Integrating ESG into the Smart City concept with focus on transport

Petr Dovolil, Miroslav Svítek

***Abstract*— This paper makes the case for integration of ESG (Environmental, Social, and Governance) into the Smart City concept. Analysis of sustainability indicators such as carbon footprints, climate resilience, circular economies, biodiversity and selected social assets (for instance, local communities and their safety and security), might provide useful data and information on sustainability performance and risk and opportunities across assets in the built environment. EU Taxonomy and European Sustainability Reporting Standards offer a basis for consistent and granular gathering of information. This information can be embedded into Digital Twins to serve as a multi-purpose sustainability data platform. ESG 'Digital Twins' might, therefore, be a powerful tool for addressing sustainability and resilience challenges. They may also offer significant potential in contributing to strong sustainable social, environmental and economic outcomes based on continuous improvement.**

Index Terms* — *Built environment, ESG (Environmental, Social and Governance), Smart City, Sustainability, Climate change, EU Taxonomy, Non-financial (sustainability) reporting, ESRS (European Sustainability Reporting Standards), GHG emissions, Urban District Digital Twin, Transportation Digital Twin, Public Good.

I. Introduction

The financial investment sector is experiencing one of the most fundamental milestones in its history. It concerns a paradigm change in large parts of international political, industrial and financial communities towards clearly defined ESG (Environmental, Social and Governance) investment. As a result, new aspects of investment are being integrated into asset design and project cycle management frameworks, such as carbon footprint (greenhouse gas emissions), resilience (in particular climate resilience), circular economy, biodiversity, natural capital, human rights, equality, non-discrimination, risk and opportunities processes.

If properly and reliably measured, these characteristics can provide broader and more detailed sustainability data and information on investment and asset performance. They can also, if incorporated into systemic tools such as Building Information Modeling (BIM) and Digital Twins, establish robust and strong data platforms for ongoing conceptualising, tracking, planning and managing wider built environment via integrated ESG datasets. This is especially true if facilitated by artificial intelligence and machine learning.

As sustainability, which also embraces resilience, becomes a new overriding orientation of modern societies, the built environment and cities are at the centre of this transformation. Cities consume 78 percent of the world's energy and produce more than 60 percent of greenhouse gas emissions, even though they cover less than 2 percent of the Earth's surface. Simply stated, "climate change and sustainability challenges for humankind will be lost or won in cities". The Smart City concept is critical in the transition to better functioning communities, environments and economies worldwide. It has the potential to provide a measurable and transparent sustainability data management ecosystem, which can facilitate credible, data-driven action and intelligent decision-making in cities [1] to help deliver strong social, environmental and economic outcomes.

Fig. 1. History of investment

II. EU Taxonomy, Sustainable Finance and Sustainability Reporting

A. *Sustainability and climate change = the changing DNA of capitalism*

Sustainability and climate change drive today's political agenda. The 1992 United Nations Framework Convention on Climate Change[1] (UNFCCC), 2015 Paris Agreement[2] and 2022 Kunming-Montreal Global Biodiversity Framework[3] (GBF) are just a few prominent international treaties that have been fueling global political action in sustainability to date. The same sustainability convergence is seen in financial and investment communities via initiatives, such as the Task Force on Climate-related financial disclosures[4] (TCFD), the Task force on nature-

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[1] www.ipcc.ch
[2] www.unfccc.int
[3] www.undp.org
[4] www.fsb-tcfd.org

related financial disclosures[5] (TNFD), the UN's Compact[6], Net Zero Coalition[7] and Race to Zero and The Institutional Investors Group on Climate Change[8] (IIGCC).

Recent years have been marked by a proliferation of sustainability and climate change actions and increasing acknowledgment and promotion in both the public and private sectors. Never in the history of investment has there been a situation when business-as-usual life expectancy of assets, such as buildings, infrastructure and technological units have become so problematic and divergent.

The drivers of this phenomenon are climate change, environmental degradation, biodiversity loss and negative social impacts, such as migration, poverty and pandemics. These all have the potential to render life on Earth increasingly challenging, particularly for vulnerable communities. In principle, it has always been sufficient to invest with regard to existing climatic and natural conditions (see Fig. 1). In the absence of unexpected technical failure, accidental human-induced events such as war or voluntary asset upgrade, or natural disaster took place, physical assets reached more or less their design lifetimes. This approach to investment, however, is no longer viable given the sheer scale of potentially disruptive trends, which are already underway and will further evolve, at global, regional, national and local levels.

