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Do Technologies Influence Indirect the Sustainable Urban Transport in Developing Countries? A Mediating Roles of Infrastructure, Vehicles, and Operations in Tanzania

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ABSTRACT

Increasing mobility demand and rapid urbanization in developing countries have intensified environmental degradation, congestion, traffic inefficiencies, and unsustainable transport practices. Although technological innovations such as digital platforms. intelligent transport systems, and smart mobility solutions are encouraged as remedies, empirical evidence clearing up how these technologies translate into sustainable urban transport outcomes remains limited. In specific, inadequate attention has been given to the mediating role of transport systems (infrastructure, vehicles, and operations) in linking technology adoption to sustainability of urban transport. This study therefore examined the influence of technology on sustainable urban transport, emphasizing infrastructure, vehicles, and operations as mediating constructs. The study adopted positivism research paradigm and an explanatory research design to test hypothesized causal relationships. A stratified sampling technique was employed to obtain a sample of 300 respondents drawn from key urban transport stakeholders. Data were collected through documentary review and structured questionnaires to enhance contextual reliability and validity. Descriptive statistics data were computed using IBM SPSS Statistics Version 26 to analyze respondents' demographic characteristics while Partial Least Squares Structural Equation Modeling (PLS-SEM) with SmartPLS 4 was used to assess both measurement and structural models in inferential data analysis. The results show that technology adoption significantly influences indirectly sustainable urban transport. Furthermore, transport systems particularly infrastructure modernization partially mediates this relationship, strengthening sustainability outcomes. The study reveals new insights to the existing body of knowledge by providing empirical evidence that technology alone is insufficient; its influence on sustainable urban transport depends on the effectiveness of transport system integration. The findings offer managerial and policy implications for urban transport authorities and planners seeking to promote sustainable urban transport in developing countries, Tanzania in particular.

Keywords: Technologies, Infrastructure, Vehicles, Operations, Sustainable Urban Transport

1.0 INTRODUCTION

1.1 Problem Setting

Urban transportation and urban sustainability are significant issues in contemporary society and major cities worldwide and are striving to enhance their sustainability (Elassy et al., 2024; Przybyłowski et al., 2024; Monteiro et al., 2024; Ngossaha et al., 2024; Alam, 2024; Merkert & Nelson, 2024; Huang, 2024; Abdelhady, 2024; Majumdar, 2020). Over time, as the population grows, there is an increased demand for public transportation, leading to a rise in the number of automobile vehicles in cities worldwide (Majumdar, 2020). The sustainability of urban transportation is crucial for attaining targeted urban outcomes that have economic, social, and accessibility implications (Ali, 2021). Urban areas have several challenges that impede the implementation of sustainable and intelligent transportation systems, affecting daily mobility (Zhang et al., 2015; Ali, 2021; Johnson & Nica, 2021; Golinska-Dawson & Sethanan, 2023; Adom-Asamoah et al., 2021).

Recent literature highlights the transformative role of technology in urban transport sustainability (Son et al., 2025; Yusuf et al., 2025; Sikdar, 2025; Shamsuddoha et al., 2025; Pandipati, 2025; İnce, 2025; Liyanage & Dia, 2025; Buics et al., 2025). Intelligent Transport Systems (ITS), digital ticketing, smart traffic management, mobile ride-hailing platforms, and data-driven governance tools enhance operational efficiency and reduce environmental impacts (Nyazabe et al., 2025; Oyebamiji et al., 2025). In Dar es Salaam, mobile phone technologies have reshaped decentralized transport modes such as motorcycle taxis, improving coordination and responsiveness (Nkonoki & Hamza, 2025). Importantly, transport systems act as mediating mechanisms between technological adoption, governance reform, and sustainable urban outcomes. Rather than exerting direct effects, sustainability improvements often occur through mediators such as: service efficiency, accessibility enhancement, congestion reduction, institutional restructuring, hybrid integration of formal and informal transport modes. For example, passenger satisfaction in Tanzania is influenced by operational efficiency, which mediates the relationship between infrastructure investment and user acceptance (Shatta & Myamba, 2024). Similarly, transport infrastructure contributes to inclusive growth through its mediating effect on accessibility and economic participation (Ouni et al., 2025).

Technologies are essential in influencing sustainable urban transport by facilitating inventive solutions, improving effectiveness, and mitigating environmental consequences (Ali, 2021; Buldeo Rai et al., 2017; Majumdar, 2020; Simões & Suen, 2023; Nicolas, 2000). Similarly, technologies play a significant role in sustainable urban transport by facilitating data-driven decision-making, streamlining operations, enhancing efficiency, and promoting the shift towards more sustainable and intelligent urban transportation solutions (Zhang et al., 2015; Ali, 2021). Adopting technology advancements is crucial for developing urban transportation systems that are more environmentally friendly, efficient, and adaptable to the changing demands of urban populations, while also reducing negative effects on the environment (Johnson & Nica, 2021; Golinska-Dawson & Sethanan, 2023).

In addition, transportation systems have a significant impact on the sustainability of urban environments by influencing aspects such as air pollution, traffic congestion, energy consumption, and general quality of life (Ali, 2021; Buldeo Rai et al., 2017; Majumdar, 2020; Simões & Suen, 2023; Nicolas, 2000). Above all, transportation systems have a significant effect on sustainable urban mobility by influencing the movement of people within cities, affecting the environment, economics, and general quality of life (Adom-Asamoah et al., 2021;

Nicolas, 2000; Zhang et al., 2015; Gnap et al., 2020; Pencheva et al., 2020). Cities may strive for more sustainable urban mobility by advocating for efficient and low-emission forms of transportation and making investments in sustainable infrastructure (Toan & Van Dong, 2019; Borowska-Stefańska et al., 2021; Pyddoke, 2016; dell'Olio et al.,2014; Adom-Asamoah et al., 2021).

Although public transit systems have been enhanced globally, a significant number of users still feel inadequate accessibility in most systems and encounter physical obstacles that hinder their free movement in urban walking areas (Pencheva et al., 2020). The existing literature lacks sufficient information about the role of transport systems as mediators in facilitating sustainable urban transport. There is a need for a research that examines the factors that influence sustainable urban mobility, considering the role of transport systems (infrastructure, vehicles and operations) as mediators. This study will fill a gap in the present literature.

Urban transportation is central to contemporary sustainability discourse, particularly in rapidly urbanizing cities (Elassy et al., 2024; Son et al., 2025; Yusuf et al., 2025; Sikdar, 2025; Przybyłowski et al., 2024; Shamsuddoha et al., 2025; Pandipati, 2025; Monteiro et al., 2024; İnce, 2025; Ngossaha et al., 2024; Alam, 2024; Liyanage & Dia, 2025; Merkert & Nelson, 2024; Huang, 2024; Buics et al., 2025; Abdelhady, 2024). As urban populations expand, demand for mobility intensifies, resulting in increased motorization, congestion, environmental degradation, and socio-spatial inequalities. Dar es Salaam, Tanzania, exemplifies this trend, experiencing rapid vehicle growth alongside mounting mobility challenges (Bruun et al., 2015; Lizárraga & López-Castellano, 2014). Sustainable urban mobility extends beyond environmental considerations to include economic efficiency, social inclusion, and accessibility equity. Transport systems significantly influence air pollution, congestion levels, energy consumption, and overall quality of life (Alamoudi et al., 2024). However, many African cities face structural challenges including fragmented governance, informal transport dominance, infrastructural deficits, and weak institutional coordination (Jacobsen, 2020; Appelhans, 2024).

1.2 Literature Review and Hypotheses Development

This part offers a thorough breakdown of the theoretical and practical features of the Resource-Based View (RBV) and its use in attaining a competitive advantage for urban regions and cities. Moreover, the hypotheses were formulated based on the motives put forward in the previous literature.

1.2.1 Resource-Based View (RBV)

The strategic management paradigm known as the Resource-Based View (RBV), which stresses a firm's internal resources as the main way to achieve a sustainable competitive advantage, was employed in this study. This concept emerged from businesses in the 1980s and 1990s as a way to understand a company's elements in order to gain a long-term, sustainable competitive advantage (Wernerfelt, 1984). According to RBV, organizations are heterogeneous because they have a variety of resources at their disposal, which allows them to implement different strategies (Chi, 1994). The RBV's central thesis is that a firm's resources must be valuable, uncommon, imperfectly imitable, and non-substitutable in order for it to gain a sustained competitive advantage.

