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The Role of Demand-Responsive Transport Systems in Sustainable Urban Mobility: A Systematic Literature Review and Stakeholder Analysis †

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Abstract: On-demand transportation, such as demand-responsive public transit (DRT), is gaining prominence as a mobility service tailored to passengers' needs, offering flexibility in routes, pick-up/drop-off locations, and timing. This study aims to delve into the challenges and technological advancements within the DRT system, focusing on its application and effectiveness in various European Union states. The research first applied a systematic literature review using the PRISMA methodology with a PEO framework. Then, the research aims to provide information on how demand-responsive transportation operates in Central Eastern European countries by collecting and analyzing the characteristics of DRT service processes with a business process modeling approach. The findings aim to inform policymakers and stakeholders about the effectiveness and potential of DRT systems, facilitating informed decision making and policy formulation.

Keywords: on-demand transportation; demand-responsive transportation; urban mobility; systematic literature review; stakeholder analysis

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1. Introduction

According to the United Nations, nowadays, more than 50% of the world's population lives in cities and even the urban areas will be projected to account for 60% of the global population by 2030 [1]. The role of demand-responsive transport (DRT) systems is important in sustainable urban mobility because they offer flexible, efficient transportation solutions that adapt to real-time passenger demand. DRT systems optimize routes and vehicle usage, reducing empty rides and lowering emissions. By complementing traditional public transport, they improve accessibility and convenience, decrease traffic congestion, and support the shift away from private car use. This leads to more sustainable urban mobility, enhancing the overall efficiency and environmental friendliness of urban transportation networks.

The growing population along with urban growth will certainly trigger increasing mobility demands. Therefore, access to transportation in urban development is essential. Unfortunately, the mobility increment leads to traffic congestion and environmental issues due to gas emissions, especially with the tendency of using a personal vehicle, which contributes considerably to approximately 40% of all CO_2 emissions and 70% of pollutants in urban areas [2]. In contrast, public services such as subways [3], bus rapid transit [4], intercity railways [5], and light trail [6] are firmly expected to decrease pollution like $PM_{2.5}$, SO_2, NO_2, Co, and NO, but the service is not preferable because of the lack of space and comfort, less control of travel duration and time, less convenient [7], and low level of service [8]. The problems with public transit service may be solved by the implementation of digitalization, for instance, the application of a transport-sharing system, digital and

smart mobility services, provision of information on the accessibility of connectable means of transport, and provision of uncommon travel hours and accessibility. The location and accessibility of public transport are highly important [9], especially for those who are old and with disabilities. DRT system implementation brings high potential benefits to mobility development, both in rural areas and urban areas. However, it obviously faces challenges to perform effective and efficient on-demand transportation. The main challenge is to ensure the DRT system works efficiently and effectively, while being easy to operate by the passenger as it is usually perceived as a slow and inefficient way of transport. Moreover, there are several barriers and challenges of DRT application, including technical and management barriers, awareness raising, information dissemination, and regulatory challenges. Experience suggests that the strong connection and coordination between stakeholders play a significant role in the success of DRT implementation [10].

This research aims to present the problems encountered by the provider, the main technologies within the system, and the possible improvements or innovation opportunities through a systematic literature review (SLR) and the identification of the essential stakeholders, with their primary responsibilities by collecting and analyzing the characteristics of DRT service processes with a business process modeling approach in Central–Eastern European Union countries.

2. Materials and Methods

This study is established with two primary goals. The first objective is to identify various challenges and opportunities faced by DRT services with the help of a systematic literature review using the Scopus database. The second objective of the research aims to review and analyze demand-responsive transportation systems established across European Union countries. The PRISMA methodology (preferred reporting items for systematic reviews and meta-analyses), combined with the PEO framework (population, exposure, and outcome), enhances systematic literature reviews by providing a structured and transparent approach to selecting and categorizing studies based on population, exposure, and outcome. This ensures the inclusion of relevant studies, leading to more targeted and reliable results. Collected data from the literature review process were not strictly limited to the specific period and status of DRT application; both finished projects or currently operating systems and long-term or short-period applications were included within the analysis. In addition, there was no specific time window requirement for data inclusion to provide more information about DRT system implementation and development in Europe. The topics focus on how different DRT systems operate in Europe, who the essential stakeholders are, and the business process chart of DRT system. Business process modeling (BPM) was applied to provide a visual representation of work processes in an organization to identify efficiencies and areas for improvement. It helps simplify processes, optimize performance, and align operations with organizational objectives.

