is a distributed system; thus, the trust between two nomadic ITS stations must be ensured. The implementation [80] is based on conventional PKI systems. Each ITS station signs the transmitted messages with their private keys using asymmetric cryptography. The public key of the key-pair is signed by an upper-level certification authority, which ensures trustworthiness. It is important to note that the messages are not encrypted; they are only signed. They are typically broadcast messages and are relevant to all receivers in the dissemination area; thus, the encryption of the messages is typically not justified. However, the traceability of the clients raises privacy issues. In order to avoid such issues, pseudonymity techniques are implemented. This means that regular vehicle ITS stations need to change their unique identifiers in all protocol layers after a certain time and traveled distance. The pseudonyms include the MAC address, the GeoNet address, the StationID, and the path history. The certificate used to sign the messages needs to be exchanged as well because the public key is also a unique identifier; thus, the vehicular ITS stations need certificate provisioning. Technically, the certificates are implemented in the Networking layer and typically use the IEEE 1609.2 security certificates—in both EU and US regions [72].

Naturally, the distributed system also expects some kind of common requirement set. The applied techniques are described below. If an ITS station fulfills the set of requirements, it can go through the so-called enrollment process. In this process, a long-term identification token is registered with the related authority (Enrollment Authority) [81]. Then, the ITS station is able to request short-term certificates via the proper authority, which ensures the valid registration of the requester ITS station in the Enrollment Authority during the certificate authorization. The PKI usually applies the butterfly key expansion technique to ensure scalability. The Enrollment and Authorization Authorities are validated by a Root Certificate Authority. The public keys of the trustworthy Root Certificate Authorities—and, via those keys, the individual ITS stations—are distributed via the European Certificate Trust List (ECTL) [82]. A Root Certificate Authority can be added to the ECTL after various audits. The revocation is handled via the European Certificate Revocation List (ECRL). The names and the number of levels of the certificate authorities in the PKI architecture can be different, but the base roles are the same in all regions.

For successful C-ITS deployments, the understanding of the security architecture is crucial. From a business perspective, Montenegro belongs to the European vehicle market. This means that besides the bitwise compatibility, which can be ensured by the adoption of the proper ITS standards, the harmonization of the PKI systems is also essential to effectively support C-ITS use cases.

The Management layer is responsible for some cross-layer operations. It enables distributed congestion control and multi-channel operation use cases by facilitating communication across the architecture layers.

In order to further specify and concretize the operation of the protocols, agree on triggering conditions, and provide commonly agreed requirements, profiling activities were performed. The C2C-CC [83] and the C-Roads project [59] created triggering conditions and standard profiles for V2V, I2V, and V2I use cases. These profiles specify performance and functional requirements for the ITS stations. They also define use cases and triggering conditions for the use cases. Some use cases extended with V2V use cases are listed in Table 1. These profiles typically define transmission-side behavior because the reception side has to be defined by the OEMs. The Common Criteria document [84] also specifies security requirements.

Table 1. Sample V2X use cases.

Use Case	Type	Most Relevant Deployment Location	Expected Impact (1–5)
Do not pass warning	V2V	Rural main roads	5
Slow moving vehicle	V2V	Rural main roads	3
Roadworks warning	I2V	Rural main roads, Urban	3
Hazardous location notification	I2V	Rural main roads, Urban	4
In-vehicle signage	I2V	Rural main roads	3
Signalized intersections	I2V	Urban	3
Signalized intersections with preemption	I2V, V2I	Urban	4
Adverse weather conditions	I2V	Rural main roads	4
Probe vehicle data	V2I	Urban	1

2.4. Relevant Features and Attributes of Montenegro

Montenegro is a small (13,812 km^2 total area), yet greatly diverse country, particularly in terms of geography. While it has a 293.5 km-long coastline at the Adriatic Sea—the altitude of which is by definition close to sea level—it is generally a mountainous country. In fact, the native name of Montenegro is "Crna Gora", which translates as "black mountain", referring to Mount Lovćen, a mountain in the southwestern region of the country [85]. However, it is not a single mountain that defines the terrain configuration of Montenegro. There are 50 peaks within the modest area of Montenegro that reach over 2000 m. The highest peak of the country is Zla Kolata at 2534 m, located on the border of Montenegro and Albania; although, historically, it was thought to be Bobotov Kuk at 2522 m, located in the Durmitor mountain range. Furthermore, even with such a long coastline and 17 islands, the average elevation is 1086 m.

The mountainous nature of Montenegro affects its transportation, as the roads connecting the major cities tend to span across mountains. One may think that the roads near the coastline form an exception to this statement; however, even those roads may be situated on mountains, as it is common that the elevation steeply rises from the coast towards the inland. A typical example of this is Budva, where the main road circumventing the town is actually up in the mountains and not on the coastline. Additionally, there are numerous tunnels in Montenegro. The longest tunnel in the country is Sozina, as mentioned earlier, which has a length of 4189 m.

The overall length of paved roads in Montenegro is 1729 km. This includes the recently (July 2022) inaugurated 41 km-long section of the Bar-Boljare motorway, which contributes to the motorway connection between Podgorica and Belgrade. At the time of writing this paper, this is the only motorway section of the country. Among the paved roads, there are 12 main roads (i.e., highways) and 31 regional roads. Furthermore, Montenegro has 3548 km of unpaved roads [86].

The paved main roads are typically composed of one lane for each direction, built as a single carriageway (i.e., no physical separation between the lanes). This structure is sometimes extended with a third lane for overtaking. In the mountains, overtaking is often prohibited, as the terrain may occlude the line of sight of the driver. The main roads are often steep, winding, and narrow. There are no guardrails or barriers to prevent vehicles from falling off the road at several places.

