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A phase-based perspective on urban demand responsive transport: A case study of Viavan pilot in Helsinki Capital Region

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ABSTRACT

Despite decade-long efforts, real-time demand-responsive transport (DRT) services are still struggling to be a part of sustainable urban mobility systems. Among various approaches to understand the changing nature of DRT service, a longitudinal perspective has been found very effective. This study presents the case of an urban DRT pilot operated by Viavan in the Helsinki Capital Region, Finland. Research develops and implements a framework for longitudinal analysis, while drawing from the multi-level perspective (MLP) on sustainability transitions. DRT trip data is used to understand the service trajectory longitudinally over specific phases, delineated through key changes in service design. In addition, the framework uses three-level analysis of service parameters, to provide in-depth analysis in studying inter-phase and intra-phase changes. Case study approach also provides a comprehensive service area background and service implementation context to support the analysis. Results shows the complementary role of the urban DRT to fixed public transport services and points out certain challenges for efficient coordination. In addition, the analysis points towards a set of regime factors that should be considered for further understanding of the service trajectory. In practice, special emphasis should be paid on developing the mobility ecosystem and managerial practices. Future DRT case studies should develop additional frameworks, indicators and methods by drawing from sustainability transitions theory, to further understand service trajectories over time.

1. Introduction

1.1. Challenges of urban DRT as part of urban mobility system in transition

In the past, demand responsive transport (DRT) services were usually implemented in rural areas (Brake et al., 2004; Avermann and Schlüter, 2019), or focused on serving the need of special passenger groups (Mageean and Nelson, 2003; Nelson et al., 2010; Mulley and Nelson, 2009; Preston and Rajé, 2007). Recent advancements in real-time communication and routing have enabled a design of more customized and flexible DRT services (Haglund et al., 2019; Attard et al., 2020). Due to those technological advancements, DRT nowadays is being more frequently deployed in urban areas and for a wider range of passenger groups (Coutinho et al., 2020; Jokinen et al., 2019; Haglund et al., 2019; Sanaullah et al., 2021; Zwick et al., 2022; Kostorz et al., 2021; Gilibert et al., 2019; Jokinen et al., 2019; Alonso-Gonźalez et al., 2018; Coutinho et al., 2020; Zhou et al., 2021; Perera et al., 2020; Shah and Hisashi, 2022; Abdullah et al., 2021). In urban areas, DRT services are implemented for a range of goals, such as improving accessibility, responding to changing user needs, and contributing to the modal shift away from private driving (Haglund et al., 2019; Attard et al., 2020; Coutinho et al., 2020; Jokinen et al., 2019; Sanaullah et al., 2021; Alonso-Gonźalez et al., 2018; Perera et al., 2020; Ribeiro and Rocha, 2013; Daniels and Mulley, 2012).

Despite the active deployment of DRT services worldwide, there has been only limited success, with 70 % of the services stopping within three years of service operation (Currie and Fournier, 2020). It is also important to acknowledge the fact that among those 70 %, some of the services were introduced as predefined fixed-duration pilots, often due to constraints with predefined budgets. Thus, high rate of service discontinuation is partly explained through this predefined duration aspect. In addition, some studies show that there has not been enough growth in demand for DRT trips (Kaddoura et al., 2020; Alonso-Gonźalez et al., 2017; Gonźalez et al., 2017). Simultaneously, DRT service operation is also presumed to be free from subsidy, which can bring its own public or political challenges (Ryley et al., 2014). Consequently, scaling-up the DRT operation from a niche to the part of urban mobility

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regime is challenging (HSL, 2016; Jokinen et al., 2019; Becker et al., 2021).

This DRT scaling up challenge has to be contextualized as part of the urban mobility transition challenges, relying on the attributes of the most often used heuristic within the sustainability transitions field, the so-called multi-level perspective (MLP) (Geels, 2011; Geels, 2012). In particular, these attributes are longitudinal analysis and analysis cross levels, while incorporating the wider mobility context into the evaluation framework, among others. MLP posts that transition in a (mobility) system comes about through interaction processes within and among trajectories of three levels, namely Niche, Regime and Landscape (Geels, 2002). Niches are defined as the newly developed technologies and emerging practices, regime level includes the existing and established technologies, practices, industries and institutions, while the landscape level includes the long-term and broader trends, such as cultural or environmental trends. The key point of introducing these micro, meso, and macro levels is to recognize that a niche cannot simply become a part of the existing regime by its own properties, but there is a need to reconfigure the regime, which often happens when windows of opportunity emerge from the landscape level such as the recent COVID-19 pandemic. Thus, in order to evaluate a DRT service, we cannot only look for factors related to service design, but have to understand the wider context, including both the existing mobility regime and potential landscape pressures relevant for the mobility system.

Besides the three levels, MLP also underlines the longitudinal (i.e., temporal) perspective in understanding the dynamic interaction between and within levels (Geels, 2011; Geels, 2002). Longitudinal perspective relates to both *in situ* and *ex post* evaluation. On the one hand, various stakeholders involved in deploying and steering a DRT service in particular context have to continuously take into account changing user trends, societal needs, and implementation constraints (Alonso-Gonźalez et al., 2018; Coutinho et al., 2020). As much as these changes can be evaluated in a timely manner, this can help practitioners with making informed decisions about effective changes in DRT service, such as changes in the fare policy (Circella and Alemi, 2018; Jokinen et al., 2019). On the other hand, longitudinal perspective helps in establishing the sequence of events, with a potential to describe patterns of change in service trajectory by excluding recall bias regarding the past. This pattern of change in service trajectory can help to establish the direction and magnitude of causal relationships. Thus, a longitudinal perspective helps with generalizing across individual cases, since it helps clarify associations and relationships between different factors shaping service trajectories, including those related to wider policy and governance, not just service design itself.

Previously, there is only one case study that has used MLP for further understanding of a DRT case (Sharmeen and Meurs, 2019). This seminal study focused on the Brengflex service in the Netherlands, and included a qualitative analysis of interactions between factors at different MLP levels. Similarly, some of the previous research efforts on DRT have tried to incorporate broader aspects for an improved understanding of DRT cases (Attard et al., 2020; Zhou et al., 2021; Perera et al., 2020; Sanaullah et al., 2021). In addition, previous studies have used complementary methods and data sources, such as user surveys (Abdullah et al., 2021; Shah and Hisashi, 2022), and empirical trip data analysis, to understand the service usage and operational aspects at different scales (Perera et al., 2020; Attard et al., 2020; Haglund et al., 2019). The section 2 provides details about the investigated topics, perspectives of analysis, methods, and indicators using trip data in previous DRT research efforts focused on addressing the aforementioned challenges. However, despite the plethora of previous research, there is still a lack of studies more explicitly and simultaneously taking multi-layered and longitudinal perspective to understand DRT cases.

1.2. Introduction to case study

This study focuses an urban DRT service called Viavan, offered as a 6 month pilot in the Helsinki Capital Region (HCR), Finland, during 2019–2020. During the pilot, several changes were made in the service design. Besides the changes in service design, this pilot has also experienced changes in service usage levels over time. At start of the service operation, service usage levels were initially increasing, followed by a drop, while daily trips remained rather stable until the end of the pilot. Finally, this pilot has been implemented in an urban area with already diverse set of mobility services. Given that longitudinal trip data is available for this pilot, this pilot provides an excellent case for an in-depth longitudinal analysis of DRT service trajectory.

1.3. Aims and outline

The study aims to develop further understanding on DRT service trajectory over time by implementing a phase-based perspective. Each phase in this study represents a time period within pilot duration without considerable service design changes, internal events that potentially triggered any long-term behavioral change among service users. In addition, the study aims to provide extensive pilot implementation setup and service area background with a focus on mobility context for wider understanding the DRT services. The paper is structured as follows. Section 3 provides the case study background. Section 4 presents the evaluation methodology. Section 5 includes the results of this study. Section 6 discuses the findings and practices of DRT and Section 7 concludes the paper with the contribution to scholarly knowledge, study limitations and directions for future research.

