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SMART INFRASTRUCTURE AND DIGITALIZATION: CONTENT ANALYSIS OF METRO'24 ROCKLINE, SLOVAKIA

Abstract. *Smart infrastructure has become a key aspect of urban development, driven by digitalization and sustainability goals. The integration of technologies such as artificial intelligence, big data analytics, and IoT is reshaping cities, making them more resilient, efficient, and sustainable. Digital transformation facilitates urban life while addressing environmental and economic challenges. Collaboration among stakeholders in IT, spatial planning, and sustainability is crucial for fostering innovation, ensuring inclusivity, and addressing urban challenges. In Slovakia, Metro'24 RockLine brought together policymakers, industry leaders, researchers, and urban planners to discuss opportunities and challenges in data-driven societies and smart infrastructure. The event served as a platform for knowledge exchange and strategic partnerships, emphasizing the importance of data-driven decision-making in urban development. Discussions focused on integrating emerging technologies, regulatory frameworks, and the socio-economic impacts of smart city initiatives. This qualitative study analyzed the event through content analysis of textual and audio-visual materials presented during the conference. Findings identified five dominant themes: cybersecurity, virtuality and energy ecosystems, artificial intelligence in tourism, intelligent buildings and districts, and electromobility. These topics reflect the increasing role of technology in shaping modern cities. Despite certain limitations, the study provides valuable insights for academia, industry, and the general public. It contributes to the growing body of research on smart cities, offering perspectives on how digital innovations can improve urban environments. Industry professionals can leverage these insights to refine technological applications, while policymakers can align regulations with emerging trends. Future research should explore the long-term impact of smart infrastructure, the scalability of solutions, and the socio-economic effects of digital integration. As cities continue evolving, the synergy of technology, governance, and sustainability will be essential for creating efficient, inclusive, and livable urban environments.*

Keywords: Smart; Infrastructure; Digitalization; Cities; Information Technology; Slovakia

Introduction

The synergy of smart cities and digitalization has been gaining momentum and witnessed exponential growth in the last two decades. Similarly, the introduction of artificial intelligence has further expedited this process, and city and regional planners are counting on AI to transform the conventional city infrastructure into a more digitally oriented, in alignment with the virtual and sustainable global agenda. It is safe to say that this merger of smart (cities) infrastructure and digitalization has revolutionized the city planning needs and demands along with a paradigm shift for the digital sustainability of the cities.

In the domain of cities, smart infrastructure is associated with data interoperability between logistics entities and smart environments that are supporting or impacted by logistics activities [1]. This infrastructure merges digital and physical infrastructures to enable faster decision-making, data-driven optimization, and redistribution of resources, by using sensor-based information in real-time [2]. The prevalent factors necessitating the smart infrastructure are sustainability, limited resources, economic deprivations, and rapid growth in technologies of sensor networks, and computational and communication systems [3]. Primarily destined to provide robust and tech-oriented solutions for cities, smart infrastructure has been gaining fame in the fields of city and regional planning, sustainable development, and tourism. Despite this global attention, there exists a theoretical gap in the context of Slovakia – being a Central European country

– in the context of smart infrastructure and digitalization. This study aims to address this academic vacuum and provides an overview of ongoing collaboration between the stakeholders of smart infrastructure and digitalization. By selecting an even – Metro'24 RockLine – the objective of this study is the unravel the avenues that are emphasized in Slovakia.

This study has one key question:

RQ1. How does Metro'24 RockLine contribute towards the synergy of smart infrastructure and digitalization in the data-driven context of Slovakia?

In acquiescence to this focal question, this study has used content analysis CA to analyze the official website of Metro'24 RockLine, see Fig. 1. The analysis resulted in the creation of several inductive themes. Furthermore, a word cloud generator has also been used to create a word cloud from the text on the Metro'24 RockLine website detailing the frequency of prominent words and phrases, see Fig. 2. These prevalent words and phrases have also been discussed to provide results for the theoretical side, industrial domains, and general readers as well. While acknowledging the limitations of this study, cornerstones for future studies are identified.