During the 1990s, the resource-advantage hypothesis, or RBV, became the dominant concept in strategic planning (Barney, 1991). In a similar vein, RBV emphasizes the importance of both material and immaterial resources. Specifically, knowledge and skills which are considered intangible assets are often the main source of sustained competitive advantage (Chi, 1994). The RBV model states that relying only on external opportunities is less effective than exploiting internal resources to gain a competitive advantage (Barney, 1991). Additionally, the RBV highlights the significance of capabilities in creating extra value and achieving a competitive advantage over rivals. Capabilities are an organization's abilities generated from its resources (Wernerfelt, 1984). In order to outperform competitors and achieve long-term success in the market, the RBV model places a strong emphasis on identifying, developing, and using a company's unique resources and abilities (Wernerfelt, 1984; Barney, 1991; Chi, 1994). A model explaining the RBV and highlighting its key features is shown in Figure

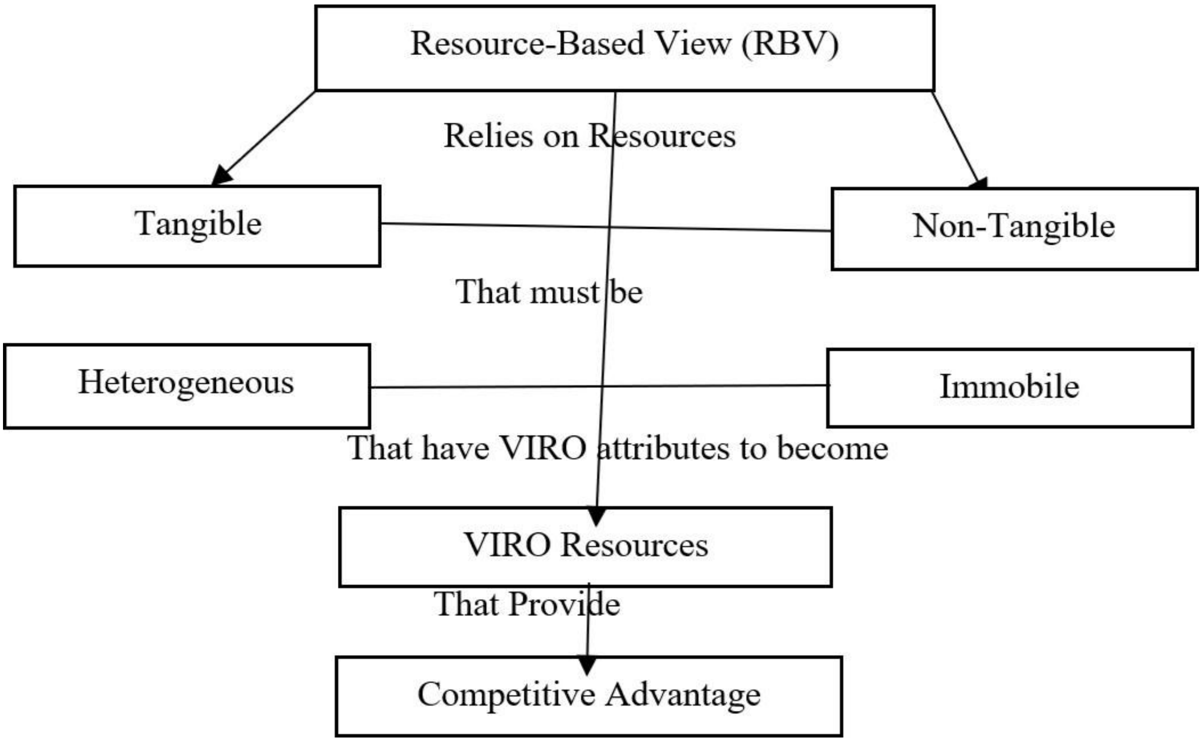

Figure 1: Resource-Based View (RBV) and its Key Points
Source: Conceptualized from Literature

Based on the information shown in Figure 1, technology and transport systems are seen as important resources for the world's emerging cities, since they may provide a competitive edge and have VRIO characteristics (Wernerfelt, 1984; Barney, 1991; Chi, 1994). Additionally, the infrastructure, cars, and activities involved in transporting people, products, or materials from one place to another fall within the purview of this inquiry. The efficient and secure movement of people and goods is made possible by these systems. Sustainable environmental development, social connectedness, and economic growth all depend on efficient transportation infrastructure. By offering vital transportation alternatives for people and companies, they have a substantial impact on the lovability and operation of cities and regions.

Similarly, via a process of learning, route cost optimization is made possible by the incorporation of Information and Communication Technologies (ICTs) into urban delivery systems. Fleet managers may increase city sustainability by decreasing travel lengths, boosting economic sustainability for businesses, and encouraging environmental sustainability for local administrations by utilizing developing technologies, such as e-ICTs (Russo & Comi, 2021). Although the direct effects of transportation systems and technology on sustainable urban transportation are well recognized, the literature currently in publication does not sufficiently address the indirect effects of these factors. By using RBV, this research sought to ascertain if the adoption of new technologies would have an indirect impact on sustainable urban transport via the transport systems (infrastructure, vehicles, and operations).

1.2.2 The Influence of Technologies (T) on Sustainable Urban Transport (SUT)

Urban transport networks' sustainability may be measured with the use of technology-driven assessments that identify smart mobility indicators. Technology helps evaluate and improve the sustainability of urban mobility patterns by emphasizing economic, social, and accessibility variables. This helps academics and policymakers improve sustainable urban transport operations (Ali, 2021). The current literature asserts that advanced technologies can significantly improve sustainable urban transport, especially when paired with multimodal, supportive policies and active-transport–first planning (Elassy et al., 2024; Son et al., 2025; Yusuf et al., 2025; Sikdar, 2025; Przybyłowski et al., 2024; Shamsuddoha et al., 2025; Pandipati, 2025; Monteiro et al., 2024; İnce, 2025; Ngossaha et al., 2024; Alam, 2024; Liyanage & Dia, 2025; Merkert & Nelson, 2024; Huang, 2024; Buics et al., 2025; Abdelhady, 2024)

The integration of autonomous driving perception algorithms and connected vehicle technologies in networked transport networks encourages the adoption of sustainable urban mobility behaviours. These advancements facilitate the development of more intelligent and ecologically conscious transportation alternatives by enhancing safety, efficiency, and environmental sustainability in urban transportation (Johnson & Nica, 2021). This study demonstrated the impact of connected car technologies, predictive analytics, and big data-enabled visual perception and recognition on improving the decision-making process of automated collision avoidance systems in urban driving environments. Additionally, it highlighted the influence of networked digital infrastructures on promoting sustainable urban transport (Johnson & Nica, 2021).

In addition, energy-efficient smart cities are greatly aided by technologies like electric automobiles, autonomous delivery robots, urban freight consolidation, and smart transportation modes. Logistics service providers may improve the sustainability of urban freight operations, lower energy consumption, and lessen negative externalities like traffic congestion and greenhouse gas emissions by using cutting-edge hardware and software solutions (Golinska-Dawson & Sethanan, 2023). Transportation for people and commodities that is low-emission and energy-efficient is essential for smart cities. In order to improve the sustainability of urban transportation, consider the following modes of transportation: drones, autonomous delivery robots, autonomous vehicles, cargo bikes (including e-cargo bikes and e-tricycles), electric vehicles (primarily vans), and combined passenger-and-cargo transportation rapid-transit systems (Golinska-Dawson & Sethanan, 2023). Likewise, smart signals, virtual traffic lights, and mobility prediction improve traffic flow, safety and fuel efficiency, supporting smart, low-emission cities (Elassy et al., 2024; Sikdar, 2025; Pandipati, 2025). On the other hand, Internet of Things (IoT)-based smart mobility systems monitor congestion, pollution, energy use and public transport performance, enabling eco-routing and demand-responsive control that raise overall sustainability indicators (Alam et al., 2024). A mobile roadside-unit concept using motorbike taxis cuts CO_2 by 10%, NOx by 15%, fuel use by 11% and waiting time by 15% in simulations (Ngossaha et al., 2024). Recent literature shows that predictive analytics, real-time data, optimization, and digital twins improve congestion management, safety, emissions reduction and multimodal planning (Son et al., 2025; Yusuf et al., 2025; Huang, 2024). Similarly, other scholars assert that Big Data supports transit prediction, traffic forecasting, and multimodal integration but face issues of model validation, equity and “black box” transparency (Yusuf et al., 2025). In addition, transportation 5.0 frameworks emphasize multimodal hubs, shared mobility and renewable energy to cut environmental impacts while improving accessibility and user convenience (Shamsuddoha et al., 2025). Bicycle sharing scores highest on environmental impact and cost efficiency in evaluation of urban modes, outranking BRT (Pandipati, 2025). Sustainable outcomes depend on pairing technology with transit-oriented development, compact urban form and electric mobility (Monteiro et al., 2024; Yusuf et al., 2025; Przybyłowski et al., 2024; Liyanage & Dia, 2025; Buics et al., 2025). Furthermore, contract frameworks and legal must flexibly accommodate rapid innovation while attaining measurable sustainability outcomes (Merkert & Nelson, 2024; Abdelhady, 2024).