2. Literature review

As transport service design is influenced by the needs and expectations of their customers, first set of studies have used stated preferences surveys to understand the user perspective (Geržinič et al., 2022; Li et al., 2021; Alonso-Gonźalez et al., 2021; Choudhury et al., 2018; Frei et al., 2017; Liu et al., 2019; Saxena et al., 2020; Ryley et al., 2014; Miah et al., 2020). In particular, studies have tried to understand questions related to demand (Geržinič et al., 2022; Frei et al., 2017), potential markets (Ryley et al., 2014; Gilibert et al., 2019), user requirements (Gilibert et al., 2019), dissimilarities among user groups (Li et al., 2021), willingness to share (Alonso-Gonźalez et al., 2021), behavioral attitudes (Shah and Hisashi, 2022) and user satisfaction (Avermann and Schlüter, 2019) among others. Other studies have used interviewing methods to understand opportunities and barriers from user's perspective (Miah et al., 2020; Abdullah et al., 2021).

Second set of studies on DRT have used interviews and focus group methods to understand DRT from key stakeholder perspectives (Sharmeen and Meurs, 2019; National Academies of Sciences, 2019; Jokinen et al., 2019; Miah et al., 2020; Abdullah et al., 2021). Most of these studies have tried to investigate the opportunities and barriers to DRT services (Miah et al., 2020; National Academies of Sciences, 2019; Abdullah et al., 2021). In addition, researchers have tried to understand it from different evaluation perspectives such as city and regional governments, operators, consultants and other experts such as researchers (Sharmeen and Meurs, 2019; Ryley et al., 2014; National Academies of Sciences, 2019; Jokinen et al., 2019; Enoch et al., 2006).

Third set of studies used trip-based empirical data for DRT analysis. There has been a wide set of indicators used in those studies. Research using trip data have mainly investigated the service usage characteristics and evaluated a wide range of services productivity indicators (Alonso-Gonźalez et al., 2018; Jokinen et al., 2019; Attard et al., 2020; Haglund et al., 2019; Zhou et al., 2021; Perera et al., 2020; Coutinho et al., 2020; Sanaullah et al., 2021).

From an operational point of view, many studies used trip data to understand the patronage levels and spatio-temporal dynamics of the offered services (Haglund et al., 2019; Jokinen et al., 2019; Sanaullah et al., 2021; Perera et al., 2020; Attard et al., 2020; Coutinho et al., 2020; Alonso-Gonźalez et al., 2018; Zhou et al., 2021). Regarding the spatial dimension, urban DRT trips have been researched through average trip length (Attard et al., 2020; Haglund et al., 2019), pick-up and drop-off locations (Haglund et al., 2019; Zhou et al., 2021; Perera et al., 2020) and OD flow patterns (Sanaullah et al., 2021; Attard et al., 2020). Aggregated operation statistics (Haglund et al., 2019; Attard et al., 2020; Coutinho et al., 2020), impacts of demographic characteristics (Sanaullah et al., 2021); spatio-temporal variations (Haglund et al., 2019; Zhou et al., 2021; Perera et al., 2020; Alonso-Gonźalez et al., 2018), and trip variations for various passenger groups (Perera et al., 2020; Haglund et al., 2019; Alonso-Gonźalez et al., 2020) are commonly used in studying DRT operation.

Regarding the analysis of temporal dimension, urban DRT trips have been researched through demand patterns (Alonso-Gonźalez et al., 2018; Coutinho et al., 2020), pick-up times (Haglund et al., 2019), waiting times (Haglund et al., 2019; Jokinen et al., 2019; Attard et al., 2020; Sanaullah et al., 2021),journey duration (Perera et al., 2020; Haglund et al., 2019),difference between promised and performed pick-up times (Perera et al., 2020; Haglund et al., 2019), advance time of booking (Perera et al., 2020) and walking times (Attard et al., 2020).

Most of the empirical studies have focused on understanding the service from a non-longitudinal perspective. Evaluation frameworks used in those studies present a converged cross-sectional picture of the service using aggregated timescale (Alonso-Gonźalez et al., 2018; Coutinho et al., 2020; Attard et al., 2020; Zwick et al., 2022). Studies have tried to analyze the service trajectory by aggregating the operations at different scales such as monthly (Jokinen et al., 2019; Coutinho et al., 2020; Zwick et al., 2022), weekly (Perera et al., 2020), calendar (Zwick et al., 2022), clock time (Jokinen et al., 2019; Haglund et al., 2019; Perera et al., 2020; Zwick et al., 2022; Coutinho et al., 2020) and peak hours (Haglund et al., 2019). Those aggregated cross-sectional time scale studies can analyze multiple variables to provide a snapshot at a given time. However, these previous perspectives do not provide enough understanding of the changing nature of DRT service over time.

A few empirical studies have tried to understand patronage analysis level over time (Perera et al., 2020; Haglund et al., 2019; Jokinen et al., 2019; Coutinho et al., 2020). Among those, studies focusing on developing longitudinal understanding of urban DRT are limited (Perera et al., 2020; Coutinho et al., 2020; Jokinen et al., 2019). Previous studies have used different methods to understand the longitudinal perspective of DRT services. In fact, only two previous studies have some indication of the need to understand the service trajectory from a phase-based perspective (Zhou et al., 2021; Jokinen et al., 2019). The first study (Jokinen et al., 2019) has tried to understand the service trajectory by dividing the service timeline into two fare-based phases which are disaggregated at hourly timescale. However, the analysis does not investigate the service longitudinally throughout the service duration. It also limits the scope of phasing by analyzing the two disconnected periods of time for longitudinal analysis. The study does not analyze all of the service changes during the service operation. Similarly, (Zhou et al., 2021) introduced the phasing of service timeline to analyze the service usage trends for pre-pandemic emergency and post-pandemic emergency time periods. Study uses 2.5 and 4.5 months time periods for the analysis. Besides having similar challenges to (Jokinen et al., 2019; Zhou et al., 2021) does not focus on any service changes over time. Therefore, the need for the phase-based approach for longitudinal analysis remains intact.

As expectations from a DRT service depend on the existing service ecosystem, studies have tried to establish a connection between service and service area background (Sanaullah et al., 2021; Jokinen et al., 2019). Those studies provide the description of service area background (Haglund et al., 2019),comparing the urban DRT trip characteristics with other available mobility options (Alonso-Gonźalez et al., 2018; Haglund et al., 2019; Jittrapirom et al., 2019; Volinski, 2019) and accessibility (Alonso-Gonźalez et al., 2018). However, all of the available case studies do not provide all relevant information related to the service area context, information of the mobility ecosystem and service implementation setup (Attard et al., 2020; Zhou et al., 2021; Perera et al., 2020) or the required depth of it. Therefore, further studies that help in understanding the service dynamics over time and in relation to the service area background and mobility context are needed.

3. Case study background

3.1. Helsinki Capital Region and service area

HCR is located on the shore of Gulf of Finland and had population of 1.49 million in 2019. It covers the municipalities of Helsinki, Espoo, Vantaa and Kauniainen (City of Helsinki, 2020). Viavan pilot operated in municipality of Espoo, the second largest municipality in Finland. Espoo is a polycentric urban cluster with five major urban centers (European Commission, 2022). It covers 312 km^2 of land area and is home to approximately 290,000 residents with a population density of 933 residents/km^2 (City of Espoo, 2022). It is worth mentioning that population density of the city is relatively low in comparison with other metropolitan cities of Europe such as Paris (20,500 residents/km^2) and Stockholm (5,228 residents/km^2).

Demography of the city is relatively cosmopolitan with 18.1 % of the population having a foreign background, and 69.8 % aged between 14 and 64 years (City of Espoo, 2022).

3.2. Available mobility services

HCR has a range of mobility services including fixed PT, micro-mobility services and ride-hailing. Fixed PT services include train, metro, bus, tram, and ferry lines. A high-quality walking and cycling infrastructure with over 1200 km cycling track is also offered (Helsinki, 2022; Woods and Masthoff, 2017). Micro-mobility services in the HCR include shared electric scooters offered by providers like Voi and Lime and over 3500 shared regular bikes. All of these services are integrated in a mobility-as-a-service (MaaS) platform operated by Whim (Hirschhorn et al., 2019).

Due to extensive fixed PT investments in recent years (Weckström et al., 2019), the number of daily journeys per person with fixed PT are among the highest (i.e., 3.5 journeys per day per person) among other cities in Europe (EMTA, 2020). During the weekdays, most of the trips made are leisure trips, followed by work, shopping and educational commute trips (Albacete et al., 2017). Despite the fact that region has a diverse range of shared mobility alternatives, earlier studies reveal that 39 % of journeys were completed by private car, followed by 22 % by fixed PT, 29 % on foot, 9 % by cycling, and 2 % by other modes (Helsinki Regional Transport Authority, 2021).