Whilst in the first two decades of the 21st century, sustainability topics were largely discussed in the domain of public relations departments, the third decade has seen a deep rethink. This particularly applies to the traditional project management triangle of activities, time and cost. This approach can no longer plausibly capture the non-financial (sustainability) aspects of investment, which cannot be comprehensively captured by technical, time and financial parameters (see Fig. 2). Resultantly, the emerging new investment paradigm is to invest more into projects which can be holistically risk assessed beyond the classic project management parameters, which have the potential to marginalise sustainability.

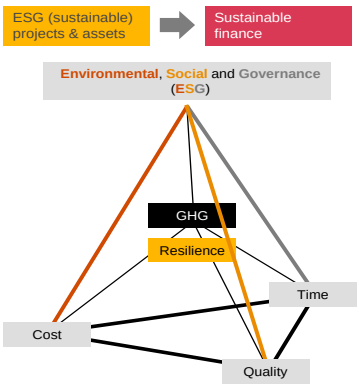

Fig. 2. The role of ESG in updated project management triangle

This emerging new approach follows capitalistic logic, in that the cost of capital is a function of the market's risk-free rate, plus a premium for the risk inherent in the investment. Consequently, ESG investment means, *ceteris paribus*, better access to finance and lower cost of capital as it provides much more transparency about sustainability risk and opportunities [2].

B. ESG frameworks, standards and taxonomies = from general sustainability goals to non-financial reporting in the EU and beyond

In the private sector a general trend is for organisations to attempt to rapidly integrate sustainability themes by implementing ESG rules and criteria into all corporate levels, including administrative and supervisory bodies and management, strategies, and processes. Additionally, reporting on a voluntary basis has been recently accelerated. The advent of ESG frameworks, such as the UN Sustainable Development Goals, standards such as CDP[9], The Global Reporting Initiative[10] (GRI), The International Financial Reporting Standards Foundation[11] (IFRS Foundation) and taxonomies, like the EU Taxonomy[12] and the UK Green Taxonomy[13] enable uniform benchmarks and yardsticks through the creation of common sustainability ontologies and classification systems.

Also, the trend is unequivocally targeted towards non-financial (sustainability) reporting being on a par with financial reporting and integrated into the main body of corporate annual reports. This shift has been recently marked in the EU by the publication of the Corporate Sustainability Reporting Directive[14] (CSRD) in December 2022. The Directive will make it obligatory for all large companies in the EU, around 50,000 firms, to include a sustainability report in their management reports as part of their financial statements. CSRD also, to some degree, extends to the companies' value chains for the 2025 financial year. The largest companies are even obliged to report in the 2024 financial year. In 2028, CSRD will also be obligatory for foreign operators with substantial trade within the EU.

Similar regulation is already in place for financial institutions by way of 2019's Sustainable Finance Disclosure Regulation[15] (SFDR). This regulation's deadlines are gradually becoming binding on the EU financial sector. SFDR is a European regulation introduced to improve transparency in the market for sustainable investment products. This is aimed at preventing 'greenwashing' and increasing transparency around sustainability claims made by financial market participants, such as banks, insurance companies and financial market participants offering listed securities.

Moreover, the entire sustainability ecosystem in the EU is rapidly maturing, supported by the new rules on green labels (e.g. ecodesign), avoidance of greenwashing and unsubstantiated green claims statements, the European standard for green bonds based on the EU Taxonomy adopted in late 2023 [3] and ESG ratings.

[5] www.tnfd.global
[6] www.unglobalcompact.org
[7] www.un.org
[8] www.iigcc.org
[9] www.cdp.net
[10] www.globalreporting.org
[11] www.ifrs.org
[12] finance.ec.europa.eu
[13] www.greenfinanceinstitute.co.uk
[14] finance.ec.europa.eu/capital-markets-union-and-financial-markets/company-reporting-and-auditing/company-reporting/corporate-sustainability-reporting_en
[15] finance.ec.europa.eu/regulation-and-supervision/financial-services-legislation/implementing-and-delegated-acts/sustainable-finance-disclosures-regulation_en

In the public sector, the process in the EU is more complex. Certain ESG aspects are reflected in the Multiannual Financial Framework 2021-2027, European Structural and Investment Funds and NextGenerationEU funds. However, there has not, as of yet, been a binding compulsory budgeting and reporting regime in the public sector. Only voluntary initiatives, such as the Green Budgeting Reference Framework (GBRF), show a way forward for public sector sustainability reporting[16].

