Advancing Rural Mobility:
Cutting-Edge Performance of Integrated Demand-Responsive Transport

Silvio Nocera*[1], Federico Cavallaro[1]

[1] Università IUAV di Venezia - Venice, Italy

SHORT SUMMARY

Integrated passenger–freight transport has primarily been developed in urban areas and for long-distance travel. This contribution presents a methodological framework for designing and assessing an innovative service called integrated demand-responsive transport (I-DRT) in rural regions. Using the Osterwalder Business Model Canvas, the framework outlines the requirements for infrastructure, vehicles, and personnel, as well as the implementation costs, revenues, and involved partners. The service's performance is evaluated based on key financial, operational, environmental, and social performance indicators. To test the practical viability of I-DRT, its implementation in Misano Adriatico (Italy) is assessed. The findings show a reduction in kilometers traveled, fuel consumption, and air pollution, while the service area expands, daily freight deliveries increase, and vehicle occupancy rates rise. Over a five-year period, the service also leads to an overall reduction in costs.

Keywords: Integrated Freight Passenger Transport; Demand Responsive Transport; Shared mobility; Rural Areas; Key Performance Indicators.

1. INTRODUCTION

In rural areas, one of the key challenges to efficiency is the need to use limited resources to ensure adequate access to major regional hubs. Conventional public transport (PT) solutions often fail to meet both accessibility and efficiency needs due to high operational costs for transport providers, which are ultimately passed on to the community supporting the service. This results in significant portions of the population relying on private motorized transportation because of limited access to essential services (Mageean and Nelson, 2003). Demand-responsive transport (DRT) is theoretically a potential solution to this issue, as it combines the flexibility of on-demand services with spatial flexibility, allowing for various origin-destination configurations (Mounce et al., 2018). However, the operational, technical, and market challenges associated with DRT systems remain complex (Coutinho et al., 2020). As a result, there is an ongoing debate about its effectiveness; some scholars highlight its potential to address the underutilization of conventional PT (e.g., Navidi et al., 2018), while others argue it may not be financially viable (e.g., Ryley et al., 2014).

To address efficiency issues, the European Commission proposed the development of a new paradigm integrating passenger and freight transport (EC, 2007), referred to as "integrated passenger freight transport" (Bruzzone et al., 2021). A recent literature review on this integration (Cavallaro and Nocera, 2022) indicates growing interest in this approach, primarily within urban areas and for long-distance travel. Various forms of integration have been explored, including shared infrastructure for both freight and passenger vehicles, such as dedicated bus and lorry lanes or shared urban rail systems (Cochrane et al., 2017). Additionally, integration has been examined for specific vehicle types, such as trams (Strale, 2014), airplanes (Vajdová et al., 2019), and bus rapid transit systems (Fatnassi et al., 2016).

To the best of our knowledge, previous scientific literature has not yet discussed the possibility of merging the DRT scheme with the integration of passenger and freight transport to reduce some problems that are typical to rural areas. Issues related to PT in rural areas are mostly related to the efficiency and frequency of the service, adaptability to the needs of potential users, high operational cost for the service provision, and continuous need to optimise the routes according to fluctuating travel demand. Freight transport in rural areas is characterised by high cost, poor service quality, small network ranges, and long periods for distribution. All these aspects prevent the sustainable development of rural logistics, a trend exacerbated by the development of e-commerce businesses (Kou et al., 2022). Merging freight and passenger transport in rural areas may have several benefits, which include not only financial (minor overall expenses) and environmental (less energy consumption) benefits, but can also include a better user perception of the service. Indeed, cost reductions resulting from the integration of transit services and freight deliveries would allow for additional, more frequent transit or delivery services. Finally, reducing the perceived cost of PT may relieve the feeling of isolation typical of several rural areas.
This study attempts to address this research problem by proposing a conceptual framework to deal with the integration of passenger and freight transport in rural areas, by developing a service called integrated DT (I-DRT), evaluating its performance through a series of relevant key performance indicators (KPIs), and discussing the related implications.

