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A Framework for Assessing the Sustainability Impact of Intelligent Transport Systems in the Smart City Context

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***Abstract*—In their transition to smart cities, an increasing number of cities are pursuing strategies to improve efficiency of transport. One strategy is to achieve smart mobility, for which cities implement intelligent transport systems (ITS). Simultaneously, municipalities recognize their responsibility for creating a sustainable environment for citizens in the face of challenges like overpopulation, land shortage, and climate change. Interestingly, many ITS initiatives mainly focus on technical outcomes and overlook their impact on sustainability despite its key benefit for smart mobility. To fill this gap, we develop a framework for assessing the sustainability impact of ITS initiatives in this paper. We analyze the Sustainable Development Goals (SDGs) defined by the United Nations and relate them to various concepts of ITS to derive our framework. Thereby, our work bridges two fundamental perspectives for further research and supports decision-makers in choosing ITS initiatives that contribute to both smart mobility and sustainability.**

***Index Terms*—smart city, smart mobility, smart traffic management, intelligent transport systems, sustainability**

I. Introduction

SMART mobility can be viewed as a comprehensive and collective term encompassing various data-driven concepts for maneuvering individuals, groups of people or objects in one or multiple geographies and influences our present and future [1]. Considering the complex challenges of the current decade, such as overpopulation, demographic change, globalization, space shortage, and dense traffic, cities aim to stay attractive to their citizens and provide a livable environment [2], [3]. With over 50% of the global population living in urban areas, their citizens can especially profit from the opportunities of smart traffic management and the management of high traffic volume in congested environments [4]. Simultaneously, the environmental and social challenges driven by climate change raise the need for municipalities to take responsibility and counteract the negative influences on their citizens. Consequently, more cities aim to use the advances of digitalization to create value for smart and sustainable mobility of citizens [5]–[8]. Some researchers even point out that cities cannot become smart without being sustainable, making sustainability an important factor in smart city projects [9].

Intelligent transport systems (ITS) provide a set of technical applications and aim to provide innovative services for different modes of transport and traffic management [1], [10], [11]. They empower citizens to make better decisions regarding their mobility and enable safer and better-coordinated transport networks. Since road traffic is responsible for about 65% of the CO2 emissions in cities and is likely to increase in the future, ITS promise to mitigate the negative effects of traffic on the environment [12]. However, while sustainability is a key factor in smart mobility initiatives, many ITS projects are still mainly focused on technical criteria and measures and do not seem to analyze their impact on sustainability [13]–[15].

Therefore, we target the intersection of sustainability and ITS in this paper. We analyze the Sustainable Development Goals (SDGs) defined by the United Nations (UN) to determine which goals, targets, and indicators have implications for the development of ITS in the context of smart mobility towards a sustainable smart city. Specifically, we explore different perspectives on ITS and relate them to the SDGs to answer the following question:

> Which Sustainable Development Goals, targets, and indicators are relevant for assessing the sustainability of intelligent transport systems?

To answer this question, we review the relevant literature and combine it with international agreements and resolutions to derive a framework for measuring the effectiveness of ITS strategies on sustainability. Therefore, the paper is structured as follows. First, we define the term intelligent transport systems and set it into the context of smart cities and sustainability. We then develop our framework based on the literature and describe the implications for further research and practice.

With our research, we contribute to the research fields of sustainable smart cities and mobility while also providing practical implications for sustainable ITS. With our findings, we want to inspire municipal decision-makers and technical leaders to consider sustainability factors to build data-driven solutions that leave a positive impact on society and nature. In fact, we are currently facing this specific challenge in a project for data-driven traffic management funded by the German Federal Ministry for Digital and Transport. Hence, we want to share our approach to support other cities considering or planning ITS projects.

II. Related Literature

A. Smart Cities and Smart Mobility

With the trend of urbanization and population growth, cities become increasingly populated while space and resources are limited. Urban areas will face challenges in meeting the needs of their growing number of citizens in many sectors, such as housing, transportation, energy systems, education, and healthcare, which leads to the need for sustainable development [16]. The concept of smart cities has been evolving in the last decade and aims to enhance quality of life in urban areas by using the opportunities of information and communication technologies (ICT), hardware, algorithms, and data to create a positive impact on life in cities [7].