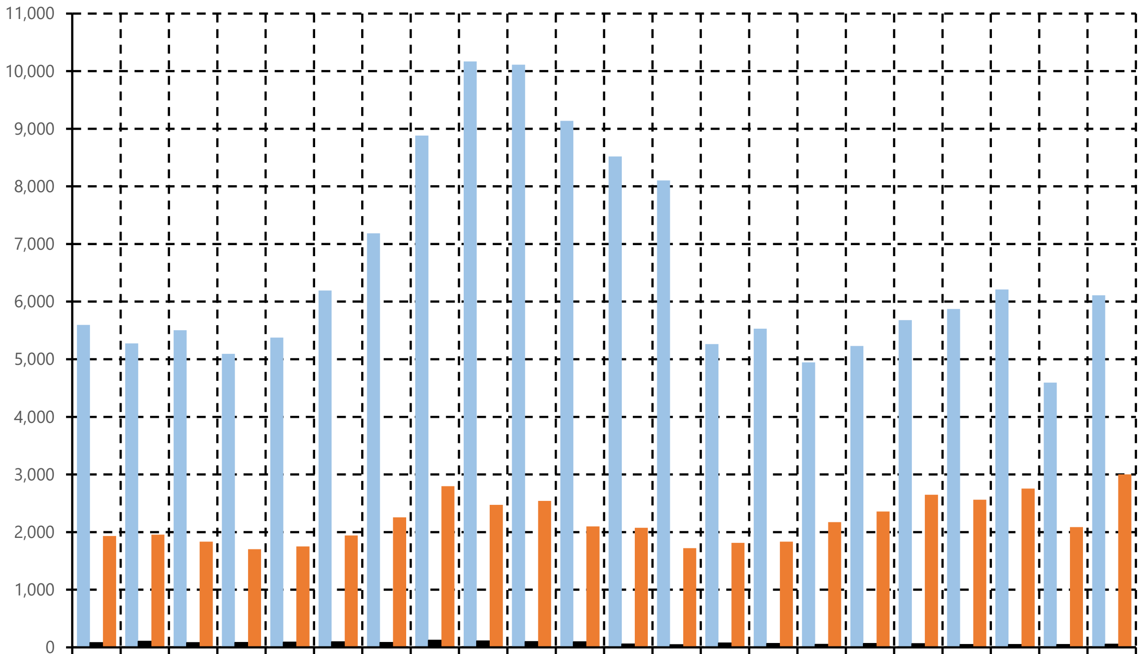
A well-known dangerous area for road transport in Montenegro can be found north of Podgorica. The road through the Morača Canyon is a twisting, two-lane highway, usually overcrowded during summer, and is subject to frequent rockslides. During winter, this road segment and northern parts of Montenegro, in general, are covered with snow, seriously slowing down traffic and creating hazardous road situations. The roads leading to the country's coastal regions are in better condition but are overcrowded in summer. Extreme caution is required because local drivers can be reckless and often attempt to pass on winding roads and hills.

The total number of towns in Montenegro is 20, having populations between 136,473 (the capital, Podgorica) and 1073 (the smallest city, Andrijevica) [87]. Podgorica traffic lights are coordinated, and in some areas, the city has implemented smart traffic lights that can adapt to traffic conditions in real-time. With only a few exceptions, the cities are relatively tiny, often comprising only one or two traffic lights and roundabouts. The most commonly used vehicles in the country are cars and motorcycles; together, they make up nearly 88% of the vehicles on the roads. The remaining fractures consist of other vehicles used but less frequently than the two main types, such as buses, vans/minivans, and trucks.

There is a set of international standards increasingly accepted as basic minimum specifications for vehicle manufacture/assembly. The WHO works for the global implementation of those, and several countries' regulations now consider them as basic requirements for all vehicles. Unfortunately, Montenegrin regulations implement zero out of the eight key vehicle standards [88]. Surrounding countries—Bosnia and Herzegovina, Serbia, North Macedonia, and Albania—have the same situation, but countries in the broader region—Greece, Bulgaria, Romania, Hungary, Croatia, Slovenia, and Italy—implement eight out of eight.

The existing railway network in Montenegro consists of single-track rails of standard width in three main lines: (1) Vrbnica–Bar (part of the Belgrade–Bar railway through Montenegro); (2) Podgorica–Tuzi state border; and (3) Podgorica–Nikšić. The total length of the three lines is 248.6 km—together with station tracks, it is 327.6 km—of which 167.4 km are electrified. The number of level crossings (i.e., intersections where a railway line crosses a road at the same level) is 23, where 19 are equipped with signal-safety solutions (automatic barriers, light/sound signals) and 4 with road horizontal/vertical signalization (without barriers) [89]. The railway network density is 1.8 km/100 km^2, a condition that is unsatisfactory regarding its density and quality, and with a permanent danger of system-level vulnerability due to the concentration of the road and rail traffic in the same corridor passing through challenging terrains. In Montenegro, 204 accidents/incidents were reported in the five years between 2014–2018, with 21 accidents in level crossings (around 10%) [89].

Road traffic in Montenegro is considered relatively safe. According to current WHO data, the total number of deaths on the roads per year reported by Montenegro is 65, meaning 10.7 deaths in a year per 100,000 inhabitants [88]. Detailed statistics are depicted in Figure 1 [90–92].



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Total number of road accidents	5597	5275	5503	5094	5377	6192	7185	8882	10170	10112	9138	8519	8103	5264	5531	4944	5229	5678	5872	6210	4595	6109
Number of killed	81	105	81	84	91	95	85	122	111	100	95	58	46	74	65	51	65	63	48	47	48	55
Number of injured	1933	1957	1834	1702	1750	1942	2257	2796	2473	2542	2099	2075	1722	1812	1835	2173	2358	2648	2563	2754	2087	3003

Figure 1. Annual statistics of road traffic accidents and casualties in Montenegro [90–92].

2.5. Considerations and Implications

The peculiarities of the Montenegrin topography—and thus, the road network—imply the need for special V2X use cases.

Due to the mountainous terrain in Montenegro, the road network contains several tunnels. A tunnel means an additional traffic-related risk (e.g., due to the rapidly changing environment, namely, the brightness, temperature, or wind speed), which can be mitigated by using V2X techniques. Brož et al. [93] presented the challenges of V2X use cases in tunnels, especially the coverage and positioning issues. V2X systems increase the awareness of the drivers so that they can prepare for changing conditions, such as standing vehicles, road works, strong wind, black ice, etc.

