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Investigating Rural Logistics and Transportation through the Lens of Quadruple Bottom Line Sustainability

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Abstract: *Background:* An alternative to unsustainable urban developments, rural living is on the rise, but it already has its challenges. To that end, rural logistics and transportation (RLT) calls for a comprehensive analysis of its context, especially in a climate-changed and socially turbulent world. Unlike urban logistics, there is limited focus on RLT in academic literature. However, rural areas' lack of transportation and limited logistics operations negatively affect rural residents' daily lives, especially socially disadvantaged groups such as older people, children, women, and low-income households. *Methods:* This study first identifies the key literature on RLT and sustainability using a systematic literature review. Then, it synthesizes from the extant literature the challenges in RLT and proposed solutions to understand how to improve accessibility and address some barriers to implementation, all through the perspective of quadruple bottom line (QBL) sustainability pillars. *Results:* The lack of opportunities presented to rural residents due to limited RLT leads to inequality between rural and urban populations, requiring academic attention. Moreover, despite the growing emphasis on sustainability in academic literature, there is a noticeable lack of attention to sustainability in RLT. *Conclusions:* This study leads policymakers toward a better understanding of rural communities' complexities, directs practitioners to adopt the QBL perspective in decision-making, and aims to stipulate innovative RLT topics for further research for academicians.

Keywords: rural logistics; transportation; sustainability; quadruple bottom line (QBL); accessibility; mobility; UN Sustainable Development Goals (SDGs); culture; equity

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1. Introduction

Transportation-related operations are crucial for people to access various services. These operations are concerned with the transportation of both freight and people. Freight transportation deals with delivering goods to businesses or households to meet the demand of the people living in that area. On the other hand, public transportation must provide affordable and safe transport options for passengers [1]. However, the lack of a proper public transport system may necessitate employing private vehicles, which may not be a willingly made decision by the users [2]. This case is mainly related to rural areas, which can be referred to as areas with less than 2500 residents and a population density of fewer than 500 individuals per square mile [3].

The low population size of rural areas results in low and dispersed demand and may hinder the effective operations of public transport [4] and logistics systems [5]. Limited transportation and logistics services in rural areas pose a challenge for the rural residents, affecting their daily lives. Children cannot access education; patients have difficulties accessing healthcare services, especially in emergencies [6]. Rural residents experience difficulties obtaining the commodities they need or demand. The number of jobs available in rural areas is also limited; thus, many rural residents are looking for jobs in the nearest

urban area that require long distances to travel [7]. Therefore, compared to its urban counterpart, limited resources are available in rural areas, resulting in rural residents experiencing inequality in many aspects of their lives and facing barriers to accessing essential services as fewer resources exist. Based on extant literature, this paper investigates rural logistics and transportation (RLT) through the lens of sustainability. In this context, logistics implies transporting and inventorying goods, whereas transportation refers to public transportation.

Rural logistics covers transportation, distribution, material handling, storage and packaging of goods, and the flow of information. It includes transporting agricultural products from and delivering commercial products to rural areas [8]. Especially after COVID-19, contemporary customers tend to order commercial products online instead of visiting a store [9]. In addition, given the limited local product options, online shopping has become a preferred option for rural residents when companies can offer delivery services to their areas. However, the faster development of urban logistics in response to high demand and available resources has widened the economic and social gap between urban and rural areas [10]. Therefore, addressing the needs of rural logistics is essential for promoting equity between urban and rural populations.

In the rural transportation literature, accessibility and mobility are two similar terms that are exhaustively studied. Accessibility is defined as "the extent to which land-use and transport systems enable (groups of) individuals to reach activities or destinations employing a (combination of) transport mode(s)" [11]. Access to essential services such as healthcare, education, amenities, and employment opportunities is vital for people's quality of life, community development, and social inclusion. Therefore, accessibility plays a crucial role in sustainable development. Similarly, mobility is related to people's ability to move from one place to another and their transportation options. Transport-related inequity is highly concerned with mobility, and lack of mobility influences people's social well-being [12]. Especially in rural areas, the transport supply still needs to meet the demand for individuals' mobility needs [13]. Hence, improving the transport system can enhance the accessibility and mobility of rural residents.

A poor public transport system forces individuals to use private cars [2]. However, dependence on private cars is not only a result of limited public transportation but is also a cause of it [1]. As the number of people using private cars increases, the demand for public transportation will become even smaller. In the absence of adequate demand, public transport operations will lessen or even be canceled. On the other hand, the increasing use of private cars causes inefficiency, congestion, higher greenhouse gas (GHG) emissions, and air pollution. It also creates inequality since not all individuals can afford to drive a car. Some examples are socially disadvantaged groups such as older people, children, women, and low-income households [12]. Therefore, poor transportation and high car dependency are serious issues influencing environmental, social, economic, and cultural sustainability, the quadruple bottom line (QBL) pillars.

The literature is limited in its focus on RLT and its sustainability aspects. In contrast, more studies focus on different QBL pillars of sustainability in urban transportation, such as Lu et al. [14], Labarthe et al. [15], and Ecer et al. [16]. Based on extant literature and through the lenses of QBL sustainability aspects, this study aims to identify the main challenges of RLT and pointers to some solutions. Furthermore, the barriers to implementing these solutions, which can provide valuable insights for researchers and practitioners, are discussed. Also addressed is the need to focus on four QBL aspects while studying RLT and developing solutions that consider the needs and characteristics of the communities. Therefore, this study aims to investigate from a sustainability perspective what challenges, barriers, and solutions in RLT exist in the literature.

The layout of this paper is as follows: Section 2 explains the research framework and motivation of this study. Section 3 describes the research methodology. Section 4 explains the results of the analysis. Lastly, Section 5 concludes with remarks and future research venues.

2. Research Framework and Motivation

This study utilizes QBL sustainability pillars to analyze the suggested solutions in RLT literature because for a solution to be applicable and sustainable, it should successfully consider all four sustainability pillars of QBL. As illustrated in Figure 1, these pillars are economic, social, environmental, and cultural, also known as the four Ps: profit, people, planet, and purpose [17]. QBL introduces culture as a fourth pillar to the commonly used triple bottom line (TBL) approach. The TBL perspective does not adequately consider community engagement and the community's cultural values. However, acknowledging culture is crucial for sustainable and applicable solutions in rural areas. Proposals made without regarding culture and community engagement can be ineffective for some communities as the community's cultural values and ideas can affect the acceptance of the solution within the community.