2. METHODOLOGY

The method consists of two main steps (Figure 1): first, the definition of the general characteristics of the I-DRT service and its operational details through the Osterwalder Business Model Canvas; second, its evaluation and comparison with the initial layout through appropriate KPIs.

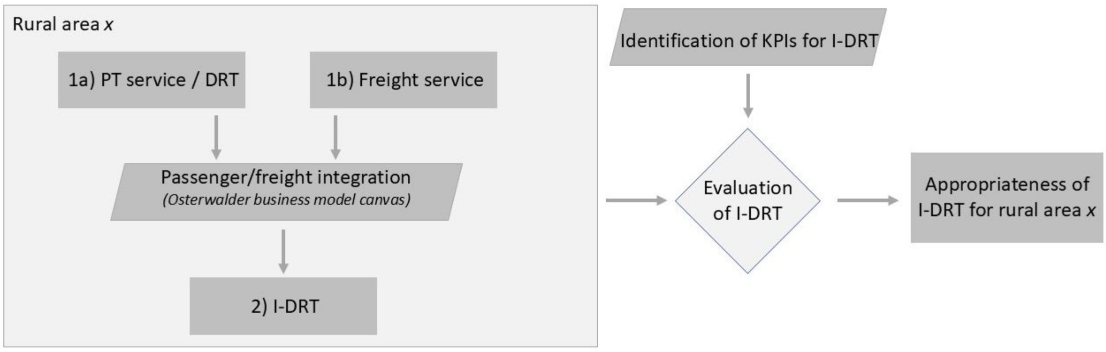

Figure 1: Method for planning and evaluating an I-DRT service in rural areas

The Osterwalder Business Model Canvas is a strategic management tool to describe how an organisation or a service creates, delivers, and captures value. It comprises nine boxes: customer segments, value propositions, channels, customer relationships, revenue streams, key resources, key activities, key partnerships, and cost structure (Osterwalder and Pigneur, 2010). For the present study, Osterwalder Business Model Canvas can contribute to make the I-DRT scheme more operational by fixing the main characteristics of the service referring to each of the nine points mentioned above and underlying those components of the existing service that need to be redefined.

