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The Impact of Factors Affecting the Effectiveness and Development of ITS on the sustainability of road transport through the Mediating Effect of The Effectiveness and Development of ITS

Aya Elgarhy

Abstract

Purpose: The study investigates the importance of applying Intelligent Transport Systems (ITS) on road transport. ITS provides transport solutions based on advanced telecommunication and information technology, offering great potential for improving road safety for road users. The study also has the purpose of suggesting a proposed framework to overcome these challenges and to help transport operators benefit from the current status in Egypt.

Research Approach: The study uses a mixed research method approach. A descriptive case study that is applied on Egyptian roads through qualitative methods through semi-structured interviews with road stakeholders and a quantitative method using surveys for road users is implemented and results are revealed.

Findings and Originality: The results of the qualitative analysis determined the research variables that were investigated through the quantitative analysis. The findings revealed that there is no significant relationship between Factors Affecting the Effectiveness and Development of ITS dimensions and the sustainability of road transport. Additionally, there is a partially significant relationship between Factors Affecting the Effectiveness and Development of ITS dimensions and The Effectiveness and Development of ITS. Finally, there is no significant relationship between the Effectiveness and Development of ITS and the sustainability of road transport.

Research Impact: The paper provides: (1) A review of the current status of road transportation; (2) An illustration of the road transport stakeholders' tasks and problems in developing countries; (3) a comprehensive description of road transport operators and governmental bodies challenges through conducting in-depth interviews in addition to the road users survey results will be discussed; (4) proposing a conceptual framework as a preliminary guide for Egypt and the other countries to overcome these challenges.

Practical Impact: Determining the main challenges and opportunities for applying ITS on road transport in Egypt. This has a positive effect on improving the efficiency of freight transport as well as other users by road in Egypt. The impact of road public transport on urban transportation cannot be ignored, however, the quality of services provided is not high enough. Both society and businesses benefit from the new transportation methods. The proposed conceptual framework can be further used as a guide to overcome those challenges in other developing countries having similar circumstances as Egypt.

Keywords: Road Transport, Intelligent Transport System, Egypt.

1. **Introduction**

The transportation industry provides simple access to commodities and people to benefit global civilization in every nation. Road transportation is one of the most practical transportation methods out of the three modes of transportation (air, water, and land). It offers dependable services such as moving commodities from the point of production downstream to the place of delivery. The globalization of modern society has established a close relationship between energy use, human activity, and pollution control measures. Any nation's growing GDP needs greater transportation for its industrial and economic growth, which increases fuel consumption and pollutes the environment. Road transportation is the greatest option for people since it makes it easy for them to go from their location to other necessary destinations. The movement of businesspeople rises in tandem with the GDP. On the other hand, these actions compound the rise in urban air pollution. The difference between the world's supply and demand for crude oil has been widening rapidly in recent years and is expected to do so for the foreseeable future until global economic activity persists (Salvi and Subramanian, 2015).

In the last decade, globalization and technological advancements have intensified competition in the international arena, prompting companies to seek new ways to mitigate risks. To compete effectively on national and international levels, companies must explore innovative solutions within the business environment (Ersoy and Tanyeri., 2021). Intelligent transport systems (ITS) have become an integral part of modern transportation, characterized by the adoption and application of advanced information and communications technologies (ICT) within the transport sector. ITS represents a significant evolution, transitioning a mature industrial system into the digital age. Technologically, ITS embodies the convergence of transport and ICT, necessitating the application of systems theory and engineering for effective management, design, procurement, operation, and development. Numerous examples of ITS architectures exist across private sector corporations, local and national authorities, and multinational entities like the European Union. ITS offers innovative financial and budgetary solutions to transportation challenges, potentially delaying the need for traditional physical infrastructure investments. However, the economic evaluation of ITS projects remains underdeveloped, with traditional cost-benefit analyses often failing to account for the unique characteristics of ITS investments (Leviäkangas., 2013).

The road transport sector faces significant challenges in achieving environmental sustainability due to its complexity and the high costs associated with intervention. Addressing vehicle emissions requires substantial behavioral and lifestyle changes, which often encounter resistance from drivers who value their freedom of choice. Intelligent Transportation Systems (ITS) offer a promising solution by leveraging real-time data, communication technologies, and automated control systems to optimize traffic flow, reduce congestion, and lower emissions. Several factors, including technological advancements, supportive policy frameworks, financial investments, public awareness, and stakeholder collaboration influence the effectiveness and development of ITS. These factors collectively enhance ITS's ability to mediate the impacts on sustainability by encouraging more efficient and environmentally friendly transportation behaviors. By addressing these factors and integrating ITS technologies, policymakers, and stakeholders can create a more efficient, safe, and sustainable transportation system (Al-Rawi et al., 2021).

Therefore, this study explores the importance of applying Intelligent Transport Systems (ITS) on road transport through the mediation role of the effectiveness and development of ITS. Understanding the impact of ITS on effectiveness and development can lead to more efficient and sustainable transportation solutions in the future. Additionally, the findings of this study can provide valuable insights for policymakers and transportation authorities on the benefits of integrating ITS into road transport systems.

2. **Literature Review**

This section provides a comprehensive overview of existing research and theoretical frameworks related to the topic of study. It synthesizes key findings and identifies gaps in the current literature that the present study aims to address.

2.1.The Effectiveness and Development of ITS

The effectiveness and development of Intelligent Transport Systems (ITS) involve assessing how well these systems enhance transportation efficiency and their progress over time. Effectiveness includes evaluating how ITS improves traffic flow, reduces congestion, and optimizes routes, leading to better overall transportation performance. It also encompasses how ITS contributes to energy conservation by increasing vehicle efficiency and reducing idle times, as well as its role in emission reduction through decreased congestion and the promotion of cleaner technologies. Additionally, ITS effectiveness is measured by its impact on road safety, user convenience, and satisfaction through features like real-time updates and improved public transport services (Lv et al., 2023). Furthermore, effectiveness in the context of ITS refers to how well these systems improve the efficiency of transportation operations, including aspects such as route optimization, real-time tracking, and dynamic scheduling. The effectiveness is typically measured by improvements in delivery times, cost reductions, and overall customer satisfaction (Pramudito et al., 2024).

The effectiveness of ITS also refers to how well these systems contribute to the goals of enterprise green transformation. ITS can enhance environmental sustainability by optimizing transportation routes, reducing fuel consumption, and lowering greenhouse gas emissions. This effectiveness is measured by improvements in operational efficiency, reduction in environmental impact, and cost savings achieved through smarter transportation management (Guo et al., 2024).

On the other hand, development refers to the continuous advancement and enhancement of ITS technologies, including the integration of innovations, upgrades to existing systems, and the expansion of ITS applications to address new transportation challenges (Lv et al., 2023). Moreover, the development of ITS involves the creation and enhancement of technologies that support intelligent transportation. This includes designing and implementing software and hardware solutions that enable better management and operation of transportation networks. If the e-commerce system includes features that interact with ITS, such as tracking shipments or optimizing delivery routes, it would contribute to the overall development of ITS by integrating new functionalities that enhance transportation management (Pramudito et al., 2024).

The development of ITS involves the advancement and implementation of technologies that support smarter and more efficient transportation systems.

This includes integrating digital infrastructure such as sensors, data analytics, and communication systems to enable real-time monitoring and management of transportation networks. In the context of the article, the development of ITS is likely discussed in terms of how these technologies can be leveraged to support green transformation initiatives by enhancing the sustainability of logistics and transportation operations (Guo et al., 2024).

2.2.**Sustainability of Road Transport**

Numerous challenges, such as climate change, economic growth, social fairness, and environmental protection, have led to an increase in interest in sustainable development. offered the initial full understanding of sustainable development, and its significance is immeasurable in any period. Work on improving sustainable development has started in all directions. In developed countries, a lot of attention is being paid to sustainable transportation development. Sustainable forms of transportation ensure social cohesion and economic progress by safeguarding the environment and public health. After discussing solutions for sustainable development, the paper delves into the significance of transportation in three domains: social, economic, and ecological (Ivanova et al., 2023).

The sustainability of road transport is essential for achieving sustainable development and is closely linked to eight of the 17 Sustainable Development Goals (SDGs) established by the United Nations. Achieving these SDGs requires advancements in sustainable transport. The OECD has been a pioneer in promoting sustainable transport since 1994, aiming to provide guidelines for environmentally sustainable transport (EST) policies among its member countries. Despite ongoing efforts, OECD countries still face significant financial burdens due to environmental problems in transport, with air pollution from road transport costing an estimated US$1.7 trillion in health impacts (Mo and Wang., 2019).

The concept of sustainable transport, popularized in the 1990s, encompasses the environmental sustainability of transport, which has been studied from various perspectives, including social, economic, environmental, cultural, and technical. This broad range of research covers issues such as definitions, analytical frameworks, planning, policy, regulation, and implementation. Data Envelopment Analysis (DEA) is a valuable methodology for assessing environmental sustainability in transport, offering insights into urban planning, policy formulation, regulation, resource allocation, and fleet configuration. DEA's ability to model multiple inputs and outputs provides a comprehensive perspective on transport efficiency across various entities and transportation modes, including roads (Mo and Wang., 2019).

Unified definitions of sustainable transportation are still pending. Nevertheless, it is indisputable that achieving sustainable mobility requires an awareness of how transportation affects the economy, ecology, and society. The transportation system cannot be sustained permanently for a number of reasons. The lack of oil, the large number of car-related fatalities and injuries, and the expansion of urban sprawl are three of the main issues. Less important, but not insignificant, are the detrimental impacts of pollutants derived from petroleum on air quality. In many cities, congestion reaches almost impasse, resulting in a host of negative effects including noise pollution, vibration from motor vehicles damaging structures, water pollution from runoff from streets and highways, loss of wetlands, open spaces, and historic buildings, and ocean pollution from oil spills and secondary effects (Ivanova et al., 2023).

The sustainability of road transport involves creating a system that meets current mobility needs without compromising the ability of future generations to meet their own needs. This encompasses minimizing environmental impact through reduced emissions and pollution, enhancing resource efficiency by prioritizing renewable resources and recycling, and ensuring economic viability by providing reliable and efficient transportation options. It also involves promoting social equity by ensuring accessibility and affordability for all demographics and supporting human and ecosystem health by maintaining cleaner air and water. Overall, a sustainable transportation system balances environmental, economic, and social dimensions to achieve long-term viability and minimal negative impact on the environment (Kamran et al., 2019).

2.3. **Research Development**

To develop the hypotheses to be tested in the following sections, this section is concerned with illuminating the previous investigations

The Relationship between Factors Affecting the Effectiveness and Development of ITS Dimensions and Sustainability of Road Transport

Chen et al. (2022) explored how urbanization interacts with and influences the achievement of Sustainable Development Goals (SDGs). The study involved a comprehensive analysis of existing literature and data to identify and map the connections between urbanization trends and various SDGs. The results revealed that urbanization had complex interlinkages with several SDGs, both positive and negative. It was found that while urbanization could drive progress in areas like economic growth and infrastructure, it also posed challenges for sustainability, such as increased environmental impacts and social inequalities.