The mountainous terrain also results in tortuous roads and serpentines. On these roads, the visibility is restricted, and the roads are sometimes possibly narrow. Thus, road users' awareness is especially important. For example, road works, road closures, or slow-moving vehicles (e.g., snow plows) after a curve can surprise drivers, which can result in dangerous situations. The execution of an overtaking maneuver is also cumbersome due to restricted visibility. In order to avoid accidents caused by unforeseeable traffic, "do not pass" use cases can be implemented. In these use cases, the overtaking vehicle gets notified about the upcoming traffic, so it can avoid dangerous maneuvers.

A further potential feature use case could be the Cooperative Intersection Collision Warning (CICW) [94–96]. This C-ITS application would improve safety at intersections, which are known to be high-risk areas for collisions, particularly in Podgorica, as the city is known to have heavy traffic and a high volume of vehicles passing through, especially during peak hours. The CICW system would use V2X communication to transmit real-time information about the location and speed of vehicles approaching an intersection, allowing other vehicles and traffic signals to anticipate and respond to potential conflicts. This could reduce the number of accidents caused by human error, such as running red lights or failing to yield.

Another C-ITS feature that could be implemented in Montenegro is Real-Time Traffic Information (RTTI) [97–99]. This system would use V2X-based data exchange to gather and disseminate information about the current traffic conditions on the roads. This would allow drivers to make more informed decisions about their routes and could help to reduce congestion and travel times. RTTI could also be used by traffic management authorities to better understand and respond to traffic patterns and incidents, improving the efficiency of the transportation system overall.

The hilly terrain also affects the deployment questions. In European C-ITS standards, message dissemination is technically handled by the GeoNet layer. Practically, the facility layer service defines a dissemination area and the GeoNet protocol tries to distribute the messages in the particular area. The GeoNet, however, does not support altitude information. This has to be considered in service deployments at serpentines or roads with high elevation differences. For example, in the case of in-level roads where one Roadside Unit (RSU) could cover a particular area, multiple RSUs could be needed. This is particularly true because most RSUs do not have omnidirectional antennas—instead, directional antennas are more widespread with a focused, narrowed radio wave beam. Therefore, the signal strength below the RSUs' might not be sufficient. Hence, the antenna placement and direction/gain parameters and settings are also critical to achieving the proper service quality. The terrain can also hinder line-of-sight communication, which reduces the effective range of the RSUs. This means that more RSUs with more sophisticated placement design considerations might be needed to cover a certain road section.

2.6. Summary

V2X and C-ITS have great perspectives to make road traffic safer and more efficient. The road network of Montenegro can also benefit from these developments. However, in order to successfully launch V2X-based deployments, the proper developments and harmonization activities have to be performed.

In Montenegro, the immaturity of the ITS, in general, can severely limit C-ITS V2I/I2V use case deployments. In urban scenarios, the deployment of traffic light controller-based V2X scenarios could be limited by immature traffic light systems. Most V2I/I2V use cases assume the proper amount and quality of data availability on the road operator side. However, the parallel design of legacy ITS with the advanced C-ITS schemes could facilitate advanced solutions. This is also true for the V2X use cases aiming to support safer level crossings; future road-rail infrastructure optimization in the Montenegrin network can be designed with the potential benefits of near-future C-ITS capabilities in mind.

According to our assumptions, the nomadic use cases could be the easiest to be deployed in the first phases. Such use cases are "do not pass" warnings, slow-moving vehicles (road operator), road works with mobile RSUs, and classic V2V applications.

It is important to note that harmonizing Montenegrin C-ITS deployment with European projects, especially with the C-Roads project, is essential. If the harmonization is not performed, then the vehicles produced for the Montenegrin market will likely not accept information from the road infrastructure. Therefore, as an initial step towards C-ITS applications, it is essential for Montenegro to join C-Roads and start the contribution to the platform first, at least as an associated partner.

In the short term, the deployment of C-ITS in Montenegro—considering the current state of transportation in the Western Balkans—may face a number of challenges. One of the main issues is the heterogeneous quality of the transportation infrastructure in the region, meaning the lack of well-developed road networks and the immaturity of supporting ITS system components in several areas of the country, which could seriously impede the deployment of C-ITS. Another challenge that may arise is the lack of standardization and interoperability among countries in the Western Balkans. This could lead to difficulties in integrating C-ITS systems across borders and could hinder the full potential of the technology to improve transportation in the region. On the other hand, the deployment of C-ITS in Montenegro could also bring some benefits in the short term. Besides the expected improvements in the safety of road traffic and enhancements in the efficiency of transportation in the country, it could also pave the way for future infrastructure improvements in the Western Balkans.

The introduction of C-ITS in Montenegro has the potential to not only improve transportation efficiency and safety, reduce congestion, and lower emissions within the country, but also to take a leading role in the harmonization and deployment of C-ITS in the Western Balkans region. With the proper investment and support, Montenegro's C-ITS deployment could serve as a model for other countries in the region, promoting the development of a more integrated and efficient transportation system across the Western Balkans. However, to achieve this potential leading role, Montenegro may need to overcome some challenges, such as the lack of infrastructure and funding, limited technical expertise, and the lack of standardization and interoperability across the region. Nevertheless, with the successful deployment of C-ITS, Montenegro could pave the way for a more connected and sustainable transportation system throughout the Western Balkans.

3. Digital Agriculture and Smart Farming

3.1. Introduction and Concepts

Especially in the north of Montenegro—the mountainous part of the country—agriculture is one of the most important sectors and represents a significant source of employment and income. The share of agriculture in Montenegro's GDP [100] should not be underestimated at around 7.6%.