C. EU Taxonomy = uniform sustainability classification system

The EU Taxonomy or EU taxonomy of sustainable economic activities is currently the most granular and robust holistic classification system of sustainable economic activities in force worldwide. It represents a uniform, technology-neutral and scientifically based EU classification system for determining which economic activities, i.e., projects, assets or their components through which these economic activities are implemented, are "environmentally sustainable" ("green"). The fundamental law on EU Taxonomy was already adopted in June 2020 through Regulation of the European Parliament and of the Council (EU) 2020/852 [14] of 18 June 2020 on the establishment of a framework to facilitate sustainable investment, and amending Regulation (EU) 2019/2088. Following this Regulation [15], EU Taxonomy is to be based, when fully completed, on the following core legislative and regulatory package:

- a minimum of six delegated acts of the European Commission issued pursuant to Article 19 of the Regulation on EU Taxonomy and establishing the so-called technical screening criteria of environmental sustainability. This must include detailed technical requirements for compliance with the EU Taxonomy for each economic activity under all six EU environmental objectives for two qualitative levels of "substantial contribution" and "do no significant harm", namely [4]:
  - climate change mitigation,
  - climate change adaptation,
  - sustainable use and protection of water and marine resources;
  - transition to circular economy;
  - pollution prevention and control; a
  - protection and restoration of biodiversity and ecosystems.
- methodologies for determining the share of sustainable economic activities based on the EU Regulation from July 2021 [5];
- other delegated implementing regulations expected to be issued according to the Regulation on the EU Taxonomy.

In June 2023, the first remaining delegated regulations defining the technical screening criteria for the four non-climate EU environmental objectives were adopted and came into effect on 1 January 2024 [6].

For the purposes of establishing the degree to which an investment is environmentally sustainable, an economic activity shall qualify as environmentally sustainable where it:

(a) contributes substantially to one or more of the six EU environmental objectives [7],

(b) does not significantly harm any of the six EU environmental objectives;

(c) is carried out in compliance with the minimum safeguards laid down in Article 18 of the Regulation; and

(d) complies with technical screening criteria.

As the EU Taxonomy and its technical screening criteria are a universal sustainability code in the EU, it makes sense to integrate its approach into the Smart City concept.

D. European Sustainability Reporting Standards (ESRS) = emerging non-financial reporting standards in the EU

For many large European companies, an obligation of non-financial reporting pursuant to the CSRD became reality in 2024 and will apply to many more in 2025. Relevant technical standards to this end were prepared by the European Financial Reporting Advisory Group (EFRAG). On 31 August 2023, the Commission based on the proposal from EFRAG released the first general set of 12 sector-agnostic ESRS [8], which came into force at the end of 2023. They are composed of the following twelve (two horizontal and ten thematic) sustainability reporting standards:

- two general standards:
  - General requirements (ESRS 1),
  - General disclosures (ESRS 2);
- five environmental standards:
  - Climate change (ESRS E1),
  - Pollution (ESRS E2),
  - Water and marine resources (ESRS E3),
  - Biodiversity and ecosystems (ESRS E4)
  - Resource use and circular economy (ESRS E5);
- four social standards:
  - Own employees (ESRS S1),
  - Employees in the value chain (ESRS S2),
  - Affected communities (ESRS S3),
  - Consumers and end-users (ESRS S4);
- one governance standard: Business Conduct (ESRS G1).

Furthermore, it is envisaged that they will be complemented gradually by 41 sector-specific standards ranging from agriculture and farming to recreation and leisure by June 2026 at the latest.