Zarbakhshnia et al. (2024) identified the key factors that influence the successful adoption of autonomous vehicles (AVs) within the context of sustainable urban transportation. The study involved conducting a detailed review of existing literature, case studies, and expert opinions to pinpoint the critical success factors impacting AV adoption. The results revealed that essential factors included technological readiness, regulatory frameworks, public acceptance, and integration with existing transportation infrastructure. The study found that addressing these factors comprehensively could significantly facilitate the successful deployment of AVs, thereby contributing to more sustainable and efficient urban transportation systems.

The Relationship between Factors Affecting the Effectiveness and Development of ITS Dimensions and The Effectiveness and Development of ITS.

Rani (2023) expounded on the implementation and benefits of intelligent transportation systems (ITS) integrated with Internet of Vehicles (IoV) technologies for enhancing smart city infrastructure. The study involved analyzing existing literature and case studies to evaluate how IoV-based vehicular networks contribute to the development of smart city transportation solutions. The results demonstrated that integrating ITS with IoV technologies improved traffic management, enhanced vehicle-to-vehicle and vehicle-to-infrastructure communication, and optimized overall urban mobility.

Lv et al. (2023) evaluated how intelligent transportation systems (ITS) affect energy conservation and emission reduction in transportation. The methodology involved conducting a thorough review of existing studies and data related to the impacts of ITS on energy and emissions. The results indicated that ITS significantly contributed to energy savings and reduced emissions by optimizing traffic flow, improving route planning, and enhancing vehicle efficiency.

The Relationship between the Effectiveness and Development of ITS and the sustainability of road transport

Yang et al. (2020) reviewed energy management strategies for hybrid electric vehicles (HEVs) and plug-in hybrid electric vehicles (PHEVs) within the context of intelligent transportation systems (ITS). The study involved a comprehensive review of existing literature and recent advancements in energy management techniques, including the analysis of various strategies and their implementation in ITS environments. The results showed that advancements in energy management strategies, such as optimization algorithms and real-time data integration, significantly improved the efficiency and performance of HEVs and PHEVs.

Srivastava et al. (2024) investigated recent advancements in intelligent transport systems (ITS) across different transportation modes. The study involved a thorough examination of recent developments and innovations in ITS, including case studies and technological assessments, to evaluate their impacts on various modes of transportation. The results revealed that significant progress had been made in enhancing ITS capabilities, including improvements in data integration, real-time monitoring, and autonomous vehicle technologies.

3. **Research Methodology**

The methodology presents a logical and systematic plan designed to address the research problem effectively, ensuring reliable and valid results aligned with the study's aims and objectives. The methodology encompasses the entire process of data collection, sources, and methods for data analysis, facilitating the use of extracted results to generalize theories and develop practical empirical principles (Zhang, 2022). The study adopted a positivist philosophy and a deductive method to investigate the impact of factors influencing the effectiveness and development of Intelligent Transportation Systems (ITS) on the sustainability of road transport, mediated by the effectiveness and development of ITS. Given the study's nature and subject matter, a quantitative approach was selected for data collection, analysis, presentation, and report generation.

Primary data is collected using a mixed technique, achieved through the integration of both qualitative and quantitative data collection methods. This approach allowed for a comprehensive analysis, with qualitative data providing deeper insights into participants' perspectives, while quantitative data offered measurable and statistically significant findings. Together, these methods enriched the overall research, ensuring a robust and well-rounded understanding of the subject matter.

For the qualitative analysis, the researcher conducted 15 interviews with road stakeholders in the Egyptian context, utilizing semi-structured interviews as the primary method of data collection for this study. By posing questions that elucidate their perspectives on factors influencing the effectiveness and development of Intelligent Transportation Systems (ITS) on the sustainability of road transport, the intention was to obtain essential data on the variables and dimensions of the research. The researcher presented a set of questions related to the study variables. These questions are:

1. Can you please introduce yourself and explain your role in the transportation sector?
2. How familiar are you with Intelligent Transport Systems (ITS)?
3. What do you believe are the key benefits of implementing ITS in achieving the sustainability of road transport?
4. What policies or regulations currently exist in Egypt to support the implementation of ITS?
5. How is the government planning to encourage the adoption of ITS in achieving the sustainability of road transport?
6. What specific ITS technologies do you think would be most beneficial for your operations?
7. What are the biggest challenges you face in integrating ITS into your current systems?
8. Can you share any success stories or case studies where ITS has significantly improved traffic conditions?
9. How do you ensure that ITS technologies are adaptable to the local context and infrastructure?
10. How aware are you of ITS and its potential benefits for the sustainability of road transport?
11. How do you evaluate the effectiveness of ITS implementations in improving the sustainability of road transport?
12. What are your expectations for the future of the sustainability of road transport with the integration of ITS?

By conducting the qualitative analysis, the researcher was able to develop the research framework. The insights gained from the qualitative data helped identify key themes, relationships, and variables that were crucial to the study. This informed the structure and content of the research framework, ensuring that it was grounded in real-world experiences and perspectives. The framework was then used as a foundation for the subsequent quantitative analysis, allowing for a more comprehensive and well-rounded investigation of the research questions. The hypotheses were derived from theoretical perspectives, and a descriptive explanatory design was used to elucidate the relationships between the research variables, illustrated in the research framework shown in Figure 1.

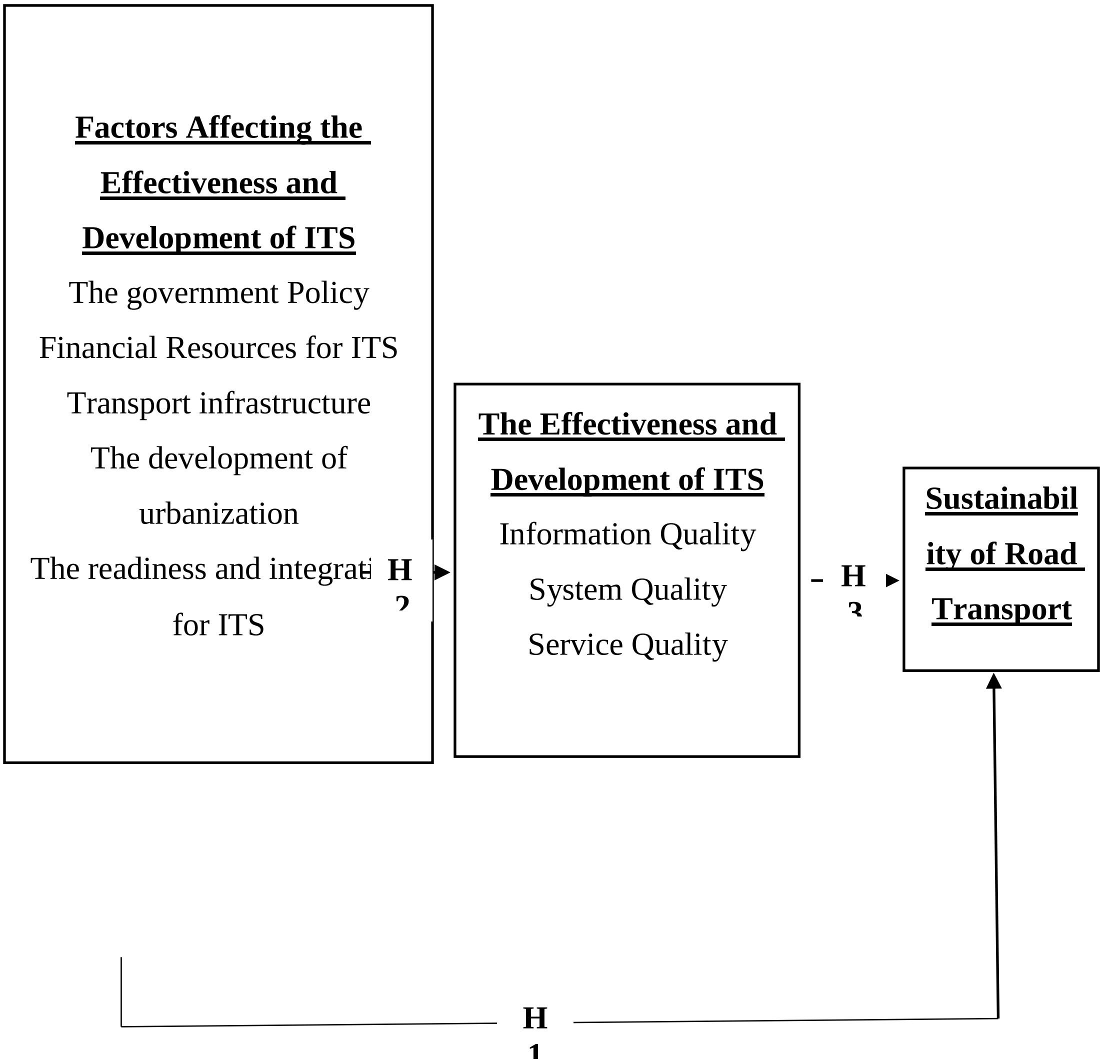


Figure 1: Theoretical Framework

Accordingly, the variables of the research can be discussed as follows:

- **Independent Variable:** Factors Affecting the Effectiveness and Development of ITS dimensions (The government Policy, Financial

Resources for ITS, Transport infrastructure, The development of urbanization, The readiness and integration for ITS).

- **Dependent Variable:** sustainability of road transport
- **Mediator:** The Effectiveness and Development of ITS (Information Quality, System Quality, Service Quality)

The following research hypotheses are based on both the prior variables and the study's framework:

H_1: There is a significant relationship between Factors Affecting the Effectiveness and Development of ITS dimensions and sustainability of road transport.

H2: There is a significant relationship between Factors Affecting the Effectiveness and Development of ITS dimensions and The Effectiveness and Development of ITS.

- $H_{2.1}$: There is a significant relationship between Factors Affecting the Effectiveness and Development of ITS and Information Quality.
- $H_{2.2}$: There is a significant relationship between Factors Affecting the Effectiveness and Development of ITS and System Quality.
- $H_{2.3}$: There is a significant relationship between Factors Affecting the Effectiveness and Development of ITS and Service Quality.

H_3: There is a significant relationship between the Effectiveness and Development of ITS and sustainability of road transport.

In addition to the interview, a quantitative method using surveys for road users, as a five-point Likert scale questionnaire was designed to gather necessary data from the study population. The survey method complemented the qualitative insights from the interviews, providing a comprehensive understanding of the study's focus area by combining both statistical rigor and nuanced perspectives. Given the lack of a defined sampling frame for startup owners and managers, a non-probability sampling method was employed. The snowball sampling technique was utilized, wherein referrals from the users of road transport were used to identify and reach the target sample. A sample was chosen to represent the study community as a whole, where a descriptive case study was applied on Egyptian roads. This approach allowed the research to focus on the specific context of Egypt's road infrastructure, providing detailed insights that could be generalized to similar settings.