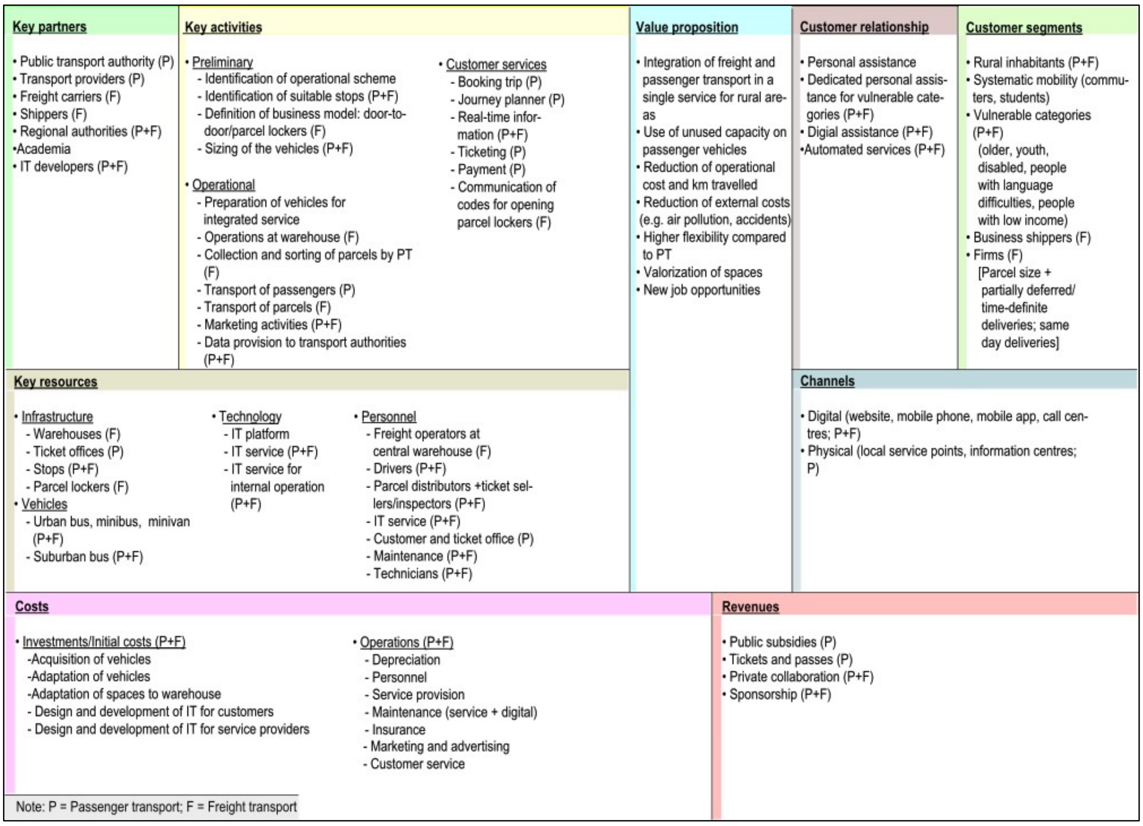

Figure 2: The business model of I-DRT based on Osterwalder Business Model Canvas

Once defined the characteristics of the service, the evaluation of the performances guaranteed by the I-DRT scheme is made through the adoption of selected KPIs, a set of metrics used to quantify the efficiency and/or effectiveness of an action. For the present study, they are used to compare two different transport layouts: the condition after the introduction of the I-DRT service and that before its introduction. We refer to them as "ex-post" and "ex-ante", which in equations below are denoted by A (after) and B (before) the implementation of I-DRT. KPIs focus on those aspects of organizational performance that are particularly critical for the current and future success of a service. The proposed KPIs are not limited to the sum of passenger- and freight-related aspects; indeed, they should be an organic synthesis of the two services, which can include their characteristics in a unique framework. The selected KPIs for I-DRT (Table 1) are based on previous evaluations of integrated passenger–freight schemes (Bruzzone et al., 2021; Bruzzone et al., 2023), with some adjustments that take into account the focus on rural areas. KPIs are clustered into four main categories (financial, operational, environmental, and social), including the perspectives of different stakeholders (PT users, clients of the freight service, transport operators and practitioners, policymakers, and community).

The financial indicators aim to understand the efficiency of I-DRT with reference to the different actors involved in the scheme (in this case, passenger and freight operators, as well as customers). *Operational indicators* evaluate the proper development of I-DRT, with reference to the efficiency and effectiveness of the service. *The environmental performances* of the integrated service calculate the differences in the economic valuation of air-pollutant emissions before and after the introduction of the service. The selection of the most appropriate pollutant depends on specific territorial conditions, but it should include both criteria and greenhouse gases. Finally, *social performances* are evaluated through the variation of the territorial coverage, which can be expressed as the difference in served civic numbers derived from the introduction of the new service. This indicator is more comprehensive than the number of inhabitants, as it includes not only the population that lives in an area, but also the people that reach that area for working or studying reasons.

Table 1: KPIs dealing with I-DRT

Category	*ID*	*KPI*	*Description*	*Service*
Financial	f_1	Service costs	Difference between *ex-post* and *ex-ante* in total yearly costs	P+F
	f_2	Affordability	Difference between *ex-post* and *ex-ante* in the fare	P
Operational	o_1	Covered distance	Difference between *ex-post* and *ex-ante* in distance covered by vehicles	P+F
	o_2	PT load factor	Difference between *ex-post* and *ex-ante* in load factor of PT	P
	o_3	Freight service frequency	Difference between *ex-post* and *ex-ante* in frequency of freight deliveries	F
	o_4	Energy used	Difference between *ex-post* and *ex-ante* in energy requirements for performing operations	P+F
Environmental	e_1	Air pollution	Difference between *ex-post* and *ex-ante* in external costs due to air pollution	P+F
Social	s_1	Service coverage	Difference between *ex-post* and *ex-ante* in civic numbers served	P+F
Note: P = passenger transport; F = freight transport				