For the past 25 years, European beekeepers have been reporting decreasing bee numbers and colony losses, and the situation is worsening. According to the EU Reference Laboratory (EURL) for honey-bee health, some countries in the EU are losing up to a third of their colonies every year. The most important contribution bees make to agriculture is the pollination service they provide. Pollinators' decline brings along a significant loss of pollination services, which has negative ecological and economic impacts, affecting the maintenance of wild plant diversity and large-scale ecosystem stability with potentially harmful effects on crop production, food security, and human welfare.

Smart farming and digital transformation in agriculture describe the idea of making all digital technologies and innovations usable for agriculture to make it more efficient, more resilient, more resource-efficient, and even more sustainable. "GNSS (GPS) and automatic steering systems ensure that agricultural machinery can operate in the field with an accuracy of 2–3 cm. Site-specific farming with section control and variable rate control enables the emergence of strong and healthy crops on each individual subplot of a field" [101].

Livestock has been used in many ways and served humanity for the production of food and consumer goods such as wool, eggs, and meat. While animals' needs—such as general welfare, the urge to move, and social relationships—have taken a back seat, there is a rethinking taking place in today's society.

Now, one of the biggest challenges our society has to master is the ability to feed a growing population while minimizing environmental impacts, ensuring human health, as well as addressing animal health and welfare. Global meat production is expected to double by 2050. This increase in production might be achieved by a combination of expansion in animal numbers and increased productivity. This increase in animal numbers makes their management more challenging, especially if the number of farmers continues to decrease [102]. To meet these challenges, the development of new technologies has gained importance. The largest potential lies in individual animal monitoring and analysis, which is referred to as precision livestock farming (PLF). PLF technologies are designed to support farmers in livestock management by monitoring and controlling animal productivity, environmental impacts, as well as health and welfare parameters in a continuous, real-time, and automated manner.

3.2. Current State in Montenegro

Montenegro has a land area of 255,564 ha/13,812 km^2 (2021). About 38% of the country's land is used for agriculture, 88% of which is used for meadows and extensive pastures. Arable land, fruit growing, and viticulture are practiced on only 58,200 ha. Over 60% of agricultural production comes from livestock production. Agriculture—including hunting, forestry, as well as food production—plays an important role in the economy of Montenegro and contributes to about 10% of the gross domestic product [103]. In Montenegro, most olive trees are grown in a conventional way, without normal pruning and with replacement yields. Due to the uneven landscape, agricultural production is limited to the valley systems and the narrow beach belt. Crop production is carried out only in some valleys and is restricted by scarce water resources. A lot of households still have small family plots for the production of fruit and vegetables. The dominant agricultural system is extensive grazing of cattle, sheep, and goats on semi-natural pastures [104].

Since the production methods and techniques in the Montenegrin viticulture sector mainly employ traditional approaches, there is plenty of room for improvement. The current irrigation practice, for example, is based on experience and visual inspection of the vineyard. Based on this, the plants are irrigated every fifth day, providing 50 liters of water. However, this does not take into account different soil compositions, and hence, more often than not results in over- or under-irrigation [105]. A long tradition has been beekeeping in Montenegro [106], which has been changing more and more to organic beekeeping in recent years. A joint effort from parties around the world emphasizes the development and integration of different technologies to monitor pollinators and their environment, as detailed in the next subsection.

3.3. Technologies and Use Cases

In the recent years, the digitization of agriculture has increased throughout the world. Figure 2 shows the number of articles counted by Google Scholar in 2022 for the various topics of digital agriculture. Although digital beekeeping and vineyards are less investigated in comparison, these are two highly relevant topics to Montenegro.

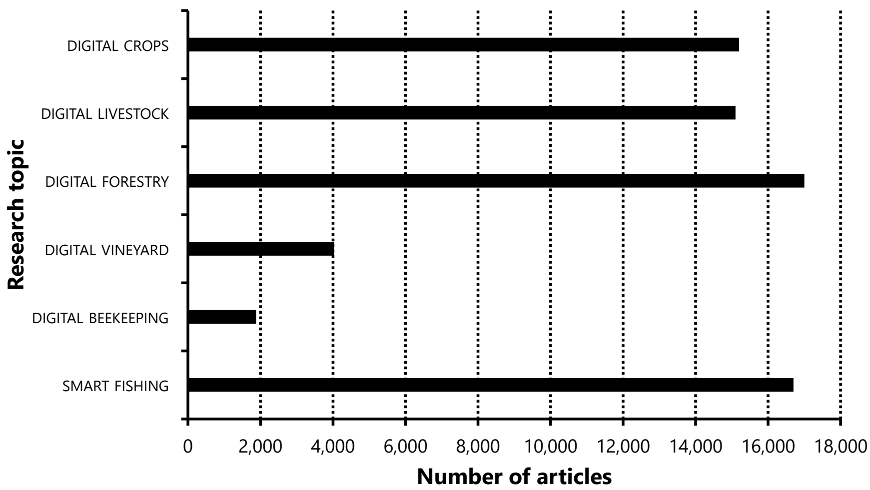


Figure 2. Number of articles on Google Scholar in 2022 for the topics of digital agriculture.

In order to improve the well-being of the bees and make the beekeepers' work easier, the Montenegro-based startup BeeAndme [107] equips beehives with intelligent sensors measuring all significant parameters such as local humidity, temperature, collected amount of honey, and bees' health through sound. Artificial intelligence is also used. The company counts how many bees fly in and out with the help of TensorFlow and Open CV [108]. Furthermore, data mining and machine learning algorithms are collected in order to help to increase the number of bees. The IoBee project [109], for example, addresses in-hive and in-field monitoring, as well as the implementation of satellite imagery and Spatial Decision Support Systems (SDSS). BeeLife [110] is a solution-oriented non-profit organization working to improve conditions for bees and pollinators.

In PLF, tools and sensors are used to continuously and automatically monitor key performance indicators (KPIs) of livestock in the areas of animal health, productivity, and environmental load. A variety of systems using technologies such as sensors, cameras, or microphones can directly alert farmers via connected devices (e.g., phones, computers, or tablets) about detected anomalies, allowing farmers to intervene at an early stage. Research is pointing toward the great potential for these smart technologies to help livestock farmers in monitoring the welfare of their animals, and several countries are already investing in their development, reflecting their potential to be part of strategies to move toward sustainable agriculture. A metastudy classifying the different technologies was undertaken by Schillings et al. [111].