Although non-financial reporting will be predominantly the domain of large companies in the EU, these companies will be collecting necessary or useful ESG data and information from their value chains. The same applies to participants in the financial market which will be extracting similar data and information from their value chains. Consequently, these obligations will sooner or later generate a need for robust and reliable data management. This must be verifiable using established quality standards, such as relevant ISO standards. These data management approaches could be also integrated into the sustainability management of urban areas, where they could play a reporting and disclosure role about metrics and

[16] economy-finance.ec.europa.eu

targets. They could also facilitate the solving of major sustainability problems at the systems level. This can include strategic and emergency planning, intervention, future-proofing and operational real-time management, in particular in urban district Digital Twins. This is the value of curated public data and their robust federated management, which is emerging as a key positive disruptor to tackle sustainability challenges which was previously unavailable.

III. Urban District DigitalTwin

A. System Model

The system architecture of the proposed solution is shown in Fig. 3. First of all, it is about creating a Digital Twin of the whole urban district or neighbourhood area, which connects individual urban area nodes. The district Digital Twin enables the coordination/management of the entire district with the cooperation of individual urban Digital Twin nodes.

The urban Digital Twin node interconnects the physical world, its virtual model together with the human elements, such as people interacting with the Digital Twin, residents and users of the urban node. The datasets are driven by the EU Taxonomy and environmental and social ESRS characteristics (i.e., indicators and data points) to enable flexible definitions for primary and secondary impact areas for measuring impacts of individual operations.

At the urban node level, risk, opportunity and impact information (historical events and online data) is processed in such a way as to create various scenarios for operational management. It is also used for further evolution, strategic planning and modelling and future-proofing of interventions, in particular on complex in-combination effects and impacts. These scenarios are evaluated so that the ESG parameters can be addressed in the best way possible.

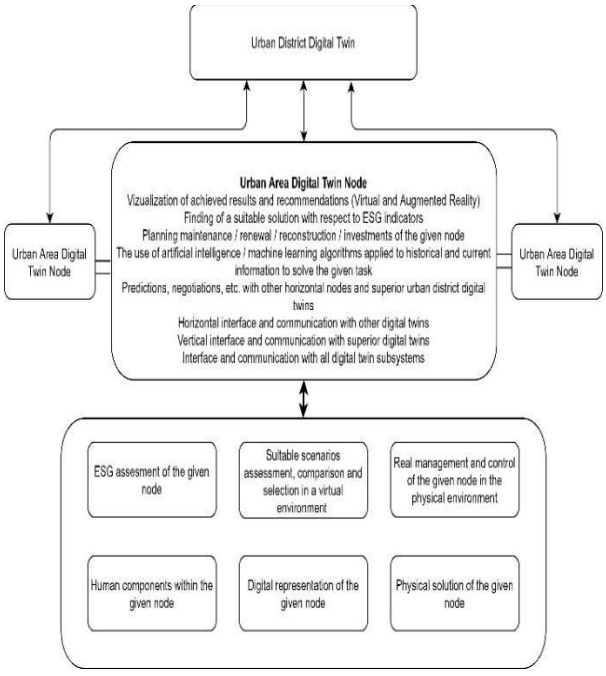

Fig. 3. Urban District Digital Twin

Furthermore, the Digital Twin generates myriad data-evidenced lessons learned, which can be applied in future interventions in similar urban environments and thus facilitates the desirable robust improvement process.

One of the key ESG information sets to start with when designing the urban district Digital Twin could be the data and information on the EU Taxonomy alignment of physical assets and selected characteristics, such as:

- The energy efficiency of particular buildings with use of energy efficiency certificates and additional information[17];
- The vulnerability to climate change, adaptation characteristics and adaptation plan on a district level;
- Selected environmental data derived from ESRS E2 – ESRS 5); and
- Selected social, including security and safety, data derived from ESRS S3 – ESRS S4, in particular robust social baselines.

The value of such Digital Twins could be multi-purpose and provide public goods for various stakeholders, for example by the doing the following:

(1) Enabling a fast, multi-criteria, system-of-systems analysis of critical states and pressures on sustainability and resilience of the district. This would include the identification of key risks, opportunities, dependencies, interrelatedness, based on sound data across all infrastructure and asset categories, service sectors and owners/users of assets within the district. It would also encompass key external factors outside the district (external connections).

(2) Facilitating informed and fact-based stakeholder engagement and policy-making, decision-making about sustainable and resilient interventions in the district and their economic, social and environmental impacts through applying EU Taxonomy by relevant planning and construction authorities, including scenario-planning, through visually strong and data-rich presentational outputs across multiple criteria showing connections and synergies.