Smart cities are characterized by the six areas *smart economy, smart people, smart governance, smart environment, smart living,* and *smart mobility,* which are all interlinked [17]. Smart mobility is an especially relevant building block of smart cities. The improvement of mobility with technical advances can save resources, increase efficiency, and provide accessibility [4]. More specifically, smart mobility is defined as "a set of coordinated actions addressed at improving the efficiency, the effectiveness and the environmental sustainability in cities," which is characterized by transport and the use of information and communication technology [6]. It further consists of local accessibility, (inter-)national accessibility, availability of ICT infrastructure, and sustainable, innovative and safe transport systems [17]. Smart mobility has direct implications for fulfilling the Sustainable Development Goals defined by the United Nations and will contribute to the future of city planning and logistics [18]. However, research still shows gaps regarding the consideration of potential sustainability factors that directly affect citizens, e.g., air quality [19]. The field of smart mobility therefore leaves high potential for future research for more sustainable cities.

B. Smart Traffic Management and Intelligent Transport Systems

A variety of terms is employed to denote the technical applications, data-driven services, and conceptual advances for data-driven traffic management; the most frequently used terms are intelligent transport systems, smart traffic management, transport/travel demand management, and smart mobility management. Though not completely congruent, these terms exhibit a high semantic overlap and are used interchangeably. In this paper, we consistently use the term intelligent transport systems (ITS) since it has been researched for more than two decades now [20] and is used by the United Nations and European Parliament [11].

ITS are defined as all technical solutions and construction concepts related to traffic [1]. The United Nations Economic Commission for Europe (UNECE) further describes them as "a set of procedures, systems and devices that enable (a) improvements in the mobility of people and transportation of passengers and goods, through the collection, communication, processing and distribution of information and (b) the acquisition of feedback on experience and a quantification of the results gathered" [21]. The European Parliament defines ITS in a slightly more generalized manner as communication systems to provide services related to different modes of transport and traffic management which supports a safer, more coordinated, and smarter use of transport networks for users [11]. All definitions, however, have the target of technology-based and data-driven traffic management in common that aims to improve mobility. ITS further consist of various tools based on information and communication technology and support the concept of smart mobility [10]. Examples for specific applications are traffic light control systems or analytical tools that influence transport management.

In addition to various definitions, several perspectives on ITS focus on different means and needs. In Fig. 1, we summarize four of the most prominent perspectives and definitions and in the following describe them in more detail for a broad understanding of the concept.

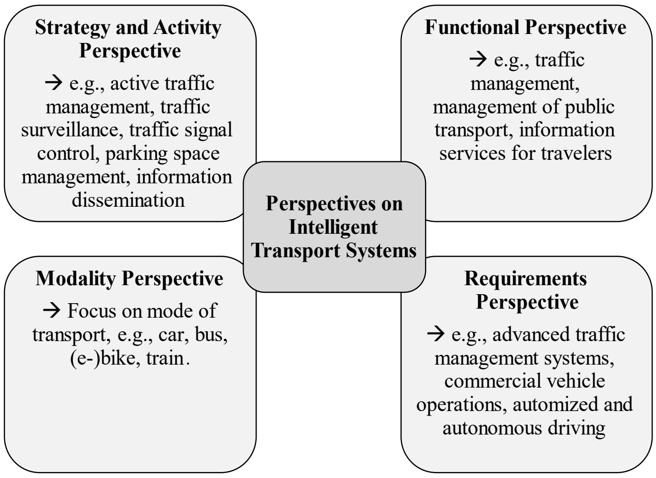

Fig. 1. Perspectives on intelligent transport systems, own illustration derived from [1], [10], [21], [22], [23]

The strategy and activity perspective on ITS [22], [23] is defined by the U.S. Department of Transportation and provides the broadest and most granular perspective. It is focused on ITS strategies and details them into activities. Depending on the publication, 16 to 26 related activities are defined. The strategies and sample activities are:

- Traffic management and operations (e.g., traffic surveillance, traffic signal control, speed and intersection warning systems, bicycle and pedestrian crossing enhancements),
- Road weather management operations (e.g., road weather information systems, winter roadway operations),
- Maintenance and construction management (e.g., coordination activities for construction management, work zone management),
- Incident and energy management (e.g., emergency management, emergency vehicle routing), and
- Public transportation management (e.g., electronic fare collection and integration, multimodal travel connections, transit surveillance).

The functional perspective [10] on ITS describes functions of ITS like management or information provision, consisting of:

- Traffic management,
- Management of public transport,
- Management of cargo transport and fleet of vehicles,
- Traffic safety management and monitoring systems for violation of regulations,
- Management of road incidents and emergency services,
- Information services for travelers and electronic payment services, and
- Electronic systems for collecting tolls for road use.

Some of these functions also overlap with the activities from the strategy and activity perspective, which shows that there is no clear separation of the different perspectives. According to this definition, ITS operation is particularly focused on information collection from different systems, processing of this information, and the provision of related recommendations.