Likewise, Golinska-Dawson and Sethanan (2023) claim that parcel consolidation in micro-depots, parcel lockers, and mobile depots may increase energy efficiency in smart cities. Moreover, smart technologies such as digital twins, big data, artificial intelligence, and the Internet of things can be applied to sustainable urban transportation because they improve operational planning and infrastructure sharing among logistics service providers, lowering fuel demand and enabling energy efficiency. Also, to lower energy consumption and emissions from automobiles, research, development, and promotion of efficient energy-saving strategies and emission-reducing technologies are required (Zhang et al., 2015; Ali, 2021; Johnson & Nica, 2021; Golinska-Dawson & Sethanan, 2023). Although the present literature has a good understanding of the direct impact of technology on sustainable urban transport, the indirect impact of technologies on sustainable urban transport is not well understood. This study hypothesized that technologies (T) would have an indirect impact on sustainable urban transport via their influence on infrastructure, vehicles, and operations, to fill the existing gap in the body of literature.

H_1: Technologies (T) positively influence sustainable urban transport (SUT) through their effect on infrastructure (INF), vehicles (V) and operations (OP)

1.2.3 The Influence of Infrastructure (INF) on Sustainable Urban Transport (SUT)

Infrastructure has a wide range of implications on sustainable urban transport, and it is essential for encouraging economical and ecologically responsible city transportation. Previous research emphasizes how crucial well-planned infrastructure is to fostering sustainable urban transportation, considering elements such as pricing structures, mode-specific regulations, and the availability of infrastructure specifically designed for alternative forms of transportation like bicycles (Toan & Van Dong, 2019; Borowska-Stefańska et al., 2021; Pyddoke, 2016; Dell'Olio et al., 2014). These factors are essential for lowering emissions, easing traffic, and encouraging more sustainable and healthful urban transportation choices. For instance, Borowska-Stefańska et al. (2021) showed that allowing Electric Vehicles to use bus lanes in a big city had a negligible negative effect on traffic but had no effect on how long buses took to travel (Borowska-Stefańska et al., 2021). On the other hand, demand for automobile travel is mostly responsive to the availability of public transportation, and car usage is more price-sensitive in metropolitan areas (Pyddoke, 2016; Adom-Asamoah et al., 2021).

Ling et al. (2024) assert that upgrading transport infrastructure (e.g., high-speed rail, freight capacity) increases urban green development efficiency by approximate 4%, through green innovation. Likewise, transport infrastructure construction significantly improves a composite index of economic, social and environmental sustainability, mainly through boosting technological innovation and employment (Yang et al., 2025). In addition, Gutman and Malashenko (2025) revealed that at national level, transport infrastructure is a key driver of regional economic growth, but must integrate sustainability principles to avoid pollution and inequality. On the other hand, green infrastructure such as bike lanes, walkable sidewalks and green corridors reduces emissions, improves public health and air quality, and enhances urban lovability (Hapriyanto & Azmi, 2025; Bénichou, 2024; Ngcobo et al., 2024). A study by Bland et al. (2024) revealed that all cost–benefit analyses have benefit–cost ratios >1, with health benefits making up approximate 77% of total benefits, supporting major reallocation of funds toward active-transport infrastructure. Investment in high-quality bus/rail infrastructure and interchanges are central to sustainable mobility, cutting congestion and pollution when prioritized over road expansion (Monteiro et al., 2024; Elassy et al., 2024; Huang, 2024). Comparative work shows that integrated metro/rail plus transit-oriented development and "rail + property" financing can shift modal share toward public transport and reduce urban pollution (Akram et al., 2025). New equity-focused indicators combine supply (bus/rail/cycle infrastructure) and demand to locate areas where infrastructure gaps undermine sustainable transport access (Ballantyne et al., 2024. Better non-motorized and public-transport infrastructure is strongly associated with larger city size, exposing deficits in small and medium cities and calling for targeted sustainable urban transport investment (Banerjee et al., 2024). Reviews emphasize compact, mixed-use urban form and transit-oriented infrastructure as crucial for lowering energy use (Monteiro et al., 2024; Viatkin et al., 2025). On the other hand, the recent studies show that infrastructure determines whether urban transport becomes more sustainable, equitable, and supportive of long-term green development (Ling et al., 2024; Hapriyanto & Azmi, 2025; Yang et al., 2025; Bénichou, 2024; Ngcobo et al., 2024; Bland et al., 2024; Monteiro et al., 2024; Elassy et al., 2024; Akram et al., 2025; Ballantyne et al., 2024; Banerjee et al., 2024; Abdulhussien et al., 2024; Viatkin et al., 2025; Gutman & Malashenko, 2025).

In addition, a study conducted by Dell'Olio et al. (2014) sought to ascertain the viability of bicycles as a sustainable form of transportation. The results showed that a number of variables, such as cost, climate, and the accessibility of infrastructure like bike routes, influenced prospective bicycle riders (dell'Olio et al., 2014). To achieve sustainable urban expansion, it is essential to evaluate the traffic effect of infrastructure development projects, as noted by Toan and Van Dong (2019), Borowska-Stefańska et al. (2021), Pyddoke (2016), and Dell'Olio et al. (2014). The indirect effects of infrastructure on sustainable urban transport are little known, despite the fact that the direct effects of infrastructure on sustainable urban transport are well recognized in the current literature. To fill the gap in the body of knowledge and validate the findings of prior studies, this study postulated that infrastructure would have an indirect and direct influence on sustainable urban transport via their effect on vehicles and operations.

H_2: Infrastructure (INF) indirectly and positively influences sustainable urban transport (SUT) through its effect on vehicles (V) and operations (OP)
H_4: Infrastructure (INF) directly and positively influences sustainable urban transport (SUT)

1.2.4 The Influence of Vehicles (V) on Sustainable Urban Transport (SUT)

Vehicles have a wide range of effects on sustainable urban transportation, including infrastructure, pollution, traffic, and the encouragement of alternate forms of transportation. For instance, the research of Nicolas (2000) claims that automobiles especially those driven by fossil fuels have a major influence on greenhouse gas emissions and air pollution, which in turn affects urban environments and public health. The analysis shows, for instance, that the influence of predicted increases in traffic and advancements in car environmental efficiency outweigh the effects of a worsening in traffic conditions. Therefore, regulated urban growth is necessary if cities and urban transportation are to achieve sustainable development (Nicolas, 2000; Adom-Asamoah et al., 2021).

Road vehicle exhaust gas emissions have an impact on the environment and people's quality of life, particularly in metropolitan areas. The benefits of newer, greener automobiles are eliminated by the vastly rising number of vehicles on the road, particularly in industrialized nations. The introduction and promotion of alternative propulsion systems in automobiles, such as hybrid and fully electric cars, seems to be a practical approach for protecting the health of city dwellers (Gnap et al., 2020). Due to traffic congestion caused by the large number of automobiles in urban areas, travel times, fuel consumption, and emissions are all increased. Improving the effectiveness and sustainability of urban transportation networks requires addressing congestion (Gnap et al., 2020). The existence of automobiles affects the planning and upkeep of urban infrastructure, such as parking lots, public transit routes, and roadways. Planning for sustainable urban transportation must consider the infrastructure required to provide economical and environmentally responsible mobility alternatives (Zhang et al., 2015).

The recent literature asserts that vehicles support sustainable urban transport when they are electric, shared, efficiently operated and integrated with public transport and renewables; simply electrifying a privately-owned car fleet, without mode shift or equity-focused policy, delivers only a partial and potentially fragile sustainability gain (Musida et al., 2025; Shamsuddoha et al., 2025; Garus et al., 2024; Munawar, 2024; Timilsina et al., 2025; Alsaleh, 2025; Armenta-Déu, 2024; Mohammed et al., 2024; Ferreira &Esperança, 2025; Hargroves et al., 2024; Tilly et al., 2024; Aldhanhani et al., 2024; Zaino et al., 2024; Hafiz et al., 2025; Hayati, 2025; Ndhlovu et al., 2025; Singh et al., 2024; Kashem et al., 2024).