Table 1 shows the questions that measure the study variables and the sources that they are adapted from.

Table 1: Research Variables Measurement

Variables	Statements	References
Factors Affecting the Effectiveness and Development of ITS		
The government policy	1. The government provides financial support for the adoption of the intelligent transport system. 2. The government arranges training and workshops for companies on the intelligent transport system. 3. Policies related to sustainability for roads are not effective since they prioritize economic development	Kousar et al. (2017)
Financial resources for ITS	1. Balance sheets and income statements are prepared at least annually, based on the calendar or tax year. 2. Cash flow budgets are prepared at the beginning of the year, and actual cash flow is compared to these projections at least monthly or quarterly. 3. Key performance measures and ratios for critical areas such as production, marketing, finance, and capital are calculated annually and compared to historical trends. 4. Partial budget techniques are understood and used when evaluating partial shifts in the business.	Langemeier (2018)
Transport infrastructure	1. Fixed costs related to owning transportation means are properly accounted for. 2. Variable costs for the operation of transportation means are efficiently managed. 3. The time value associated with	Korytárová and Hromádka., (2014)

	transportation is suitably considered. 4. Costs associated with car accidents, including those borne by society, are effectively managed.	
The development of urbanization	1. The current policies for the transport system are incapable of catching up with technological changes. 2. The intelligent transport system adapts to urban growth. 3. There is a need for new transport infrastructure.	Nguyen et al. (2021)
The readiness and integration for ITS	1. Our organization has established processes for evaluating the effectiveness of ITS. 2. We actively seek and implement feedback to improve ITS integration. 3. We have a dedicated team or department responsible for ITS integration and management.	Rood (2010)
The Effectiveness and Development of ITS		
Information Quality	1. Logistics services of the intelligent transport system are stable and reliable. 2. The intelligent transport system provides the right services at the right time as committed. 3. The intelligent transport system always informs customers about the time its services are provided to customers.	Le et al. (2020)
System Quality	1. The intelligent transport system has modern and advanced equipment. 2. The intelligent transport system's equipment always meets the logistics services requirements. 3. In providing logistics services, the intelligent transport system does not make any significant mistakes.	Le et al. (2020)

sustainability of road transport	1. Should transportation policies prioritize environmental concerns? 2. Can public participation enhance the effectiveness of sustainable transport? 3. Is reducing car usage the most effective strategy for achieving sustainable transport? 4. Are you willing to reduce personal luxuries to improve sustainable transportation at a national level?	Kamran et al., (2019)

4. Results and Findings

This section will provide the results of the conducted empirical study with the main findings and results extracted from both the interviews and questionnaires survey after running the data analysis.

4.1. Qualitative Analysis Results and Findings

The research examines the importance of intelligent transportation systems (ITS) in the sustainability of land transportation in Egypt, focusing on implementation challenges and benefits. It also proposes a framework to overcome these problems and benefit transportation operators in Egypt. Therefore, this research used the qualitative method to collect data, to develop a practical framework on how factors affecting the effectiveness and development of ITS can affect the sustainability of road transport. Therefore, 15 semi-structured interviews were held with road stakeholders. In this section, these interviews will be analyzed using thematic analysis of qualitative data.

The interviewees were asked 12 questions about how factors affecting the effectiveness and development of ITS can affect the sustainability of road transport, and the answers of these interviewees were analyzed using thematic analysis. Thematic analysis is a widely used method in qualitative research for identifying, analyzing, and reporting patterns within data. The process begins with familiarization, where the researcher immerses themselves in the data, such as interview transcripts, survey responses, or observational notes, to become deeply acquainted with its content. This step involves reading and re-reading the data, taking notes, and highlighting initial ideas or patterns that stand out. Therefore, First, the 15 interview audio recordings were transcribed into Microsoft Word documents for initial data familiarization before being imported into NVIVO.

The next step is generating initial codes. This involves systematically coding interesting features across the entire dataset. Codes are short labels that capture significant aspects of the data and can be data-driven (emerging directly from the data) or theory-driven (informed by existing theories or research questions). Once initial codes are established, the researcher moves on to searching for themes. In this stage, different codes are grouped into potential themes, and all data relevant to each theme are collated. This helps in organizing the codes into broader themes that represent significant patterns within the data. In this research, the second phase entails assigning suitable codes to data extracts and examining any connections between them that can aid in the creation of a theme.

After identifying potential themes, the next step is reviewing them. This involves refining the themes by checking if they work to the coded extracts and the entire dataset. Therefore, making a word cloud or thematic map is the third phase in the process, which involves searching for topics. The top 150 words with three or more appearances are shown in the word cloud. A set of words shown in different sizes is called a word cloud. Stronger and more pronounced words tend to be chosen or voted for more frequently by the audience. Word clouds are a great tool for learning what people's true opinions are on a certain topic. Figure 2 depicts the previously indicated phase and was derived from the word frequency table. The terms that appear the most frequently in the word cloud are sustainability, technologies, transport, road systems, and traffic.

Figure 2: Word Cloud

During this process, some initial themes may be combined, separated, refined, or even discarded. The goal is to ensure that the themes accurately reflect the data and are coherent. By putting related codes together and segregating separate codes from one another, the researcher can first find themes. Three themes emerge from the interview replies, and these are Theme of Factors Affecting the Effectiveness and Development of ITS, The Effectiveness and Development of ITS and the sustainability of Road Transport.

Once the themes are reviewed, the researcher defines and names them. This step involves writing detailed analyses for each theme, identifying their essence and scope, and creating concise and informative names that clearly communicate what each theme represents. At this point, the related codes, or sub-themes, are identified, and the themes are clearly defined. The outcome of this step is displayed in Table 2.

Table 2: Themes Defining and Naming

Major Themes	Sub-themes	Reference	Total
Factors Affecting the Effectiveness and Development of ITS	1. The government Policy	8	56
	2. Financial Resources for ITS	13	
	3. Transport infrastructure	14	
	4. The development of urbanization	9	
	5. The readiness and integration for ITS	12	
The Effectiveness and Development of ITS	1. Information Quality	6	29
	2. System Quality	7	
	3. Service Quality	9	
	4. Environmental Sustainability	7	
The	1. Telecommunication And Information Technology	3	45

Sustainability of Road Transport	2. Traffic Management	7	
	3. Operations And Delays	10	
	4. Accident Rates and Safety Level	14	
	5. Real-Time Traffic Monitoring	11	

The final step is writing the report. This involves weaving together the themes into a coherent narrative that explains how they relate to the research questions. The report should be compelling, using data extracts to support the themes and providing insightful interpretations. Throughout the process, maintaining consistency in coding and theme development is crucial for ensuring reliability. Finally, Composing the final analysis and explaining the codes and themes that are obtained from the quotes from the interviews constitute writing the report. The following subheadings explain this procedure.

Theme of Factors Affecting the Effectiveness and Development of ITS

The first theme that emerged from the interview responses is the theme of factors affecting the effectiveness and development of intelligent transportation systems (ITS). This theme was identified based on five key codes: government policy, financial resources for ITS, transport infrastructure, the development of urbanization, and the readiness and integration for ITS. Interviewees consistently highlighted these factors as crucial in determining the success and progression of ITS initiatives. Government policy sets the regulatory and strategic framework, while financial resources ensure the availability of necessary funding. Transport infrastructure provides the physical foundation for ITS, and the development of urbanization influences the scale and scope of ITS deployment. Finally, the readiness and integration for ITS determine how well these systems can be implemented and used effectively. Figure 3 illustrates an intellectual map of the theme of factors affecting the effectiveness and development of ITS and its associated codes, visually representing the interconnectedness of these critical factors.

Figure 3: Mind Map of Theme of Factors Affecting the Effectiveness and Development of ITS

Government Policy: This code refers to the regulatory framework and strategic directives established by governmental bodies that guide the development and deployment of ITS. Interviewees indicated that supportive and clear government policies are crucial for creating a conducive environment for ITS initiatives, ensuring alignment with national and regional transportation goals. In interview one, the following evidence indicating this code was explained:

"Egypt has several policies aimed at supporting ITS implementation, including national strategies for smart cities and digital transformation".

While interview five provided the following evidence that confirms this code:

"The Egyptian government has recently introduced policies aimed at modernizing transportation infrastructure".

In addition to the evidence shown in Interview nine, which states the following:

"Government policy and ongoing technological advancements will be pivotal in achieving these objectives".

Financial Resources for ITS: This code encompass the availability and allocation of financial investments required for the development and maintenance of ITS infrastructure and technologies. Interviewees highlighted that adequate funding is essential to support research, implementation, and ongoing operations of ITS projects, directly impacting their effectiveness and sustainability. In interview one, the following evidence indicating this code was explained:

"The biggest challenges include securing adequate financial resources, ensuring inter-agency coordination, and adapting ITS technologies to fit our existing infrastructure".

While interview six provided the following evidence that confirms this code:

"Financial Constraints: Balancing the cost of new technologies with the budgetary limitations and achieving a clear ROI".

In addition to the evidence shown in Interview twelve, which states the following:

"In order to promote ITS adoption and integration, the government also lays out financial assistance programs".

Transport Infrastructure: This code pertains to the physical and organizational structures, such as roads, bridges, and traffic management systems, that are necessary for the operation of ITS. According to the interviewees, the quality and extent of existing transport infrastructure significantly affect the feasibility and efficiency of integrating ITS solutions. In interview two, the following evidence indicating this code was explained:

"These systems integrate advanced communication and information technologies into transportation infrastructure and vehicles to enhance the efficiency, safety, and sustainability of transport systems."

While interview four provided the following evidence that confirms this code:

"We actively promote ITS as a key component of modernizing Egypt's transportation infrastructure".

In addition to the evidence shown in Interview Fifteen, which states the following:

"In Egypt, there are several policies aimed at modernizing transport infrastructure and incorporating ITS".

The Development of Urbanization: This code relates to the patterns and pace of urban growth and expansion. Interviewees noted that rapid urbanization creates both opportunities and challenges for ITS, as increasing population density and transportation demand require more sophisticated and scalable ITS solutions to manage urban mobility effectively. In interview four, the following evidence indicating this code was explained:

"The development of urbanization and improvements in transport infrastructure will further enhance the effectiveness and development of ITS".

While interview nine provided the following evidence that confirms this code:

"These policies are designed to promote urbanization, improve the quality of information systems, and ensure the effective integration of ITS into our transportation infrastructure".

In addition to the evidence shown in Interview twelve, which states the following:

"It's also crucial for optimizing the sustainability of road transportation and adapting to the growing demands of urban development".