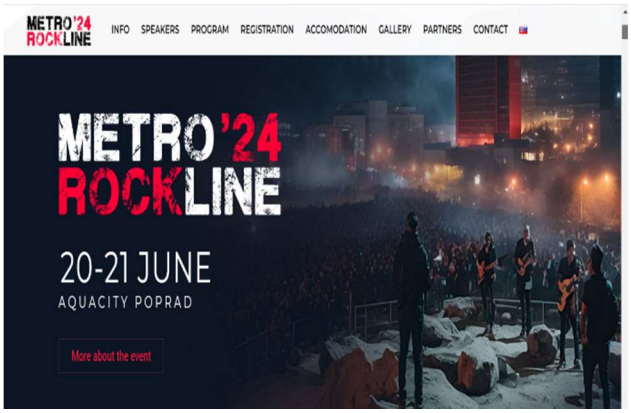

Figure 1 – Website of METRO' 24 ROCKLINE 2024
Source: https://metroonline.sk/en/home-en/

Literature and Method

Infrastructure is a combination of various merged sets of facilities to provide livable conditions for inhabitants of a specific place. It includes water services, electricity, and communication services. Concomitantly, smart infrastructure is a network of such services with efficient land use patterns along with a communication system with coordinated information technology [4]. In alignment with the sustainability agenda of sustainable development goals, the smart concept is an urban design collating the basic services of a city with information and communication technologies. Given this, various essential elements of a smart city include but are not limited to the populace, governance, economy, and sustainability [5]. On an applied level, smart city infrastructure is the usage of real-time information in collaboration with cost-effective transportation for the populace keeping in the domain of environmental sustainability [6].

Considering the nature of the study and the orientation of the research question, a qualitative approach has been used to analyze the textual and audio-visual interface of METRO' 24 ROCKLINE, using content analysis. This selection of qualitative approach and content analysis has been argued as imperative and result-oriented primarily in the studies concerning the ICT's role in urban spaces [7]. Word cloud and Microsoft Excel have been used to analyze the data which was extracted from the official website of METRO' 24 ROCKLINE 2024. Word cloud through text mining has remained a pivotal analysis technique in the domain of the Internet of Things IoT and Industry 4.0 [8]. The following dominant terminologies and prevalent themes emerged during the content analysis of METRO' 24 ROCKLINE 2024, see Fig. 2 & Table. The most significant terms that emerged during the analysis were 'smart projects', 'buildings', 'tourism', and 'energy', see Fig. 2. In addition, five major themes have been identified namely Cyber Security, Virtuality, Energy, & Ecosystem, Artificial Intelligence & Tourism, Intelligent Buildings & Districts, and Electromobility, see Table.

Figure 2 – Word Cloud of METRO' 24 ROCKLINE 2024
Source: Authors own elaboration

Cyber Security

Cyber Security, in an ongoing digital-oriented global milieu, is a pivotal dimension. Particularly, amid the privacy concerns and misuse of technological applications and gadgets, this field has gained fame for securing individual and state-level privacy. In the context of smart cities, cyber security has been asserted as one major dimension, that should be emphasized without any malicious cyber-attacks or data breaches [9 – 11]. For instance, technological intervention amid smart city development should follow a holistic approach to synchronize technological advancements with security measures [12]. This event of METRO' 24 ROCKLINE, in acquiescence to these concerns, has corroborated the facets of cyber security by inviting various stakeholders directly associated with the field of cyber connectivity (Table). Given this, this event has unveiled the pros and cons of juxtaposition of cyber-security and smart cities, in an in-depth context. As a result, a balanced approach has been presented by the relevant stakeholders.

Virtuality, Energy, & Ecosystem

The notion of virtuality is immensely significant in the face of smart cities. Primarily, virtual reality VR is important in smart cities as it provides real-time simulation and visualization assistance for various fragments including but not limited to community services, waste management systems, transportation systems, information systems, power plants, and water supply systems [13]. Furthermore, the Metaverse platform also can create a 'parallel virtual world' that can provide an alternative to physical reality [14]. Similarly, energy management in smart cities needs to be focused, owing to the complex facades of energy systems [15]. Moreover, the functionality of smart cities depends upon the formation of a digital ecosystem, strengthening each sector involved, particularly the governance sector [16]. Owing to these compulsions, in the METRO' 24 ROCKLINE, the trilateral importance of virtuality, energy, and ecosystem has been extensively debated by the relevant stakeholders (Table). Their discussions highlighted that the concept of smart cities is incomplete without these three dimensions and each of these should be properly emphasized.