3. Results and Discussions

3.1. Problems, Implemented Technologies, and Innovation Opportunities

Initially, 914 articles were collected from the Scopus database. Using the first criterion, open access, 643 documents were removed, leaving 271. Eight non-English-language studies were then excluded. A preliminary analysis of the abstracts was performed to determine the relevance of the research question to avoid unnecessary reading. Thus, 96 articles remained for further content analysis. The 96 collected articles were categorized according to publication year and type. Between 2004 and 2016, the number of selected articles was relatively low, between 1 and 5 per year. After that, it showed an upward trend, reaching 24 articles in 2021. The majority of articles were published in journals (77), followed by conference proceedings (18), and only one book chapter. The most productive source was *Transportation Research Procedia* with nine conference articles, followed by *Transportation Research Part C: Emerging Technologies* with eight journal articles and *Research in Transportation Business and Management* with six journal articles.

3.2. Demand-Responsive Transportation Problems

Bus Scheduling: Four papers, from 2012 to 2022, focus on bus scheduling with real-time customer insertion [11,12]. This approach improves system efficiency by allowing new passengers to board without significantly delaying existing passengers, optimizing occupancy and reducing travel distances. Research [13] investigated the integration of bypasses into fixed route services, highlighting the need for time windows at fixed stops to manage timetable effects.

Fleet Sizing: Four studies discuss fleet size optimization for DRT services with the latest topic being in 2021 and the oldest in 2019. The topic was dominated by the determination of vehicle numbers in unknown and varied demand levels, as analyzed by [14,15]. The other topic considered the combination of classical transit and DRT services studied by [16] and the minimum passenger level by which to run the vehicle [17].

Pricing: Customized delivery usually costs more than traditional solutions due to the special service. Finding the optimal tariff policy is challenging, but crucial for competitiveness. The researchers emphasize fairness for all parties, as the DRT service must meet the various expectations of passengers. If passengers feel that the system is not worth the cost, taking into account factors such as time spent in the vehicle and walking time, they will not use it in the future.

Routing problem: Studies between 2010 and 2022 focused on the dialing problem, especially time window and fleet size [18–21]. After 2014, research turned to dynamic routing, which includes real-time traffic, vehicle status, and dynamic demand [22–24]. Among the innovations was horizontal cooperation between transport organizers, which provides insight into the benefits of cooperation. Recent studies have also emphasized environmental aspects, which are key to promoting sustainability in demand-responsive transport.

Defining Possible Market: Almost all of the research, conducted by [25–28], attempted to discover and understand user requirements or preferences for transport services. Thus, according to that information, the authors could define the essential operational attributes and system design of flexible mobility before achieving a successful introduction and sustainable service operation. In order to gather information from passengers, surveys and focus group discussion methods were the widely used approach.

DRT Assessment—User Satisfaction: According to the collected articles, topics were discovered not only about user satisfaction with the service but also about the relation between their perception of the service with their demographic characteristics. Therefore, the researchers could better understand several reasons behind their opinion and avoid research bias. Interesting to mention is that all of the research was conducted with the use of questionnaire surveys.

DRT Assessment—System Evaluation (performance evaluation): Most of the studies initially proposed an assessment framework for DRT service evaluation, either through a model framework or simulation framework, which was followed by a case study, conducted by [29–32]. One study by [33] only conducted an analysis of system performance. According to the collected studies, the simulation scheme became the most used method, followed by the exploratory study, which was mainly used for the assessment setting.

Transition from traditional services to DRT: While DRT offers benefits, stakeholders should recognize that it is not always the ideal solution. Timing and circumstances are crucial for implementation. Research shows that two studies focus on the transition from traditional services to flexible systems, especially for first-/last-mile and feed-in services [34,35]. In addition, the exploration of flexible service options at certain times, such as off-peak hours and weekends [36], is noteworthy.