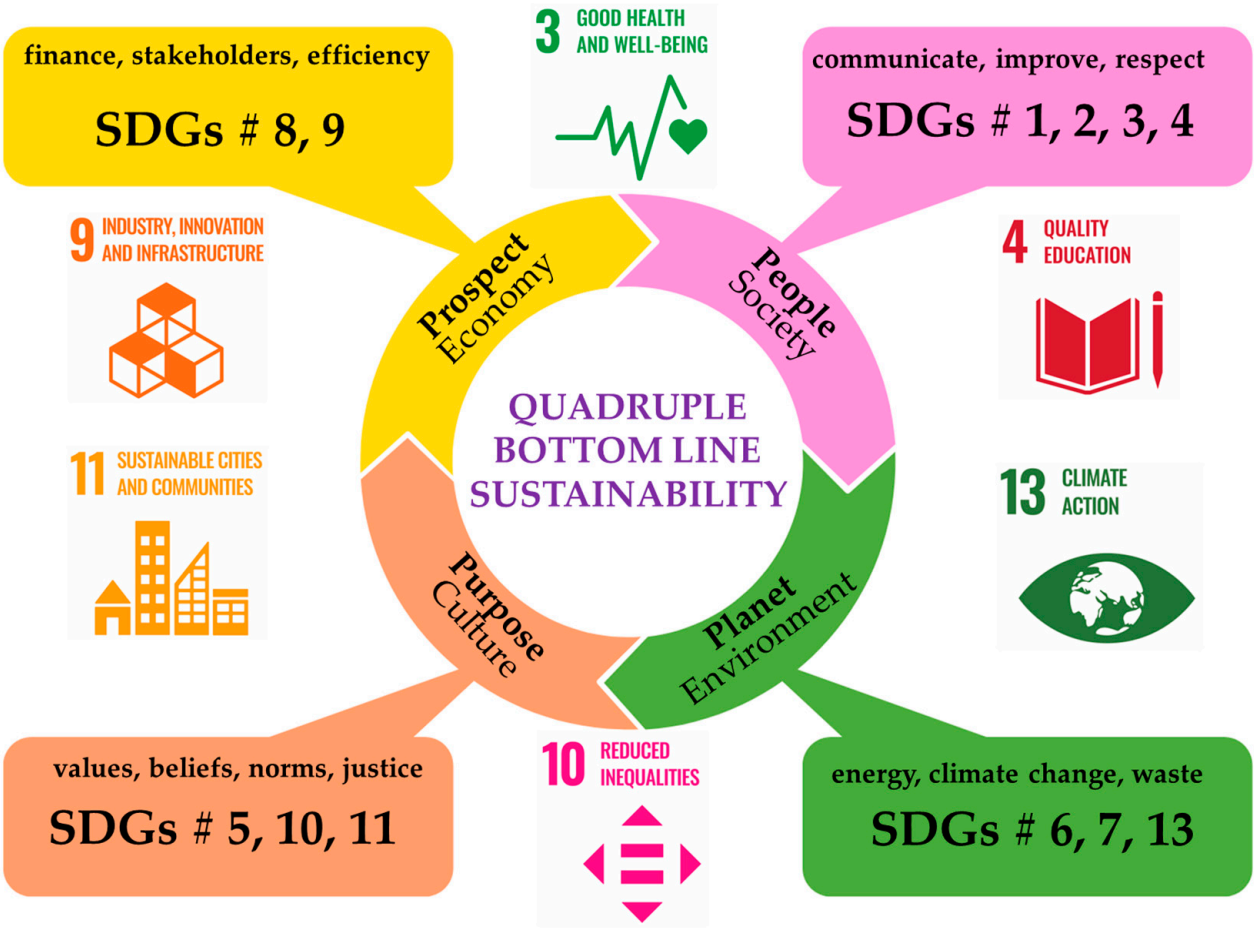

Figure 1. The quadruple bottom line (QBL) sustainability pillars.

On the other hand, applying these proposals may damage the communities' identity. Therefore, considering culture by acknowledging these rural communities' unique beliefs, values, norms, and identities is vital while proposing a sustainable solution for RLT. According to the United Nations, cultural diversity is an indispensable asset in reducing poverty and sustainable development. UNESCO developed the Culture 2030 indicators to assess the contribution of culture to the 2030 Agenda for Sustainable Development [18]. An essential means to live a fulfilling intellectual, emotional, moral, and spiritual life, culture requires meaningful community engagement. The inclusion of culture in the QBL addresses a limitation of the TBL by focusing on the differences between community identities and traditional value systems that influence how they engage with RLT.

Besides culture, evaluation of the RLT solutions in terms of society, environment, and economy is equally important. Rural residents are experiencing inequality in various aspects of their lives, and a lack of a sustainable RLT system is an essential reason. Therefore, a sustainable solution for RLT should aim to improve people's lives to ensure it is socially sustainable. Furthermore, RLT is highly concerned with energy consumption and climate change due to the usage of fossil fuels in conventional vehicles. Lastly, a proposed solution must be economically sustainable. Because rural areas may receive a scarce budget, the RLT solutions should be cost-efficient. Hence, analysis of the RLT in the context of QBL is pivotal to ensure long-term sustainable solutions.

The transportation of freight and people in rural areas is related to more than half of the United Nations Sustainable Development Goals (UNSDGs; SDGs, hereafter). In 2015, all United Nations Member States adopted the 2030 Agenda for Sustainable Development, containing 17 SDGs. These goals charted an urgent call for action for developed and developing countries. Various challenges that humankind faces were considered in formulating these goals, including poverty, food security, access to essential services, inequality, clean energy, and climate change. The aim is to accomplish these 17 goals by 2030 to ensure a sustainable, equitable, and better future [19].

Even though there does not appear to be a particular SDG target for rural access, there are strong connections between RLT and the SDGs [20]. The implementation of safe, affordable, and sustainable RLT can significantly contribute to the attainment of several (12 among 17) SDGs, which are #1 No poverty, #2 Zero hunger, #3 Good health and well-being, #4 Quality education, #5 Gender equality, #6 Clean water and sanitation, #7 Affordable and clean energy, #8 Decent work and economic growth, #9 Industry, innovation, and infrastructure, #10 Reduced inequalities, #11 Sustainable cities and communities, and #13 Climate action.

Certain SDGs can be related to more than one QBL aspect because these goals are complex, and the QBL pillars are linked. For example, SDG #6 (Clean water and sanitation) directly relates to the environment. However, its impact on the environment affects humankind, which is related to society and, after all, the economy [21]. As shown in Figure 1, each of the twelve SDGs is linked to RLT with an essential QBL sustainability pillar.

Sustainable logistics and transportation operations should support the SDGs [22], and they are concerned with all four pillars of sustainability, as exhibited in Figure 1. Considering the 12 SDGs determined among 17, three goals contribute to the environment. The most evident is the lack of sustainable rural transportation, leading to a high dependence on private motorized vehicles. This results in GHG emissions and pollution, ultimately contributing to climate change, which seriously concerns humankind. This underscores the critical role of the environment as the foundation of societal existence and the far-reaching impact of environmental shifts on society (c.f., [23]).

Improvements in RLT can have multifaceted benefits for society. For instance, facilitating the logistics of market products and agricultural goods to rural areas can reduce costs. Furthermore, rural farmers face difficulties accessing resources, machinery, and equipment. Ensuring sustainable RLT will enable agricultural production, thereby contributing to the goals of poverty reduction and hunger alleviation. It will reduce crop waste, enhance production, improve food security, and promote rural employment [20]. Additionally, access to health services and quality education is a challenge for rural residents due to limited transportation opportunities, which causes poverty and social exclusion. Therefore, better RLT can create better prospects for individuals in rural communities by providing access to such services.