According to the detailed benchmarking in European service of public transport (BEST) surveys from 2018, Helsinki's fixed PT was evaluated as the second best in comparison to other BEST European urban regions (HSL, 2018). Survey shows that second to Geneva, 75 % of the HCR residents are satisfied with fixed PT service where reliability and willingness to recommend fixed PT was highest among BEST cities (HSL, 2018). Similarly, the survey shows an increase in perceived quality of fixed PT services as residents were more satisfied with the access to outskirts, environmental friendly vehicles and service fare, among others. However, the respondents from Espoo were particularly critical about changes in western structure of fixed PT network (HSL, 2018; HSL, 2019).

3.3. Viavan pilot setup

In 2018, Helsinki Regional Transport Authority (abbreviated as HSL due to its Finnish title) initiated a contest seeking for experiments with new mobility services. Proposals were ranked based on their feasibility, effectiveness, scalability and passenger's orientation. Among 26 proposals submitted, Viavan Technologies' proposal on urban DRT and Samocat Sharing proposal on kick scooter and e-scooter were selected

(IdeaLab, 2018). The DRT pilot aimed to test and analyze the response of passengers towards DRT service and to investigate if this service complements the fixed PT system (HSL, 2019).

The Viavan DRT service started operation on the September 16, 2019, lasting for 6 months until the March 14, 2020. The service used minibuses with seating capacity of 8 passengers. Taxi and ride-haling drivers were contracted. Stop location for DRT service included using both existing fixed PT stops in the operating area, as well as addition of virtual stops. These additional virtual stops were usually located on the corner of streets, enabling dense stop-to-stop service. Service was supported by a smartphone application in which passengers could book rides up to 45 min in advance. The algorithmic model automatically determined the locations of passengers and vans, and determined the routes. The cost of the trip was displayed in the Viavan app before confirming the offer. After confirmation, the application displayed the vehicle's registration number, model and stop location. Extensive marketing of the Viavan pilot was steered through multiple platforms to spread the information of the service. During the early months of operation, leaflet marketing at several metro stations and office locations was conducted to provide information of the service arrival and usage rules.

3.3.1. *Trajectory of service usage*

Fig. 1 shows the daily service usage levels throughout the pilot duration. During the first two months of the pilot, the service usage kept increasing. Towards the turn of the year, usage started stabilizing and later on dropping. Thus, from the middle of the service duration, usage level stabilized at a lower level, lasting until the end of the pilot.

3.3.2. *Operational time and service area changes*

When the service was launched in September 2019, vans were operating only on weekdays from 7:00 to 21:00. However, service was extended to 6 days of operation per week to include Saturdays operation between 7:00 and 23:00 on the November 4, 2019. The previous DRT service, called Kutsuplus, in HCR operated on weekdays between 9:00 to 17:00 at the start, which later was extended to 6:00 and 24:00 (Jokinen et al., 2019). Fig. 2 shows initial (1) and extended.

(2) service area. More specifically, initial area included the neighborhoods of Niittykumpu to the west, seashore in the south, up to the border of Espoo and Helsinki to the east, and Leppävaara (rail transit hub) in the north. On October 24, 2019, service area was extended to Matinkylä area, including terminus metro station, and swimming hall north from Leppävaara. In comparison, Kutsuplus service operated on a considerably larger area, covering roughly the area within Ring road 1 (Jokinen et al., 2019).

3.3.3. *Service fare changes*

Timeline of fare changes is depicted in the Fig. 3. Service operation started with fare of 2 Euro per trip for all trips. First change in the fare was made on January 1, 2020 followed by second fare change on February 11, 2020. Changed fare were defined based on distance (short distance trips (< 3 km) and long-distance trips (>3 km)) and for time of the day (peak and off peak periods). In addition to regular trips, service offered a weekly pass called ViaPass with capacity of 4 journeys per day. The cost of Via-Pass was increased from 10 Euro/week to 18 Euro/ride and 22 Euro/ride. According to the report published by HSL after the pilot, the explanation given for prices changes is that they were made to check the user willingness to pay a higher price for the DRT service (Helsinki Regional Transport Authority, 2022). It is interesting to note that Kutsuplus offered a range of service classes named, 1-Economy, 2-Normal, 3-Fast and 4-Unnamed/Kutsuplus. Each service was priced according to the promise-based service quality parameters. Moreover, the Kutsuplus offered a distance-based pricing, that was revised five times during three years of operation (Jokinen et al., 2019).

4. Evaluation methodology

4.1. *Evaluation framework and process*

The evaluation framework (Fig. 4) implements a phase-based perspective for understanding the service trajectory of urban DRT. The developed framework relies on two specific MLP attributes, namely longitudinal analysis and analysis across multiple levels. Phases are developed based on service usage in connection to service design. Each phase in this study represents a time period within pilot duration without considerable service design changes, internal events that potentially triggered any long-term behavioral change among service users. However, single-day events causing temporary changes such as national holidays are not considered for phasing due to their short-term impacts. In addition to inter-phase analysis, each phase is further analyzed for intra-phase analysis. Intra-phase analysis is based on daily time periods.

Fig. 4 shows that DRT service is evaluated longitudinally in horizontal plane, over different phases. Inter-phase changes aim to reveal

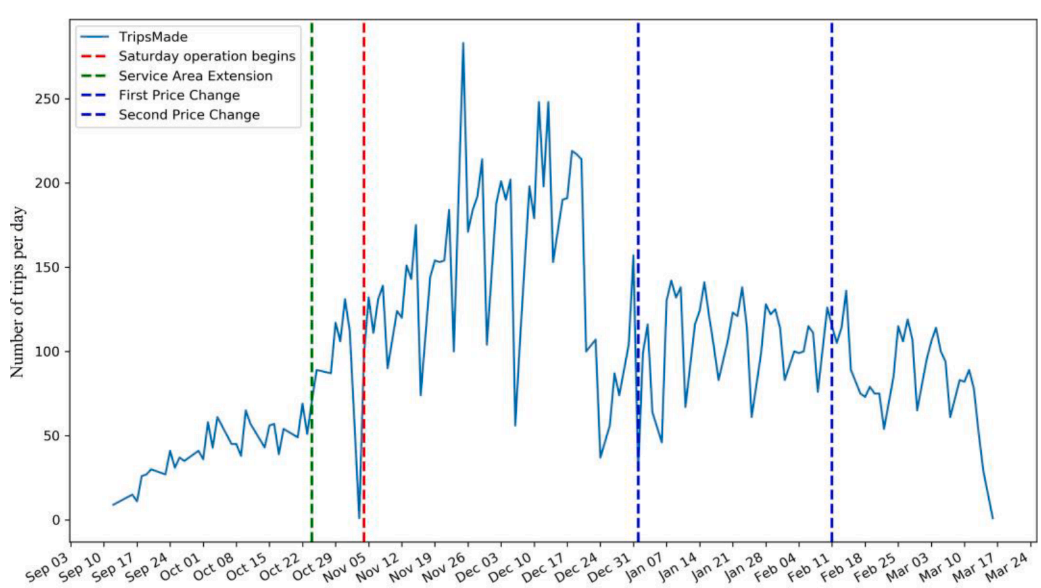

Fig. 1. Service usage per day during Viavan pilot.