3. RESULTS AND DISCUSSION

With 13,000 inhabitants and a surface area of approximately 22 km^2, Misano Adriatico is a small municipality located along the Adriatic coast of the Emilia Romagna region (northern Italy). The territory is characterised by a coastal area that directly connects the city to the Romagna Riviera. Here, high densities and territorial functions are available, including most tourist attractions and accommodations. The hinterland, which hosts the MotoGP circuit, an industrial zone, and several widespread hamlets, is characterised by several hills and *Valconca*, where the Conca River crosses the valley. This part of the territory is coherent with the definition of a rural area given in the introduction. Except for an extra-urban bus connection that links Riccione with Cattolica and Misano Adriatico with two stops (one of which is the railway station), the municipality does not have a regular bus service. Rather, for some years, a DRT service called *Concabus* has been available to the local population. This makes this area particularly suitable for testing the effectiveness of an I-DRT scheme.

The data related to the current transport condition in Misano Adriatico are taken directly from the primary sources. For passenger transport, the Agenzia Mobilità Romagnola (Romagna Mobility Agency), which develops and coordinates the PT service in the provinces of Ravenna, Forlì-Cesena, and Rimini in the Emilia Romagna region. In particular, we refer to the service *Concabus*, which for some years has been available to the local population and it is the only service available. The service is mostly conceived for commuters. The months with the highest demand were October and November (with more than 500 passengers), whereas August had the lowest value. For freight transport, we rely on the municipality of Misano Adriatico, which recently collected daily values of deliveries in its territory within a project aimed at optimising its freight distribution system. In this case, the distribution is organised with a hub-and-spoke service performed at the provincial level. Two main hubs located in the near municipalities of Rimini and Riccione are available.

The I-DRT service implies a new operational layout, where a ubiquitous network of parcel lockers is distributed close to the main PT stops. Missing stops can be identified by performing a "location-allocation" analysis using a GIS software. According to this analysis, we were able to identify three new bus stops and 24 new shelters and parcel lockers (Figure 3).