For example, lifecycle studies show electrical vehicles substantially reduce emissions and urban air pollution (Timilsina et al., 2025; Zaino et al., 2024; Ndhlovu et al., 2025; Kashem et al., 2024). Electric vehicles fleets can cut emissions by up to 40% while improving delivery efficiency and lowering long-term operating costs in logistics and last-mile delivery (Munawar, 2024; Ferreira & Esperança, 2025). Shared electric vehicles services can reduce GHG emissions by 14–65% versus conventional vehicles and easing congestion (Musida et al., 2025). However, widespread private electric vehicles adoption can amplify social inequality, strain grids, and drive resource extraction unless paired with mode shift to public and shared transport and careful charging planning (Mohammed et al., 2024; Timilsina et al., 2025; Tilly et al., 2024).

On the other hand, electric shared mobility (car-sharing, ride-hailing, bike sharing) reduces per-km costs and emissions and can support first/last-mile links to mass transit, shifting users away from private cars (Musida et al., 2025; Garus et al., 2024; Hargroves et al., 2024; Hayati, 2025; Kashem et al., 2024). Therefore, electric and autonomous vehicles in urban logistics and public transport can lower congestion, emissions and operating costs while enhancing resilience, but raise challenges in safety, jobs and regulation (Shamsuddoha et al., 2025; Garus et al., 2024; Alsaleh, 2025; Ferreira & Esperança, 2025; Hafiz et al., 2025). In addition, advanced electric vehicles improve vehicle energy efficiency by ~30%, extending range and reducing urban energy use, pollution and boosting system-level sustainability, but depends on smart charging and communication standards (Aldhanhani et al., 2024; Singh et al., 2024; Kashem et al., 2024; Armenta-Déu, 2024).

Promoting other forms of mobility including walking, bicycling, and public transportation may lessen the detrimental impact that cars have on environmentally friendly urban transportation. In order to reduce the negative effects of conventional automobiles on urban sustainability, policies that support the usage of electric vehicles and car-sharing programs are also crucial (Zhang et al., 2015). Furthermore, to lower energy consumption and emissions from automobiles, research, development, and promotion of efficient energy-saving strategies and emission-reducing technologies are required (Zhang et al., 2015).

According to Pencheva et al. (2020), passengers often have to choose between a route and a vehicle. This decision is influenced by many things. However, it is the outcome of the passenger's socioeconomic features, the quality of the transportation service, and time, money, and environmental limits (Pencheva et al., 2020). To create more sustainable urban environments, it is necessary to take a comprehensive approach that addresses emissions, traffic, infrastructure development, and the promotion of alternative transportation modes. These factors are significant and varied when it comes to the influences that vehicles have on sustainable urban transport (Nicolas, 2000; Zhang et al., 2015; Gnap et al., 2020; Pencheva et al., 2020). The indirect impacts of vehicles on sustainable urban transport are little understood, despite the fact that the direct effects of vehicles on sustainable urban transport are thoroughly documented in the present literature. To bridge a knowledge gap, this research hypothesized that vehicles will have an indirect impact on sustainable urban transportation via their effect on operations.

H_3: Vehicles (V) indirectly and positively influence sustainable urban transport (SUT) through its effect on operations (OP)

1.2.5 The Influence of Operations (OP) on Sustainable Urban Transport (SUT)

Achieving the intended urban results that affect the economic, social, and accessible aspects requires careful consideration of the implications of operations on sustainable urban transport. For instance, a study by Ali (2021) focused on finding smart mobility metrics for urban transportation systems that are sustainable. In evaluating the sustainability of transportation operations in urban settings, the research emphasizes the significance of economic, social, and accessibility indices (Ali, 2021). Sustainable urban transportation is essential to attaining targeted urban outcomes that affect accessibility, social, and economic aspects (Buldeo Rai et al., 2017).

On the other hand, everyday mobility in many of the expanding cities is impacted by a number of variables that impede efficient and sustainable transportation systems (Buldeo Rai et al., 2017). The potential for creative operational solutions to improve the sustainability of urban transport operations is highlighted by looking at crowd logistics as a chance for more sustainable urban freight transport, especially when it comes to freight transportation (Buldeo Rai et al., 2017). According to a research on the potential for sustainable car transportation, operational procedures and policy play a critical role in advancing sustainable urban transportation in certain metropolitan settings (Majumdar, 2020). The significance of operational factors including traffic volume, road speeds, and vehicle fleet composition in influencing the environmental impact of transport operations is emphasized by research examining the effects of road traffic on air pollution. In order to accomplish sustainable urban growth and lessen the detrimental impacts of automobile traffic on air quality, it emphasizes the need of appropriate policies (Nicolas, 2000). In order to provide inclusive, sustainable, and resilient transport services that satisfy the various mobility needs of urban communities, operational factors like accessibility, safety, and resilience are crucial. This is highlighted by a conceptual framework integrating service quality assessment in community transport systems. The significance of operational techniques in guaranteeing secure, convenient, and dependable transportation services for all customers is emphasized, particularly when confronted with unforeseen circumstances and obstacles (Simões & Suen, 2023). Numerous elements, such as smart mobility indicators, crowd logistics, local prospects, air pollution consequences, and service quality concerns, are influenced by operations on Sustainable Urban Transport. Promoting resilient, inclusive, and sustainable urban transport systems that meet the various needs of urban populations while reducing adverse environmental effects requires addressing these operational influences (Ali, 2021; Buldeo Rai et al., 2017; Majumdar, 2020; Simões & Suen, 2023; Nicolas, 2000; Adom-Asamoah et al., 2021). Based on the findings of these studies, the direct effects of operations on sustainable urban transport are well recognized in the current literature. To validate the findings of prior studies, this study postulated that operations would have a direct influence on sustainable urban transport.

H_5: Operations (OP) directly and positively influence sustainable urban transport (SUT)

1.2.6 Conceptual Model of the Study

The conceptual model of the study was created by considering the results of earlier researches as well as inferences about the effects of technologies and transport systems on sustainable urban transport. The study's conceptual model is shown in Figure 2.