The Readiness and Integration for ITS: This code describes the preparedness of a region or organization to adopt and integrate ITS technologies into existing transportation systems. Interviewees emphasized that readiness includes factors such as technological infrastructure, workforce skills, and institutional support, all of which are critical for the successful implementation and seamless operation of ITS. In interview three, the following evidence indicating this code was explained:

"With the integration of ITS, I expect significant improvements in traffic management, road safety, and transportation efficiency and sustainability".

While interview five provided the following evidence that confirms this code:

"They are also investing in training programs to enhance the readiness of local authorities and transport operators".

In addition to the evidence shown in Interview seven, which states the following:

"The government is investing in ITS infrastructure, promoting public-private partnerships, offering training, and updating regulations to support ITS integration".

Theme of The Effectiveness and Development of ITS

The second theme that emerged from the interview responses is the theme of the effectiveness and development of intelligent transportation systems (ITS). This theme was identified based on four key codes: information quality, system quality, service quality, and environmental sustainability. Interviewees emphasized that the quality of information provided by ITS, including its accuracy, timeliness, and relevance, is crucial for effective decision-making and operational efficiency. System quality, encompassing the reliability, functionality, and performance of ITS technologies, was also highlighted as a critical factor. Service quality, which refers to the user experience and satisfaction with ITS services, plays a significant role in their adoption and success. Additionally, the theme underscores the importance of environmental sustainability, indicating that ITS should contribute to reducing environmental impact through efficient transportation solutions. Figure 4 presents an intellectual map of the theme of the effectiveness and development of ITS and its associated codes, illustrating the key components and their interrelations.

Figure 4: Mind Map of Theme of the Effectiveness and Development of ITS

Information Quality: This code refers to the accuracy, timeliness, relevance, and completeness of the data provided by ITS. Interviewees emphasized that high-quality information is crucial for effective decision-making and operational efficiency in ITS. Accurate and reliable data enable better traffic management, route planning, and overall system performance. In interview two, the following evidence indicating this code was explained:

"Ensuring the quality of information collected by ITS technologies is crucial, as accurate, reliable, and timely data is essential for effective traffic management".

While interview five provided the following evidence that confirms this code:

"Improvements in information quality and better alignment with government policies will be crucial for realizing these benefits".

In addition to the evidence shown in Interview nine, which states the following:

"ITS also provides high-quality information to drivers, which helps in making informed decisions and improving travel experiences".

System Quality: This code pertains to the reliability, functionality, and performance of ITS technologies. Interviewees highlighted that the effectiveness of ITS heavily depends on the quality of the system, including its ability to function correctly under various conditions, its ease of use, and its overall technical robustness. High system quality ensures that ITS can deliver consistent and dependable services. In interview five, the following evidence indicating this code was explained:

"These include incentives for adopting ITS technologies and regulatory frameworks to support their integration into existing systems".

While interview thirteen provided the following evidence that confirms this code:

"Ensuring that these systems work well with our existing operations could be a concern".

In addition to the evidence shown in Interview fifteen, which states the following:

"Improved system quality, better service quality, and advanced technologies will likely transform how we travel and manage the sustainability of road transportation in the future".

Service Quality: This code describes the user experience and satisfaction with ITS services. Interviewees noted that for ITS to be effective, it must meet the needs and expectations of its users. This includes aspects such as responsiveness, accessibility, and the overall level of service provided. High service quality leads to greater user adoption and trust in ITS. In interview four, the following evidence indicating this code was explained:

"Implementing ITS in road transport offers numerous benefits, such as improved traffic flow, enhanced safety, environmental benefits, cost savings, and better service quality for road users"

While interview nine provided the following evidence that confirms this code:

"Overcoming these challenges is crucial for maintaining high service quality"

In addition to the evidence shown in Interview eleven, which states the following:

"I expect that ITS will play a crucial role in modernizing our road transport systems. Over time, we should see advancements that lead to more efficient traffic management, greater safety, and improved service quality"

Environmental Sustainability: This code relates to the contribution of ITS to reducing the environmental impact of transportation. Interviewees underscored the importance of ITS in promoting environmentally friendly transportation solutions, such as reducing emissions, improving fuel efficiency, and supporting sustainable urban mobility. Environmental sustainability is a key aspect of the development of ITS, ensuring that technological advancements align with broader ecological goals. In interview one, the following evidence indicating this code was explained:

"ITS can lead to significant reductions in fuel consumption and emissions, contributing to environmental sustainability".

While the interview two provided the following evidence that confirms this code:

"Environmental benefits are also substantial, as ITS can reduce emissions through better traffic management and promoting eco-friendly driving practices".

In addition to the evidence shown in Interview Six, which states the following:

"Supporting Sustainable Development: By integrating ITS, we can better manage transportation's environmental impact and support sustainable urban growth".

Theme of the Sustainability of Road Transport

The third theme that emerged from the interview responses is the theme of the Sustainability of Road Transport. This theme was identified based on five key codes: telecommunication and information technology, traffic management, operations and delays, accident rates and safety level, and real-time traffic monitoring. Interviewees highlighted that advancements in telecommunication and information technology are pivotal for enhancing the efficiency and connectivity of the Sustainability of Road Transport. Effective traffic management is essential to optimize traffic flow and minimize congestion, thereby improving delivery times. Operations and delays were frequently mentioned as critical factors affecting the reliability and cost-effectiveness of road transport. Additionally, the importance of reducing accident rates and improving safety levels was underscored, as safety concerns can significantly impact the logistics industry. Real-time traffic monitoring emerged as a vital component, enabling more responsive and adaptive management of the Sustainability of Road Transport. Figure 5 provides an intellectual map of the theme of the Sustainability of Road Transport and its associated codes, visually depicting the interconnections and influences among these key factors.

Figure 5: Mind Map of Theme of the Sustainability of Road Transport

Telecommunication and Information Technology: This code refers to the use of advanced telecommunication and IT solutions to support road operations. Interviewees highlighted that robust telecommunication and IT infrastructure enable real-time communication, data sharing, and coordination across the supply chain, enhancing the overall efficiency and reliability of the sustainability of road transport. In interview one, the following evidence indicating this code was explained:

"ITS plays a critical role in modernizing our road transport systems by utilizing advanced telecommunication and information technology".

While interview two provided the following evidence that confirms this code:

"Vehicle-to-Infrastructure (V2I) communication technologies would improve safety and traffic efficiency by facilitating direct communication between vehicles and traffic signals".

In addition to the evidence shown in Interview nine, which states the following:

"I am well-versed in Intelligent Transport Systems (ITS). These systems leverage cutting-edge telecommunication and information technology to improve the overall quality of road transportation, making it safer, more efficient, and more sustainable".

Traffic Management: This code pertains to the strategies and systems used to optimize traffic flow and reduce congestion on road networks. According to interviewees, effective traffic management is essential for minimizing delays and ensuring smooth operations. It includes measures such as traffic signal optimization, route planning, and congestion management, which are crucial for maintaining timely deliveries and reducing transportation costs. In interview one, the following evidence indicating this code was explained:

"We anticipate significant improvements in traffic management, road safety, and the overall user experience."

While interview two provided the following evidence that confirms this code:

"I have kept myself updated on the latest developments in ITS and have been involved in several projects aimed at implementing these technologies in our city's traffic management systems".

In addition to the evidence shown in Interview three, which states the following:

"The implementation of advanced traffic signal control systems has significantly reduced congestion during peak hours, improving overall traffic flow and safety."

Operations and Delays: This code covers the day-to-day activities involved in the sustainability of road transport and the factors that cause delays. Interviewees pointed out that operational efficiency is key to the success of sustainable road transport systems. Delays can be caused by various issues, such as vehicle breakdowns, loading and unloading inefficiencies, and regulatory bottlenecks. Addressing these operational challenges is vital for improving the reliability and cost-effectiveness of road transport services. In interview one, the following evidence indicating this code was explained:

"Another example is the use of automated toll collection systems on major highways, which has streamlined operations and reduced delays for achieving the sustainability of road transportation".

While interview four provided the following evidence that confirms this code:

"And the electronic toll collection on major highways, which has streamlined toll operations and reduced delays for the sustainability of road transportation".

In addition to the evidence shown in Interview ten, which states the following:

"From what I know, they seem to involve some technology for managing transportation, but I'm not entirely clear on the details or how they might directly impact our operations".

Accident Rates and Safety Level: This code refers to the frequency of accidents and the overall safety standards within the Sustainability of Road Transport. Interviewees emphasized that high accident rates and poor safety levels can severely impact the logistics industry by causing delays, increasing costs, and posing risks to drivers and cargo. Enhancing safety measures and reducing accident rates are critical for maintaining a reliable and secure transportation system. In interview two, the following evidence indicating this code was explained:

"Key performance indicators such as reductions in travel time, accident rates, and emissions are used to measure the impact of ITS projects".

While interview five provided the following evidence that confirms this code:

"Implementing ITS can bring numerous benefits, including improved traffic flow, reduced congestion, enhanced safety, and more efficient use of road infrastructure".

In addition to the evidence shown in Interview eight, which states the following:

"We evaluate ITS effectiveness by measuring key performance indicators such as traffic flow improvements, accident reduction rates, and user satisfaction".

Real-Time Traffic Monitoring: This code involves the use of technology to continuously monitor traffic conditions in real-time. Interviewees noted that real-time traffic monitoring allows for dynamic adjustments to routes and schedules based on current traffic conditions, helping to avoid congestion and improve delivery times. It provides valuable insights for better decision-making and more efficient management of road operations. In interview three, the following evidence indicating this code was explained:

"Traffic management systems, real-time traffic monitoring, electronic toll collection, and smart traffic signals are among the most beneficial ITS technologies for our operations."

While interview five provided the following evidence that confirms this code:

"Technologies such as advanced traffic management systems, real-time passenger information systems, and vehicle-to-infrastructure communication would greatly benefit our operations".

In addition to the evidence shown in Interview eleven, which states the following:

"ITS can improve road safety by providing real-time updates and warnings".

The interview results revealed three critical themes: Factors Affecting the Effectiveness and Development of ITS, The Effectiveness and Development of ITS, and the Sustainability of Road Transport. Each theme emerged from specific codes identified through in-depth discussions with interviewees. The first theme highlighted the significance of government policy, financial resources, transport infrastructure, urbanization, and the readiness and integration of ITS in shaping the success of intelligent transportation systems. The second theme underscored the importance of information quality, system quality, service quality, and environmental sustainability in determining the effectiveness and continued development of ITS. The third theme focused on the Sustainability of Road Transport, emphasizing the roles of telecommunication and information technology, traffic management, operations and delays, accident rates, and safety levels, and real-time traffic monitoring in enhancing sustainable road transport operations. These insights collectively provide a comprehensive understanding of the multifaceted factors influencing ITS and the Sustainability of Road Transport, offering valuable guidance for future development and implementation strategies. Figure 6 visually represents the intellectual maps of these themes and their associated codes, illustrating the interconnectedness of the identified factors.