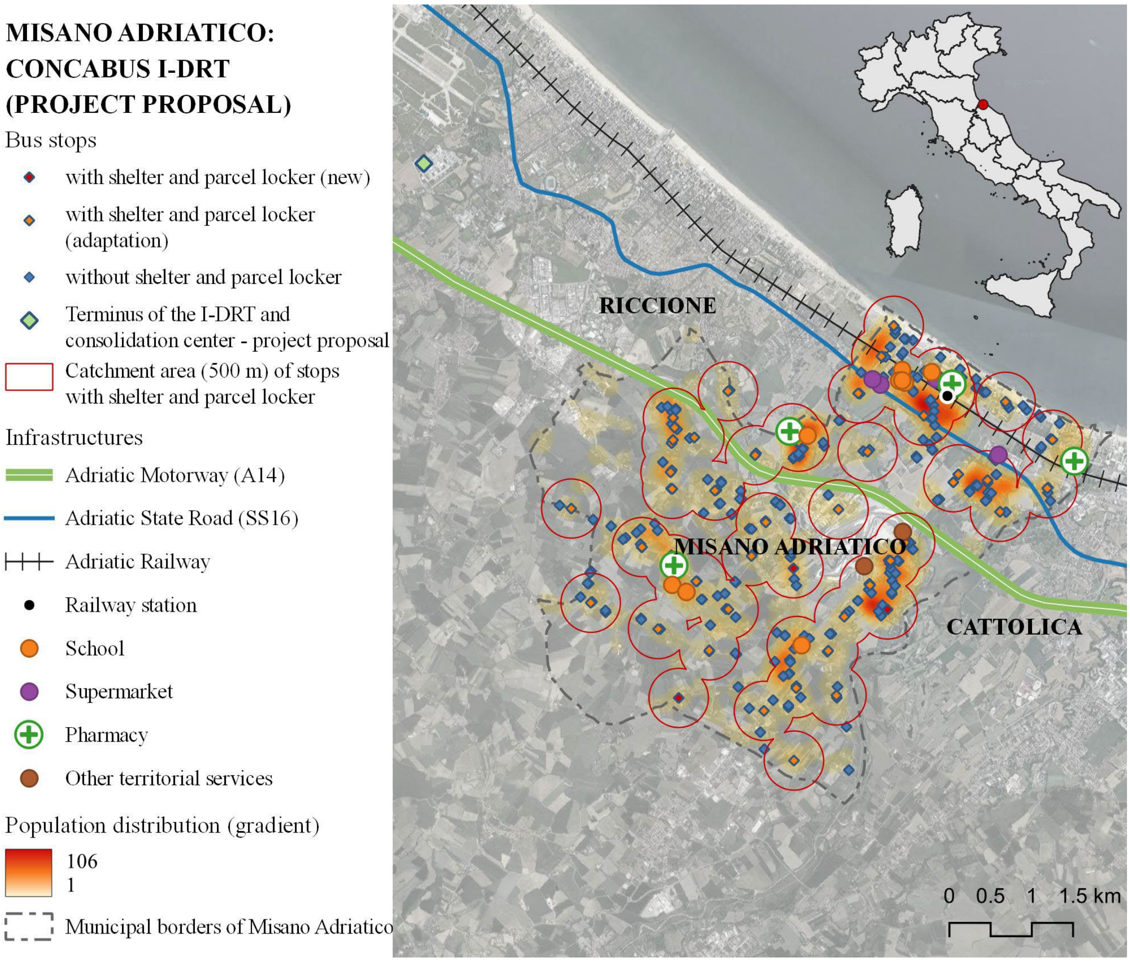

Figure 3: Proposal for an I-DRT in Misano Adriatico (Italy): territorial coverage and main stops

The performances of the eight indicators, which have been calculated individually according to the service characteristics (but cannot presented in detail here, due to the lack of available space) are summarised in Table 2. All KPIs reveal an improvement after the introduction of the I-DRT, except for *f2*, which is neutral, thus confirming the potentialities of the service.

Table 2: Variation of KPIs deriving from the introduction of the I-DRT service

Variation of KPIs between *A* and *B* in Misano Adriatico							
f1	*f2*	*o1*	*o2*	*o3*	*o4*	*e1*	*s1*
service costs	Fare	distance covered	PT vehicle occupancy	freight deliveries	Energy consumption	economic impact of air emissions	civic numbers served
€	*€/ticket*	*km/year*	*variation*	*n°/day*	*MJ/year*	*€/year*	*n°*
- 186,447 €	no changes	-96,640	+18%	+1 (minimum)	- 21,080	-3,379	+796

4. CONCLUSIONS

The provision of efficient and effective transport services in rural areas has been a subject of ongoing research since the mid-20th century. Recent concerns about the environmental impacts of transport, including the carbon footprint of mobility solutions, along with technological advancements in information technology, have introduced new dimensions to the academic discussion. As a result, integrated passenger–freight transport has been proposed to reduce travel distance and associated transport externalities without compromising service quality. This approach has primarily been explored in urban and long-haul contexts, where demand for both freight and passenger transport is high, and system efficiency is achievable. However, there is a lack of similar evaluations for rural areas, combining demand-responsive transport with integrated passenger-freight schemes.

An assessment of the Misano Adriatico (Italy) case study, using selected key performance indicators (KPIs), revealed promising results in adapting the existing demand-responsive transport (DRT) service with minimal infrastructure investment and low staffing costs. This adaptation can lead to daily savings in kilometers for parcel delivery, alongside reductions in fuel consumption and transport-related externalities. The performance evaluation was based on assumptions about the types of goods suitable for I-DRT, an essential consideration given the challenges in obtaining reliable data on freight transport conducted by private operators.