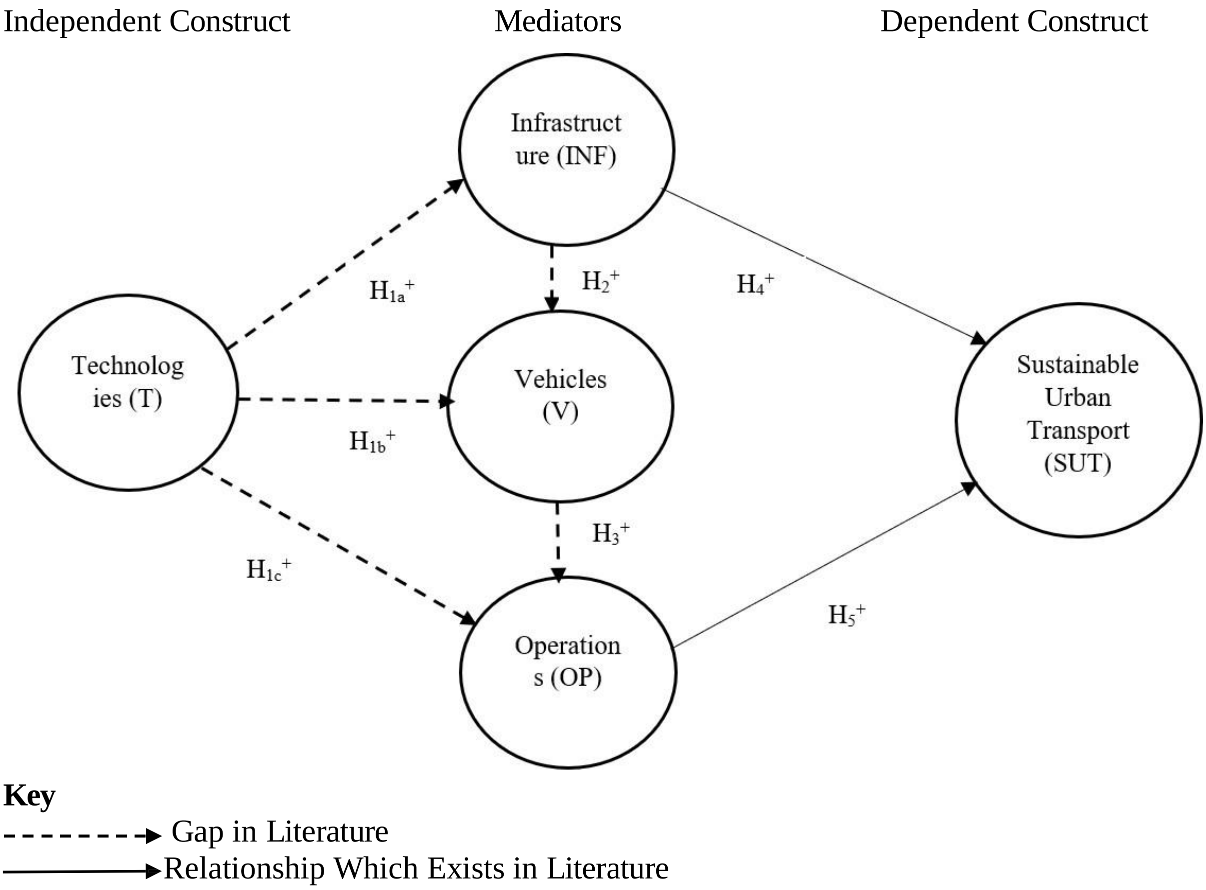

Figure 2: Conceptual Model of the Study
Source: Author

1.2.7 The Mathematical Model

As can be seen in Figure 2, the research used the mathematical equation x = lY + e to show the relationships between latent variables and their indicators. The variable x denotes the visible indicator, whereas the variable Y is the hidden variable. A statistical measure known as the loading coefficient L expresses the strength of the relationship between the latent variable Y, which is independent of external influences, and the observable indicator x, which is reliant on external factors. The stochastic measurement error is represented by the variable e (Sarstedt et al., 2022; Shatta, 2023).

2.0 METHODOLOGY

2.1 Research Paradigm, Design, Sampling Technique, Data Collection Methods and Tools

The need to test the research hypotheses drove the establishment of positivism philosophy. In addition, data from a specific sample of passengers were gathered for the study using explanatory cross-sectional survey research techniques. This is because data was only gathered once and just a portion of the unit was looked at (Creswell & Plano, 2018). Comparably, the survey method used in this research allowed for the collection of data and the quantitative analysis of that data using inferential and descriptive statistics. Nevertheless, this study employed PLS-SEM and SmartPLS 4 software to determine the appropriate sample size needed to test the study model's hypotheses in accordance with the tenth rule of thumb put out by Hair et al. (2019).

The tenth rule of thumb, according to Hair et al. (2019), states that ten times the maximum number of exogenous construct indicators is the minimal sample size needed to assess the hypotheses of a particular research model. Each of the four exogenous constructs in this study contains four indicators. The tenth rule of thumb states that as the sample size of 300 respondents was more than the minimal number of respondents needed, it was deemed sufficient for assessing the study's hypotheses. In addition, numerical values were given to closed-ended surveys in order to enhance the precision and speed of processing quantitative data. IBM SPSS Statistics Software Version 26 was used to assist in the descriptive statistics analysis of the quantitative data acquired for the respondents' profiles. Using the SmartPLS 4 software and partial least squares structural equation modeling (PLS-SEM), inferential statistical analysis was carried out to evaluate the hypotheses. To resolve missing data, the additional response approach was used by the SmartPLS 4 program. In this research, the missing data from the questionnaires were replaced with the number 99. But according to Hair et al. (2019), this method helped create a systematic division between observed and unseen data.

2.2 Evaluation of Models

Partial Least Squares Structural Equation Modeling (PLS-SEM) was used in this study to evaluate reflecting models. A reflecting model was thought to be suitable for this study since all indicators were reliant on their constructs (Hair et al., 2019). Furthermore, the suggested research model's measurement and structural models were assessed by the application of the standards set out by Hair et al (2019). The examination of reflecting measuring models included several processes. First, the reliability of the indicators was evaluated, and a reliability value greater than 0.708 was required. Second, a threshold bigger than 0.708 was used to assess the internal consistency reliability of the composite reliability of constructs. Third, the Average

Variance Extracted (AVE) value which had to be more than 0.5 was used to evaluate the constructs' convergent validity. Ultimately, the Heterotrait-Monotrait Ratio of Correlations (HTMT) criteria which need a value of less than 0.9 were used to ascertain the discriminant validity. Furthermore, the collinearity of the constructs within the structural model was assessed.

In addition, Hair et al. (2019) state that the VIF values need to be about 3 or lower. The following were the primary variables used in PLS-SEM to evaluate the structural model after collinearity was considered: If the t-statistic for each path coefficient is more than 1.96 at a significance level of 0.05, then path coefficients with a significance level are acceptable; p-values of 0.05 or less are deemed significant (Hair et al., 2019). Similarly, according to Hair et al. (2019), R^2 values of 0.75, 0.50, and 0.25 are categorized as significant, moderate, and weak, respectively. Hair et al. (2019) discovered that f^2 effect values above 0.02, 0.15, and 0.35 signify small, medium, and high impact sizes, correspondingly. Overall, the assessment outcomes for the structural and measurement models were satisfactory and satisfied every requirement set out by Hair et al. (2019).

3.0 RESULTS

3.1 Demographic Characteristics of the Respondents

The data on respondents' gender, age group, level of education, and experience is shown in Table 1. Men made up around 69% of the respondents, while women made up about 31%. Moreover, 75% of the participants were in the age range of 31 to 50. Furthermore, about 46 percent of the participants had a bachelor's or master's degree. On the other hand, 86 percent of participants had used public transport at some point in the past in Dar es salaam city, ranging in experience from one to twenty years. These outcomes align with previous research findings. For instance, Okoth (2017) found that around 53% of individuals had a master's or bachelor's degree. The results of this research, however, are in contrast to those of Obsie et al. (2020), who found that around 37% of the participants had a bachelor's, master's, or doctoral degree, and that about 30% of the participants were between the ages of 30 and 50.

Table 1: Demographic Characteristics of the Respondents (n=300)

Characteristics		Frequency	Percentage (%)
Gender	Male	206	68.7
	Female	94	31.3
Age Group	21-30	48	16.0
	31-40	133	44.3
	41-50	92	30.7
	51-60	19	6.3
	61+	8	2.7
Education	Secondary Education	41	13.7
	Certificate Level	54	18.0
	Diploma Level	68	22.7
	Bachelor Degree	94	31.3
	Master's Degree	43	14.3
Experience	1-10	172	57.3
	11-20	86	28.7
	21-30	32	10.7
	31+	10	3.3

3.2 Indicator’s Reliabilities, R^2 Values and Relevance of the Path Coefficients

Upon using the PLS-SEM approach with the aid of SmartPLS 4 software, it was determined that the loadings of the majority of indicators for the constructs above the suggested threshold of 0.708, as stated by Hair et al. (2019). The R^2 values of 0.289, 0.490, 0.528, and 0.633 suggest that about 28.9% of the variability in the infrastructure (INF) can be explained by the exogenous variable technologies (T). Furthermore, the analysis revealed that 49.0 percent of the variability in operations (OP) may be attributed to the technologies (T). In addition, the study found that 52.8 percent of the variability in vehicles (V) can be attributed to technologies (T), while 63.3 percent of the variability in sustainable urban transport (SUT) can be attributed to a combination of exogenous constructs such as technologies (T), infrastructure (INF), vehicles (V), and operations (OP). Furthermore, all proposed impacts had positive path coefficients, suggesting that a one standard deviation rise in the exogenous construct, coupled with the mediators, resulted in an advancement in the level of sustainable urban transport (SUT). Figure 3 displays the reliabilities of the indicators, the R^2 values, and the relevance of the path coefficients.