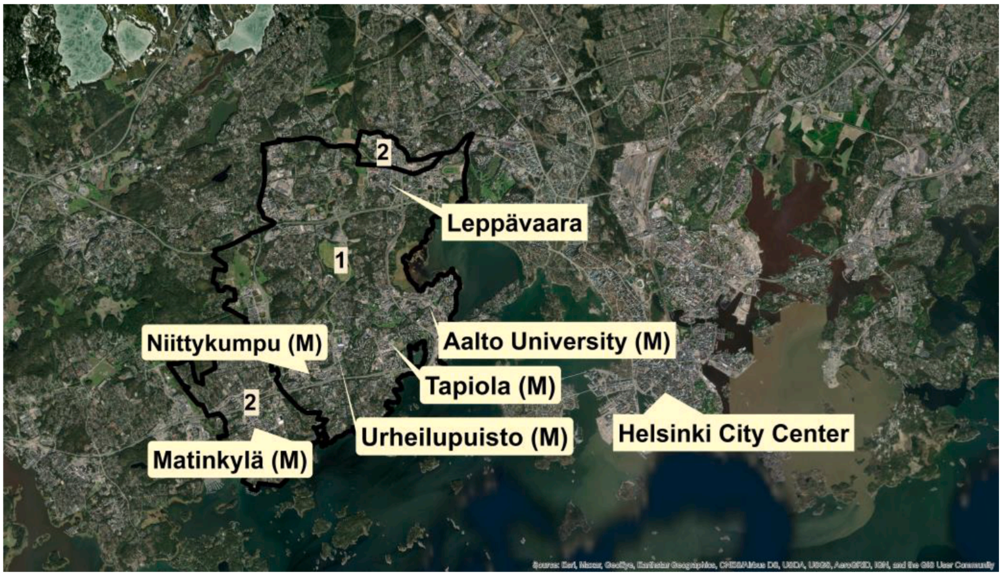

Fig. 2. Changes in boundaries of service area of Viavan pilot.

Regular rides	All times
All rides	2€

Regular rides	Peak times	Off peak times
Short rides	3€	2.5€
Long rides	4€	3.5€

Regular rides	Peak times	Off peak times
Short rides	3.5€	2.5€
Long rides	4.5€	4€

Short rides: Less than 3 Km
Long rides: Equal or greater than 3 Km
Peak times: Weekdays 07:00-09:30 and 16:00-19:00
Off-peak times: All other times including weekends and public holidays

Fig. 3. Timeline of fare schemes.

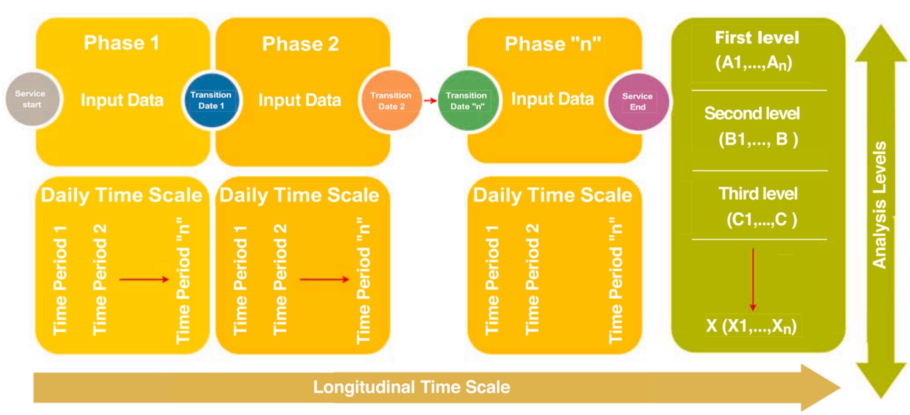

Fig. 4. Evaluation framework of research.

phase-to- phase changes in service trajectory. The change from one to another phase is marked by transition dates. These dates mark changes causing substantive- enough impacts on the service operation. An example of operator change could be the change of fleet size.

Based on the service change and internal events, 3 transition dates are identified. The change of service area is the first identified transition date. This leads to phasing the service timeline in two periods, before and after the service area expansion. Change in fare policy is identified as the second transition date, leading the further phasing of the timeline. The second change in fare policy is identified as the third transition date leading to the further phasing of the service timeline. These transition dates lead to the following phasing scheme:

Phase 1: From beginning of pilot - October 23, 2019 (29 days (19.46 %) of operation).

Phase 2: From October 24, 2019 - December 31, 2019 (56 days (37.58 %) of operation).

Phase 3: From January 1, 2020 - February 10, 2020 (35 days (23.49 %) of operation).

Phase 4: From February 11, 2020 - end of pilot (29 days (19.46 %) of operation).

The next step refers to the further division of the phases into daily time scales. Results for these levels of analysis are sliced into four time periods of a day. Four daily time periods within a day are defined as morning time period (07:00–09:30), mid-day time period (09:31–15:59), afternoon time period (16:00–19:00) and evening time period (19:01–23:00) and thus phases follows the same pattern. Then, daily time scales are analyzed by calculating or estimating indicators that are selected on three levels as described above.

The framework develops three levels of analysis to provide depth of the service related attributes. First level focuses on the description of service usage including the relationship with fixed PT network. The second level focuses on the trip characteristics changes. The third level focuses on operational changes. These three levels are depicted in green color on right hand side of the Fig. 4.

These three levels are represented with a set of indicators. The selection of the indicators have considered the performance measures used in existing literature and available dataset (Sanaullah et al., 2021; HSL, 2016; Perera et al., 2020; Jokinen et al., 2019; Attard et al., 2020; Alonso-Gonźalez et al., 2018; Coutinho et al., 2020). Further details of indicators for each of these levels are presented in section 3.3.

Finally, the comparison among the values of indicators per phase shows how the service changed with the course time. Analytical process of the research is presented in Fig. 5.

4.2. DRT trip data

Operational dataset for 15,639 accepted trip requests was provided for analysis by ViaVan. The dataset referred to the time period of September 16, 2019 to March 14, 2020, covering the entire operational period of the DRT pilot. For each requested trip, the following information was included in the input dataset:

1. Request date and time
2. Estimated pick-up date and time
3. Estimated drop-off date and time
4. Pickup date and time
5. Drop-off date and time
6. Coordinates of origin and destination
7. Fare of ride
8. Number of passengers in booking
9. Status of ride

The status of ride in dataset refers to if the trip was completed, cancelled by the passenger, cancelled by the admin or passenger did not show up. Available dataset does not provide the information about the length of performed trip, idle time of the vehicles, occupancy of the vehicle during the trip and during overall operational times. Similarly, available dataset does not include the trips made using weekly ViaPass.

The normality of time series data is checked through Shapiro-Wilk's test, although the sample sizes in a phase can be considered large enough (approximately 30) not to require normality check (according to Central Limit Theorem). Phases are assumed unpaired since there are different trips with different characteristics. Whether the variances of the two phases are equal or not is investigated through F-test.

4.3. Evaluation indicators

4.3.1. First level analysis – service usage changes

- Number of trip requests per day per phase

This indicator refers to average service usage per day to compare the usage levels for each phase. Previous studies have also focused on similar measures of average usage for various daily and monthly time intervals (Haglund et al., 2019; Jokinen et al., 2019; Coutinho et al., 2020; Perera et al., 2020). However, this measure investigates the average usage per day for each phase to understand the changes on longitudinal time scale. The statistical significance of the change is confirmed through *t*-test.

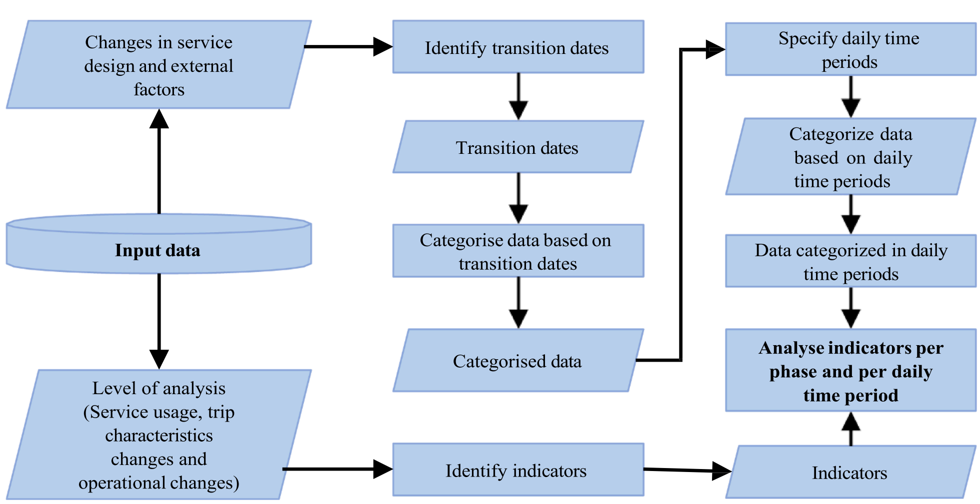

Fig. 5. Analytical process of proposed methodology.