Society's activities form the economy, and culture sustains societal well-being and economic welfare [21]. Limited RLT and infrastructure hinder the economic growth of rural communities. The poor RLT operations and infrastructure affect firms operating in rural areas or planning to enter this market. Moreover, individuals face difficulties due to the lack of job opportunities in rural regions. Hence, people living in rural areas are exposed to inequalities in several areas of their lives, facing challenges due to a lack of opportunities

compared to urban citizens. Addressing RLT-related challenges is crucial in reducing these inequalities and fostering the development of sustainable rural communities.

The development of the SDGs and the Culture 2030 framework [24] demonstrates the importance of sustainability and the inclusion of culture to achieve the 2030 goals. These are global goals that apply to both urban and rural settings, and their accomplishment through sustainable solutions will bear positive results. Moreover, sustainable RLT solutions are a critical step in achieving several SDGs. Considering the significance of each QBL sustainability pillar, it is critical to analyze the proposed solutions in the RLT literature within the QBL framework.

This research is motivated first by conducting a high-level keyword search in Scopus, a widely recognized academic database, to observe the trends in RLT. The keywords "rural logistics" and "rural transportation", along with their synonyms, were searched, and then the keyword "sustainability" was added to discern its use in the RLT literature. The English peer-reviewed articles published between 2004 and 2023 were included and analyzed over four-year periods. As depicted in Figure 2, the results of this search serve as the foundation for this research, highlighting the use of these keywords anywhere in the text in the articles published in the last two decades.

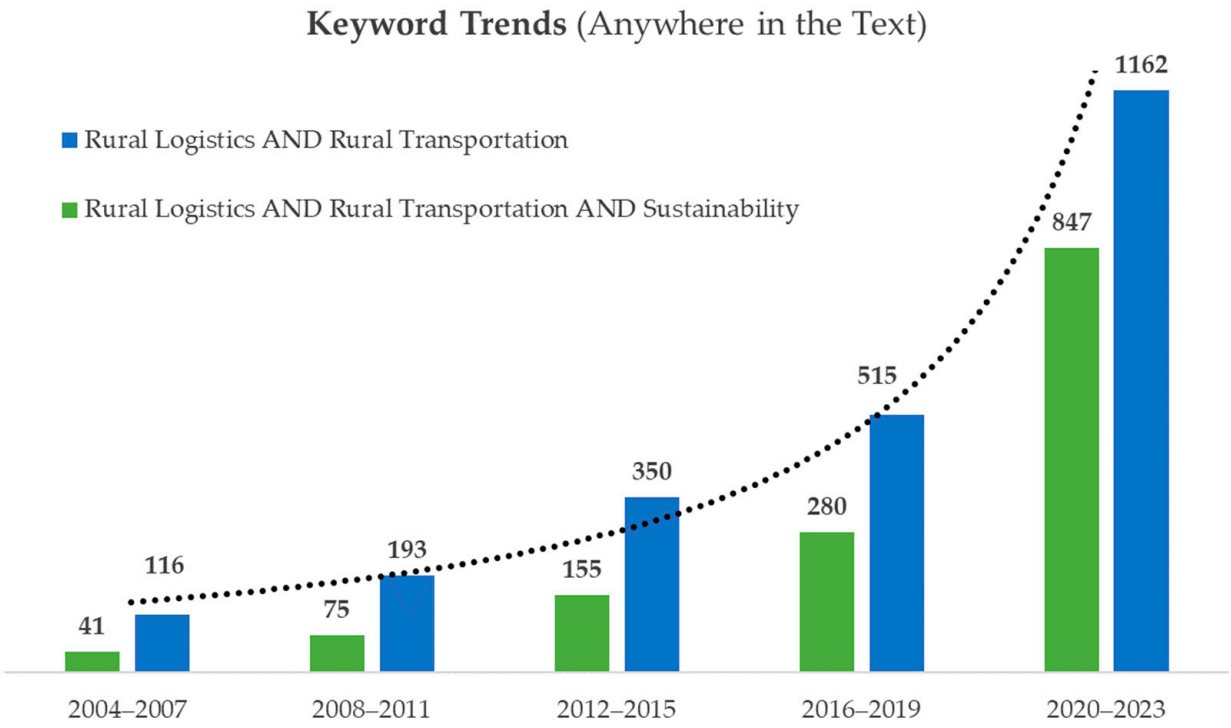

Figure 2. Keyword trends anywhere in the text between 2004 and 2023.

Figure 2 presents a compelling narrative of the evolving RLT literature: there is an upward trend in the appearance of the keywords "rural logistics", "rural transportation", and "sustainability". The studies with the keywords rural logistics and rural transportation doubled from 2016–2019 to 2020–2023. In the same period, studies containing the keyword sustainability within the RLT literature quadrupled. In 2020–2023, almost 73% of the articles containing rural logistics and transportation keywords also contained "sustainability" in their text. This ratio was around 54% in 2016–2019 and 44% in the prior period, showing that more papers refer to sustainability in their text every passing period. To have a more focused viewpoint, Figure 3 demonstrates the use of these keywords in title, abstract, and keywords, providing a more detailed breakdown of their distribution.

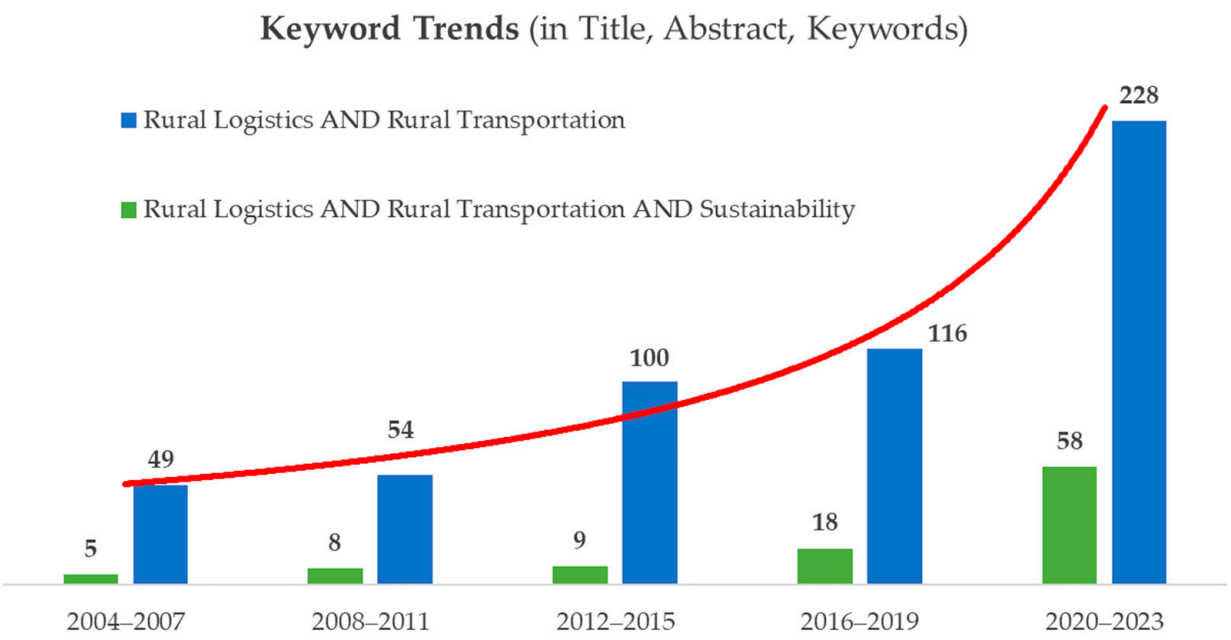

Figure 3. Keyword trends title, abstract, and keywords during 2004–2023.