Artificial Intelligence & Tourism

The synergy of artificial intelligence and tourism is significant and evident in the ongoing tech-dominant era. The inclusion of artificial intelligence in tourism determinants has leveraged the attainment of sustainable tourism [17]. In addition, the deployment of AI-assisted robots would facilitate seamless service, predominantly in the hospitality sector, by automation and personalization [18]. It is evident that in all three determinants of tourism – demand; supply; intermediaries – artificial intelligence has been swiftly altering the conventional practices of tourism to more technologically oriented, a phenomenon commonly known as Tourism 4.0 in parallel to the Industry 4.0 paradigm. Similarly, during the event of METRO' 24 ROCKLINE, the duality of artificial intelligence and tourism has been corroborated. Representatives from academia, industry, and government have presented their insights on this synergy and highlighted the merits and demerits of involving artificial intelligence in the tourism system (Table 1). Pertinently, amid the excessive usage of artificial intelligence in tourism, concerns for technostress have been highlighted. Furthermore, to tackle the technostress, the framework of digital free tourism is presented as an alternative, offering a digitally detoxed tourist experience.

Intelligent Buildings & Districts

Intelligent buildings and districts have become essential constructs of smart cities, and their development offers smart solutions amid the global notion of sustainability [19; 20]. Predominantly, the positive energy districts PED advocates for minimum energy consumption, eventually reducing the carbon footprints. However, the nature of intelligent buildings and districts is quite complex and involves two major components. The first component is hardware which consists of energy devices within these buildings or districts. The second component is virtual and is often termed as intelligence or software. Both these components should operate in a synchronized way to provide smart energy solutions, which in turn make these buildings intelligent buildings and districts as smart energy districts. The theme of METRO' 24 ROCKLINE has adhered to this manifesto of intelligent buildings and districts and panelists from stakeholders of smart cities have asserted the need to transform the conventional buildings and districts into intelligent buildings and smart districts (Table).

Electromobility

Electromobility, particularly smart electromobility, is one of the fundamentals of smart cities. The approach of smart mobility answers the calls of energy crises and contributes to zero-emission economies [21]. Smart electromobility revolves around electric commuting solutions and smart technologies, both enhancing energy efficiency and leading towards emission reduction. This enhanced version of mobility offers state-of-the-art and smart methodologies. For instance, it enables users to change their traditional way of commuting by ridesharing and using electric vehicles instead of vehicles using fossil fuels. This segment has also been at the discussion table of METRO' 24 ROCKLINE and officials from various transportation sectors endorsed the smart electromobility approach (Table).

Conclusion, Implications, and Limitations

The infrastructure of cities, particularly the smart infrastructure, is entirely changing amid the introduction and intervention of digital technologies. To keep up with this global dominant pace, the Republic of Slovakia in general and the city of Poprad specifically planning certain activities to invite and collate the various stakeholders and shareholders of city planning, digital technology, and sustainability for achieving a competitive position in the ongoing global data-driven domain. Given this, Metro OnLine has been arranging such events on an annual basis since 2006. This year, under the title METRO' 24 ROCKLINE was organized to contemplate this competitiveness. This study analyzed through the content analysis of METRO' 24 ROCKLINE to unveil the emphasis of this year's event.

Table – ***Thematic of METRO' 24 ROCKLINE 2024***

Theme	Code	Speakers	Company/Organization
Cyber Security	CS1	Jozef Pivarník	Slovanet
	CS2	Miloslav Eis	2N Telekomunikace
	CS3	Ondrej Gombárik	LastMile
	CS4	Zuzana Hudzíková	Phillip
	CS5	Martin Murín	HDS
	CS6	Ján Michlík	Metro ON Line
Virtuality, Energy, & Ecosystem	VIE2	Radoslav Mizera	SOLVED
	VIE2	Arash Aazami	Synergy Hackathon
	VIE3	Róbert Pazúr	Slovak Academy of Sciences
	VIE4	Peter Hamor	Himalaya Adventure
Artificial Intelligence & Tourism	AIT3	Tomáš Barnáš,	OVERHE4D
	AIT2	Farhad Nazir	SPECTRA Center STU
	AIT3	Marek Harbuľák	Ministry of Tourism and Sports
Intelligent Buildings & Districts	IBD1	Štefan Koluš	SOHO Bratislava, IURIS
	IBD2	Mária Giertl	Resitech
	IBD3	Libor Bešenyi	Xolution
	IBD4	Maroš Finka	SPECTRA Center STU
Electromobility	EM1	Simona Kalinovská Lhotová	3MON
	EM2	Ján Zuštiak	AgeVolt
	EM3	Jozef Králik	GARAGE.Systems
	EM4	Gabriel Megó	HaZZ
	EM5	Marek Košuda	Faculty of Aviation TUKE