Independent Variable Mediator Variables Dependent Variable

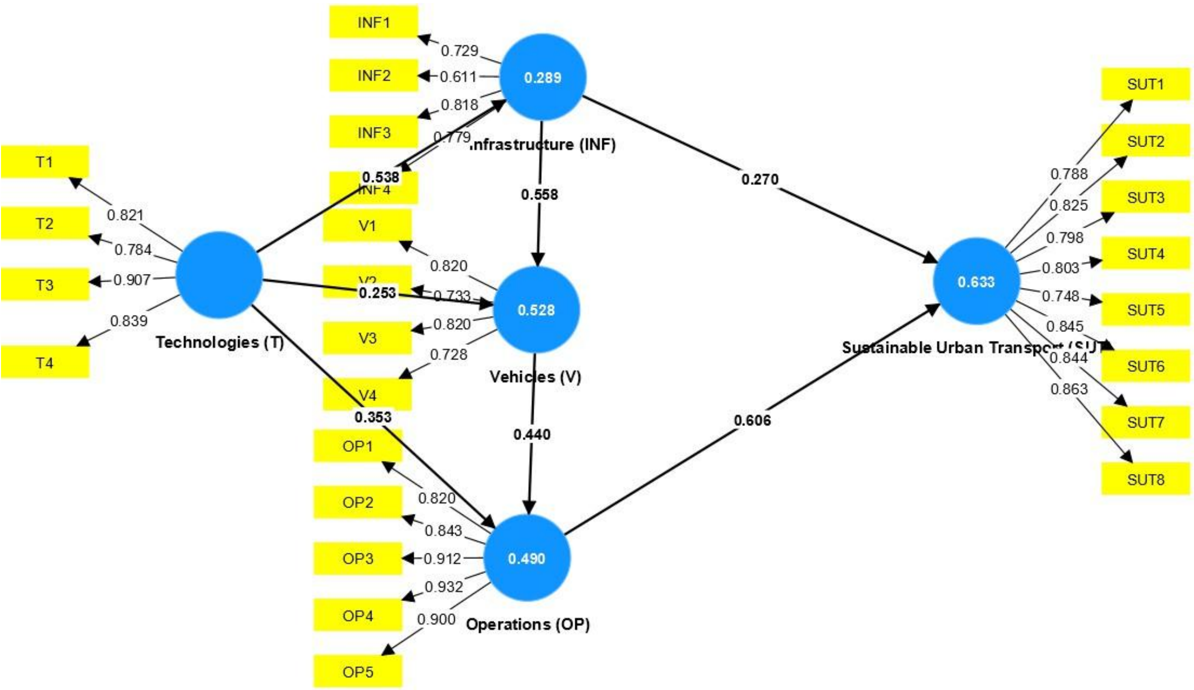

Figure 3: Indicator’s Reliabilities, R^2 Values and Relevance of the Path Coefficients

3.3 Reliability and Convergent Validity Analysis Results

If the composite reliability (CR) score of a construct is more than 0.708, then it is deemed trustworthy according to Hair et al. (2019). In addition, the Average Variance Extracted (AVE) value of a construct must be more than 0.5 for it to have convergent validity. Composite reliability (CR) values greater than 0.708 were used to assess the reliability of all constructs in this study. Also, the AVE value, which stands at more than 0.5, was used to evaluate the convergent validity of all constructs. Positive response patterns were seen in this study, and each construct facilitated to explain the variance in its own item, according to the results (Hair et al., 2019). The findings of the constructs' validity and reliability are shown in Table 2.

Table 2: Reliability and Convergent Validity Analysis Results

	Composite Reliability (CR)	Average Variance Extracted (AVE)
Infrastructure (INF)	0.826	0.545
Operations (OP)	0.946	0.779
Sustainable Urban Transport (SUT)	0.94	0.664
Technologies (T)	0.905	0.704
Vehicles (V)	0.858	0.603

3.4 Discriminant Validity Analysis (HTMT Results)

As shown in Table 3, the HTMT values for all influences examined in the research model were less than 0.90. According to the findings, every element in the research model revealed empirical distinction from the remaining elements in the structural model, as recommended by Hair et al. (2019).

Table 3: Discriminant Validity Analysis (HTMT Results)

	Infrastructure (INF)	Operations (OP)	Sustainable Urban Transport (SUT)	Technologies (T)	Vehicles (V)
Infrastructure (INF)	0.738				
Operations (OP)	0.592	0.882			
Sustainable Urban Transport (SUT)	0.629	0.766	0.815		
Technologies (T)	0.538	0.596	0.504	0.839	
Vehicles (V)	0.694	0.635	0.582	0.554	0.777

3.5 Collinearity Statistics by VIF Metric for Inner Model

In order to analyze collinearity data, the researcher employed the Variance Inflation Factor (VIF) metric. On the contrary, Hair et al. (2019) discovered that VIF values falling below 3 signify the lack of collinearity issues in the proposed research model's predictor constructs. The statistical results regarding collinearity in the interior model of the suggested study model are displayed in Table 4. The VIF metric was employed to assess collinearity in the predictor constructs; values falling below 3 indicate the absence of such issues.

Table 4: Collinearity Statistics (VIF) for Inner Model Results

Construct	Infrastructure (INF)	Operations (OP)	Sustainable Urban Transport (SUT)	Vehicles (V)
Infrastructure (INF)			1.540	1.407
Operations (OP)			1.540	
Technologies (T)	1.000	1.442		1.407
Vehicles (V)		1.442		

3.6 F^2 Values Results

Hair et al. (2019) classify impact sizes of 0.02, 0.15, and 0.35 as small, medium, and large f^2 values, respectively, in accordance with their research. As shown in Table 5, the analysis of this study yielded effect sizes (f^2) of 0.097, 0.129, 0.169, 0.263, 0.407, 0.469 and 0.650 for each distinct association. The numerical values denote the occurrence of small, medium, and substantial effect sizes, correspondingly, for every hypothesis included in the research model.

Table 5: F^2 Values Results

	Infrastructure (INF)	Operations (OP)	Sustainable Urban Transport (SUT)	Vehicles (V)
Infrastructure (INF)			0.129	0.469
Operations (OP)			0.650	
Technologies (T)	0.407	0.169		0.097
Vehicles (V)		0.263		

3.7 Statistical Significance Results for the Hypothesized Relationships

Upon conducting bootstrapping using SmartPLS 4 software, it was observed that all proposed relationships were confirmed with p-values less than 0.05. This indicates that the conceptual research model employed in this study is appropriate for informing management decisions concerning sustainable urban transport (SUT). These phenomena provide empirical evidence in support of every postulated relationship exist in real life. The statistical significance results of the hypotheses are illustrated in Figure 4.

Independent Variable Mediator Variables Dependent Variable

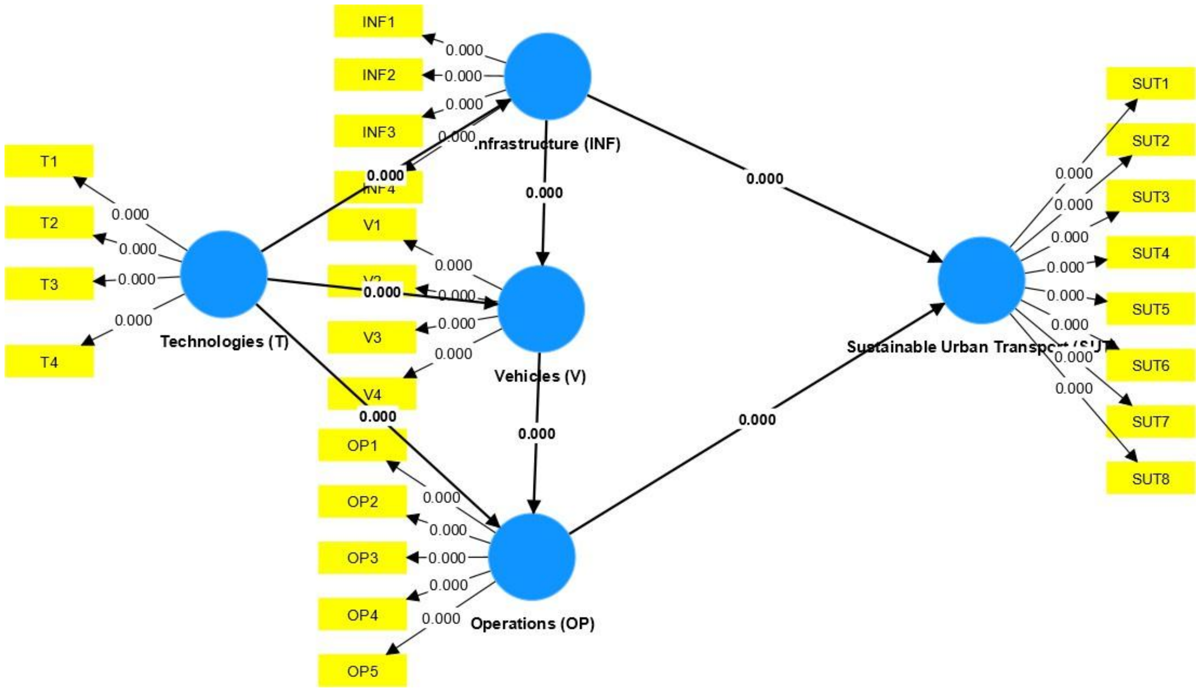

Figure 4: Statistical Significance of the Hypothesized Relationships

3.8 Indirect Statistical Significance Results of the Hypotheses

The results of the assessment of the indirect assumptions derived from the study's theoretical framework are summarized in Table 6. Upon generating the bootstrapping report utilizing the SmartPLS 4 software, it was determined that the outcomes of the indirect predictions were statistically significant (p values < 0.05). This implies that the connections observed in the model are present in tangible circumstances, and the validated model could potentially be effectively applied to decision-making processes concerning transportation sector matters, specifically sustainable urban transport (SUT).