As shown in Figure 3, the keywords "rural logistics" and "rural transportation" again illustrate an upward trend. Different from Figure 2, the appearance of the keyword sustainability was almost stable until the end of the 2012–2015 period. From there, it started to increase. The development of SDGs in 2015 may have an impact on this increase. Despite an upward trend, one can perceive that the number of studies with the keywords rural logistics and rural transportation is limited and that the ones possibly having a sustainability perspective are even fewer. In 2020–2023, only 25% of the articles containing rural logistics and rural transportation keywords also contained "sustainability" in their title, abstract, or keywords. Compared to Figure 2, a significantly lower percentage indicates that although the word sustainability can appear in the study, researchers are only referring to it rather than focusing on it in the RLT literature.

This study identifies scholarly works focusing on sustainability in the RLT context to analyze their viewpoints and highlight the need for more attention. Poltimäe et al. [25] examined sustainable mobility solutions in rural areas using grey literature, and they studied the social, environmental, and economic aspects, not the cultural ones. To the best of the authors' knowledge, no systematic literature review from a sustainability perspective examines the perils and solutions in RLT with the QBL pillars, and hence, this study.

3. Methodology

The research on hand deployed a systematic literature review outlined by Tranfield et al. [26] to review the extant RLT literature. It followed the three stages: planning, conducting, and reporting, as illustrated in Figure 4.

Planning the review: In this initial stage, the research questions were framed which are not just academic inquiries but hold the key to understanding and addressing real-world issues:

- What are the main challenges in RLT?
- What solutions exist for sustainable logistics operations and transportation?
- What are the barriers to the implementation of these solutions?
- Which QBL pillars pertinent to RLT are studied in the extant literature?

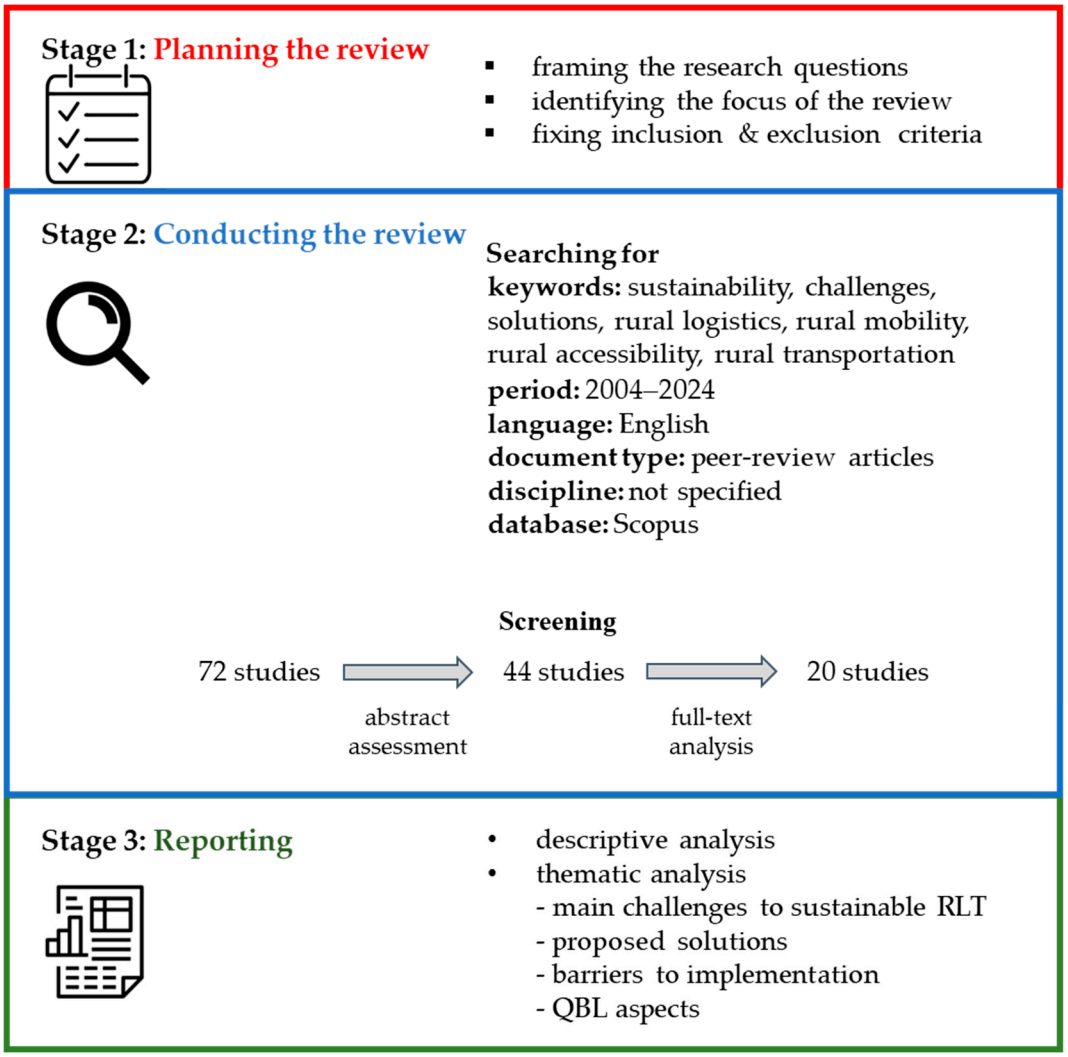

Figure 4. Review process.

In addressing these research questions, the literature review was scoped down to studies focusing on RLT with a sustainability perspective. No particular geographic region was selected as an inclusion/exclusion criterion to bring together diverse applications and generality.

Conducting the review: In this stage, the topical keywords were selected to find papers examining the challenges in RLT and potential solutions to these challenges from a sustainability perspective. Those keywords were "rural logistics", "rural transportation", "rural mobility", "rural accessibility", "sustainability", "challenges", and "solutions", accompanied by their synonyms using Boolean operators. For more relevant results, the search was conducted for articles containing these keywords in their title, abstract, or keywords in Scopus, a widely recognized and reputable literature database with comprehensive coverage and high-quality sources. The focus was on peer-reviewed papers published between 2004 and 2024. Only papers published in the English language were included. The scope was not narrowed down to any specific disciplines to ensure that no pertinent articles were missed, as there are already a limited number of studies in RLT.