(3) Strengthening understanding of accurate initial states and the impacts of various interventions, changing climate conditions and user patterns in the district. This would be particularly based on an ongoing analysis of trends, behavioural patterns and changing conditions in the district. This is particularly important for companies subject to sustainability reporting to justify interventions related to their local operations. These can be based on sound and verifiable data on environmental and social aspects. They can facilitate alignment with the ongoing or planned activities of other local actors.

(4) Improving access to sustainable finance for asset owners in the district by providing sound data on sustainability indicators and key risks, including those related to resilience, to attract investment and raise attractiveness of the locality.

[17] digitaltwinhub.co.uk/credo

(5) Providing sound evidence on the attainment of the European Green Deal objectives in the district. This could include a net-zero carbon target by 2050 and a system-of-systems approach through ongoing tracking interventions in the district, their characteristics and impacts with use of the EU Taxonomy and other relevant reference frameworks.

(6) Increasing capabilities and skills of the relevant district administration and other key stakeholders, including private sector, in the sustainable management of their assets and urban resilience with use of smart, digital and low or zero carbon solutions.

(7) Understanding key real-time constraints/risks positive feedback in the district through residents and visitors via the use of the Digital Twin in mobile applications. This could be achieved through a network of sensors monitoring the likes of online air pollution, traffic congestion, street temperatures, traffic or other infrastructure accidents and more, including spin-off opportunities in marketing of services and products in the district.

(8) Gaining insights and real-time understanding of key constraints/risks or positive feedback in the district by public authorities, infrastructure owners and utilities providers to enable delivery of their services based on actual conditions to gain new efficiencies, including effective management of emergency situations.

(9) Supporting data-driven research and assessments on various topics via access to comprehensive data sets.

(10) Providing a tested seed Digital Twin to be potentially upscaled for the whole territory of a municipality and beyond in the future.

Multi-agent technology (MAT) appears to be the most suitable method, where each urban node is represented by its SW agent [9], which negotiates with other nodes and with the superior urban district agent to find the best solution for the entire urban area. The result of the negotiation are specific control commands that must be used to control the physical components of urban nodes.

The Digital Twin function also includes evaluating the chosen solution, assessment of performance parameters [10] and learning from past mistakes. Historical events, and reactions to them, and the success of these reactions are part of the use of historical data for future decision-making. The sound standardised framework for urban Digital Twins in the EU is currently emerging via the Digital Building Logbook [11].

In this regard, the Triple Access model[18] could be inspirational for the development of such a Digital Twin, as it considers physical mobility, spatial proximity, and digital connectivity within a new accessibility framework. This model diverges from traditional 'predict and provide' paradigms by adopting a vision-led 'decide and provide' approach. It uses artificial intelligence to predict and adapt to uncertainties in urban development, ensuring mobility plans can withstand various future scenarios. One of the values of the model is to build resilience to various threats in terms of the local system's capacity to absorb shocks and adapt to them and transform itself to become more resilient.

In practice, the Triple Access link to ESG reporting lies in the model's comprehensive approach to accessibility which is dramatically changing in recent years due to digital technologies. It indirectly contributes to the sustainability objectives encapsulated in ESG criteria by framing the accessibility challenge into three components which need to be developed as one internally consistent and mutually supportive ecosystem supporting intelligent mobility decisions of its users.

By fostering a more sustainable, accessible, and efficiently governed urban mobility system, the Triple Access model inherently supports the achievement of broader ESG goals at the asset, network and system level, providing a structured approach to measure, report, and improve the sustainability performance of urban transportation systems. Such a system might, if based on federated access and fine-grained record controls within the Digital Twin, be connected to a generative Artificial Intelligence (AI) chatbot and provide fast and reliable information for multiple public and private users.

B. Digital, simulation and modelling tools

Digital Twin tools are based on digital maps (GIS - geographic information system), passports of physical components, models of infrastructure elements (BIM - Building Information Modeling).

Of course, a very important area is the collection, transmission and processing of diverse data, including validation of completeness and correctness of data, data fusion, use of the city's data platform (Golemio in Prague), ontologies, knowledge graphs and Business Intelligence (BI).