- Changes in number of trip requests within daily time period

This indicator refers to trip requests with each of the four daily time period scale, i.e., morning peak, inter-peak, afternoon peak and after-peak. Previous research has also used the indicator to understand the changes in service usage (Jokinen et al., 2019; Zhou et al., 2021). However, values of this indicator are expressed in terms of relative percentage change between phases. This indicator serves to access the time of day that is associated with the greatest change in service usage.

- Spatial usage changes

This indicator focuses on both temporal and spatial distribution. It provides visualization of the DRT trip requests during three fare policies and the relationship between fixed PT to the urban DRT service. Similar distribution measures focusing both at aggregate and time intervals have also been used in previous research (Zhou et al., 2021; Haglund et al., 2019).

4.4. Second level analysis - trip characteristics changes

- Requested trip distance

The distance traveled by a shared DRT service often differs from the distance that would be traveled if the request was served individually (i.e., the former is greater than the latter). Requested trip distance refers to the mean distance length (km) of the requested trips per phase (Attard et al., 2020; Haglund et al., 2019). This distance per request is calculated through an algorithm developed by the authors. The algorithm uses Open Street Maps (OSM) with the local network and a trip request's origin and destination coordinates to estimate distance needed for the trip and the respective travel time. The percentage of longer trips with an increase in fare for longer trips reveals the service usage changes over different phases and time periods.

- Requested trip time

Refers to the time length (min) of the requested trips (Perera et al., 2020; Haglund et al., 2019; Zhou et al., 2021). This measure is not directly available but can be estimated. It is a combined indicator between (1) and (2), since the requested time length of the trip is a result of the distance length of the trip and the network speed that is almost constant within different time periods within a day.

- Number of passengers per request

Refers to the number of passengers that are included in a single trip request (Haglund et al., 2019; Perera et al., 2020). It is a critical value in DRT systems, since it determines how many trips can be combined as part of the shared nature of the service, and thus the passenger comfort on-board and the overall travel times. A request with a number of passengers equal to full seating capacity implies a taxi-like trip, in which passengers experience only their own pick-up and drop-off times. During the pilot, a user could request a trip for four passengers in a vehicle of 8 seats. However, there is no information about the average occupancy of the vehicles throughout the pilot's implementation.

4.5. Third level analysis - operational changes

- Difference between performed shared and inferred single trip time

Refers to the difference (min) between the riding time needed for the shared DRT service to complete a trip and the riding time that would be needed if the trip was served by a private car (Haglund et al., 2019). The latter value is estimated since it is not directly available. The difference between actually performed shared and estimated single trip time per trip is an indicator of the shared mobility disutility for the DRT passengers. The statistical significance of the change is confirmed through *t*-test.

- Difference between promised and performed trip time

Refers to the difference (min) between the trip time that the DRT operator promised and the time that was actually needed to serve a request (Haglund et al., 2019; Attard et al., 2020; Perera et al., 2020). It is expected that greater differences between the two should indicate passenger's dissatisfaction.

- Difference between promised and performed pick-up time

Refers to the difference (min) between the pick-up time that the DRT operator promised and the performed pick-up time (Perera et al., 2020). This measure is expected to generate both negative (i.e., earlier pick-up than promised) and positive (i.e., later pick-up) values.

- Difference between promised and performed drop-off time

Refers to the difference (min) between the drop-off time that the DRT operator promised and the performed drop-of time (Perera et al., 2020). An earlier drop-off might be a preferable condition for passengers that do not need to attend some appointment, but for passengers who do, earlier drop-off might be associated with inconvenient waiting times (e.g., waiting outdoors during winter months). On the other hand, later drop-off could lead to high disutilities. Similar to above, this measure is expected to generate both negative (i.e., earlier drop-off than promised) and positive (i.e., later drop-off) values, and both of them are considered as indicators.

5. Results

5.1. First level analysis – service usage changes

5.1.1. Number of trip requests per day per phase

In order to better understand the usage changes, the time series is divided in Fig. 6 for each one of the four phases. In Fig. 6(b), it is noted that after the area expansion, there is a maximum peak that corresponds to November 25, a day during which there was a bus strike in HCR. On December 6, on the other hand there is a minimum due to a Finnish national holiday.

During phase 1, before the service area expansion, the mean usage per day equals 37.9 pax/day, while after the expansion equals 141.3 pax/day (i.e., an increase of 272.8 %). There is increasing trend during the phase 1 and phase 2. During phase 3, the mean usage per day has dropped to 105.7 pax/day (i.e., a decrease of 25.2 %), with an almost flat trend. In phase 4, the mean daily usage equals 84.4 pax/day, which corresponds again to a decrease of 25.2 % The usage related mean values, standard deviations and sample sizes corresponding in each subcategory are presented in Fig. 6. The mean values of usage in 4 phases are statistically different according to *t*-test, with p-values almost zero in all investigations.

5.1.2. Changes in number of trip requests within each daily time period

Table 1 shows the percent change in service usage between two consecutive phases for different time periods within a day. According to the Table, morning peak time period between phase 1–2 experiences highest change with 324 % increase in usage. In contrast, between phases 2 and 3 there is a greater decrease of usage during afternoon time period, while mid-day and afternoon time periods also have high percentage of change. Although the change during morning time period is not statistically significant at a significance level of 0.05, it presents the smallest percent change of usage compared to the other time periods of the day. This is contradicting to the fare policy which had a greater

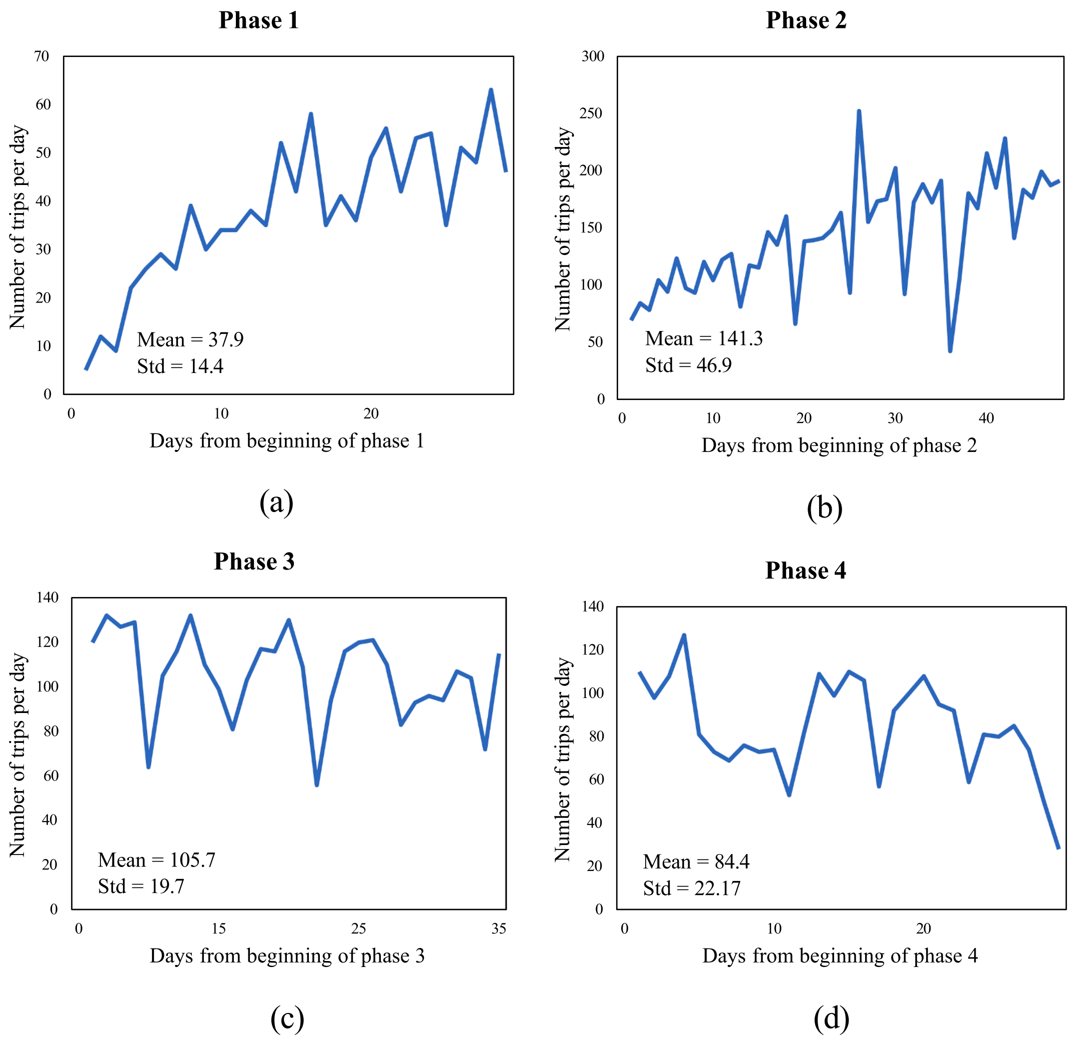

Fig. 6. Service usage time-series for a) Phase 1, b) Phase 2, c) Phase 3, and d) Phase 4.