Initially, the search yielded 72 papers. After two screening processes, the sample was finalized. In the first screening, the abstracts were meticulously examined to exclude those outside the scope of this study. Because "accessibility" and "mobility" are both interdisciplinary terms, the articles focused on health or physical activity were excluded, and those related to transportation and those whose link to sustainability were unclear

from the abstract were kept for further review. Thus, 44 articles were left after the abstract assessment. In the second screening, a full-text analysis of these articles was conducted to conclude the final set of articles. Following this comprehensive review, 24 articles were excluded due to their lack of focus on sustainability while proposing a solution for RLT and failure to reference at least two pillars of QBL. The study selection process was completed after this step, resulting in 20 papers (i.e., key articles) that were most pertinent and significant to this research.

Reporting: Based on those 20 key articles, the descriptive analysis shows that papers on sustainable RLT were mostly published after 2017. Considering the emergence of the SDGs in 2015 and the increasing interest in sustainability in the last years, this is as expected. The top three publishing countries among the selected papers are the United Kingdom, Germany, and China. Moreover, these articles are primarily written by social sciences, engineering, and environmental science scholars.

An in-depth reading of these key articles was utilized to address the research questions related to the main challenges to sustainable RLT, suggested solutions, and barriers to implementing sustainable RLT. Also discussed are which QBL pillars were studied in the literature and to what extent. Lastly, the research gaps and future avenues are investigated.

4. Results and Discussion

This section addresses the research questions (e.g., RQ1 to RQ4) in Sections 4.1–4.4, respectively. Based on extant literature, this study delineates the main challenges in RLT and proposed solutions and identifies the barriers to implementing these solutions through the lenses of QBL pillars.

4.1. Main Challenges to Sustainable RLT

This section presents the main challenges to sustainable RLT that were identified after having an in-depth reading of the key articles included in this study. Since a comprehensive review was conducted without limiting the literature to specific geographic regions, those key papers discuss RLT in several countries. Due to these countries' distinct cultures, development levels, and living and weather conditions, some unique challenges exist. However, the analysis herein shows that the significant challenges in RLT are similar in distinct regions of the globe despite these differences. Nevertheless, the magnitude of the challenge is dependent on the context of the specific region and its people and culture.

4.1.1. Low Population Density

Policymakers and practitioners encounter several challenges when planning for RLT, a trending topic in the literature. From the set of articles examined, the most frequently mentioned challenge is the low population density of rural areas (e.g., [2,27–29]). By definition, the population of rural areas is less than 500 individuals per square mile, according to [3]. The houses and other buildings are located far away from each other, leading to dispersed demand characteristics for freight and passenger transportation [30].

Rural areas have experienced demographic shifts in recent years, leading to additional challenges. Migration to urban areas has been increasing due to the lack of services and job opportunities in rural areas, resulting in a depopulation in these regions. Notably, the younger population is migrating to cities with more opportunities. Thus, the proportion of older people increases in rural areas, and the studies focusing on that group transpire. However, even though the older population relies more on public transportation, the demand remains insufficient. As a result of the scarce population, various services, including public transport and freight logistics, have experienced a loss in business due to an inadequate demand to financially maintain their operations [2].

4.1.2. Long Distances

Another major challenge is the long distances between rural areas and people's desired destinations [28,31]. These destinations include the essential needs of the residents, such as

hospitals, schools, and markets, or their needs to sustain a higher quality of life. The lack of accessibility to these locations and services can lead to social isolation and negatively impact individuals' social well-being [12]. Unfortunately, such services are often insufficient in rural areas, leading rural residents to rely on the nearest urban areas with more facilities, thereby requiring long distances to access necessary services.

In addition, the distance to the nearest public transport stop in rural areas is often longer compared to urban areas. This poses a problem for individuals, especially older people and those with mobility disabilities, as accessing public transportation becomes challenging if the distance is more than walking distance. Moreover, the need for transfers between buses to reach urban areas further complicates the use of public transportation. The distance to the closest transport stop and the number of required transfers make public transportation unappealing for rural residents. As a result, rural residents may favor using cars, as public transportation requires more physical effort in these situations [25].

4.1.3. High Distribution Costs

The combination of low demand in rural areas and long distances leads to high distribution costs, which challenges rural logistics [5,29,32]. More than half of the distribution cost is incurred in the last-mile delivery, which is higher in rural regions than in urban areas [5]. These costs significantly impact companies' operational decisions. Because companies may not find it justifiably profitable to provide logistics service offerings to rural areas due to high distribution costs, many companies prefer not to cater to demand from rural dwellers [5].

The literature primarily discusses freight logistics and the delivery of commercial products to rural communities through e-commerce platforms. Particularly after COVID-19, online shopping has become a more popular way of consumption as it is practical [32]. However, rural residents sometimes lack the option to shop online because companies either do not deliver to their locations due to high distribution costs or if they do, the shipment costs for the consumer are high. Similarly, the high logistics costs of agricultural products are affecting rural farmers. The costly delivery of products to consumers and price volatility in the market are negatively impacting farmers' income and profits [33].

4.1.4. Poor Infrastructure and Road Conditions

Poor infrastructure and road conditions are a significant obstacle for RLT [28,31]. In some rural areas, people often rely on walking or intermediate transport modes due to poorly maintained roads. The high costs associated with transport infrastructure and road maintenance further exacerbate this issue, with limited provincial budgets hindering essential investments in this area [31]. Poor road conditions pose a critical challenge for RLT, as it hampers the applicability of current resources and innovative solutions. Hence, the lack of attention and investment in transport infrastructure in rural areas is not just a challenge but a call for action.

These four challenges are the main reasons rural residents lack logistics and public transportation services, affecting their daily lives and quality of life. Due to the lack of public transportation modes, there is a heavy reliance on cars [2]. This dependency predominantly affects socially disadvantaged groups such as older individuals, women, children, and low-income groups [12,13]. Some members of these groups, such as children and some older people, may not be allowed to drive cars. Additionally, those in the low-income bracket may struggle to afford car purchases and maintenance. As a result, the absence or scarcity of sustainable RLT hinders equal opportunities. Furthermore, the high dependency on cars contributes to environmental concerns, as using motorized private vehicles leads to the emission of greenhouse gases and air pollution [7].

4.2. Suggested Solutions

The extant literature proposes some practical solutions to mitigate the perils of RLT, such as different transport modes and riding alternatives, policy recommendations, and

analytical solutions. These solutions were identified by analyzing the methodology section of the selected articles. Since solutions vary depending on the country in which they are intended to be applied, the publishing countries of those selected key articles were also included to provide more insights. This section presents the solutions and their relations to QBL aspects.