The requirements perspective [1] focuses on requirements profiles and specific technical systems. Again, there are overlaps to both the strategic and functional perspectives. The related systems are:

- Advanced Traffic Management (ATMS),
- Advanced Traveler Information (ATIS),
- Advanced Vehicle Control (AVCS),
- Commercial Vehicle Operations (CVO),
- Advanced Public Transportation (APTS),
- Rural Transportation (ARTS),
- Automized and Autonomous Driving,
- Intelligent Traffic Data (Smart Traffic), and
- Vehicle Networks (Connected Vehicles).

These systems have a direct impact on activities such as emergency management, information management, or innovation management.

While the previous perspectives provide a more generic view, ITS can also be categorized according to the modes of transport they address. That leads to the modality perspective [1], comprising:

- (Motor) car traffic,
- Public transport (bus, train, city train, subway),
- (e-)Bike,
- Motorcycle,
- Plane, or
- Vessel.

The modal split is especially important in relation to sustainable solutions. However, in contrast to the previous ones, this perspective does not present activities or strategies. In summary, every perspective provides a slightly different view on ITS while they have a focus on more efficient, safe, and sustainable intelligent traffic management and the consideration of the modal split in common.

C. Sustainable Development Goals

In 2015 the United Nations formally acknowledged the need for transformative change towards sustainability and defined 17 goals for sustainable development (SDG). The resulting resolution defines sustainability as "meeting the needs of the present without compromising the ability of future generations to meet their own needs" by considering environmental concerns, social aspects, and economic development [16]. Therefore, sustainability encourages growth and technological progress by focusing on people's needs while also making sure that choices in the present do not exhaust resources needed in the future.

All 17 goals are interdependent, and they are defined by 169 targets overall. The progress for achieving these targets can be tracked by 231 unique indicators (ibid). The goals are set to be achieved by 2030 and have universal relevance, as they have been aligned between all 191 UN member nations and thus represent a collective understanding of sustainability.

Many of these goals build an important foundation for the progress towards smart mobility. The application of traffic-related technology and smart services in cities reflects the original idea of smart mobility. However, smart mobility also calls for a balance of technology with the needs of citizens that are reflected by the sustainability factors [24]. Recent research shows that there is high potential for analyzing the contribution of smart cities to achieve sustainable development [25] and some researchers even go as far as to point out that cities cannot become smart without being sustainable, making sustainability an important factor in smart city projects [26]. Further, researchers have covered ICT adoption for sustainable development in the industry context, highlighting the link between ICT and sustainability [27].

The presented literature shows that sustainability is important for smart mobility in smart cities. Therefore, we aim to provide a framework of the important SDGs that relate to ITS in order to be able to assess related projects and support decision-making in smart mobility initiatives.

III. Methods

In the previous chapter, we showed the need for ITS that are not only smart but also sustainable. However, to our knowledge, there is no framework that would help researchers and decision-makers assess whether and how smart traffic management measures contribute to sustainability. Therefore, we dedicate this research to analyzing the various perspectives on ITS and bringing them into the context of the SDGs. To answer our research question, we combine the Sustainable Development Goals, their targets, and related indicators in a framework that shows the sustainability factors ITS can influence. Based on the relevant literature on sustainability, smart mobility, and ITS, we conduct conceptual development in our study. Besides scientific literature, we also include international agreements and recommendations into the development for several reasons: First, UN resolutions can be seen as universally relevant because 191 states from the world community have committed to their achievement. Recommendations by the UNECE are similarly relevant and, while not legally binding, provide a more detailed view than the resolutions. Second, we aim to ground our framework on existing work while developing a new concept through the combination of several perspectives. A literature exploration can provide different views and serve as a foundation for developing a unified understanding. Third, the combination of scientific literature with international agreements allows for both rigorous and relevant contributions. The detailed process of the framework development is described in the following chapter.

IV. Framework Development

A. Overview

In the following, we describe the process of our framework development in detail and explain how we combined the SDGs with perspectives from ITS, filtered and refined them across different stages, and finally brought them together for a central view. Fig. 2 summarizes this process and shows how both strands are first considered individually and then merged into the final framework.

B. Determination of Relevant Sustainable Development Goals

To determine the relevant SDGs for our framework and their relation to ITS, we searched for key terms in the resolutions A/RES/70/1 as the original 2030 Agenda for Sustainable Development and A/RES/71/313, which additionally contains the later-adopted indicators to the goals [16], [28]. We started out with all 17 goals, 169 targets, and 231 indicators (248 indicators including duplicates) and filtered them according to the terms in Table 1. We determined the terms according to the perspectives of ITS described in the previous chapter and used collective terms, e.g., “transport,” for all related terms. We further added terms that focus on cities since we used them as the application context of our study. Additionally, we added the pollution perspective as a result of traffic and as one goal of ITS. The detailed rationale behind the terms can also be found in Table 1.