Table 1
Percent change of usage between phases.

	Morning Period		Mid-day Period		Afternoon Period		Evening Period	
Phases	%	p-value	%	p-value	%	p-value	%	p-value
1—2	324.62	0.00	314.90	0.00	251.23	0.00	267.06	0.00
2—3	−12.93	0.09	−27.85	0.00	−23.17	0.00	−40.42	0.00
3—4	−17.96	0.00	−23.00	0.00	−22.39	0.00	−1.60	0.88

increase of fare during morning and mid-day peak periods compared to afternoon and evening time periods. Especially for longer rides during morning and mid-day time periods, the fare was doubled.

The percent change of usage from phase 3 to 4 remains at similar levels for all time periods except evening time period, during which there is no further reduction. Mid-day and afternoon periods have similar levels of percent reduction which is again greater than that of morning period. In summary, the reduction in service usage mostly correspond to mid-day, afternoon peak and evening time periods. The number of trips duration evening time period reduced to nearly half after the implementation of phase 3, while afternoon and evening periods have a steady and comparable percent reduction from phase 2 to 3 and then 4.

5.1.3. *Spatial usage changes*

Local fixed PT network is also considered in order to investigate its relationship to the urban DRT service, shown in Figs. 7 and 8 for the requested trips' origin and destination, respectively. These figures show that most of the high-density trip origin and trip destination locations are clustered around PT hubs (i.e., Leppävaara, Aalto-University (M) station, Tapiola (M) station and Matinkylä (M) station).

5.2. *Second level analysis – trip characteristics changes*

5.2.1. *Requested trip distance*

Table 2 summarizes the average trip length of a requested trip in terms of distance that needs to be traveled, if this trip is served individually (in km). The average values are shown per time period and phase. Despite the higher fare for longer trips, the average requested trip distance remains same throughout the pilot's implementation. Similar to (Sanaullah et al., 2021), the average distance remained around 5 km.

The percentage of long trips over all trips during a phase and daily

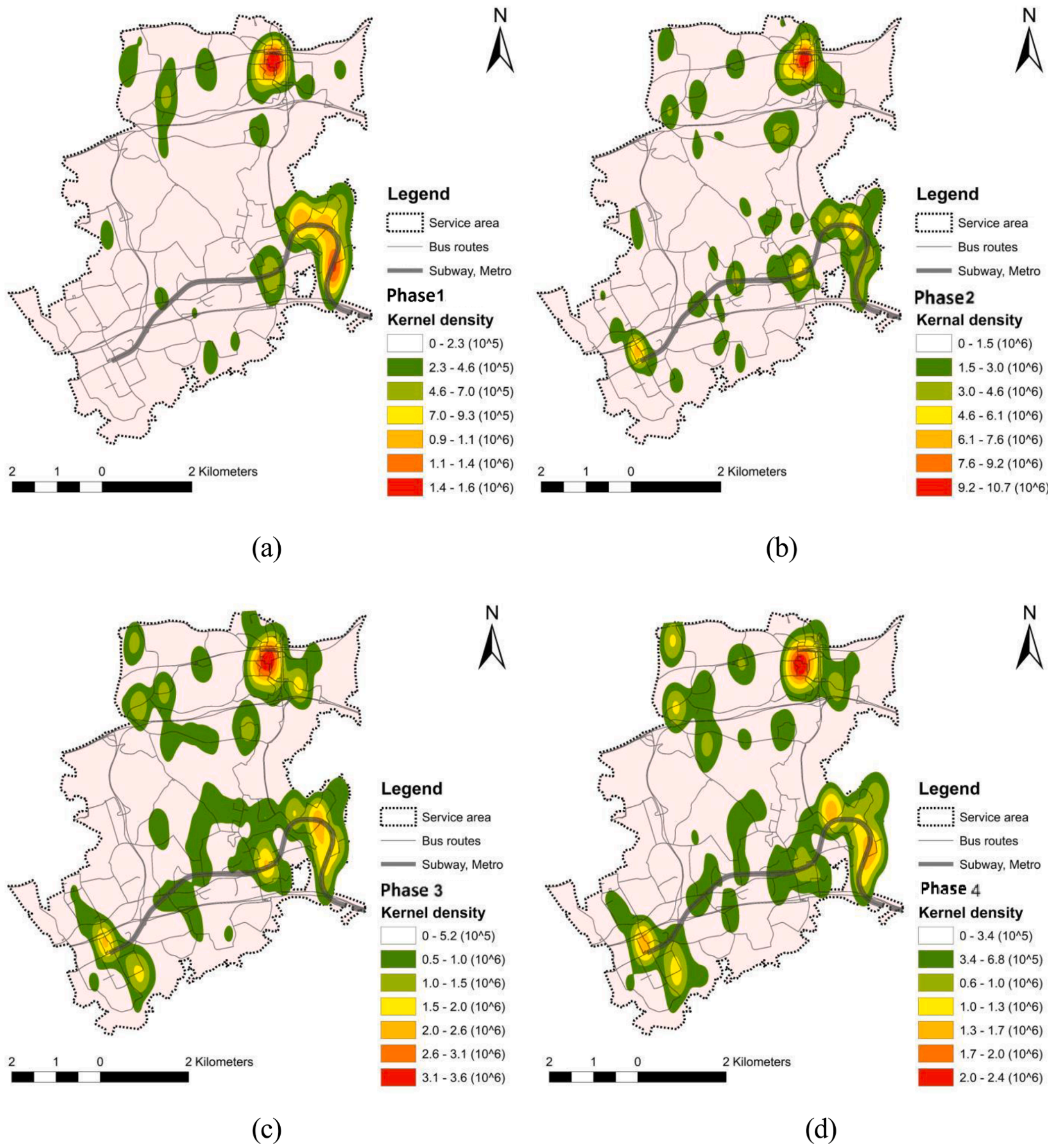

Fig. 7. Usage (Origin) density of Viavan trips with fixed PT network a) Phase 1, b) Phase 2, c) Phase 3 and d) Phase 4.

period is shown in Fig. 9. One can see from this figure that the great majority of trips belongs to the type of long trips, with phase 1 having the greatest percentages in all daily periods. The long trips do not seem to be reduced in percentage even when the price was higher for these trips in phase 3 and 4.

5.2.2. *Requested trip time*

Table 3 shows the requested trip time in minutes. Assuming that the network conditions remain the same within time periods of a day during the pilot, it can be concluded from this table that there are no significant phase to phases changes. However, there is an exception during the afternoon period of Phase 1 and 2.

5.2.3. *Number of passengers per request*

Fig. 10 shows the histogram of the number of passengers per trip request in all phases and time periods. The great majority of requests refers to one passenger, whereas there are some requests with two passengers. The cases of 3 or 4 passengers per trip request are more rare.

5.3. *Third level analysis – operational changes*

5.3.1. *Difference between performed shared and inferred single trip time*

Table 4 presents the change in the mean difference between performed (i.e., shared) and estimated (i.e., non-shared) trip time from phase to phase for the four time periods per day. Negative values indicate a decrease. According to *t*-test, there is a statistically significant increase of this parameter between phases 1 and 2 during mid-day and evening time periods. Thus, before the drop of service usage, there was an increase of shared mobility disutility during inter-peak and after-peak times. The drop of usage between the two phases is greater for evening time period (see Table 1). Between phase 2 and 3 there is a statistically significant decrease of the shared service disutility during morning period. Afternoon peak and after-peak periods present an increase of this disutility, even though there is a decrease of usage.