Table 6: Indirect Statistical Significance Results of the Hypotheses

Indirect Hypothesis	STDEV	T statistics (|O/STDEV|)	P values
T-> INF -> V -> OP	0.026	5.036	0.000
T -> V -> OP	0.034	3.308	0.001
T -> OP -> SUT	0.058	3.666	0.000
T -> INF -> V -> OP -> SUT	0.016	5.129	0.000
T -> INF -> V	0.038	7.814	0.000
V-> OP -> SUT	0.039	6.776	0.000
T-> INF -> SUT	0.030	4.856	0.000
INF-> V -> OP	0.046	5.329	0.000
T-> V ->OP -> SUT	0.020	3.454	0.001
INF ->V -> OP -> SUT	0.026	5.822	0.000

3.9 Total Statistical Significance Results of the Hypotheses

The findings of the evaluation of the direct and indirect assumptions generated from the theoretical framework of the research are outlined in Table 7. The bootstrapping report generated using the SmartPLS 4 software revealed that the combined direct and indirect predictions yielded statistically significant results (p values < 0.05). This suggests that the relationships identified in the model exist in real-world situations, and the model that has been confirmed might be successfully used in decision-making processes related to transportation, particularly sustainable urban transport (SUT).

Table 7: Total Effects Results

	STDEV	T statistics (|O/STDEV|)	P values
INF -> OP	0.046	5.329	0.000
INF -> SUT	0.054	7.816	0.000
INF -> V	0.044	12.819	0.000
OP -> SUT	0.055	11.028	0.000
T -> INF	0.058	9.220	0.000
T -> OP	0.066	8.986	0.000
T -> SUT	0.059	8.551	0.000
T -> V	0.065	8.551	0.000
V -> OP	0.074	5.913	0.000
V -> SUT	0.039	6.776	0.000

3.10 Importance-Performance Map Analysis Results

The technologies (T) and operations (OP), shown in Figure 5, show higher importance and performance than the average for the desired construct 'sustainable urban transport'. This outcome suggests that it is crucial to prioritize and provide more resources to operations (OP) and technologies (T) in order to assure the viability of sustainable urban transport (SUT) in urban areas. However, the significance of sustainable urban transport (SUT), which is the primary emphasis, surpasses the important ratings of vehicles (V) and infrastructure (INF). This suggests that these constructs have a limited influence on the target construct, sustainable urban transport (SUT). Nevertheless, these constructs are situated higher than the average on the performance map of the primary target construct (sustainable urban transport (SUT)). This indicates that they are also important for developing and improving transportation systems in urban areas.

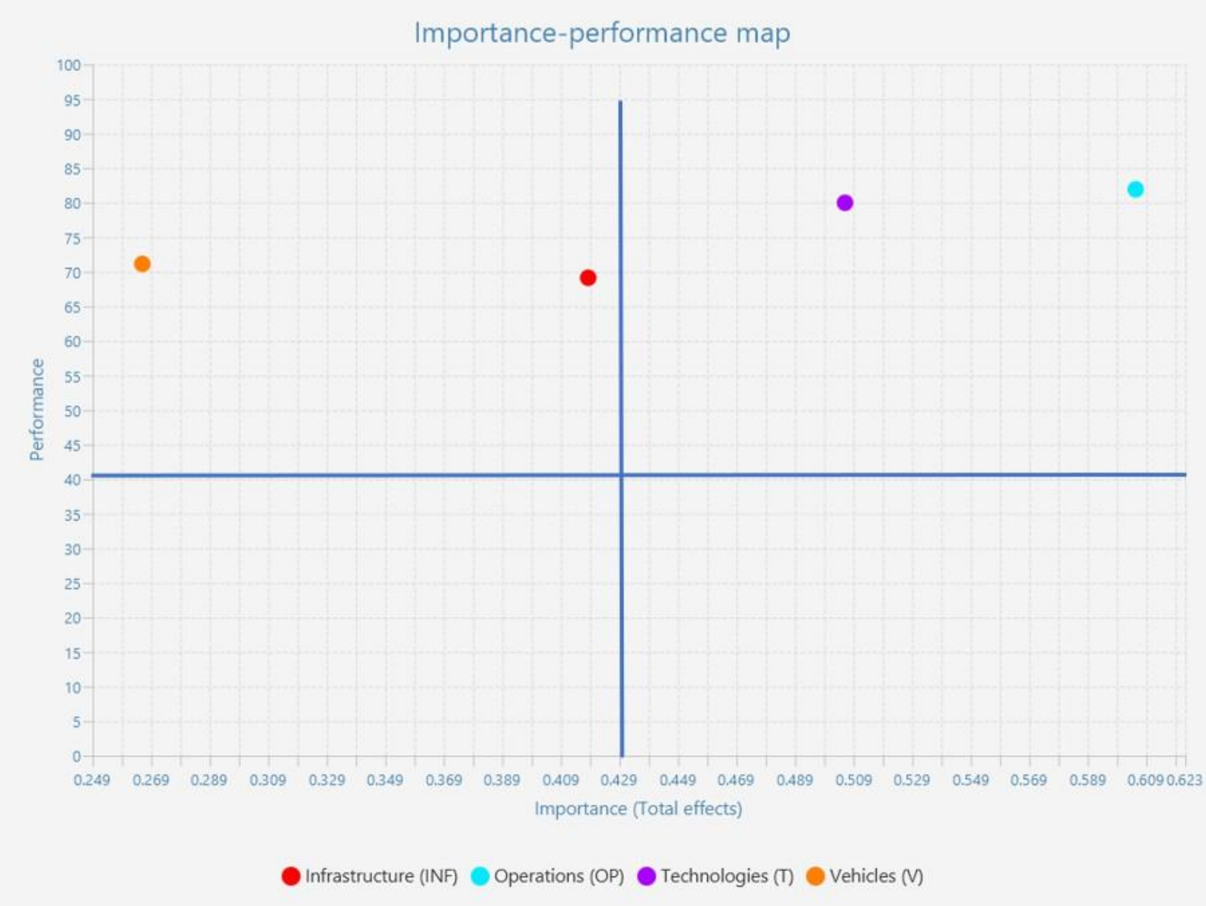

Figure 5: Importance-Performance Map Analysis Results

4.0 DISCUSSION

4.1 The Hypotheses Tested

This study posited that the degree of technological advancements (T) would have an indirect impact on the sustainability of urban transportation (SUT) through the intermediary factors of infrastructure (INF), vehicles (V), and operations (OP). The results depicted in Figure 3 indicated the presence of positive path coefficients. This indicates that an increase of one standard deviation in technologies (T) resulted in an increase in both infrastructure (INF), vehicles (V), and operations (OP), as well as sustainable urban transport (SUT), and vice versa. Furthermore, the results presented in Table 6 and Table 7 have substantiated the existence of statistically significant effects, both direct and indirect, at a significance level below 0.05 (p value <0.05). These findings confirm the presence of the expected connections in real-world scenarios. However, these findings are inconsistent with the conclusions derived from prior research (Elassy et al., 2024; Son et al., 2025; Yusuf et al., 2025; Sikdar, 2025; Przybyłowski et al., 2024; Shamsuddoha et al., 2025; Pandipati, 2025; Monteiro et al., 2024; İnce, 2025; Ngossaha et al., 2024; Alam, 2024; Liyanage & Dia, 2025; Merkert & Nelson, 2024; Huang, 2024; Buics et al., 2025; Abdelhady, 2024; Zhang et al., 2015; Ali, 2021; Johnson & Nica, 2021; Golinska-Dawson & Sethanan, 2023) that have shown the direct significant impact of technologies on sustainable urban transport (SUT).