Additionally, some practical considerations related to the implementation of the service must be addressed. I-DRT requires reorganization of the service, which could lead to operational challenges. The economic analysis conducted, using indicator f_1, takes a global perspective by evaluating the total cost variation for both passenger and freight services. However, more detailed economic assessments are necessary, including cost analysis for each involved partner. The I-DRT business model should involve a redistribution of total costs, with freight operators covering a larger share due to lower operational costs from the reduced volume of parcels to be delivered. This redistribution could make the public transport (PT) service more affordable, reducing costs for operators and public administrations that subsidize the service.

Furthermore, challenges may arise with the local PT provider (if I-DRT is outsourced to another company), freight sectors, and competing transport operators (such as minicabs, taxi services, and local freight carriers), who might perceive the new service as a threat, particularly if it is subsidized by public funds. These issues need to be anticipated and addressed to prevent conflicts that could ultimately lead to the service's failure.

REFERENCES

Bruzzone F., Cavallaro F., Nocera S., 2021. The integration of passenger and freight transport for first-last mile operations. Transport Policy, 100, pp. 31-48.

Bruzzone F., Cavallaro F., Nocera S., 2023. Appropriate Key Performance Indicators for Evaluating Integrated Passenger-Freight Transport. In: Nathanail E.G., Gavanas N., Adamos G. (eds.), Smart Energy for Smart Transport. CSUM 2022. Lecture Notes in Intelligent Transportation and Infrastructure, pp. 1278–1290. Springer. DOI: 10.1007/978-3-031-23721-8_103

Cavallaro F., Nocera S., 2022. Integration of passenger and freight transport: A concept-centric literature review. Research in Transportation Business & Management, 100718.

Cochrane K., Saxe S., Roorda M.J., Shalaby A., 2017. Moving freight on public transit: Best practices, challenges, and opportunities International Journal of Sustainable Transportation, 11, 2, pp. 120-132.

Coutinho F.M., van Oort N., Christoforou Z., Alonso-González M.J., Cats O., Hoogendoorn S., 2020. Impacts of replacing a fixed public transport line by a demand responsive transport system: Case study of a rural area in Amsterdam, Research in Transportation Economics 83, 100910.

EC, European Commission, 2007. Green Paper on Urban Mobility. Online at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52007DC0551&from=EN [14.01.2021]

Fatnassi E., Chaouachi J., Klibi W., 2015. Planning and operating a shared goods and passengers on-demand rapid transit system for sustainable city-logistics. Transportation Research Part B: Methodological, 81, pp. 440-460.

Kou X., Zhang Y., Long D., Liu X., Qie L., 2022. An Investigation of Multimodal Transport for Last Mile Delivery in Rural Areas. Sustainability 2022, 14, 1291. https:// doi.org/10.3390/su14031291

Mageean J., Nelson J.D., 2003. The evaluation of demand responsive transport services in Europe, Journal of Transport Geography, Volume 11, Issue 4, 2003, pp. 255-270.

Mounce R., Wright S., Emele C.D., Zeng C., Nelson J.D., 2018. A tool to aid redesign of flexible transport services to increase efficiency in rural transport service provision, Journal of Intelligent Transportation Systems, 22 (2) (2018), pp. 175-185.

Navidi Z., Ronald N., Winter S., 2018. Comparison between ad-hoc demand responsive and conventional transit: a simulation study. Public Transp 10, pp. 147–167.

Osterwalder A., Pigneur Y., 2010. Business model generation: a handbook for visionaries, game changers, and challengers. John Wiley & Sons.

Ryley T.J., Stanley P.A., Enoch M.P., Zanni A.M., Quddus M.A., 2014. Investigating the contribution of Demand Responsive Transport to a sustainable local public transport system, Research in Transportation Economics, Volume 48, 2014, pp. 364-372.

Strale M., 2014. The cargo tram: Current status and perspectives, the example of Brussels. Transport and Sustainability, 6, pp. 245-263.

Vajdová I., Jenčová E., Liptáková D., Lučanská L., 2019. The perspective of using airships in commercial operation. Transport Means - Proceedings of the International Conference 2019-October, pp. 1175-1179.