5.3.2. *Difference between promised and performed trip time*

The differences between the actually performed and promised trip times are investigated in Fig. 11. The negative values correspond to performed times lower than promised times (in minutes). The mean values are always around minus 2 min, indicating that the service

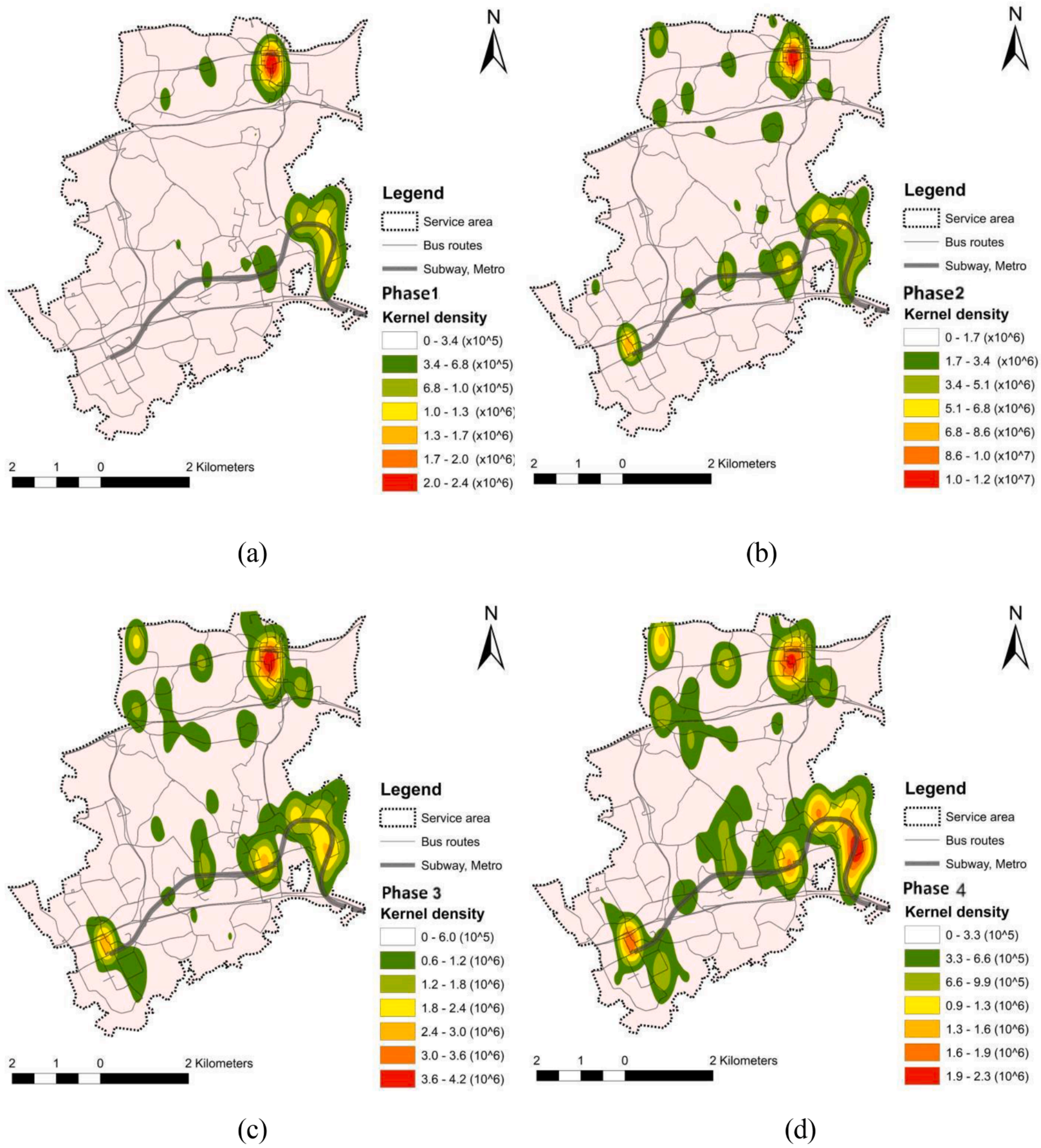

Fig. 8. Usage (Destination) density of Viavan trips with fixed PT network a) Phase 1,b) Phase 2, c) Phase 3 and d) Phase 4.

Table 2
Mean requested trip distance (km).

Phase	Morning Period	Mid-day Period	Afternoon Period	Evening Period
1	5.25	5.08	5.44	5.05
2	5.50	5.42	5.38	5.05
2	5.60	5.55	5.35	5.20
3	5.71	5.57	5.58	5.30

performed trips that were on average shorter than promised. Phase 2 seems to have consistently a high number of positive outliers during all time periods. Other than that, there are no major differences detected among different time periods and phases.

Table 5 includes the percent changes in mean differences between the performed and promised trip time between consecutive phases for different time periods. From phase 1 to 2 there was a statistically significant increase in the mean difference with exception of morning period, implying that the passengers were still served at lower times than promised, but not as low as it used to be during phase 1. From phase 2 to 3 there is a statistically significant decrease in the mean differences during morning period and mid- day period, which means that the DRT performance improved again after the drop of usage.

5.3.3. Difference between promised and performed pick-up time

Regarding requests picked-up later than promised, Fig. 12 shows that the phase 2 is the one associated with the greatest whisker among others during morning and mid-day periods. The total number of outliers, including the value of lateness, seem to be highest for phase 2 in all time periods. However, phase 3 during mid-day period has a maximum outlier of 25 min, while phase 2 has one of 18 min. It is noted that the greatest value of outlier is observed in afternoon period for phase 3 and is equal to 63 min. This value is not included in the graph for visual purposes. The overall observation of the graph shows that the lateness in pick-up had most of the outliers during phase 2. However, it is highlighted that the mean lateness is at very low levels (i.e., around 3 min).

In contrast with Fig. 12, Fig. 13 presents the Box and Whisker plots for the case of requests being served earlier than promised. The levels of earliness can be seen lower than those of lateness (in minutes).

5.3.4. Difference between promised and performed drop-off time

Fig. 14 show the Box and Whisker plots for trips with lateness in drop-off times. Phase 2 and 3 have very similar statistics, with a small

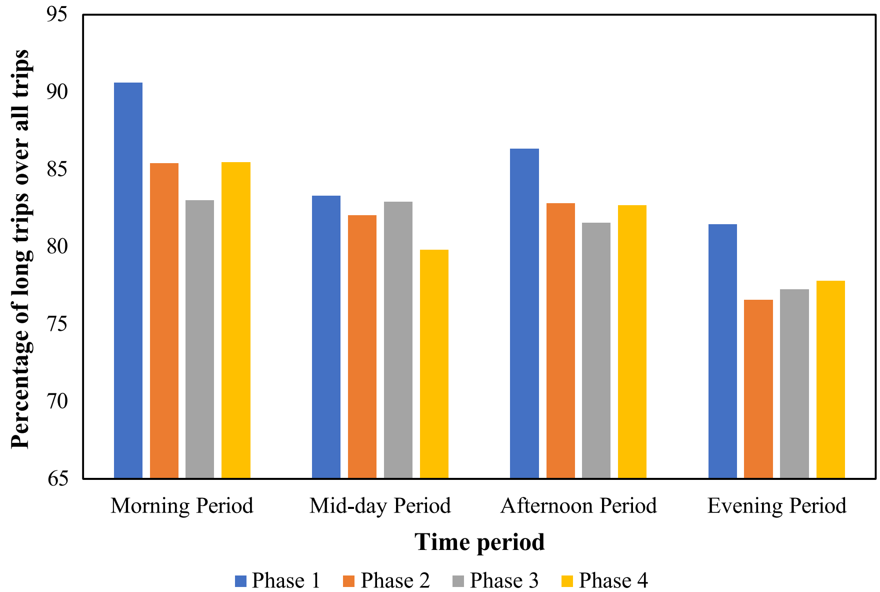

Fig. 9. Percentage of long trips (>3 km) over all trips per time period and phase (%).

Table 3
Mean requested trip time (min).

Phase	Morning Period	Mid-day Period	Afternoon Period	Evening Period
1	6.45	5.99	6.63	6.08
2	6.62	6.46	6.46	6.19
3	6.68	6.57	6.40	6.27
4	6.77	6.57	6.61	6.45

exception during evening time period, where phase 2 has more outliers and slightly greater whisker, both of which represent higher uncertainty in service. Similar observations hold for early drop-offs, with after-peak service during phase 2 being the one with the greater outliers (Fig. 15).