The resulting set contained 8 goals, 16 targets, and 16 indicators. We then eliminated two further targets and five indicators. First, we ruled out target 14.1 because it is related to marine pollution, which falls outside the scope of our framework that focuses on traffic on land. We also excluded two indicators that contained the term “urban” as a description for the measurement process and therefore did not apply in terms of content (indicators 1.1.1., 4.5.1, 11.6.1). Finally, we also excluded goal 12.c and indicator 12.c.1 because they are re-

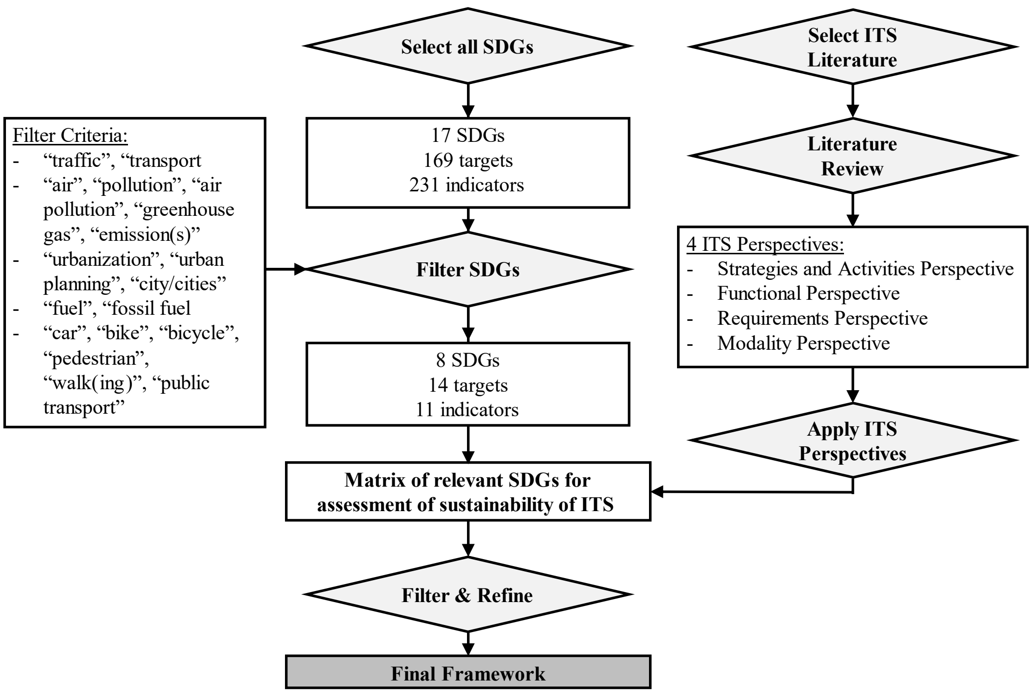

Fig 2. Method of Framework Development, own illustration

TABLE I.
FILTER TERMS FOR SUSTAINABLE DEVELOPMENT GOALS, TARGETS, AND INDICATORS

Term	Rationale
"traffic", "transport"	Direct relation to the traffic component of ITS
"air", "pollution", "air pollution", "greenhouse gas", "emission(s)"	Direct relation to the consequences of (motorized) traffic and traffic density as well as the goal of ITS to mitigate the effects on the environment with data-driven systems and technology
"urbanization", "urban", "urban planning", "city", "cities"	Application context of a (smart) city
"fuel", "fossil fuel"	Resources for motorized traffic that is the dominant form of traffic in cities
"car", "bike", "bicycle", "public transport", "train", "pedestrian", "walk(ing)"	Relation to modes of transport on land that are part of ITS

lated to subsidies that are not decided on the level of municipalities and therefore not in the scope of ITS in the context of smart cities. Afterward, we added the superordinated targets or goals related to targets or indicators since they would not apply to the search terms. Hence, we did not add indicators to related targets when they did not apply to the criteria, leaving some indicators blank. From these constraints remained 8 goals, 14 targets, and 11 indicators that we applied to different perspectives on ITS and that can be found in the matrix in Table 2.

C. Determination of Intelligent Transport System Perspectives

After the preselection of relevant SDGs, we determined the relevant ITS dimensions. As presented in the literature review, there are multiple perspectives of ITS that overlap and align in some parts but still provide different views and concepts. In general, we opted for the definition by the UNECE which contains the aspects of improvements in the mobility of people, transportation of passengers and goods, the collection, communication, processing, and distribution of information as well as the acquisition of feedback on experience and quantification of the gathered results. Based on this definition, we aimed to equally consider all four perspectives on ITS that we derived from literature and presented in Fig. 1. We decided against choosing only one of the perspectives in order to include SDGs that are relevant but do not relate to all perspectives. By using several perspectives, we further aim for more transparency, a broader view, and stability in the evaluation to assess the SDGs for developing our final framework.