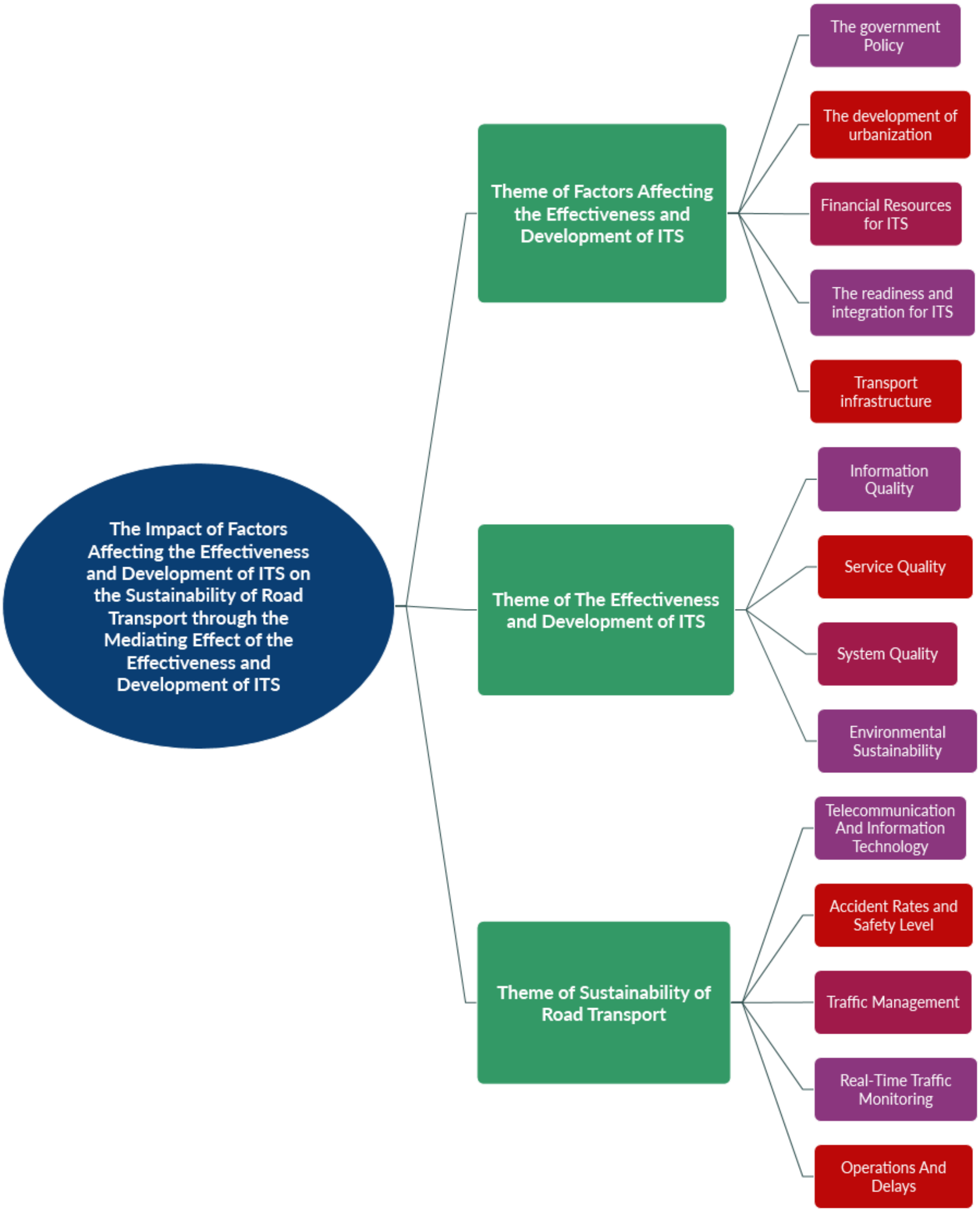
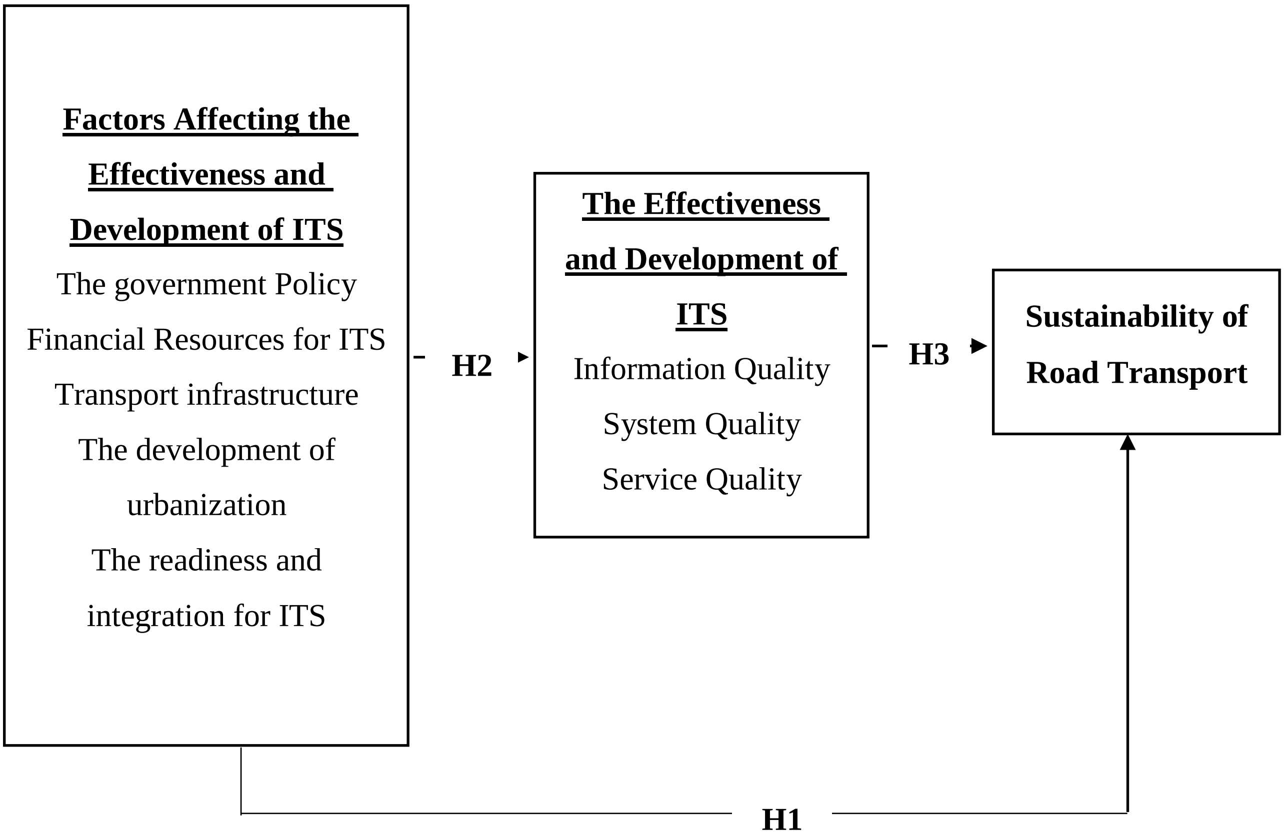


Figure 6: Mind Map of The Research

Therefore, based on the results of the interviews, the research reached a relationship between the research variables based on the main objective of the research. These variables were Factors Affecting the Effectiveness and Development of ITS (The government Policy, Financial Resources for ITS, Transport infrastructure, The development of urbanization, The readiness and integration for ITS) as an independent variable, the Sustainability of Road Transport as a dependent variable, and The Effectiveness and Development of ITS (Information Quality, System Quality and Service Quality) as an intermediary variable. Accordingly, Figure 7 shows the developed practical



framework that will be used in this research.

Figure 7: The Research Framework

4.2.**Quantitative Analysis Results and Findings**

This section undertakes an empirical investigation into understanding the importance of applying Intelligent Transport Systems (ITS) on road transport.

Data Testing using Validity and Reliability

Validity is determined by two essential elements including the Average Variance Extracted (AVE) that measures the typical commonality of each underlying component. To demonstrate adequate validity, the AVE value must exceed 0.5. Additionally, each element's (statement's) factor loading should be 0.4 or higher. For reliability, Cronbach's Alpha is the most commonly used test, assessing each component based on a series of statements that reflect how consistently the instrument measures the variable. A higher Cronbach's Alpha coefficient, ranging from 0 to 1, indicates greater reliability, with values of 0.7 or above suggesting a high level of reliability. As shown in Table (3), after removing statements with factor loadings below 0.4, all values for KMO, AVE, Cronbach's Alpha, and Factor Loadings fall within acceptable ranges.

- Regarding the variable of the government policy (GP), the factor loading of all the statements showed acceptable factor loading ranging from .662 to.636.
- Regarding the variable of financial resources for ITS (FRITS), the factor loading of all the statements showed acceptable factor loading ranging from .737 to .525.
- Regarding the variable of Transport infrastructure (TI), the factor loading of all the statements showed acceptable factor loading ranging from .439 to .628.
- Regarding the variable of the development of urbanization (DU), the factor loading of all the statements showed acceptable factor loading ranging from .729 to .807.
- Regarding the variable of the readiness and integration for ITS (RIITS), the factor loading of the statements showed an acceptable factor loading .784. However, the statement (RIITS1) needed to be deleted due to the low value of factor loading (<0.4).
- Regarding the variable of Information Quality (IQ), the factor loading of all the statements showed acceptable factor loading ranging from .679 to .729.
- Regarding the variable of System Quality (SYSQ), the factor loading of all the statements showed acceptable factor loading ranging from .765 to .638.

- Regarding the variable of sustainability of road transport (SRT), the factor loading of all the statements showed acceptable factor loading ranging from .567 to .629.

Table 3: Validity and Reliability Test

Variables	Statements	Factor Loading	AVE %	KMO	Cronbach's Alpha
The government policy	GP1	.662	67.089	.686	.750
	GP2	.715			
	GP3	.636			
Financial resources for ITS	FRITS1	.658	67.677	.789	.813
	FRITS2	.737			
	FRITS3	.525			
	FRITS4	.667			
Transport infrastructure	TI1	.439	56.407	.721	.741
	TI2	.611			
	TI3	.578			
	TI4	.628			
The development of urbanization	DU1	.729	77.055	.722	.848
	DU2	.807			
	DU3	.777			
The readiness and integration for ITS	RIITS2	.784	78.410	.500	.721
	RIITS3	.784			

Information Quality	IQ1	.679	71.158	.707	.797
	IQ2	.729			
	IQ3	.726			
System Quality	SYSQ1	.706	70.296	.686	.788
	SYSQ2	.765			
	SYSQ3	.638			
sustainability of road transport	SRT1	.626	61.122	.763	.788
	SRT2	.567			
	SRT3	.622			
	SRT4	.629			

Measurement Model using the Confirmatory Factor Analysis

Confirmatory Factor Analysis (CFA) is an essential first step in validating the researcher-defined factor structure for each dimension, serving as a measurement scale. This crucial process is conducted before applying structural equation modeling (SEM) and was carried out using AMOS 24 software. The analysis employed the Maximum Likelihood (ML) estimation method to determine factor loadings and evaluate the overall model fit. In summary, the fit indices collectively indicate that the measurement model aligns well with the observed data, exhibiting a strong overall fit, statistical significance, and an accurate representation of the covariance structure. Table (4) in this study offers a comprehensive analysis of these findings.