Source: Authors own elaboration

Five focal themes namely Cyber Security, Virtuality, Energy, & Ecosystem, Artificial Intelligence & Tourism, Intelligent Buildings & Districts, and Electromobility were the central focus of this event and speakers from various companies/organizations presented their respective scientific and industrial realities to the attendees. These themes highlight Slovakia's position about how the country is coping with the need for the inculcation of digital technology in smart infrastructure with a parallel focus on the sustainable development agenda as well. These findings validate that the country's focus is according to the global agenda of data societies and companies and organizations within Slovakia are well aware of this evolving technological paradigm. Given the generic and specific typology of the topics and themes, several implications have been orchestrated.

For academia associated with information technology, smart infrastructure, sustainability, and tourism, these findings provide the overall view regarding how the theoretical side is underpinning the foundations for a data-driven paradigm. For the industrial side, this study overviews the functionality of different companies within their defined areas. For general readers, this study in plain words, sketches an overall picture of what is happening and about to happen in the field of smart infrastructure, digitalization, and sustainability in the socio-geographical context of Slovakia.

Like other studies, this study has certain limitations related to methodology. Firstly, it is only limited to one conference and one year. Secondly, it is limited to one website. Nevertheless, these limitations provide potential for future studies to broaden the scope to other events along with the inclusion of several websites and units of data collection.

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СМАРТ-ІНФРАСТРУКТУРА ТА ЦИФРОВИЗАЦІЯ: АНАЛІЗ ЗМІСТУ METRO'24 ROCKLINE, СЛОВАЧЧИНА

Анотація. *Конференція Metro'24 RockLine у Словаччині стала значною подією, що зібрала широкий спектр зацікавлених сторін: політиків, лідерів галузі, дослідників та міських планувальників. Основною метою зустрічі було всебічне обговорення можливостей і викликів, які постають перед суспільствами, орієнтованими на дані, та*

інтелектуальною інфраструктурою. Захід ефективно виконав свою функцію, створивши платформу для інтенсивного обміну знаннями, формування стратегічних партнерств та спільної розробки інноваційних підходів до цифрової трансформації міських середовищ. Ключовий акцент робився на визнанні критичної важливості прийняття рішень, що ґрунтуються на даних, для сталого та ефективного міського розвитку. Дискусії охоплювали широкий спектр питань, включаючи інтеграцію новітніх технологій, розробку адекватних нормативно-правових рамок, аналіз соціально-економічних наслідків ініціатив "розумного міста" та механізми їхнього практичного впровадження. Це якісне дослідження здійснило детальний аналіз події за допомогою контент-аналізу представлених під час конференції текстових та аудіовізуальних матеріалів. У результаті було чітко ідентифіковано п'ять домінуючих тематичних напрямків, що відображають ключові тренди та виклики у сфері смарт-міст: кібербезпека, віртуальність та енергетичні екосистеми, штучний інтелект у туризмі, інтелектуальні будівлі та райони, а також електромобільність. Ці аспекти переконливо демонструють зростаючу та невід'ємну роль технологій у формуванні сучасних міст, забезпеченні їхньої стійкості та системній оптимізації міської інфраструктури. Попри певні методологічні обмеження, притаманні якісним дослідженням, дана робота надає цінні та актуальні висновки для академічної спільноти, представників промисловості та широкої громадськості. Вона суттєво доповнює зростаючий обсяг досліджень у сфері смарт-міст, пропонуючи глибокі інсайти щодо того, як цифрові інновації можуть суттєво покращити міське середовище, сприяти розвитку міських послуг та підвищити загальну якість життя громадян. Фахівці галузі можуть використовувати отримані знання для вдосконалення існуючих технологічних рішень та розробки нових, тоді як політики – для адаптації нормативно-правових актів відповідно до динамічних урбаністичних тенденцій. Майбутні дослідження мають стратегічно зосередитися на довгостроковому впливі смарт-інфраструктури, її масштабованості, а також на комплексних соціально-економічних ефектах цифрової інтеграції. У міру динамічного розвитку міських агломерацій синергія між технологіями, ефективним управлінням та принципами сталого розвитку стане абсолютним ключовим фактором для створення ефективних, безпечних, інклюзивних та комфортних урбаністичних просторів.

Ключові слова: smart; інфраструктура; цифровізація; міста; інформаційні технології; Словаччина

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