4.2.1. Demand-Responsive Transportation

Demand-responsive transportation (DRT) is a commonly proposed solution suggestion for low-demand areas such as rural areas (e.g., [27,29,34]). The concept of DRT has been used for decades with dial-a-ride systems where individuals call a local public transport provider to signal a demand. DRT lends itself as a good alternative for the tailored needs of specific groups, such as the older and people with impaired mobility [13]. This can improve the accessibility to services for these groups. As a solution that can be tailored to the needs of people, it can improve the social well-being and life quality of these people and contribute to social sustainability. It adjusts its route or schedule based on demand, charging per passenger rather than vehicle. In this regard, it could be viewed as a service positioned in between a taxi and a bus [34]. Based on the 20 key articles, DRT is proposed for rural areas in countries such as Germany and Italy.

DRT allows more flexible transportation regarding route and schedule as it operates according to the demand. The DRT system can operate with full flexibility, a door-to-door service, or through demand-oriented schedules [34]. More flexible systems are considered more suitable for smaller areas, while less flexible ones better suit larger communities. Therefore, the conditions of the settlement area of rural communities can affect the flexibility of the DRT. By considering these conditions and ensuring community engagement to learn the needs of the residents, the flexibility of the DRT system can be determined. Developing a solution by taking into account the conditions of rural communities can contribute to the acceptance of the solution in the community and promote cultural sustainability. Nevertheless, the DRT system is not designed to replace the public transportation system but to improve it by offering alternative transport modes and times [27].

Innovations in technology have made it possible to provide public transportation in new forms. The rural transportation literature examines DRT with different vehicle types using different technologies. Camacho Alcocer et al. [27] evaluated the use of electric vehicles (EVs) in DRT in rural areas. They discussed that it would improve the life quality of rural residents while reducing the pollutants, which is vital for sustainable mobility. Schlüter et al. [29] assessed the impact of combining DRT with autonomous vehicles (AVs), which do not require a human driver. Thus, replacing human drivers with autonomous systems can reduce operational costs, and automated DRT can improve the passengers' trip quality. In addition, automated DRT may reduce the number of vehicles and kilometers travelled, resulting in a smaller environmental footprint [29]. Thus, especially the use of EVs and AVs in DRT would improve environmental sustainability. Additionally, due to the reduction in operational costs and prices for the passengers, economic sustainability can be enhanced.

Walters et al. [35] proposed implementing connected, autonomous, and electric vehicles (CAEVs) to provide EVs with an autonomous driving function with wireless connectivity services in rural areas. DRT has a digital component where the customer requests the ride through a smartphone. Walters et al. [35] discussed that CAEVs could be applicable and beneficial in DRT due to the need for a connected device for the ride request (connectivity) while locating the user and calculating the efficient route (autonomy). Thus, CAEVs can be considered a sustainable solution [35,36]. Similarly, Camacho Alcocer et al. [27] argued that software and hardware solutions such as big data or artificial intelligence could improve the efficiency of EVs for DRT as well as the customer experience.

4.2.2. Rail Transit

Not all rural areas have the same conditions. Therefore, the differences in rural areas necessitate tailored solutions that are most practical for each community. For instance, light rail transit (LRT) may be a viable transportation solution in rural areas that are closer to and connected to larger urban areas. However, it may not be a cost-efficient option for more remote areas. Establishing an LRT system is a long-term project that requires substantial investment due to its high cost. Additionally, collaboration with the regional government and rail organization is necessary. Leveraging existing infrastructure, primarily used for rail freight, can help reduce costs. This solution is proposed to take place in the United Kingdom by considering the existing extensive railroad system, promising in terms of cultural sustainability. In the long run, an LRT system will connect the rural community to the closest urban area and also to surrounding suburban areas, increasing mobility [31]. LRT can enhance social sustainability by enabling rural residents to access services and new job opportunities in urban areas. Moreover, the high capacity of rail transport can enhance the flow of goods between rural and urban areas, improving people's access to the products they demand. The use of LRT can reduce the use of private cars as a high number of people can be carried; thus, beneficial for the environment and the economy.

4.2.3. Car-Sharing

Car-sharing systems can provide a more flexible and affordable alternative to more rurally locked areas. Unlike traditional ownership, where individuals bear the costs regardless of usage, car-sharing allows customers to pay based on the duration and distance they require a vehicle [31]. This economic flexibility enhances accessible transportation and makes it more cost-efficient for rural residents. Environmentally, the potential for reduced traffic and emissions due to shared vehicles can reduce communities' carbon footprint. Socially, car-sharing services cater to individuals who may be unable to afford or prefer not to own a motorized vehicle. Therefore, the availability of car-sharing services can positively impact rural communities by offering a more sustainable and cost-effective transportation option with the convenience of a private car [25].

4.2.4. Ride-Sharing

Based on the 20 selected articles, "ride-sharing" emerges as a potential solution for rural areas in several countries such as Germany, Finland, the United Kingdom, and Australia. In ride-sharing, passengers and drivers connect through an app to share a trip. Since the solution requires the use of an app, ride-sharing can be proposed in developed countries or where rural residents prefer using smartphones. On the other hand, in developing countries or where rural residents are not able to use mobile apps, ride-sharing may not be a culturally sustainable solution.

Ride-sharing offers semi-flexibility regarding route and schedule depending on the pick-up and drop-off locations and the driver's availability [25]. Eichholz [28] has proposed a co-created ride-sharing software solution called "ride-sharing benches" to enhance rural mobility. Ride-sharing benches, already in use in some parts of Germany, allow passengers to indicate their need for a ride by sitting on a bench, similar to hitchhiking. The placement of these benches is crucial for determining the direction of the trip, and passengers need to communicate with the driver for their exact desired location. Eichholz [28] has suggested integrating these benches with digital software so that both passing drivers and those in the vicinity can see ride requests, thereby improving efficiency. This can contribute to social, economic, and environmental sustainability. Rural passengers could travel to their destination by paying less and generating less carbon footprint because of a shared car. While the application of such digital solutions has been studied in urban settings, there is limited research on their use in rural areas. Hence, adopting such digital solutions in rural areas can be promising [28].

4.2.5. Electronic Bikes

Electronic bikes, or e-bikes, have an electrical motor to assist in pedaling and are considered a sustainable alternative mode of transportation [37]. In their study, Philips et al. [37] evaluated the use of e-bikes in rural areas such as national parks. Additionally, Dalkman et al. [31] noted that bike riding is traditional in China. Considering the traditional use of bikes among rural residents in China, it should be viewed as a culturally sustainable transport mode. E-bikes are a better alternative to traditional bikes in hilly areas and are more environmentally sustainable than private motorized cars, contributing to transport decarbonization in rural regions. However, there is a lack of research on e-bikes in rural areas compared to urban areas, indicating a gap in the literature [37].

4.2.6. Some Insights on Analytical Approaches

The literature on rural logistics has focused on addressing the high distribution costs associated with last-mile delivery in rural areas. Kou et al. [32] proposed a multimodal transport design explicitly targeting the last-mile delivery of e-commerce products to rural areas. Additionally, they developed a cost–benefit model that uses genetic algorithms. The study results indicated that multimodal transport can effectively reduce the high last-mile delivery costs in rural areas [32]. Wu et al. [5] also addressed the issue of high delivery costs in rural logistics by employing the vehicle routing problem. Their suggested solution involved making offline sales available in rural communities while couriers deliver products ordered online. By implementing this methodology in three rural communities in China and verifying their solutions with a case study, Wu et al. [5] aimed to maximize service providers' profit.