Table 4: Fit Indices and Thresholds for Final Measurement Model

Measure	Results	Threshold
Chi-square/df	3.274	< 2 excellent; < 3 good; < 5 sometimes permissible

Measure	Results	Threshold
GFI	.921	> 0.80
AGFI	.889	> 0.80
CFI	.933	> 0.80
RMSEA	.061	< 0.10

The Confirmatory Factor Analysis showed that GFI was calculated to be .921, CMIN/DF, was found to be 3.274, AGFI was .889, CFI of Bentler-Bonett was .933, RMSEA was .061. Moreover, Figure (8) represents the implementation of confirmatory factor analysis, where factor loadings are visually represented by arrows. These arrows denote robust factor loadings, as evidenced by values surpassing 0.4.

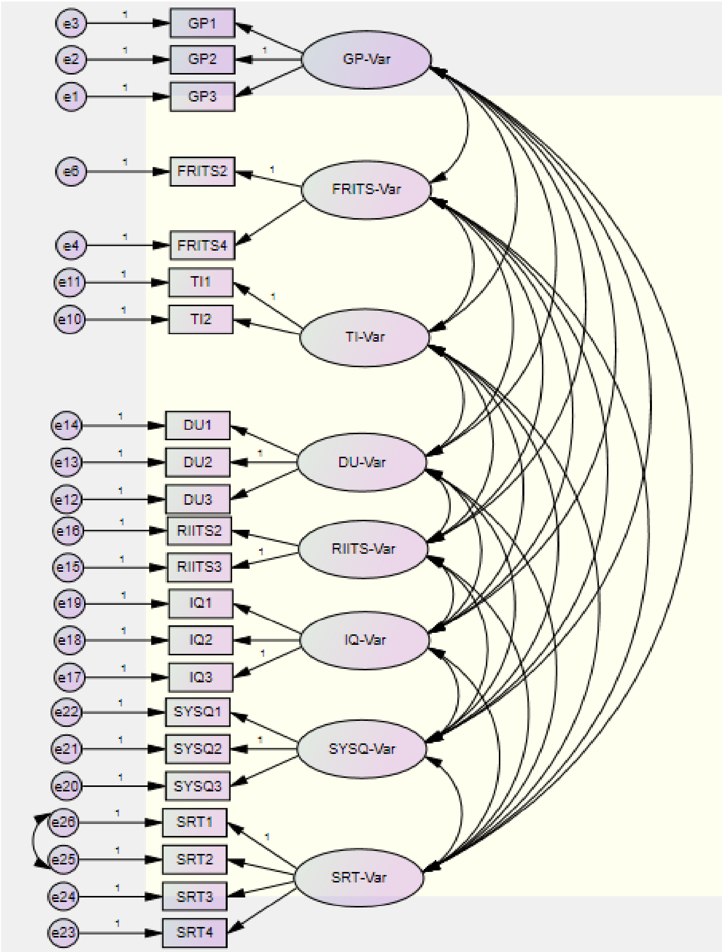


Figure 8: CFA for the Measurement Model

Descriptive Analysis

The respondent profile detailed in the table provides a comprehensive snapshot of the demographic and experiential attributes of the 622 participants in the study. The majority of respondents are male, comprising 79.6% of the sample, while females represent 20.4%. In terms of age distribution, the largest proportion of respondents falls within the 30 to less than 40 years category, accounting for 37.9%. This is followed by those aged 20 to less than 30 years, who make up 25.9% of the sample. Respondents aged 40 to less than 50 years constitute 22.8%, and those over 50 years represent 13.3%. Regarding educational qualifications, the majority of respondents hold a Bachelor's degree, representing 62.4% of the sample.

Those with a Master's degree account for 22.0%, while 10.8% hold a PhD. Additionally, 4.8% of respondents have other forms of education. The data on driving experience reveals that a significant portion of respondents (31.8%) have between 5 and 10 years of driving experience. This is closely followed by those with 10 to 15 years of experience, who make up 30.9% of the sample. Respondents with 1 to 5 years of experience constitute 13.5%, while those with more than 20 years of driving experience represent 13.3% of the sample. Additionally, 10.5% of respondents have 15 to 20 years of driving experience.

Table 5: Respondent profile

	Frequency	Percent	Total
Gender			
Male	495	79.6	622
Female	127	20.4	
Age			
20 – less than 30	161	25.9	622
30 – less than 40	236	37.9	
40 – less than 50	142	22.8	
More than 50	83	13.3	
Level of Education			
Bachelor Degree	388	62.4	622
Master Degree	137	22.0	
PhD	67	10.8	
Other	30	4.8	
Years of Experience in Driving			
1-5 years	84	13.5	622
5-10 years	198	31.8	
10-15 years	192	30.9	
15-20 years	65	10.5	
More than 20 Years	83	13.3	

The following table presents the descriptive analysis of the research variables, including the minimum and maximum values, as well as the mean and standard deviation:

- **Government Policy (GP):** The mean value of GP is 2.0161, with a standard deviation of 0.86238. Values range from a minimum of 1.00 to a maximum of 5.00.

- **Financial Resources for ITS (FRITS):** The mean value of FRITS is 4.0916, with a standard deviation of 0.78202. Values range from 2.00 to 5.00.
- **Transport Infrastructure (TI):** The mean value of TI is 4.0514, with a standard deviation of 0.81487. Scores range from 1.00 to 5.00.
- **Development of Urbanization (DU):** The mean value of DU is 3.8762, with a standard deviation of 0.89862. Values range from 2.00 to 5.00.
- **Readiness and Integration for ITS (RIITS):** The mean value of RIITS is 3.9325, with a standard deviation of 0.92136. Values range from 1.00 to 5.00.
- **Information Quality (IQ):** The mean value of IQ is 4.1527, with a standard deviation of 0.78890. Values range from 2.00 to 5.00.
- **System Quality (SYSQ):** The mean value of SYSQ is 4.1656, with a standard deviation of 0.78013. Values range from 2.00 to 5.00.
- **Sustainability of Road Transport (SRT):** The mean value of SRT is 3.9952, with a standard deviation of 1.07750. Values range from 2.00 to 5.00.

Table 6: Descriptive Analysis for the Research Variables

	GP	FRITS	TI	DU	RIITS	IQ	SYSQ	SRT
Mean	2.0161	4.0916	4.0514	3.8762	3.9325	4.1527	4.1656	3.9952
Std. Deviation	.86238	.78202	.81487	.89862	.92136	.78890	.78013	1.07750
Minimum	1.00	2.00	1.00	2.00	1.00	2.00	2.00	1.00
Maximum	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00

Normality Testing for the Research Variables

The following table presents the results of normality testing for the research variables using skewness and kurtosis. An acceptable range for normalcy typically falls between -1 and 1 for both skewness and kurtosis. However, some variables exceed this range, indicating deviations from a perfectly normal distribution.

- **Skewness**: The skewness values range from -0.827 (for SRT) to 1.178 (for GP). The skewness for GP exceeds the acceptable range, indicating a positive skewness. This suggests that the distribution of GP has a longer tail on the right side.

- **Kurtosis**: The kurtosis values range from -0.594 (for DU) to 1.851 (for GP). The kurtosis for GP is notably above 1, signifying that its distribution is more peaked than that of a normal distribution.

The results indicate that although certain variables, such as GP, deviate from a normal distribution, the data remains reliable and appropriate for further analysis. Given that the skewness and kurtosis values are within or close to the acceptable range, the data can be effectively analyzed using non-parametric methods like Spearman correlation for a more precise interpretation.

Table 7: Normality Testing

	GP	FRITS	TI	DU	RIITS	IQ	SYSQ	SRT
Skewness	1.178	-.567	-.525	-.422	-.510	-.731	-.747	-.827
Std. Error of Skewness	.098	.098	.098	.098	.098	.098	.098	.098
Kurtosis	1.851	-.113	-.140	-.594	-.377	.169	.242	-.104
Std. Error of Kurtosis	.196	.196	.196	.196	.196	.196	.196	.196

Testing Multicollinearity Assumption

This section addresses the multicollinearity assumption among the independent variables, which is essential for ensuring model accuracy. Multicollinearity arises when predictors are highly correlated, potentially distorting model results. To assess this, the Variance Inflation Factor (VIF) values for the research variables were examined. The VIF values for all variables are well below the threshold of 5, ranging from 1.287 to 2.021. These low VIF values indicate minimal correlation among the variables, thereby meeting the multicollinearity assumption and ensuring the stability and reliability of the regression model.

Table 8: VIF values for Research Variables

Independent Variables	**VIF**

GP	1.287
FRITS	1.325
TI	1.462
DU	1.910
RIITS	1.846
IQ	1.923
SYSQ	2.021

Testing the Research Hypotheses

This section addresses the empirical analysis of the variables under study, this section includes the correlation analysis and path analysis within the structural equation modeling (SEM) framework.

Correlation Analysis

In this section, correlation analyses are employed to assess the study's hypotheses. Given that the data are not normally distributed, the Spearman correlation method is applied. The findings are as follows:

Government Policy (GP): This shows a significant positive correlation with Financial Resources for ITS (FRITS), with a moderate positive correlation ($r = 0.437$, $p < 0.01$). It also exhibits significant negative correlations with Transport Infrastructure (TI): A small negative correlation ($r = -0.217$, $p < 0.01$), Development of Urbanization (DU): A small negative correlation ($r = -0.201$, $p < 0.01$), and Readiness and Integration for ITS (RIITS): A small negative correlation ($r = -0.209$, $p < 0.01$), Information Quality (IQ): A very weak negative correlation ($r = -0.112$, $p < 0.05$), System Quality (SYSQ): A very weak negative correlation ($r = -0.116$, $p < 0.05$), Sustainability of Road Transport (SRT): A small negative correlation ($r = -0.202$, $p < 0.01$).

Financial Resources for ITS (FRITS): This shows a significant positive correlation with Transport Infrastructure (TI) ($r = 0.457$, $p < 0.01$), Development of Urbanization (DU) ($r = 0.672$, $p < 0.01$), Readiness and Integration for ITS (RIITS) ($r = 0.605$, $p < 0.01$), Information Quality (IQ) (r

= 0.579, p < 0.01), System Quality (SYSQ) (r = 0.625, p < 0.01). It also exhibits no significant correlation with Sustainability of Road Transport (SRT) (r = -0.051, p > 0.05).