3.3. Implemented Technologies and Opportunities in DRT

The concept of autonomous vehicles in the DRT was proposed in 2017, but was not reviewed in the following years. Technologies implemented mainly include real-time information systems such as telematics, ZigBee communication, and smartphones to enhance information flow in DRT systems. Despite the need for advanced technology,

few articles address this topic. Two articles addressed integration into micro-mobility transit (bike sharing and scooters), and two others focused on integrating DRT into fixed transit systems for first- or last-mile transit. Two studies examined the potential for flexible transportation systems using autonomous vehicles: one proposed human-driven convoys of passenger-carrying trailers and the other proposed autonomous flexible buses. More research is needed on autonomous vehicles in DRT to ensure operability and sustainability to address fundamental stages and potential challenges.

3.4. Benchmarking Analysis of DRT Services in European Countries

This study summarizes DRT applications in the European Union, examining 33 implementations. Information was scarce for some countries. Of the applications, 14 used dynamic systems, 12 semi-dynamic, and 8 fixed-on-demand. Fixed-on-demand is least adopted, as it requires a fixed route that is unsuitable for sparsely populated areas but may fit where existing routes need extension. Dynamic and semi-dynamic systems are better for sparsely populated areas, accommodating many-to-many or many-to-few service requests. Challenges include defining bus stop locations and routing policies to minimize travel time and distance. DRT services mainly target multi-user groups, serving specific groups like the elderly or people with disabilities, alongside the general public. This ensures inclusivity, particularly for those needing access to hospitals or mobility support.

3.5. Stakeholders Analysis

In this section, this study presents several parties taking part in the provision of DRT services, including their primary responsibilities and rights. In general, the service consists of four major stakeholder groups, including the following:

Transport organization: The transport organization is the party to design the transportation scheme within the region, with extensive coordination with the government. In detail, they need to define the service area, bus stops, possible routes, operating vehicles, fare and ticketing system, and operator selection. Usually, they manage not just one means of transit service but several forms of public transportation such as buses, metros, and trams. Under the organization, usually there is a dispatcher who has to communicate with the user and driver regarding the trip information.

Transport operator: The transport operator is the stakeholder responsible for possessing the vehicles and operating the daily mobility service according to the designed system by the organizer. In detail, they are also required to perform maintenance activities for the fleets and driver training. Commonly, the driver is the employee of the transport operator.

The user: The user is the party who obtains a benefit from the service after submitting a travel request to the service management. The users are required to complete the registration process and travel booking. Also, they have the right to obtain assistance while boarding, bring their personal equipment or pets, and make a complaint.

The government: The government usually contributes to the general provision of a legal framework, unification of fares, and generic design of the transportation service. In the case of not-for-profit services, the government is the one who technically considers the detailed application area and bus stops, while in the case of for-profit service, the government commonly provides a general design of the transit service and lets the transport organizer design in detail after their approval

4. Conclusions

This study focuses on two main aspects of on-demand delivery. First, it examines the challenges of on-demand delivery, including specific issues, technologies used, and opportunities to improve operations. Second, it compares DRT service operations across European Union countries and identifies stakeholders while illustrating business processes. This study highlights key technology challenges such as scheduling strategies, fleet sizing, fare policies, and route planning. It also addresses management issues, including market

definition, passenger satisfaction assessment, performance evaluation, and the transition from traditional transit services to flexible transit services.

The second purpose of this study was to analyze the implementation of DRT services in the European Union. In total, 33 services were collected and analyzed within this study, including the operation scheme, booking method, booking process, system function, vehicle allocation, vehicle type, and target user. In detail, this study discussed the common application adopted within the European Union, discovering that the dynamic system dominates the operation system, and multi-users are the most frequently targeted users. To be more detailed, this study also describes stakeholders involved within each DRT service and depicts the relation of those parties using business process modelling. In general, there are five primary stakeholders: the government, transport organizer, transport operator, driver, and user.

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