In the realm of rural transportation, Chen et al. [38] considered equity and cost factors for rural transportation management and utilized a multi-objective optimization problem for route design. Their study also involved the development of a heuristic to analyze design options, which, when applied to a non-profit organization, resulted in better resource utilization and an increase in the total population covered [38].

Unlike these articles, Xue et al. [30] considered transporting passengers and freight together, proposing a public transport and logistics integration model to improve urban-rural transport and last-mile distribution. They aimed to enhance sustainable rural development and address the profit loss of service providers and the potential closure of services. The recommended application is a front and rear structure where passengers are placed in the front part of the vehicle, and mail, small express, and agricultural products are transported in the rear area.

Based on the key articles, China is the leading country in publishing on rural logistics. This is an expected result considering its high rural population [39] and being the leading manufacturing country in the world [40]. The articles on rural logistics proposed analytical models as solutions to reduce the high costs associated with logistics operations, which is closely related to economic sustainability. Moreover, reducing operational costs may improve the delivery of goods to rural residents. This would contribute to social sustainability by improving rural residents' access to products. While the existing literature provides valuable insights into addressing rural logistics challenges, more empirical papers are needed that integrate public transport and logistics in rural areas, taking sustainability into account.

4.3. Barriers to Implementing Sustainable RLT

Even though the solutions proposed in Section 4.2 can be promising, they come with their salient challenges to implement. These barriers are identified by examining the discussion and limitation sections of the selected articles, which are then collected under each solution, illustrated in Table 1.

Table 1. Challenges to implementing proposed sustainable RLT solutions.

Proposed Sustainable RLT Solution	Challenges to Implementation
Demand-responsive transportation with innovative technologies	• Regulations and requirements • High technology costs • Cultural and economic constraints • Need for charging stations • Lack of knowledge and testing of connected, autonomous, and electric vehicles • Mistrust towards technology
Rail transit	• High infrastructure investment cost • Topological and climatic challenges
Car-sharing	• Availability of vehicles • Poor road or climatic conditions • Availability of qualified drivers
Ride-sharing	• Safety concerns • Economic and technical difficulties for ride-sharing benches
E-bikes	• Inadequacy for long distances • Traffic safety and poor bike-safe roads • Lack of weather-proofing infrastructure • Carrying capacity concerns

As the most commonly suggested solution, DRT may effectively address the lack of public transportation in rural areas. However, its implementation with innovative technologies for more sustainable transportation can be challenging due to the cultural and economic constraints of the rural communities at hand [41]. In any case, vehicles need to have adequate energy throughout the day, especially in the case of EVs, which require charging stations in multiple rural locations. Regulations and requirements for developing DRT with EVs could emerge as a barrier. The design of these EVs, such as minibuses, should ensure barrier-free transportation to older people and those with impairments to ensure that the solution is socially sustainable [27].

Similarly, CAEVs are also subject to regulations. The authorities may hesitate to employ CAEVs for DRT due to their insufficient knowledge of the technology [35] and its lack of real-world testing [36]. Since it is a relatively new and untested technology, mistrust of the technology, acceptance among society, and high technological costs can pose barriers to its real-life implementation, similar to various digital solutions. The cultural norms and values of the rural communities and their perspective on such digital solutions are important to ensure cultural sustainability.

Rail transit can be an affordable alternative transport mode for rural residents. However, it may not be financially viable for remote areas and would require significant investment to develop the necessary railway infrastructure. Building such infrastructure is a long-term project that demands substantial time and resources [31]. Specifically, building infrastructure for the rail system has a significantly high upfront cost. In such cases, the applicability of rail transit as a solution may not be economically sustainable, which acts as a barrier to its implementation. Additionally, geographical challenges, such as mountainous terrain, can further complicate railway infrastructure construction in some rural regions.

Limited car availability can be problematic in car-sharing, as it may result in some individuals being unable to find a ride [25]. Moreover, ride-sharing raises safety concerns about dealing with strangers and potential criminal activities in the shared vehicle. Economic and technical challenges may also hinder the implementation of "ride-sharing benches" [28].

Lastly, using bicycles and e-bikes can be a sustainable solution in some rural areas; however, it may be marred in some rural areas due to long distances, traffic safety, poor bike-safe roads, and lack of weather-proofing transport infrastructure, such as delays in snow removal [37].

4.4. QBL-Sustainability Aspects for RLT

According to QBL, the four pillars of sustainability are cultural, economic, environmental, and social imperatives. Table 2 displays how the selected articles, albeit weakly or strongly, relate to the QBL aspects. The selected articles' relation to QBL sustainability pillars is determined based on the full-text analysis. Among the studies with a sustainability perspective, social and economic sustainability are more frequently studied in the RLT literature, followed by environmental sustainability.

Next, the key articles identified and displayed in Table 2 are discussed concerning each dimension of the QBL pillar.

4.4.1. Culture in Sustainable RLT

Plausibly the most critical pillar of the QBL in the RLT context, culture is not well-studied in the literature: Only five of the 20 papers selected touched upon the cultural aspect of sustainability. However, cultural norms and values play a significant role in sustainable mobility. For instance, Dalkman et al. [31] stated that the Chinese people have a tradition of bike riding, and while implementing sustainable solutions, their traditions should not be neglected but sustained. Additionally, Mounce et al. [13] emphasized that community engagement enables a better understanding of the needs and values of the individuals in that community. Given the diversity of rural communities, different solutions might apply to different areas [31]. Therefore, understanding the communities' specific conditions, needs, and cultural values and accordingly tailoring solutions are necessary, and this can be achieved through community engagement. Therefore, the cultural pillar of the QBL requires more attention in the literature. Future research should focus on cultural sustainability in RLT to ensure that suggested solutions are applicable and effective.

4.4.2. Economy in Sustainable RLT

Studies discussed economic sustainability primarily in terms of efficiency and cost to users. Being heavily reliant on cars due to the scarcity of public transportation can be costly for individuals. As the most commonly proposed solution, DRT arguably reduces the economic costs of transportation as it can reduce individual car usage, high personnel costs, and the inefficiency of operating public transport in areas with limited demand [34]. It is evaluated as a cost-efficient solution for individuals in rural areas [29]. However, implementing technologies in DRT may require investment due to the high cost of technologies and the need for infrastructure [28].

Transport-related issues can also lead companies to avoid entering rural areas, reducing job opportunities for rural residents. Due to the lack of job opportunities, individuals in rural areas have to travel long distances to the nearest urban areas [7]. Furthermore, the condition of roads is crucial for the economic growth of rural areas, especially for farmers. Poor road conditions impact transportation and consumption expenses of agricultural products, leading to crop loss and reduced income for rural farmers [7]. Hence, infrastructure investment can contribute to rural areas' logistics performance [42] and economic growth [43]. High distribution costs also lead companies to withdraw their operations from rural areas. However, analytical solutions discussed in Section 4.2 can reduce distribution costs and make operating more efficient for the companies.