D. Combination of SDGs and ITS

After filtering the relevant SDGs and determining the ITS perspectives, we combined both dimensions in a matrix (Table 2). On the Y-axis (e.g., in the rows), we entered the Sustainable Development Goals together with the related targets and indicators. We chose a hierarchical view to represent goals, targets, and indicators in an accessible way. On the X-axis (e.g., in the columns), we added the four perspectives on ITS. We then analyzed how measures of each of the ITS perspectives could contribute to the sustainability targets and indicators. We used the resulting intersections to record the results of our analysis. Perspectives that directly contributed to a target or indicator were marked with "XX" in the related row. Perspectives with a more indirect relation were marked with only one "X" to indicate a lower relevance.

After analyzing each relation, we summarized the findings in a central framework (Table 3). We summed up the labels that indicate each relevance per row to determine whether a target or indicator is primarily or secondarily impacted by ITS. We considered targets and indicators that were marked as relevant ("XX") in relation to all ITS perspectives as primarily impacted by ITS and indicators that were either marked as less relevant ("X") or relevant for less than all four perspectives, as secondarily impacted.

E. Final Framework

From the analysis performed, we were able to determine six main sustainability indicators and eight targets that relate to a total of six Sustainable Development Goals and are primarily influenced by ITS. The remaining five indicators and five targets can be influenced by ITS but probably with lower intensity. Therefore, they were marked as indirectly influenced. The final framework is displayed in Table III.

While SDG 11, "Sustainable Cities and Communities," is the most represented goal in the framework with the highest number of related targets and indicators, the other goals are equally relevant. Our framework especially highlights goals that do not relate directly to traffic, like SDG 7, "Affordable and Clean Energy," or SDG 6, "Clean Water and Sanitation."

Our framework provides an overall view of the most important SDGs as a recommendation for researchers and practitioners to consider in the development process of intelligent transport systems. It further stresses that there is not only one perspective on sustainability and that ITS solutions could target sustainability in multiple areas. Some measures might also contribute to multiple SDGs at the same time, e.g., targeting indicator 9.4.1, "CO2 emission per unit of value added," might also have a positive impact on indicator 13.2.2, "Total greenhouse gas emissions per year," due to the general reduction of emissions.

While it might not be possible to consider every factor equally, it serves as a starting point to create awareness of sustainability targets and indicators in the context of ITS. The framework can be used by researchers, but especially but practitioners, to reflect upon projects and initiatives related to intelligent transport systems and sustainability. We recommend using it as a checklist to determine, whether at least one of the goals, targets or indicators is addressed with the planned initiative. The framework is best used in the planning phase of new ITS projects to determine possible sustainability goals, targets, and indicators that might play a role in the projects. Throughout initiatives, it can then help in making the general assessment of the contribution to sustainability of the solutions more transparent.

V. Limitations And Implications

While we aim for a broad and deep analysis in the creation of our framework, we would like to address some weaknesses in the approach and potential for future work. First, one challenge of a literature review is to include both relevant and novel literature as well as consider established "basic" literature. Despite our diligence in the selection process, we cannot claim to have a complete overview. Further, we recognize that other researchers might choose different publications. Additionally, the selection of the four perspectives on ITS might be influenced by subjective perception. As discussed in the literature review, there are many different terms for and perspectives on ITS. One reason might be the interdisciplinary character of ITS where different perspectives from traffic engineering, traffic planning, business administration, and information systems intersect. We see potential for future work in the attempt to find one definition of ITS that includes all perspectives in order to establish a common transdisciplinary understanding.

Second, the inclusion and exclusion criteria of the relevant Sustainable Development Goals were chosen with the application context in mind but are nevertheless subjective and offer room for discussion. Applying different search terms might lead to a different result set and might influence the final matrix. Further, there might be additional SDGs that do not have a direct relation to ITS but might still be considered when developing such systems. For example, SDG target 16.7 calls for ensuring responsive, inclusive, participatory, and representative decision-making at all levels. From a more social perspective, inclusive decision-making in the process of choosing and developing ITS measures, e.g., by including citizens, could contribute to this target as well. While we do not consider the development process of the applications or social factors in our analysis, our framework is easily adjustable and could include these factors in the future or be enhanced for projects with special emphasis on these dimensions.