Like all technologies, PLF technologies are constantly evolving with every passing day. Many are adopted and highly successful across numerous farms everywhere, while some are in their early developmental stages. A few of the PLF technologies in application today are the following: automated weighing systems, water meters, and different types of feed intake sensors. Automated-weighing systems include “step-on scales” and cameras that allow calculating the weight of individuals through machine-learning analysis of images and videos. However, weight is just one of the many data that can be obtained from imaging solutions. Due to the coverage of a wide range of vital data and their affordability, imaging solutions are the most common form of precision livestock monitoring and one of the initial steps of a stepwise PLF adoption approach on a farm. An extensive literature review listing the main systems available on the market, consisting of combined sensors to monitor and manage livestock, was provided by Aquilani et al. [112].

Vineview [113] uses high-tech drones in precision viticulture to help winegrowers monitor vineyards better and more efficiently, and to plan the grape harvest in a more differentiated and precise way. The drones are equipped with infrared sensors and reconnoitre the vineyard in regular reconnaissance flights. From the air, water stress and ripeness can be observed and the vines counted. The unmanned aerial vehicles (UAVs) from VisioVitis are also used to optimize fertilizer, irrigation, and pest control.

3.4. Considerations and Implications

While their potential is promising, the use of these new PLF technologies also raises ethical concerns, such as their potential impact on the human–animal relationship, the objectification of animals, the notion of care, and farmers’ identity as animal keepers. The human–animal relationship is an important aspect that can influence both animal welfare and productivity. Some of the challenges and risks associated with PLF are listed below:

- Affordability is still a major challenge associated with the integration of expensive technologies on farms. Although studies show that PLF technologies make a farm more profitable, the diverse nature of each farm makes it a concern worth considering thoroughly before deciding to adopt PLF.
- The major risk of PLF is that since it is often integrated and automatic, a system failure can cause devastating impacts, especially if the system is fully automatic.
- Another associated risk is when the unit of animals is not individuals but a group of individuals such as poultry where flocks are measured. In such cases, special individual needs can be overlooked.
- The use of intrusive tags is a risk to animal welfare, which is still used in many PLF practices and technologies.

3.5. Summary

Many aspects have to be considered when it comes to digitalization. Farmers can readjust systems when technology detects irregularities but, still, they have to be mindful that not every problem can be detected. To be able to intervene, they need not only a sound understanding of their profession, but also good knowledge of the technologies that are in use on their farms. Yet, these tools can be successful in the long term only if they are seamlessly integrated into everyday work [101].

Short-term efforts for Montenegro are considered in the area of precision viticulture, since there are bigger farms that can invest into digitization. The precision farming applied to optimize vineyard performance—in particular, maximizing grape yield and quality while minimizing environmental effects—has impact in the long run. Precision agriculture emphasizes "doing the right thing, in the right place, at the right time", and it is practical for viticulture because of the high local variability of conditions within vineyards. The long-term efforts for Montenegro are shown in the research conducted on the Ćemovsko field [114]. Concerning beekeeping, the Montenegro-based startup BeeAndme [107] is focusing on the improvement of the well-being of the bees. A long-term need to a thriving startup scene is to support farms in digitalization. The first step into building up a startup ecosystem is in the early stage of forming.

The greatest benefits of digitalization in agriculture are seen in the potential increase in sustainability and productivity, as well as in labor time savings and facilitation. As a result, this leads to reduced use of fertilizers, pesticides, and energy, as well as improvements in animal welfare [115].

4. Digital Healthcare and eHealth

4.1. Introduction and Concepts

Digital health technologies may aid in the provision of health and social care to an aging population with growing healthcare demands. However, numerous challenges must be overcome, such as ensuring accessibility and inclusivity; digital literacy and skills; sustained patient and clinician engagement; scalability and successful integration into healthcare systems; the development of the necessary evidence base; and effective regulation [116]. The current digital landscape in healthcare delivery and clinical research conduct includes the following [117]:

- Use of digital health technologies as a diagnostic tool—detection of heart rhythm disorders (e.g., atrial fibrillation), detection of retinopathy, metastases, metabolic disorders in tumor cells, etc.—today is possible with the use of digital technologies.
- Digital health as a disease management and decision support tool—several applications related to a specific disease or condition have been established so far. Some of them are more related to diagnostic approaches, but there are a lot of them that aid in treatment.
- Digital health to improve research recruitment—MyHeart Counts and Health eHeart [118] are examples of randomized clinical trials in which digital technologies were used as a recruitment tool.

Implementing digital healthcare requires not only the development of electronic clinical guidelines but also the education of all parties involved, from physicians and healthcare workers to patients and their carers [119]. Moreover, digitalization in the field of healthcare enables not only diagnostics and treatment but also enables focusing on preventive medicine. "Prevention is better than cure" is a main principle, the fulfillment of which is made possible by the application of digital technologies in healthcare. A systematic review [120] evaluated the potential benefits of digital health interventions on cardiovascular disease outcomes and risk factors and evaluated the potential benefits of telemedicine, web-based strategies, email, mobile phones, mobile applications, text messaging, and sensor-based monitoring. These interventions reduced cardiovascular events, hospitalizations, and mortality interventions compared to usual cardiological healthcare.

The implementation of new and improvement of existing digital solutions in the healthcare system of Montenegro must be based on the following EU-based pillars [121]:

- Political commitment;
- Normative and regulatory frameworks;
- Technical infrastructure;
- Economic investments;
- Training and education;
- Research;
- Monitoring and evaluation.