Data is the input for advanced modelling and microsimulation. It is possible to combine different simulation tools from different areas.

City simulation software (CSS) enables simulation and assessment of different smart city strategies in one web-based platform [16] that provides a complementary overview of the current situation. City simulation software (CSS) works with the heterogeneous data (economic, environmental, traffic, energy, buildings, social, etc.) from different information sources and provides their integration into mathematical tool that enables to simulate possible strategies and compute the appropriate set of Key Performance Indicators (KPI), such as environmental and social state or pressure indicators.

By using the mixture of mathematical models from different areas, such as transportation, energy and environmental, it is possible to simulate "what-if" impact scenarios including different unpredictable events. City simulation software (CSS) can thus help implement "the resiliency by design framework" and answer the question how to increase urban resilience and sustainability and provide tailored-made emergency services in critical situations.

The use of a metaverse for simple models might be explored, as this provides a comprehensive, interactive virtual environment that integrates and synchronises various digital technologies and services, where users can interact with digital content or

[18] www.tapforuncertainty.eu

with each other within a shared virtual space via advanced virtual reality gadgets, such as Virtual reality (VR) headsets.

The creation of a metaverse using a transport digital twin concept is a process that will use the described transport simulations of various scenarios. This will be further connected with augmented/virtual reality (AR/VR), possibly with artificial intelligence algorithms or the Internet of Things (IoT). The result will be the creation of a detailed 3D model of a specific urban unit with its services for different types of users which would enable simulation and testing of various interventions by relevant stakeholders to future-proof them.

Eventually, this is to lead to reducing their risk profile and negative impacts and integrating additional improvements (positive programme) to achieve higher sustainability and resilience performance.

C. Transport-logistic chain and ESG = example of sector-specific Digital Twin integrating ESG aspects

The most promising areas where sustainability could be embraced with highly tangible outcomes. Transport operations consume one third of all energy in the EU and account for approximately 23% of total direct greenhouse gas emissions in the Union. Decarbonising the transport fleet and infrastructure, therefore, can therefore play a central role in climate change mitigation.

In addition, better transport and mobility management (Fig. 4) can yield strong social and environmental outcomes. These high societal values are targeted by the EU Sustainable and Smart Mobility Strategy.

The aim of the transportation Digital Twin focused on ESG would be to generate, compare and select suitable scenarios for managing transport-logistics processes in a virtual environment ("what-if" models), determine criterion functions, record various ESG data and information, calculate ESG indicators and select a suitable solution corresponding to the area of acceptability [12].

Fig. 5 shows all affected components of the transport-logistics chain after the introduction of the ESG methodology into practice. It is obvious that all processes are affected by this approach. Therefore, this variety of components makes a strong case to use a transportation Digital Twin whilst integrating ESG ontology into it.

In general, the importance of the twin green and digital agenda for decarbonisation is underscored in recent methodology on the update of the National and energy and climate plans[19] (NECPs) from December 2022. Member States are in particular *"encouraged to seek synergies between the NECPs and the national Digital Decade strategic roadmaps submitted under the Digital Decade Policy Programme 2030 (DDPP), to ensure that digital infrastructure and technologies contribute to a sustainable circular and climate-neutral economy and society in line with the European Green Deal. Member States are invited to reflect on how they will leverage the Digital Decade process and tools, and in particular multi-country projects, to accelerate the green transition".*

The economic value will grow in the future as the cost of carbon in transport would be increased by means of environmental taxes or making road transport subject to the EU Emission Trading Scheme (EU ETS) as currently envisaged by way of the amendment to the EU ETS Directive.

