Despite the potential benefits, the implementation of the new transportation system is not without obstacles. Kabul’s urban infrastructure is underdeveloped, and political instability can hinder large-scale projects. Additionally, securing the necessary financial investment and public buy-in remains a challenge. The transition phase, where current routes are modified or replaced, may lead to temporary inconveniences for residents, requiring careful planning and communication.

Recommended a phased approach to implementing the new system, beginning with pilot projects in high-density areas. Collaborations with local government agencies, international urban planning experts, and community stakeholders are crucial to ensure the project's success. Investment in modern transportation technologies, such as real-time tracking systems and automated route management, can further enhance the efficiency of the network. Public awareness campaigns should be conducted to educate residents about the benefits of the new system and how to navigate it effectively.

The rationalization of Kabul’s passenger route system represents a transformative step toward a more sustainable and efficient urban transportation network. By addressing critical issues such as congestion, environmental degradation, and unequal access, the proposed system has the potential to significantly improve the quality of life for Kabul’s residents. Continued research, stakeholder engagement, and adaptive planning are essential to ensure that the new system remains resilient and responsive to the city's evolving needs.

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PICK-UP POINTS OPTIMIZATION FOR A DEMAND-RESPONSIVE SCHOOL BUS SERVICE BASED ON WALKING DISTANCE AND DEMAND POINTS

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Abstract: This paper presents a pick-up point optimizing method for demand-responsive school bus service. In the case of a school bus service, minimizing the walking distance is especially important in order to reduce the traffic safety and security risk of vulnerable users (aka students). The method developed is based on a demand-sensitive approach, where demand points are known. The method focuses on a clustering procedure that iterates demand points into units based on the acceptable walking distance. Pick-up points can be explicitly assigned to demand point units. A case study in Szentendre, Hungary, found that the allocation method significantly reduces walking distances compared to conventional transport systems, while the low number of pick-up points may ensure service efficiency.

Keywords: demand-responsive school bus, pick-up point, walking distance, clustering procedure, optimization algorithm.

1. Introduction

In general, a demand-responsive transport (DRT) service offers a solution to increase the competitiveness of public transport in areas with low mobility demand [1]. A DRT service operates small-capacity buses and flexible routes and/or timetables, adapting to actual demand. The low mobility demand areas are usually detached house areas in a city agglomeration or in smaller villages. In these areas, school-age children are usually transported by their parents, which increases the car traffic in the calm neighborhood, resulting in higher traffic safety risks, as well as noise and air pollution. For school buses, the location of pick-up points (PU) is key to safe transport [2]. Demand-responsive school bus (DRSB) services may offer an alternative to car transport. However, providing door-to-door service can be inefficient (detours, number of stops) if there are several demand points located in the neighborhood. The efficient operation of DRSB service is based on the optimal location of PUs, which is the first step in route planning and fleet sizing. The benefits of optimal location can be realized for passengers, service providers, and society, such as shorter walking distances, avoiding unnecessary vehicle trips, and reduced environmental impact. The following research question was proposed: how to allocate PUs to DRSB services considering acceptable walking distance when the actual demand is known but dispersed? A case study was carried out in Szentendre, Hungary to validate the developed method and demonstrate its practical feasibility and utility.

DRSB implementation and development is connected to European Union objectives [3]. Replacing the traditional school bus with DRSB service can improve service quality and reduce environmental impacts [4]. Case studies have shown that serving rural communities with minibuses is beneficial for both operators and passengers [5]. Shorter walking distances to stops increase the likelihood of passengers using transport services [6], and DRT services can provide an effective solution by adapting to real needs. The PU locations for DRT services are an under-researched area. Although some articles consider walking distance, geographic characteristics, and local demand data [2], [7] the PU allocation problem is usually presented as a component of the route planning problem [8], [9], [10].

2. Method

The method is aimed at allocating PUs for the DRSB service. The method steps are summarised in Fig. 1.

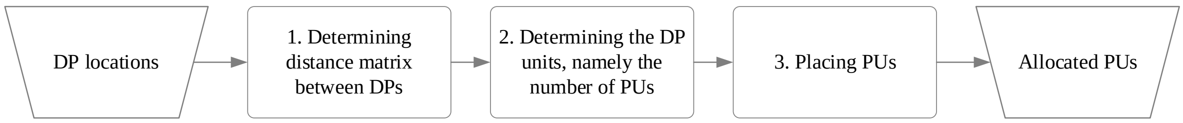

Figure 1 - Method steps

The overall aim was to minimize the walking distance, which is particularly important for traffic safety and security reasons. Real coordinates connecting to the actual demand points (DPs) were considered potential pick-up points, considering adjacent impacts and real road networks.