4.2. Current State in Montenegro

The public health system of Montenegro is organized hierarchically: the primary level of healthcare consists of health centers (i.e., elected doctors and emergency services); the secondary level of healthcare is realized through general hospitals; and at the tertiary level of healthcare, the following institutions function—Clinical Center of Montenegro, Institute of Public Health of Montenegro, Blood Transfusion Institute of Montenegro, and others. The Institute for Medicines and Medical Devices of Montenegro, the Montefarm Pharmacy Institution, and a number of other special hospitals are also part of the health system in Montenegro. In the private sector, there are several clinics, polyclinics, and hospitals, and some of them are integrated into the public health system. The Ministry of Health creates and the Health Insurance Fund finances healthcare in Montenegro.

Chronic non-communicable diseases are the leading causes of illness, disability, and premature (before the age of 65) death of the inhabitants of Montenegro. The number of doctors is lower than the European average.

In the previous period, a significant step forward was made in the digital technologies domain. First of all, an electronic service called eHealth is available to all health-insured individuals. Within the same framework, several services are available: eScheduling (a service for online scheduling of visits with doctors in primary health centers), eRecipe (an electronic service that enables patients to view prescribed and implemented prescriptions), eResults (an electronic service that enables patients to view the results of biochemical laboratory analyses), ePharmacy (an electronic service intended for patients, developed with the aim of providing information on the availability of medicines in all pharmacies on the territory of Montenegro), eInsurance (an electronic service that enables citizens to view the status of their health insurance [47]), and more.

The emergence of the COVID-19 pandemic significantly accelerated the process of digital transformation in the health system of Montenegro; new digital services were developed (e.g., the COVID-19 vaccination certificate) and, in parallel, during the COVID-19 pandemic, a number of scientific and research projects were implemented, which aimed at improvement in this area.

4.3. Technologies and Use Cases

COVID-19 influenced the development of digital solutions worldwide. Society, more than ever before, understood the necessity of digitalization, especially in the health sector. The Montenegrin health system was not an exception [122]. Digitalization of critical processes in the health system of Montenegro started before the outbreak of COVID-19, but the most significant results and popularization of the services were achieved during the crisis [122]. Digitalization of procedures of healthcare—to which digitalization was applicable—resulted in a severe reduction in human-to-human interaction [123]. This was beneficial not only by preventing the spread of the virus but also by ensuring efficient time management for both patients and doctors.

One of the main eHealth features beneficial for both the public Health Insurance Fund and the people it insures is ePharmacy, as it ensures visibility of the status of the supplies of medicines in pharmacies and their availability. This service is accessible through both eHealth and eGovernment portals, allowing all relevant stakeholders to optimize procedures of medicine procurement. On the other hand, authorities can supervise the logistics of the supply chain and optimize all inputs related to it. Such a technology created a potential for stable distribution of medicine even in times of the highest demand and market disruption.

An addition to ePharmacy, paperless prescription issuing was adopted by both citizens and medical staff through ePrescription. This service resulted in less contact between parties involved in procedures, which is especially important in times of viral diseases. Additionally, it allows supervision of patients' medication history and realization of the previous prescriptions, preventing any unwanted abuse or misuse.

In an attempt to prevent waiting for the results of biochemical laboratory analysis, the eResult service was developed for all institutions within the public healthcare system. By providing digitized reports, patients' time spent within the institution is minimized, and the system stores and thoroughly explores previous results of biochemical analysis of the patients for optimal healthcare. Such systems minimize human-to-human interaction in institutions, providing analysis and maintaining patients' safety through persevering reporting.

Healthcare system digitalization consists of improving the administrative procedures in order to optimize the processes within [124]. Providing citizens with relevant information about their Health Insurance is an administrative task, and its digitalization was conducted through the eInsurance service, which allows interested citizens to obtain relevant information without interacting with administration offices in a time-efficient manner. Additionally, patients were offered the eOrdering service, through which most of the ordering services were made available online. Through eOrdering, ordering of common reports (i.e., sick leave, reports for calculations of salary compensation during temporary incapacity for work, etc.) became a seamless effort, displaced from healthcare-providing institutions.

Making appointments to selected doctors also migrated to a digital environment, allowing patients to use the service regardless of their current location [125]. Visits to institutions providing healthcare just to schedule an appointment were completely replaced by the service, allowing safer environments and faster procedures. This service was recognized as crucial within the health infrastructure by both patients and healthcare providers.

Described technologies optimized the procedures in terms of money, time efficiency, safety, and security. These technologies are here to stay, as COVID-19 exposed the impracticality and instability of previously established and conducted practices [126].

4.4. Relevant Features and Attributes of Montenegro

Healthcare service (HCS) providers in Montenegro are structured within three main groups: public HCS providers; private HCS providers with an agreement signed with the public Health Insurance Fund; and other private HCS providers. Private HCS providers with agreement are predominantly stomatology- (175) and pharmacy-related (189) institutions. Besides those, there are general and special hospitals (2), and institutions providing radiology (2), histology (2), gynecology (3), and ophthalmology (8). There are 20 health centers, 114 special ambulances, and 32 medical–technical providers classified as other private HCS providers with no agreement. Public HCS providers are classified as follows: health centers (18); general hospitals (7); special hospitals (3); and one of each clinical center, public health, medical rehabilitation, blood transfusion, emergency medical assistance, pharmacy, and medical–technical provider.

The medical information systems described in the previous chapter support processes in all public HCS providers and private HCS providers with an agreement. The importance of such technologies and features was especially emphasized during the COVID-19 outbreak, as the greatest extent of service use peaked with the first wave of the COVID-19 pandemic. Figure 3 (provided by the Montenegrin territorial health services) illustrates the frequency of the usage of the different eHealth services in Montenegro in 2020.