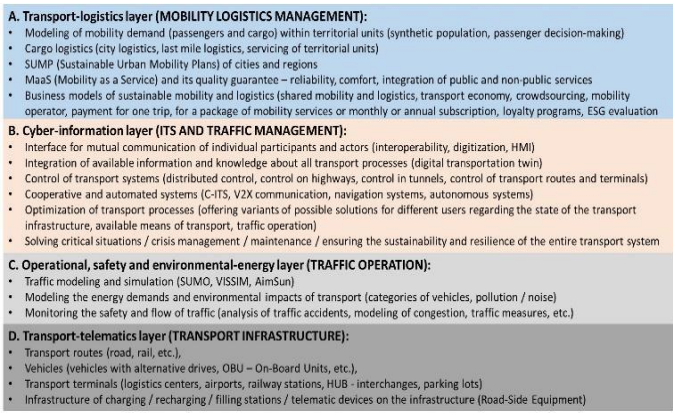

Fig. 4 The model of transportation and forwarding processes

Moreover, the Digital EU Taxonomy and draft List of ESRS Data Points – Implementation Guidance, currently being developed by EFRAG, provide for full standardised lists of data and information on relevant EU ESG datasets in MS Excel to start exploring feasibility of their integration into the Digital Twins to harness and exploit sustainability data for economic operators, regulators and public good.

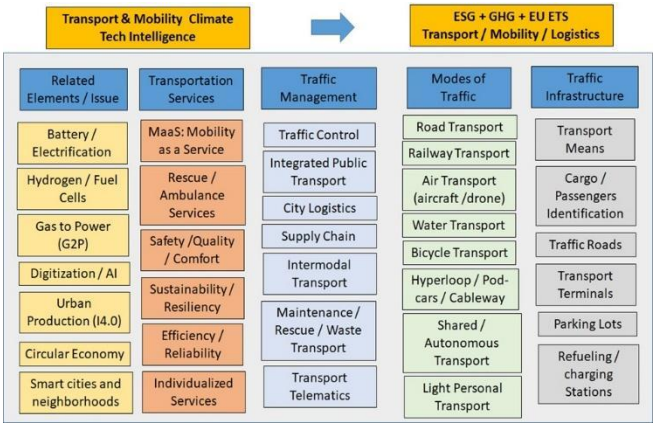

Fig. 5 The impact of ESG indicators on the transport - logistic chain

D. Evropská Avenue as Prague's Digital Testbed

So far, City simulation software (CSS) has been used in Evropská Avenue[20] in Prague. This is a very complicated urban area including the Blanka tunnel exit, commuting workers from the Central Bohemian region, connections to the airport, a university campus and a complicated roundabout at Vítězné náměstí (Vítězné Square).

The image on the left in Fig. 6. shows the sociological data and on the right the environmental parameters. Thanks to CSS, it is possible to verify in a virtual environment whether these new buildings will not cause future problems in the given urban area. Unfortunately, after the approved implementation, it will no

[19] www.ifrs.org

[20] www.gatetoeurope.eu

longer be possible to change it, and the economic and societal consequences could be enormous.

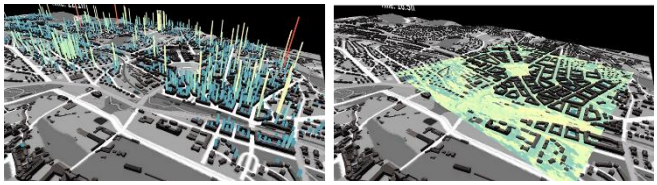

Fig. 6. The graphical outputs of City simulation software (CSS) to a Virtual Reality (VR) environment.

IV. Conclusion

In conclusion, the emerging shift towards ESG investments and the adoption of Smart City concepts marks a major milestone in the history of investment and urban planning. Sustainability aspects such as carbon footprints, climate resilience, circular economies, biodiversity and selected social assets might provide useful data and information. This can be used by multiple actors on sustainability performance and risk and opportunities across the built environment both at the asset, network and systems level.

The EU Taxonomy and ESRS provide consistent and granular concepts to measure sustainability for being able to develop and manage urban areas and their constituent sectors in a smart manner. Consequently, ESG Digital Twins might become a key instrument for making the twin green and digital transition a reality and de-risking our future. In this dimension, it has a potential to serve a substantial public good.

Among other things, the Digital Twin as a metaverse might work as a public consultation ESG platform where residents can virtually provide feedback on planned transportation projects, transportation issues, or proposed policies. This can increase transparency and public acceptance of urban sustainable mobility initiatives and considered interventions.

Continuous data collection and ESG feedback from the Metaverse will enable the continuous improvement of the transport digital twin, which will lead to a better understanding and management of the given urban entity and co-creation of stronger social, environmental and economic outcomes [13, 17].

This feedback loop promotes innovation and continuous improvement of the urban whole through digital simulations, virtual experiments and advanced stakeholder engagement.

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