Similarly, this study forecasted that the infrastructure (INF) would have a direct impact on vehicles (V) and would also have both direct and indirect effects on sustainable urban transport (SUT). The findings from Figure 3 demonstrated that there were positive path coefficients, suggesting that a one standard deviation increase in infrastructure (INF) would result in enhancements in vehicles (V), operations (OP) and sustainable urban transport (SUT), and vice versa. In addition, the results of this study, as shown in Table 6 and Table 7, demonstrate that infrastructure has a statistically significant and positive effect (p value < 0.05) on both vehicles (V), operations (OP) and sustainable urban transport (SUT). The results of this study align with the findings of previous studies (Ling et al., 2024; Hapriyanto & Azmi, 2025; Yang et al., 2025; Bénichou, 2024; Ngcobo et al., 2024; Bland et al., 2024; Monteiro et al., 2024; Elassy et al., 2024; Akram et al., 2025; Ballantyne et al., 2024; Banerjee et al., 2024; Abdulhussien et al., 2024; Viatkin et al., 2025; Gutman & Malashenko, 2025; Toan & Van Dong , 2019; Borowska-Stefańska et al., 2021; Pyddoke, 2016; Dell'Olio et al., 2014). These studies have demonstrated that the infrastructure has a direct positive effect on sustainable urban transport (SUT).

Likewise, this study proposed that the vehicles (V) would have a direct impact on the operations (OP) and an indirect impact on the level of sustainable urban transport (SUT). The results depicted in Figure 3 confirm a positive path coefficient, signifying that a one standard deviation increase in vehicles will result in an enhancement of both operations (OP) and sustainable urban transport (SUT), and vice versa. The results presented in Table 6 and Table 7 indicate that the vehicles (V) have a statistically significant positive effect (p value < 0.05) on both the operations (OP) and the level of sustainable urban transport (SUT). Nevertheless, the findings of this study are inconsistent with prior research (Musida et al., 2025; Shamsuddoha et al., 2025; Garus et al., 2024; Munawar, 2024; Timilsina et al., 2025; Alsaleh, 2025; Armenta-Déu, 2024; Mohammed et al., 2024; Ferreira &Esperança, 2025; Hargroves et al., 2024; Tilly et al., 2024; Aldhanhani et al., 2024; Zaino et al., 2024; Hafiz et al., 2025; Hayati, 2025; Ndhlovu et al., 2025; Singh et al., 2024; Kashem et al., 2024; Nicolas, 2000; Zhang et al., 2015; Gnap et al., 2020; Pencheva et al., 2020) that have shown the direct positive impact of vehicles on sustainable urban transport (SUT).

Above all, this study posited that the operations (OP) would have a direct impact on the level of sustainable urban transport (SUT). The findings depicted in Figure 3 confirm a positive path coefficient, suggesting that a one standard deviation increase in operations (OP) would result in an enhancement of sustainable urban transport (SUT). The findings presented in Table 7 indicate that the operations (OP) have a statistically significant and positive effect (p value < 0.05) on sustainable urban transport (SUT). The findings of this study are consistent with prior research (Ali, 2021; Buldeo Rai et al., 2017; Majumdar, 2020; Simões & Suen, 2023; Nicolas, 2000), which suggests that the operations (OP) have a direct positive effect on sustainable urban transport (SUT).

4.2 Theoretical Implications

This research effectively addressed the demand for a specialized model that defines the factors influencing sustainable urban transport (SUT) as mediated by the transport systems (infrastructure (INF), vehicles (V) and operations (OP)). This paradigm is missing from the present corpus of theoretical literature. The research uses the RBV, which presently lacks the concrete model which explains the relationships of the transport systems towards achieving sustainable urban transport (SUT). Figure 6 depicts a validated model for understanding the determinants of sustainable urban transport (SUT).

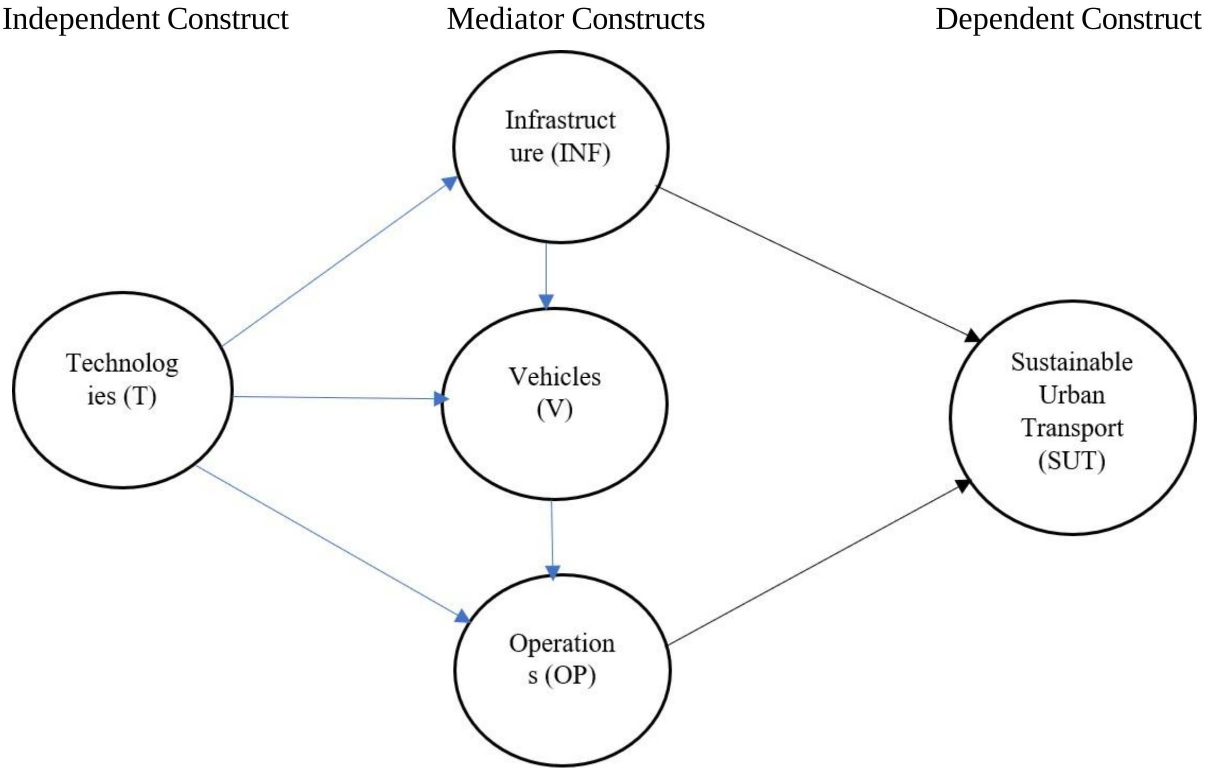

Figure 6: Validated Model for Determinants of Sustainable Urban Transport.
Key
→ Constructs and relationships which exist in literature
→ Theoretical and empirical contribution

4.3 Practical Implications

The validated model in Figure 6 shows that infrastructure (INF), vehicles (V) and operations (OP) have mediating effects on the relationship between technologies (T) and sustainable urban transport (SUT). These findings indicate that transport systems are critical to increasing sustainable urban transport (SUT). Likewise, the statistical standing of technologies (T) in indirect affects indicates that infrastructure (INF), vehicles (V) and operations (OP) always depend on technologies (T) adopted to ensure sustainability in urban transport. City planners and the Government should consider the technologies to be adopted and the transport systems to be used during planning and implementation of a sustainable urban transport (SUT).

4.4 Conclusions

The results shown in Figure 5 provide solid evidence that supports the perfection of the study model proposed in the context of decision-making, especially in terms of prioritizing the adoption of technologies (T) and improving the operations (OP) for sustainable urban transport (SUT).

4.5 Limitation and Recommendation for Future Research

This study employed a restricted set of resources from RBV to anticipate the sustainability of urban transport. Figure 3 shows that the combination of technologies (T), infrastructure (INF), vehicles (V) and operations (OP) explained only 63.3% of the observed variance in sustainable urban transport (SUT). The current study proposes that future research should incorporate more resources such as cash, regulations, policies, knowledge and skills required in planning and implementing sustainable urban transport (SUT). This method should be used to increase the variance of sustainable urban transport (SUT) and to broaden the applicability of the validated model. Furthermore, this study only included Tanzanian participants from one city. Future study should include participants from several cities and nations to improve the validated model's generalizability in predicting the factors of sustainable urban transport (SUT).

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