Table 2. Selected key articles related to QBL sustainability pillars.

Paper	QBL Sustainability Pillars			
	Culture	**Economy**	**Environment**	**Society**
Camacho Alcocer et al. [27]			✓	✓
Carroll et al. [2]	✓	✓	✓	✓
Chen et al. [38]		✓		✓
Dalkmann et al. [31]	✓	✓	✓	✓
Eichholz [28]	✓	✓	✓	✓
Hussain et al. [43]		✓	✓	✓
Jain et al. [7]		✓	✓	✓
Kou et al. [32]		✓	✓	
Mounce et al. [13]	✓	✓		✓
Philips et al. [37]			✓	✓
Poltimäe et al. [25]		✓	✓	✓
Schlüter et al. [29]		✓	✓	✓
Sinaga et al. [33]		✓	✓	✓
Sörensen et al. [34]		✓	✓	✓
Vitale Brovarone and Cotella [41]	✓	✓	✓	✓
Walters et al. [35]		✓	✓	✓
Walters et al. [36]		✓	✓	✓
Wu et al. [5]		✓		✓
Xue et al. [30]		✓	✓	✓
Zhao and Yu [12]		✓		✓

4.4.3. Environment in Sustainable RLT

The high rate of individual car usage is a significant issue in rural areas, causing damage to the environment in various ways. Consequently, most of the literature on RLT studied environmental sustainability by reducing emissions, traffic, fuel consumption, and air pollution. Proposed solutions such as DRT, rail transit, and ride-sharing can mitigate the environmental impact of private vehicles by enabling more people to travel with fewer cars and reducing traffic, congestion, and emissions [2,29,34]. Innovative solutions like electric vehicles (EVs) can further decrease emissions and fuel consumption.

In situations where biking is feasible, such as in national parks, e-bikes can serve as an alternative to motorized vehicles, helping to decarbonize rural transportation and promote environmental sustainability. Additionally, they offer personal benefits by encouraging physical activity, thus enhancing individuals' quality of life [37]. Similarly, reducing air pollution and traffic congestion can positively impact people's well-being, which is also related to social sustainability. Besides the practical solutions, suggested analytical solutions also contribute to a healthier environment by reducing the carbon emissions from motorized vehicles.

4.4.4. Society in Sustainable RLT

From the social sustainability perspective, rural residents do not have equal opportunities to access services compared to urban residents. The main issue regarding rural transportation is the deficiency of public transportation and its alternatives, leading to high car dependency. This mainly affects socially disadvantaged groups who cannot afford or drive a car [12]. Those without access to a private vehicle face additional challenges while sustaining their daily lives and accessing essential services such as education and

healthcare. Thus, alternatives to public transportation exist, as discussed in Section 4.2, to reduce social barriers and provide equal opportunities to those in need.

Regarding rural logistics, as argued, many companies do not include rural areas in their operations due to high distribution costs [5], hindering rural communities' access to these services and products. Rural residents face difficulties in accessing certain products and are limited to the options available in their community, giving them fewer choices than urban citizens. These issues with RLT may adversely affect individuals' well-being and result in social isolation [12]. Therefore, solutions to these problems can improve the quality of life of individuals living in these areas.

5. Concluding Remarks and Future Research Venues

This study, drawing upon a review of extant literature, shows that the main challenges in RLT are low population density, long distances, high distribution costs, poor road conditions, and poor infrastructure. These cause a lack of public transportation and limited logistics operations in rural areas, preventing rural residents from having equal opportunities for accessibility and mobility with people in urban areas. To eliminate such inequality and create a more accessible environment for rural residents, a search for sustainable RLT solutions is necessary. However, limited studies focus on transportation operations in a rural context compared to their urban counterpart. Even fewer studies are considering sustainability in the rural context. Therefore, there is a need for studies on RLT with a sustainability focus since sustainable development is crucial not only for urban areas but also for rural areas.

The RLT issues are also related to the accomplishment of the SDGs. People in rural regions encounter significant accessibility challenges and are searching for sustainable solutions. To that end, innovative and digitalized solutions for RLT may help increase people's accessibility to services and improve their quality of life. However, most technologies are conceptualized in urban areas. Some of these solutions, like EVs and AVs, have already been implemented in urban regions. However, the accessibility to EV charging stations remains a challenge for rural, more so than urban, areas. Even though the results of the studies in an urban context illustrate more sustainable transportation compared to the current transportation system, they cannot be transferred to rural areas directly due to the cultural, economic, and geographical differences between these areas. Even in different rural areas, these conditions differ. The analysis of the RLT literature based on the selected papers showed that most of these articles studied the social, environmental, and economic pillars of QBL. However, there is a lack of studies that consider cultural sustainability while proposing a transportation solution for rural communities. Hence, cultural sustainability warrants further investigation, which is a significant gap in the RLT literature. Future studies need to evaluate the applicability of innovative and sustainable solutions in some rural regions, considering the community's culture and the potential impacts of the proposed solution on the people's cultural values. For a solution to be culturally sustainable, it should not conflict with the community's characteristics.

The classification of rural areas varies in the literature depending on the criteria they use. Therefore, a solution applicable to one rural area might not apply to another. For instance, using bikes can be considered a sustainable transportation alternative in cities and some rural areas, such as national parks. However, it might not apply to rural areas with infrastructure issues, high hills, or wildlife. Hence, the transportation modes should be selected and, if necessary, modified considering the specific conditions of the areas. The conditions to evaluate while planning for transportation in these areas can be related to the area's demographics, the community's cultural values, and the natural environment. More inclusive transport policies are needed in rural areas. Hence, this study determines the challenges practitioners and policymakers can encounter while planning for rural transportation and informs them about the possible solutions and barriers to implementing them. Practitioners and policymakers are encouraged to pay attention to these findings, consider the communities' specific needs, and incorporate cultural,

economic, environmental, and social characteristics while planning rural transportation. As emphasized in this study, these authorities should collectively take into account the four QBL aspects to ensure that the solutions to RLT are sustainable.

This study also has further theoretical contributions. The main challenges faced in RLT, suggested solutions in the literature, and barriers to implementation were exposed. These results can guide the researchers who intend to propose a solution for RLT with a sustainability focus. The analysis shows a need for more empirical studies focusing on sustainable solutions for RLT. Passenger and freight transportation integration implies simultaneously carrying people and goods on the same vehicle with dedicated capacities for each. Considering that public transport vehicles are not too occupied in rural areas compared to urban, utilizing the free space in the vehicle for freight transport can be a resource-efficient solution. This requires an optimization approach as it concerns the route, schedule, and capacity allocation of freight and passengers. Therefore, future studies can focus on integrated transportation in rural areas as a potential solution by adopting an analytical approach.

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