Third, we recognize that the assessment of each SDG in relation to ITS might be subjective. We conducted the assessment to the best of our knowledge and based it on the descriptions of each SDG, target, and goal. However, other researchers might have rated the criteria differently. In future work, the rating could be enhanced with more expertise by including more researchers.

Fourth, our framework shows the criteria for assessing ITS from a qualitative perspective but does not provide quantitative measurement criteria. The UN does provide some implications for measurement in its definition of indicators. However, they are on a rather high level and need to be adjusted to and detailed for the specific context. Therefore, we suggest a follow-up study on developing a specific measurement for assessing ITS quantitatively.

VI. Conclusion

In this paper, we described the need for more sustainable actions in the mobility sector and pointed out that previous ITS projects and research seemed to lack the consideration of sustainability factors. We further argued that municipalities have a particular responsibility towards sustainability due to their position as decision-makers for their citizens. We developed a framework that considers both different ITS perspectives and sustainability factors and determined which Sustainable Development Goals, targets, and indicators are relevant for the assessment of the sustainability of intelligent transport systems and should be considered when developing ITS strategies.

To summarize, our framework supports decision-makers in municipalities with an approach to assess their selected or planned ITS initiatives regarding sustainability factors. This could help to make more conscious decisions towards a higher quality of living in cities and contribute to the economy, society, and nature at the same time. Hence, we call for a municipal traffic management that is not only smart but also sustainable to contribute to a livable future.

TABLE II.
ASSESSMENT MATRIX OF SDGS IN RELATION TO ITS

Sustainable Development Goals, targets and indicators			**ITS Perspectives**			
SDG	**SDG Target**	**SDG Indicator**	**STR**	**FNC**	**REQ**	**MOD**
Goal 3: Good Health and Well-Being	3.6 Halve the number of global deaths and injuries from road traffic accidents	3.6.1 Death rate due to road traffic injuries	XX	XX	XX	XX
	3.9 Substantially reduce number of deaths and illnesses from hazardous chemicals and pollution and contamination	3.9.1 Mortality rate attributed to household and ambient air pollution	XX	XX	XX	XX
Goal 6: Clean Water and Sanitation	6.3 Improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials	-	XX	XX	XX	XX
Goal 7: Affordable and Clean Energy	7.1 Ensure universal access to affordable, reliable and modern energy services	7.1.2 Proportion of population with primary reliance on clean fuels and technology	XX	XX	XX	XX
Goal 9: Industry, Innovation and Infrastructure	9.4 Upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes	9.4.1 CO2 emission per unit of value added	XX	XX	XX	XX
Goal 11: Sustainable Cities and Communities	11.2 Provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport	11.2.1 Proportion of population that has convenient access to public transport, by sex, age and persons with disabilities	XX	XX	XX	XX
	11.3 Enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management	11.3.2 Proportion of cities with a direct participation structure of civil society in urban planning and management		XX		
	11.6 Reduce the adverse per capita environmental impact of cities; special attention to air quality	11.6.2 Annual mean levels of fine particulate matter (e.g. PM2.5 and PM10) in cities (population weighted)	XX	XX	XX	XX
	11.7 Provide universal access to safe, inclusive, and accessible green and public spaces	11.7.1 Average share of the built-up area of cities that is open space for public use for all, by sex, age, and persons with disabilities				XX
	11.a Support positive economic, social and environmental links between urban, peri-urban, and rural areas by strengthening development planning	11.a.1 Number of countries that have national urban policies or regional development plans that respond to population dynamics and ensure balanced territorial development			XX	
	11.b Increase the number of cities/settlements adopting and implementing policies and plans towards inclusion, resource efficiency, mitigation, and adaptation to climate change, etc.	-	XX	XX	XX	XX
Goal 12: Responsible Consumption and Production	12.4 Environmentally sound management of chemicals and all wastes and reduce their release to air, water and soil	-	XX	XX	XX	XX
Goal 13: Climate Action	13.2 Integrate climate change measures into national policies, strategies and planning	13.2.2 Total greenhouse gas emissions per year	X	X	X	X
Goal 16: Peace, Justice and strong Institutions	16.1 Significantly reduce all forms of violence and related death rates everywhere	16.1.4 Proportion of population that feel safe walking alone around the area they live after dark	XX	X		X

Legend:

STR = Strategy & Activity Perspective

FNC = Functional Perspective

REQ = Requirements Perspective

MOD = Modality Perspective

TABLE III.
FINAL ASSESSMENT FRAMEWORK FOR THE SUSTAINABILITY IMPACT OF ITS

		Relevant Sustainable Development Goals, targets and indicators for ITS	
		SDG	**SDG Target/Indicator**
Impact of ITS on SD goals, targets and indicators	Primary impact	Goal 3: Good Health and Well-Being	3.6 Halve the number of global deaths and injuries from road traffic accidents 3.6.1 Death rate due to road traffic injuries
			3.9 Substantially reduce number of deaths and illnesses from hazardous chemicals and pollution and contamination 3.9.1 Mortality rate attributed to household and ambient air pollution
		Goal 6: Clean Water and Sanitation	6.3 Improve water quality by reducing pollution, eliminating dumping, and minimizing release of hazardous chemicals and materials
		Goal 7: Affordable and Clean Energy	7.1 Ensure universal access to affordable, reliable, and modern energy services 7.1.2 Proportion of population with primary reliance on clean fuels and technology
		Goal 9: Industry, Innovation and Infrastructure	9.4 Upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes 9.4.1 CO2 emission per unit of value added
		Goal 11: Sustainable Cities and Communities	11.2 Provide access to safe, affordable, accessible, and sustainable transport systems for all, improving road safety, notably by expanding public transport 11.2.1 Proportion of population that has convenient access to public transport, by sex, age, and persons with disabilities
			11.6 Reduce the adverse per capita environmental impact of cities; special attention to air quality 11.6.2 Annual mean levels of fine particulate matter (e.g. PM2.5 and PM10) in cities (population weighted)
			11.b Increase the number of cities/settlements adopting and implementing policies and plans towards inclusion, resource efficiency, mitigation, and adaptation to climate change, etc.
		Goal 12: Responsible Consumption and Production	12.4 Environmentally sound management of chemicals and all wastes and reduce their release to air, water, and soil
	Secondary impact	Goal 11: Sustainable Cities and Communities	11.3 Enhance inclusive and sustainable urbanization and capacity for participatory, integrated, and sustainable human settlement planning and management 11.3.2 Proportion of cities with a direct participation structure of civil society in urban planning and management
			11.7 Provide universal access to safe, inclusive, and accessible green and public spaces 11.7.1 Average share of the built-up area of cities that is open space for public use for all, by sex, age, and persons with disabilities
			11.a Support positive economic, social and environmental links between urban, peri-urban, and rural areas by strengthening development planning 11.a1 Number of countries that have national urban policies or regional development plans that respond to population dynamics and ensure balanced territorial development
		Goal 13: Climate Action	13.2 Integrate climate change measures into national policies, strategies, and planning 13.2.2 Total greenhouse gas emissions per year
		Goal 16: Peace, Justice and strong Institutions	16.1 Significantly reduce all forms of violence and related death rates everywhere 16.1.4 Proportion of population that feel safe walking alone around the area they live after dark

REFERENCES

[1] B. Flügge, Smart Mobility – Connecting Everyone. Wiesbaden: Springer Fachmedien Wiesbaden, 2017. doi: 10.1007/978-3-658-15622-0.

[2] T. Chen, J. Ramon Gil-Garcia, and M. Gasco-Hernandez, “Understanding social sustainability for smart cities: The importance of inclusion, equity, and citizen participation as both inputs and long-term outcomes,” Journal of Smart Cities and Society, vol. 1, no. 2, pp. 135–148, 2022, doi: 10.3233/SCS-210123.

[3] V. Morabito, “Big Data and Analytics for Government Innovation,” in Big Data and Analytics, Cham: Springer International Publishing, 2015, pp. 23–45. doi: 10.1007/978-3-319-10665-6_2.

[4] R. Faria, L. Brito, K. Baras, and J. Silva, “Smart mobility: A survey,” in 2017 International Conference on Internet of Things for the Global Community (IoTGC), IEEE, 2017, pp. 1–8. doi: 10.1109/IoTGC.2017.8008972.

[5] G. M. Jonathan, “Digital Transformation in the Public Sector: Identifying Critical Success Factors,” 2020, pp. 223–235. doi: 10.1007/978-3-030-44322-1_17.

[6] C. Benevolo, R. P. Dameri, and B. D’Auria, “Smart Mobility in Smart City,” 2016, pp. 13–28. doi: 10.1007/978-3-319-23784-8_2.

[7] E. Al Nuaimi, H. Al Neyadi, N. Mohamed, and J. Al-Jaroodi, “Applications of big data to smart cities,” Journal of Internet Services and Applications, vol. 6, no. 1, 2015, doi: 10.1186/s13174-015-0041-5.

[8] F. K. S. Chan and H. K. Chan, “Recent research and challenges in sustainable urbanisation,” Resour Conserv Recycl, vol. 184, 2022, doi: 10.1016/j.resconrec.2022.106346.