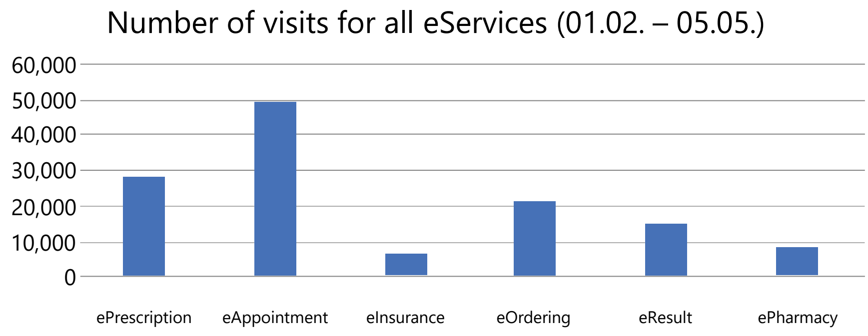


Figure 3. Frequency of usage of the eHealth services in Montenegro in 2020.

The most used service by far is eAppointments, with 49,183 registered applications. Patients showed the least interest in eInsurance and ePharmacy, while ePrescription, eOrdering, and eResult are gaining traction daily. Figure 4 (provided by the Montenegrin territorial health services) shows the number of visits for all eServices in Montenegro in 2020.

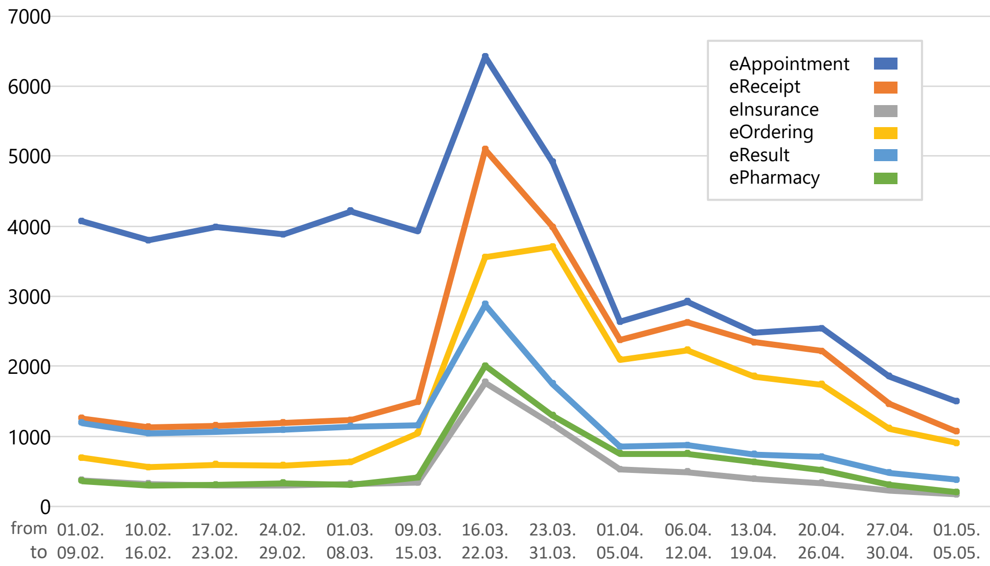


Figure 4. The number of visits for all eServices in Montenegro in 2020.

Services and features such as these prevented countless unnecessary direct contacts. Additionally, time management on both sides, patients and HSC providers, were more efficient than ever. Established digital procedures will grow in the number of users as most of the HSC providers migrate completely to certain solutions, such as prohibiting the old-fashioned means of scheduling appointments, ordering reports, or reporting the results.

4.5. Considerations and Implications

Healthcare systems are recognized as carriers of critical information infrastructure, and in the light of current cyber-attacks in Montenegro, it is of particular importance to be specially devoted to ensuring the security of the system [127]. The challenges are numerous in that regard: existing legal frameworks define boundaries that should be met with security mechanisms, as well as the future legal frameworks, while the application of IoT in healthcare—including mobile devices, smart watches, and different sensors—is rapidly growing, therefore increasing the cyber vulnerabilities of the system. The least attention is paid to checking the safety of the users and how they can be endangered.

On the other hand, the COVID-19 pandemic has imposed that the future guidelines for the development and improvement of health—not only at national but also at global level—should be focused on meeting the lessons learned during the pandemic and preparation of systems for possible future large-scale health issues [128].

The key challenges can be identified as follows: support of ecosystem coordination [129], the development of services based on the integration of a large number of devices and data, and the application of artificial intelligence—especially with regard to disease prediction (not only early diagnosis and treatment as before)—all with a high degree of user-oriented experience.

4.6. Summary

Montenegro, as a small country, recognized the importance of developing an integral health information system and started with the development of modern eHealth services. However, modern trends in development of health technologies impose a transition to a paradigm focused on health instead of healthcare, which is a task that will be necessary to achieve with the application of modern technologies, while ensuring a high level of safety and cybersecurity.

The future efforts at national level are guided by the Health Information System Development Strategy 2018–2023 and the corresponding Action Plan, and their new adoptions for the period of 2024–2029, as well as the operational program for the implementation of the Smart Specialization Strategy 2021–2024 [130]. All these documents identified the necessity of new developments in the Electronic Health Record (EHR), as an umbrella project that should be connected to all information systems in public health and in the future to all private health institutions and systems. This is a system that is designed as a "silo" of all important medical data for patients/citizens, who are the sole owners of their data and have the ability to manage the data (e.g., granting access, control and monitoring of access). With an equally important impact, continual education of staff members as well as general improvement of economic and social conditions for healthcare workers are essential for the proper implementation of ICT services in healthcare. In short-term efforts, creation of cohesion between different sectors—especially academia and business [131]—towards supporting innovation in the field of health are identified as key mechanisms for the creation of a digitally enhanced ecosystem in healthcare.

5. Conclusions

In this paper, we provided a comprehensive analysis of the digitization of Montenegrin transportation, agriculture, and healthcare. We investigated the relevant technologies and use cases based on the properties of the country and formulated the appropriate considerations and implications for each field separately.