Transport Infrastructure (TI): This shows a significant positive correlation with Development of Urbanization (DU) (r = 0.422, p < 0.01), Readiness and Integration for ITS (RIITS) (r = 0.428, p < 0.01), Information Quality (IQ) (r = 0.361, p < 0.01), System Quality (SYSQ) (r = 0.455, p < 0.01). It also exhibits no significant correlation with the Sustainability of Road Transport (SRT) (r = -0.081, p < 0.05).

Development of Urbanization (DU): This shows a significant positive correlation with Readiness and Integration for ITS (RIITS) (r = 0.571, p < 0.01), Information Quality (IQ) (r = 0.525, p < 0.01), System Quality (SYSQ) (r = 0.501, p < 0.01). It also exhibits no significant correlation with the Sustainability of Road Transport (SRT) (r = -0.019, p > 0.05).

Readiness and Integration for ITS (RIITS): This shows a significant positive correlation with Information Quality (IQ) (r = 0.498, p < 0.01), and System Quality (SYSQ) (r = 0.520, p < 0.01). it also exhibits no significant correlation with the Sustainability of Road Transport (SRT) (r = -0.055, p > 0.05).

Information Quality (IQ): This shows a significant positive correlation with System Quality (SYSQ) (r = 0.602, p < 0.01). It also exhibits no significant correlation with the Sustainability of Road Transport (SRT) (r = -0.079, p < 0.05).

System Quality (SYSQ): Exhibits no significant correlation with Sustainability of Road Transport (SRT) (r = -0.015, p > 0.05).

Table 9: Correlation Matrix for the Research Variables

		1	2	3	4	5	6	7	8
1.GP	r	1.000							
	Sig.	.							
	N	622							
2.FRITS	r	-.202**	1.000						
	Sig.	.000	.						
	N	622	622						
3.TI	r	-.266**	.457**	1.000					

	Sig.	.000	.000	.					
	N	622	622	622					
4.DU	r	-.230**	.672**	.422**	1.000				
	Sig.	.000	.000	.000	.				
	N	622	622	622	622				
5.RIITS	r	-.233**	.605**	.428**	.571**	1.000			
	Sig.	.000	.000	.000	.000	.			
	N	622	622	622	622	622			
6.IQ	r	-.129**	.579**	.361**	.525**	.498**	1.000		
	Sig.	.001	.000	.000	.000	.000	.		
	N	622	622	622	622	622	622		
7.SYSQ	r	-.153**	.625**	.455**	.501**	.520**	.602**	1.000	
	Sig.	.000	.000	.000	.000	.000	.000	.	
	N	622	622	622	622	622	622	622	
8.SRT	r	-.014	-.051	-.081*	-.019	-.055	-.079*	-.015	1.000
	Sig.	.725	.205	.043	.637	.172	.050	.706	.
	N	622	622	622	622	622	622	622	622

Structural Equation Modeling (SEM) Analysis

Structural Equation Modeling (SEM) was utilized to evaluate the effects of various research variables. SEM was chosen for its impartiality and its independence from assumptions about data normality. The outcomes of the SEM analysis, which investigates the relationships between the studied variables, are shown in the following table:

Table 10: SEM Analysis for the Research Variables

			Estimate	S.E.	C.R.	P	Label
IQ-Var	<---	GP-Var	.164	.039	4.205	***	
SYSQ-Var	<---	GP-Var	.129	.046	2.808	.005	
IQ-Var	<---	FRITS-Var	.688	.093	7.382	***	
SYSQ-Var	<---	FRITS-Var	1.204	.143	8.412	***	
IQ-Var	<---	TI-Var	.501	.109	4.596	***	
SYSQ-Var	<---	TI-Var	.423	.117	3.607	***	

			Estimate	S.E.	C.R.	P	Label
IQ-Var	<---	DU-Var	.052	.064	.820	.412	
SYSQ-Var	<---	DU-Var	-.327	.085	-3.864	***	
IQ-Var	<---	RIITS-Var	-.089	.099	-.898	.369	
SYSQ-Var	<---	RIITS-Var	-.226	.128	-1.757	.079	
SRT-Var	<---	GP-Var	-5.275	311.294	-.017	.986	
SRT-Var	<---	FRITS-Var	-49.550	2914.791	-.017	.986	
SRT-Var	<---	TI-Var	-17.472	1022.634	-.017	.986	
SRT-Var	<---	DU-Var	13.593	792.105	.017	.986	
SRT-Var	<---	RIITS-Var	9.219	547.361	.017	.987	
SRT-Var	<---	IQ-Var	-.305	.376	-.811	.418	
SRT-Var	<---	SYSQ-Var	41.372	2418.551	.017	.986	

Regarding the first Hypothesis: *"H_1: There is a significant relationship between Factors Affecting the Effectiveness and Development of ITS dimensions and sustainability of road transport."*

- H1-1: There is a significant relationship between government policy and sustainability of road transport. The result indicates no significant relationship between GP and SRT, with a p-value of 0.986, suggesting an insignificant effect.
- H1-2: There is a significant relationship between Financial Resources for ITS and sustainability of road transport. The result shows no significant relationship between FRITS and SRT, as indicated by the p-value of 0.986, indicating an insignificant effect.
- H1-3: There is a significant relationship between Transport infrastructure and sustainability of road transport. The result suggests no significant relationship between TI and SRT, with a p-value of 0.986, indicating an insignificant effect.
- H1-4: There is a significant relationship between the development of urbanization and sustainability of road transport. The result indicates no significant relationship between DU and SRT, as evidenced by the p-value of 0.986, suggesting an insignificant effect.

- H1-5: There is a significant relationship between the readiness and integration for ITS and sustainability of road transport. The result shows no significant relationship between RIITS and SRT, with a p-value of 0.987, indicating an insignificant effect.

Regarding the second hypothesis: ***"H2: There is a significant relationship between Factors Affecting the Effectiveness and Development of ITS dimensions and The Effectiveness and Development of ITS."***

- H2.1: There is a significant relationship between the government Policy and Information Quality. The result indicates a significant positive relationship between GP and IQ, with a p-value less than 0.01, suggesting a strong effect.
- H2.2: There is a significant relationship between the government Policy and Service Quality. The result indicates a significant positive relationship between GP and SYSQ, with a p-value of 0.005, suggesting a moderate effect.
- H2.3: There is a significant relationship between Financial Resources for ITS and Information Quality. The result indicates a significant positive relationship between FRITS and IQ, with a p-value less than 0.01, suggesting a strong effect.
- H2.4: There is a significant relationship between Financial Resources for ITS and Service Quality. The result indicates a significant positive relationship between FRITS and SYSQ, with a p-value less than 0.01, suggesting a strong effect.
- H2.5: There is a significant relationship between Transport infrastructure and Information Quality. The result indicates a significant positive relationship between TI and IQ, with a p-value less than 0.01, suggesting a strong effect.
- H2.6: There is a significant relationship between Transport infrastructure and Service Quality. The result indicates a significant positive relationship between TI and SYSQ, with a p-value less than 0.01, suggesting a moderate effect.
- H2.7: There is a significant relationship between the development of urbanization and Information Quality. The result shows no significant relationship between DU and IQ, with a p-value of 0.412, indicating an insignificant effect.

- H2.8: There is a significant relationship between the development of urbanization and Service Quality. The result indicates a significant negative relationship between DU and SYSQ, with a p-value less than 0.01, suggesting a strong effect.
- H2.9: There is a significant relationship between the readiness and integration for ITS and Information Quality. The result shows no significant relationship between RIITS and IQ, with a p-value of 0.369, indicating an insignificant effect.
- H2.10: There is a significant relationship between the readiness and integration for ITS and Service Quality. The result indicates a marginally significant negative relationship between RIITS and SYSQ, with a p-value of 0.079, suggesting a borderline effect.

Regarding the third hypothesis: *"H_3: There is a significant relationship between the Effectiveness and Development of ITS and sustainability of road transport."*

- H3.1: There is a significant relationship between Effectiveness and Development of ITS and Information Quality. The result shows no significant relationship between IQ and SRT, with a p-value of 0.418, indicating an insignificant effect.
- H3.2: There is a significant relationship between Effectiveness and Development of ITS and Service Quality. The result indicates no significant relationship between SYSQ and SRT, with a p-value of 0.986, suggesting an insignificant effect.

Table 11: Fit Indices and Thresholds for Final Measurement Model

Measure	Results	Threshold
Chi-square/df	3.014	< 2 excellent; < 3 good; < 5 sometimes permissible
GFI	.935	> 0.80
AGFI	.904	> 0.80
CFI	.945	> 0.80
RMSEA	.057	< 0.10

The Confirmatory Factor Analysis showed that GFI was calculated to be .935, CMIN/DF, was found to be 3.014, AGFI was .904, CFI of Bentler-Bonett was .945, RMSEA was .057. Figure (9) represents the SEM model that was employed to analyze the impact of the research model. The research variables considered are as follows:

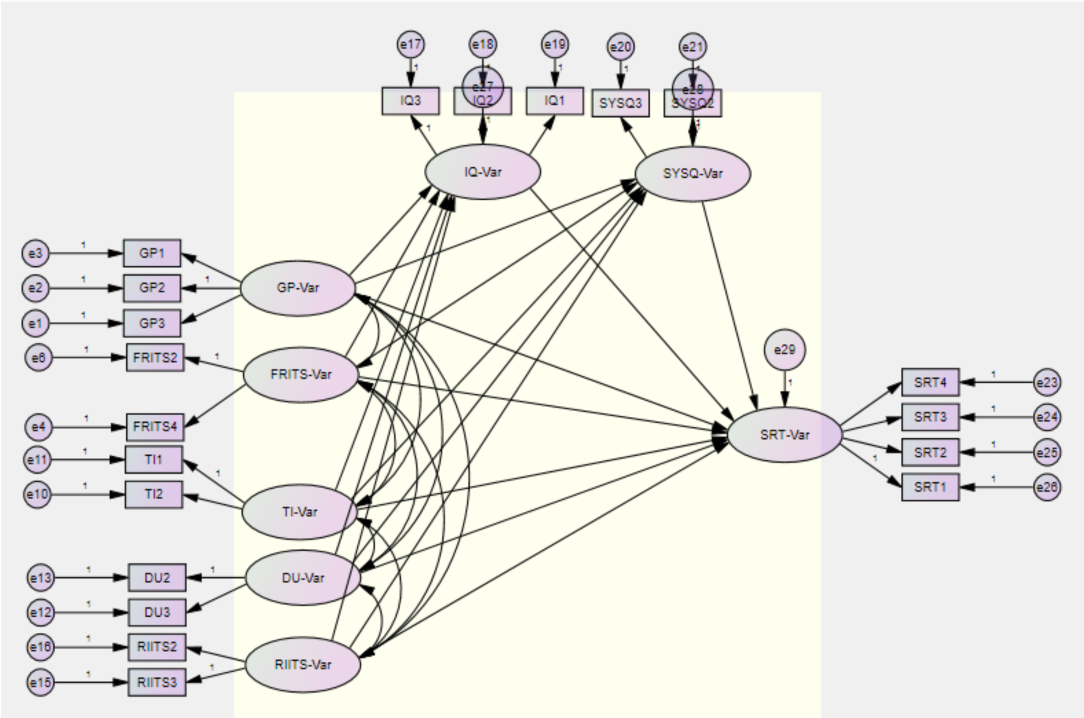


Figure 9: SEM for the Research Variables

5. Research Discussion

The empirical study investigated the role of Intelligent Transportation Systems (ITS) in enhancing the sustainability of land transportation in Egypt, focusing on the implementation challenges and benefits as mediation variables. Adopting a positivist philosophy and deductive approach, the study employed a mixed-methods design that integrated both qualitative and quantitative data collection. First of all, qualitative insights were obtained through 15 semi-structured interviews with road stakeholders. The gathered data were analyzed using the NVivo program. The results of the empirical analysis of the semi-structured interviews reached a relationship between the research variables based on the main objective of the research. These variables were Factors Affecting the Effectiveness and Development of ITS (The government Policy, Financial Resources for ITS, Transport infrastructure, The development of urbanization, The readiness and integration for ITS) as an independent variable, the Sustainability of Road Transport as a dependent variable, and The Effectiveness and Development of ITS (Information Quality, System Quality and Service Quality) as an intermediary variable. Accordingly, the researcher could develop the framework of the current research through the results of the qualitative analysis.