[9] T. Yigitcanlar, Md. Kamruzzaman, M. Foth, J. Sabatini-Marques, E. da Costa, and G. Ioppolo, “Can cities become smart without being sustainable? A systematic review of the literature,” Sustain Cities Soc, vol. 45, pp. 348–365, 2019, doi: 10.1016/j.scs.2018.11.033.

[10] B. Kos, “Intelligent Transport Systems (ITS) in Smart City,” 2019, pp. 115–126. doi: 10.1007/978-3-030-17743-0_10.

[11] European Parliament, “Directive 2010/40/EU of the European Parliament and of the Council of 7 July 2010 on the framework for the deployment of Intelligent Transport Systems in the field of road transport and for interfaces with other modes of transport,” 2010.

[12] L. Chapman, “Transport and climate change: a review,” J Transp Geogr, vol. 15, no. 5, pp. 354–367, 2007, doi: 10.1016/j.jtrangeo.2006.11.008.

[13] Z. Li, R. al Hassan, M. Shahidehpour, S. Bahramirad, and A. Khodaei, “A Hierarchical Framework for Intelligent Traffic Management in Smart Cities,” IEEE Trans Smart Grid, vol. 10, no. 1, pp. 691–701, 2019, doi: 10.1109/TSG.2017.2750542.

[14] A. Saikar, M. Parulekar, A. Badve, S. Thakkar, and A. Deshmukh, “TrafficIntel: Smart traffic management for smart cities,” in 2017 International Conference on Emerging Trends and Innovation in ICT, ICEI 2017, Institute of Electrical and Electronics Engineers Inc., 2017, pp. 46–50. doi: 10.1109/ETIICT.2017.7977008.

[15] T. Devi, K. Alice, and N. Deepa, “Traffic management in smart cities using support vector machine for predicting the accuracy during peak traffic conditions,” Mater Today Proc, vol. 62, pp. 4980–4984, 2022, doi: 10.1016/j.matpr.2022.03.722.

[16] General Assembly of the United Nations, “Transforming our World: The 2030 Agenda for Sustainable Development. A/RES/70/1,” 2015.

[17] R. Giffinger and G. Haindlmaier, “Smart cities ranking: an effective instrument for the positioning of the cities?,” ACE: Architecture, City and Environment, vol. 4, no. 12, pp. 7–26, 2010, doi: 10.5821/ace.v4i12.2483.

[18] S. Paiva, M. Ahad, G. Tripathi, N. Feroz, and G. Casalino, “Enabling Technologies for Urban Smart Mobility: Recent Trends, Opportunities and Challenges,” Sensors, vol. 21, no. 6, p. 2143, 2021, doi: 10.3390/s21062143.

[19] E. J. Tomaszewska and A. Florea, “Urban smart mobility in the scientific literature — bibliometric analysis,” Engineering Management in Production and Services, vol. 10, no. 2, pp. 41–56, 2018, doi: 10.2478/emj-2018-0010.

[20] J. Andersen and S. Sutcliffe, “Intelligent Transport Systems (ITS) – An Overview,” IFAC Proceedings Volumes, vol. 33, no. 18, pp. 99–106, 2000, doi: 10.1016/S1474-6670(17)37129-X.

[21] United Nations Economic Commission for Europe, “Intelligent Transport Systems (ITS) for sustainable mobility,” 2012.

[22] M. Grant, P. Noyes, L. Oluyede, J. Bauer, and M. Edelman, “Developing and Sustaining a Transportation Systems Management & Operations Mission for Your Organization. A Primer for Program Planning.,” Reston, Washington, Boulder, 2017.

[23] J. Clark, M. Neuner, S. Sethi, J. Bauer, L. Bedsole, and A. Cheema, “Transportation Systems Management and Operations in Action,” Washington, D.C., 2017.

[24] D. Soeiro, “Smart Cities, Well-Being and Good Business: The 2030 Agenda and the Role of Knowledge in the Era of Industry 4.0,” 2020, pp. 55–67. doi: 10.1007/978-3-030-40390-4_5.

[25] A. M. Toli and N. Murtagh, “The Concept of Sustainability in Smart City Definitions,” Front Built Environ, vol. 6, 2020, doi: 10.3389/fbuil.2020.00077.

[26] T. Yigitcanlar, “Smart cities: an effective urban development and management model?,” Australian Planner, vol. 52, no. 1, pp. 27–34, 2015, doi: 10.1080/07293682.2015.1019752.

[27] E. Ziemba, “Exploring Levels of ICT Adoption and Sustainable Development – The Case of Polish Enterprises,” Sep. 2019, pp. 579–588. doi: 10.15439/2019F145.

[28] General Assembly of the United Nations, “Global indicator framework for the Sustainable Development Goals and targets of the 2023 Agenda for Sustainable Development. A/RES/71/313,” 2017.