1. Determining distance matrix between DPs. Coordinates are assigned to the DPs, and the distance matrix is defined between the DP coordinates using real distances between them.
2. Determining the DP units, namely the number of PUs. Several DPs can form a *DP unit* which can be considered a PU. Accordingly, the adjacent DPs can be considered as one single PU. Two DPs are adjacent if the distance between them is less than a multiple of the acceptable walking distance on the road network. This approach follows the full graph, namely, each DP within the DP unit is adjacent to all other DPs within the unit.
3. Placing PUs. The PU is located considering the gravity center of its DP units and the real road network. The projection criteria: (i) the total distance between the DP-PU relations is minimal, and (ii) the excess of the walking distance is not extreme.

3. Results and discussion

The PUs allocation was executed as a case study in Szentendre, Hungary. The municipality provided the input data (DPs) for the method; a questionnaire survey was executed in 2022, revealing the parents' willingness towards a DRSB service. All together 48 PU points were realized.

The results of the PUs allocated are illustrated in Figure 2. DPs were grouped if the distance between them was twice as the accepted walking distance; the accepted walking distance was considered as 360 meters. As the walking distance decreases, the number of PUs increases, resulting in a denser PU network. We found that the DPs are concentrated around the PUs. Furthermore, for the analysis of PU-DP relationships, we used colors to indicate that a DP belongs to a PU. As all the DPs should be served, there are cases where a PU serves only one DP if the demand in that neighborhood is low. As a result of the method, 48 PU can serve 170 DPs. The average DPs served by one PU is 3.5.

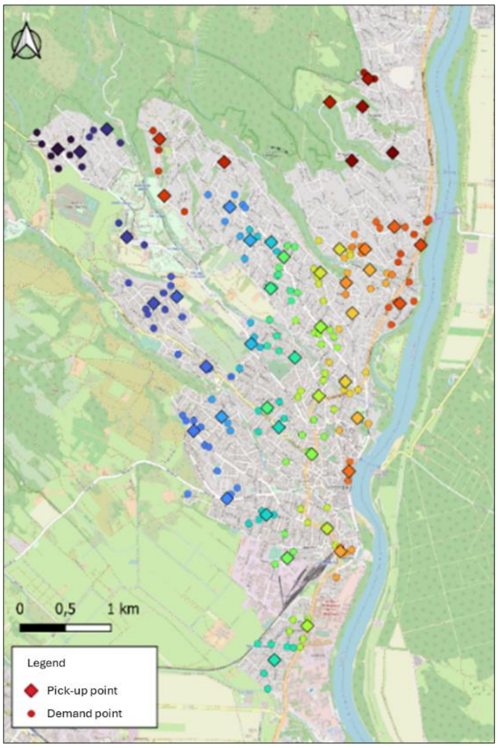

Figure 2 - Pairing DP to the nearest PU

To test the feasibility of the method, we analyzed the accessibility to the current high-capacity, regular public bus service. We found that the PUs have equalized the outliers, and the average walking distance has significantly decreased. With the determined 48 PU, the average walking distance is only 240 meters, while accessing public transport stops is possible with an average of 425 meters of walking.

4. Conclusion

The efficient operation of DRSB services on flexible routes relies on the PU's optimal location. As a main contribution, we have developed a PU allocation method considering and grouping existing demand points. We found with the application of the method in Szentendre, Hungary, that 170 DPs can be served by 48 PUs only with a 240 m average walking distance. The method can significantly and substantially contribute to raising the level of service through shorter walking distances, which is especially important for a service where the users are among vulnerable user groups (aka students). The results can provide guidance for introducing or developing a DRSB service.

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URBAN DISTRIBUTION SYSTEMS IN THE CONTEXT OF SUSTAINABLE MOBILITY DEVELOPMENT

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With the development of e-commerce and the focus of consumer demand on individual orders, the share of small shipments in the total volume of cargo transportation has increased significantly. This is especially true for transportation that takes place in cities that differ in their road transport and industrial infrastructure, as well as the characteristics of the demand for transportation [1]. In this regard, the formation of optimal routes for the transportation of small cargo in cities is a very urgent task. Logistics cost is a big part of the expenses for many manufacturers and companies in managing the movement and transportation of goods. Therefore, businesses wish to find ways to reduce logistics costs, especially at the "last mile" stage.

On the other hand, companies strive to find ways to minimize the negative impact on the environment caused by transportation activities. By implementing environmentally friendly practices and technologies, businesses can contribute to a greener and more sustainable supply chain. To reduce the negative impact of transport on the climate, important steps are the transition to more sustainable energy sources, the development of public transport, and the promotion of electric and other environmentally friendly modes of transport.

For the transport of small loads in the city, the potential advantages of cargo bikes in terms of energy consumption, environmental impact and road load are proposed as an alternative to trucks. In densely populated cities, electric cargo bicycles are becoming increasingly popular as a replacement for vans and cars for delivering goods such as groceries and parcels [2, 3].