In the next step, the study conducted a quantitative analysis by gathering the data via a five-point Likert scale survey of road users. The collected data were analyzed through descriptive and correlation analysis using programs such as SPSS and Amos. Three main hypotheses were analyzed, and the results of this testing were shown as follows:

H_1: "There is a significant relationship between Factors Affecting the Effectiveness and Development of ITS dimensions and sustainability of road transport"

The first main hypothesis is divided into five sub-hypotheses. By examining the first sub-hypothesis of the first hypothesis **"There is a significant relationship between the government Policy and sustainability of road transport"**, it was observed that the relationship between the variables is insignificant. Regarding the second sub-hypothesis of the first hypothesis **"There is a significant relationship between Financial Resources for ITS and sustainability of road transport"**, the results indicated that there is no significant relationship between the variables. Similarly, by examining the third sub-hypothesis of the first hypothesis **"There is a significant relationship between Transport infrastructure and sustainability of road transport. The result suggests no significant relationship between TI and SRT"**, it was demonstrated that there is no significant relationship between TI and SRT. The same result appeared when investigating the fourth sub-hypothesis of the first hypothesis **"There is a significant relationship between the development of urbanization and sustainability of road transport"**, as the findings revealed that there is no significant relationship between DU and SRT. As for the fifth sub-hypothesis of the first hypothesis **"There is a significant relationship between the readiness and integration for ITS and sustainability of road transport"**, the result shows no significant relationship between RIITS and SRT.

According to the aforementioned results, it can be indicated that the first main hypothesis **"There is a significant relationship between Factors Affecting the Effectiveness and Development of ITS dimensions and sustainability of road transport."** is not supported.

H_2: "There is a significant relationship between Factors Affecting the Effectiveness and Development of ITS dimensions and The Effectiveness and Development of ITS"

Regarding the second hypothesis, it was also divided into ten sub-hypotheses. By investigating the first sub-hypothesis of the second hypothesis **"There is a significant relationship between the government Policy and Information Quality"**, the second sub-hypothesis of the second hypothesis **"There is a significant relationship between the government Policy and Service Quality"**, the third sub-hypothesis of the second hypothesis **"There is a significant relationship between Financial Resources for ITS and Information Quality"**, the fourth sub-hypothesis of the second hypothesis **"There is a significant relationship between Financial Resources for ITS and Service Quality"**, the fifth sub-hypothesis of the second hypothesis **"There is a significant relationship between Transport infrastructure and Information Quality"**, and the sixth sub-hypothesis of the second hypothesis **"There is a significant relationship between Transport infrastructure and Service Quality"**, it was demonstrated that all these hypotheses have a significant positive relationship.

However, by testing the seventh sub-hypothesis of the second hypothesis **"There is a significant relationship between the development of urbanization and Information Quality"**, it was observed that there is no significant relationship between DU and IQ. Conversely, the results clarified that the eighth sub-hypothesis of the second hypothesis **"There is a significant relationship between the development of urbanization and Service Quality"** is a significant but negative correlation. Otherwise, by examining the ninth sub-hypothesis of the second hypothesis **"There is a significant relationship between the readiness and integration for ITS and Information Quality"**, it was demonstrated that there is no significant relationship between RIITS and IQ. Additionally, the findings revealed that the tenth sub-hypothesis of the second hypothesis **"There is a significant relationship between the readiness and integration for ITS and Service Quality"** is not significant.

Therefore, the second main hypothesis of the current research **"There is a significant relationship between Factors Affecting the Effectiveness and Development of ITS dimensions and The Effectiveness and Development of ITS"** is partially supported.

H_3: "There is a significant relationship between the Effectiveness and Development of ITS and sustainability of road transport"

Furthermore, the third main hypothesis of the study contains two sub-hypotheses. By examining the first sub-hypothesis of the third hypothesis

"There is a significant relationship between Effectiveness and Development of ITS and Information Quality", it was revealed that there is no significant relationship between IQ and SRT. As for the second sub-hypothesis of the third hypothesis "There is a significant relationship between Effectiveness and Development of ITS and Service Quality", it was demonstrated that there is no significant relationship between SYSQ and SRT

Accordingly, the third main hypothesis of the study **"There is a significant relationship between the Effectiveness and Development of ITS and sustainability of road transport"** is not supported.

6. **Research Recommendations**

The findings of this study have provided valuable insights into the impact of factors affecting the effectiveness and development of ITS on the sustainability of road transport through the mediating effect of the effectiveness and development of ITS. Based on these findings, it is imperative to offer a set of recommendations designed to guide stakeholders, practitioners, and researchers in implementing more sustainable transportation solutions, improving infrastructure, and ensuring the long-term success of ITS initiatives. Recommendations for stakeholders can be summarized in the following:

1. Stakeholders are encouraged to foster stronger partnerships between government agencies, private sector companies, and research institutions to ensure the successful development and implementation of ITS. Collaborative efforts can lead to more coordinated planning, resource sharing, and innovation in transportation solutions.
2. The Ministry of Transport in Egypt should consider implementing incentives for the adoption of electric vehicles and promoting public transportation as a viable alternative to private car usage.
3. It is also important to prioritize investment in the necessary infrastructure to support ITS, such as advanced traffic management systems, smart sensors, and communication networks. Upgrading existing road networks with intelligent technologies can significantly improve traffic flow, reduce congestion, and enhance overall transportation sustainability.

4. The ministry should enhance Infrastructure Investments to support the integration of intelligent transportation systems, such as dedicated lanes for buses and improved traffic signal coordination. By prioritizing infrastructure investments, the Ministry can create a more sustainable and efficient transportation network for the country.
5. Stakeholders are advised to launch awareness campaigns and educational programs to inform the public about the benefits of ITS and how they can contribute to sustainable transportation. Increased public understanding and acceptance of ITS can lead to better compliance with new systems and more widespread adoption of sustainable practices.
6. The Ministry of Transport in Egypt should evaluate the impact of government policies on road transport sustainability, invest in infrastructure improvements to support sustainable transportation practices, and collaborate with stakeholders to develop and implement strategies for reducing carbon emissions from vehicles.
7. It is also recommended to establish clear policies and regulations that support the implementation of ITS, including incentives for adopting smart technologies and penalties for non-compliance. Regulatory frameworks should be designed to facilitate the integration of ITS with existing transportation systems while ensuring the protection of public safety and the environment.
8. The ministry should assess the Allocation of Financial Resources for ITS to ensure that adequate funding is allocated towards the development and maintenance of intelligent transportation systems. This will help optimize traffic flow, reduce congestion, and improve overall transportation efficiency in the long run.
9. reate platforms for regular engagement with stakeholders, including road users, local communities, and industry experts. Solicit feedback on ITS initiatives and incorporate their input into the ongoing development and refinement of transportation strategies.
10. Urbanization Development's Role should be addressed in the need for improved transportation systems, as urban areas continue to grow and face increased congestion. By investing in intelligent transportation systems, cities can better manage traffic flow and provide more sustainable transportation options for residents.

11. Implement continuous monitoring and evaluation processes to assess the effectiveness of ITS initiatives. Use data-driven insights to make informed decisions, adjust strategies as needed, and ensure that ITS systems are meeting sustainability goals.

However, there are several recommendations for the users of road transport, and these recommendations are as follows:

1. Road users should embrace and effectively utilize ITS technologies, such as real-time traffic information systems, to optimize travel routes, reduce congestion, and minimize fuel consumption.

2. Road users are encouraged to adopt eco-friendly driving habits, such as maintaining steady speeds, avoiding unnecessary idling, and reducing the use of air conditioning, to lower emissions and contribute to a greener environment.

3. possible, road users should support and use public transportation options that are integrated with ITS. This reduces individual vehicle use, alleviates traffic congestion, and lowers overall emissions.

4. Road users should engage in and support sustainable transport initiatives, such as carpooling, cycling, or walking, which not only reduce environmental impact but also promote healthier lifestyles.

5. Road users should stay informed about new ITS developments and sustainability practices. By understanding the benefits and functionalities of ITS, users can make more informed decisions that contribute to the overall sustainability of road transport systems.

On the other hand, this research offers several recommendations for future researchers to build upon and further explore the findings. Researchers are encouraged to expand research variables to include factors such as population density, traffic patterns, and economic development to gain a comprehensive understanding of the impact of urbanization on transportation systems. This will help identify key areas for improvement and inform strategic planning for future infrastructure projects. Moreover, researchers should explore potential interaction effects between different factors affecting road transport sustainability and ITS effectiveness to understand how they may jointly influence outcomes. Moreover, it is important to consider the long-term implications of urbanization on transportation systems, including potential environmental and social impacts. By taking a holistic approach to studying these factors, researchers can provide valuable insights for policymakers and urban planners to create sustainable and efficient transportation systems for growing cities.

7. Research Limitations and Suggestions for Future Research

After addressing the study's findings, there were several research limitations. These limitations will be discussed in this section along with some recommendations for future studies to stay clear of them. First, is the spatial limit. Because this research was completed in a brief amount of time, the research sample size was relatively small. This is because using a larger research sample would have increased the reliability of the results and produced results that differed from those of the study. To investigate the association between the factors in greater detail, the research suggests that future researchers undertake research over a longer period and with a bigger sample size. Moreover, the current study offers a suggestion for future studies to focus on additional factors affecting the effectiveness and development of ITS in order to gain a more comprehensive understanding of its impact. By expanding the scope of research to include various variables, future studies can provide a more nuanced analysis of the factors influencing the effectiveness of ITS.

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