C-ITS is still in its infancy stage in Montenegro, and there are as yet no focused strategies, regulations, or plans for preparing any pilot deployments. We believe that the first step on the long road towards initial pilot C-ITS services in Montenegro should be becoming an associated C-Roads partner and starting the collection of expertise within the platform at a national level. The necessary know-how can be built-up in the appropriate decision-making bodies relatively fast by relying on the experiences gathered in C-Roads, and the tested deployment approaches can be adapted to the Montenegrin peculiarities. With proper planning and considering the milestones on the path foreseen in the intelligent transport systems evolution already discovered and made available by Core Member pilots, Montenegro could tremendously benefit from the transportation digitalization possibilities the continent-wide harmonized C-ITS ecosystem offers.

The need to feed a growing population not only leads to the development of smart technologies for agriculture but also for livestock management. Honey bees, along with pigs and cattle, are some of the most important farm animals. Modern technologies offer beekeepers new solutions to protect these valuable creatures. Precision livestock farming technologies in Montenegro may improve both production efficiency and preservation.

Our work presented the current state of development of eServices in the healthcare of Montenegro, with a special focus on services developed during the COVID-19 pandemic, as well as records of their use and exploitation. As the imperatives in the development of modern health systems are focused on prevention and the improvement of the services themselves, it is necessary in the near future to integrate scientific results, available data, and technologies in order to ensure the preservation of the well-being of the inhabitants, and the early detection and proactive intervention of various diseases that will certainly not disappear as long as science and society progress.

Summa summarum, Montenegro still has a long way to go on the road towards digitization, but these efforts contribute to a significantly more advanced country and society. By adapting to the changes that Industry 4.0 brings, Montenegro may embrace the vast benefits that engineering and science in these fields can provide.

It is important to note the most pertinent limitations of this work. First of all, while transportation in Montenegro is composed of many vital means and modes—particularly the usage of waterborne vessels enabled by the long shoreline—our research effort narrows its transportation-related focus to land-vehicle-based C-ITS. One reason is that in the EU—to which Montenegro aims to ascend within the upcoming years—C-ITS is one of the hottest research areas in transportation science, and regulation/harmonization has already begun on the levels of both the EC and standardization organizations. Regarding agriculture, autonomous tractors or cow milking robots—typical digitization applications for huge farms—have not been addressed, since most Montenegrin farms are typically small, operate on much thinner margins, and are thus usually less willing to spend money on ventures that might not work out for such small farms. As for healthcare, while the presented work is focused on providing a comprehensive picture related to its digitization in Montenegro—with a particular emphasis on the COVID-19 period—there are, in fact, certain limitations of the analysis, lacking themes such as specialized topics of surgery (e.g., efforts of neurologists to pilot AI use for stroke patients [132]) and deeper investigation of Montenegrin telemedicine [133].

Due to the well-defined scope and the above-listed limitations of this work, there is still much to be covered by such research efforts. Beyond the unaddressed means of transportation, future work should study education and training, manufacturing, production, all forms of logistics, cyber-physical systems, business models, human–machine interfaces, the various applications of IoT, privacy and trust, and many more, all of which are fundamentally affected by the transformative power of Industry 4.0 and digitization in general.

Author Contributions: Conceptualization, P.A.K., I.O., C.R. and L.B.; methodology, P.A.K., I.O., C.R. and L.B.; investigation, P.A.K., I.O., I.M., J.M., A.W., R.Š., L.L., M.R., C.R., A.S. and L.B.; resources, P.A.K., I.O., I.M., J.M., A.W., R.Š., L.L., M.R., C.R., A.S. and L.B.; writing—original draft preparation, P.A.K., I.O., I.M., J.M., A.W., R.Š., L.L., M.R., C.R., A.S. and L.B.; writing—review and editing, P.A.K., I.O., C.R., A.S. and L.B.; visualization, P.A.K., I.O., C.R. and L.B.; supervision, P.A.K., I.O., C.R. and L.B.; project administration, P.A.K., I.O., C.R. and L.B.; funding acquisition, P.A.K., I.O., R.Š., C.R. and L.B. All authors have read and agreed to the published version of the manuscript.

Funding: The work was supported by the European Commission Erasmus+ Project Digital Entrepreneurial Nest and Industry 4.0 in Montenegro (DigNest) 619099-EPP-1-2020-1-ME-EPPKA2-CBHE-JP, and by the Cooperative Doctoral Programme–National Defence Subprogramme of the National Research, Development, and Innovation Fund of Hungary (NVKDP-2021).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

Abbreviations

The following abbreviations are used in this manuscript:

3GPP	3rd Generation Partnership Project
BSM	Basic Safety Message
BTP	Basic Transport Protocol
C2C-CC	CAR 2 CAR Communication Consortium
CALM	Communications Access for Land Mobiles
CAM	Cooperative Awareness Message
CEDR	Conference of European Directors of Roads
CICW	Cooperative Intersection Collision Warning
C-ITS	Cooperative Intelligent Transportation System
C-V2X	Cellular Vehicle-to-Everything
CSMA/CA	Carrier-Sense Multiple Access with Collision Avoidance
DENM	Decentralized Environmental Notification Message
DG MOVE	Directorate-General for Mobility and Transport
ECRL	European Certificate Revocation List
ECTL	European Certificate Trust List
EHR	Electronic Health Record
ETSI	European Telecommunications Standards Institute
Euro NCAP	European New Car Assessment Programme
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HCS	Healthcare service
I2V	Infrastructure-to-Vehicle
IEEE	Institute of Electrical and Electronics Engineers
IoT	Internet-of-Things
ISO	International Organization for Standardization
ITS	Intelligent Transportation System
IVI	In-Vehicle Information
LTE	Long-Term Evolution
MAC	Media Access Control
OEM	Original Equipment Manufacturer
OSI	Open Systems Interconnection
PKI	Public Key Infrastructure
PLF	Precision Livestock Farming
RSU	Roadside Unit
RTTI	Real-time Traffic Information
SAE	System Architecture Evolution
SDSS	Spatial Decision Support Systems
UAV	Unmanned Aerial Vehicle
V2I	Vehicle-to-Infrastructure
V2N	Vehicle-to-Network
V2V	Vehicle-to-Vehicle
V2X	Vehicle-to-Everything
WAVE	Wireless Access in Vehicular Environments
WEF	World Economic Forum

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