6. Discussion

6.1. Discussion of case study results

This framework develops a relational understanding that can be

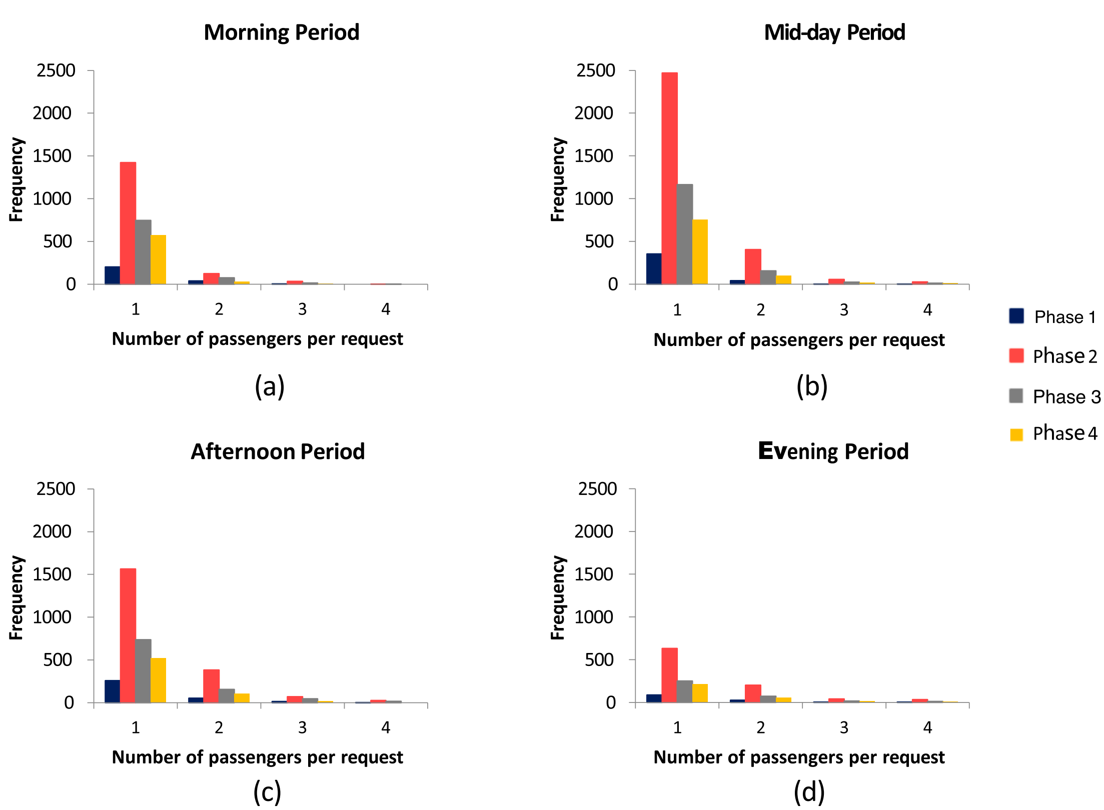

Fig. 10. Histogram with the number of passengers per trip request.

Table 4
Change of percentage difference between performed (i.e., shared) and estimated (i.e., non-shared) trip time between phases per time period.

	Morning Period		Mid-day Period		Afternoon Period		Evening Period	
Phases	change	p-value	change	p-value	change	p-value	change	p-value
1–2	–22 %	0.00	25 %	0.00	−7%	0.12	47 %	0.00
2–3	−8%	0.01	−4%	0.17	8 %	0.03	13 %	0.02
3–4	8 %	0.06	0 %	0.97	−5%	0.21	−3%	0.70

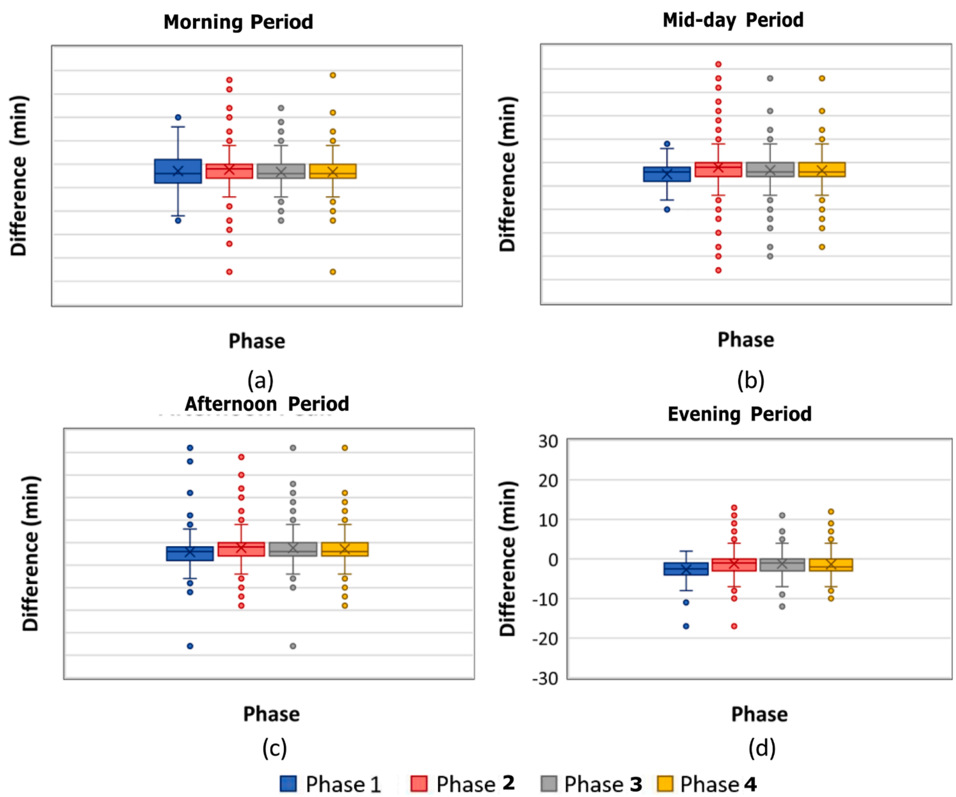

Fig. 11. Box and Whisker plots of differences between performed and promised trip time (minutes) for a) morning period, b) mid-day period, c) afternoon period, and d) evening.

Table 5
Change of percentage difference between performed and promised trip time be- tween phases per time period.

	Morning Period		Mid-day Period		Afternoon Period		Evening Period	
Phases	change	p-value	change	p-value	change	p-value	change	p-value
1–2	20 %	0.27	59 %	0.00	46 %	0.00	56 %	0.00
2–3	−42 %	0.00	−59 %	0.00	−7%	0.57	0 %	1.00
3–4	3 %	0.81	−3%	0.73	−17 %	0.23	−14 %	0.56

helpful for practitioners to implement an emerging service in a well establish and multimodal mobility ecosystem. This urban DRT pilot analysis and its findings can be considered by practitioners when investigating the service usage trajectory. The findings of the case study results at three analysis levels are as follows:

6.1.1. First level analysis – service usage changes

Similar to Kutsuplus pilot that also operated in Espoo HCR, highest service usage was observed during morning time period (Jokinen et al., 2019). Focusing on changes in usage characteristics, the analysis shows that during phase 1 to phase 2, service usage observed a rapid peak with highest usage observed during morning time period. However, an exception is the low and non-statistically significant decrease for morning time period during phase 3. In contrast to existing literature with a significant decrease in service usage over time during morning time period (Zhou et al., 2021), results indicate that service usage did not change. During phase 3 and phase 4, the highest reduction in service usage occurred during the mid-day time period. Whereas following the first increase in service usage, greatest decrease between phase 2 and phase 3 occurred during the evening time period.

Analysis shows that the origin and destination locations of trip requests were well-aligned with the fixed PT network of the service area. Therefore, a strong connection between the existing fixed PT and DRT trips can be inferred. As highlighted in the ViaVan report, this connection also implies that DRT passengers were choosing the services to access/egress fixed PT (Helsinki Regional Transport Authority, 2022). Moreover, it can be seen that service extension from phase 1 to phase 2 that enabled access to more transport hubs resulted in an increase in the

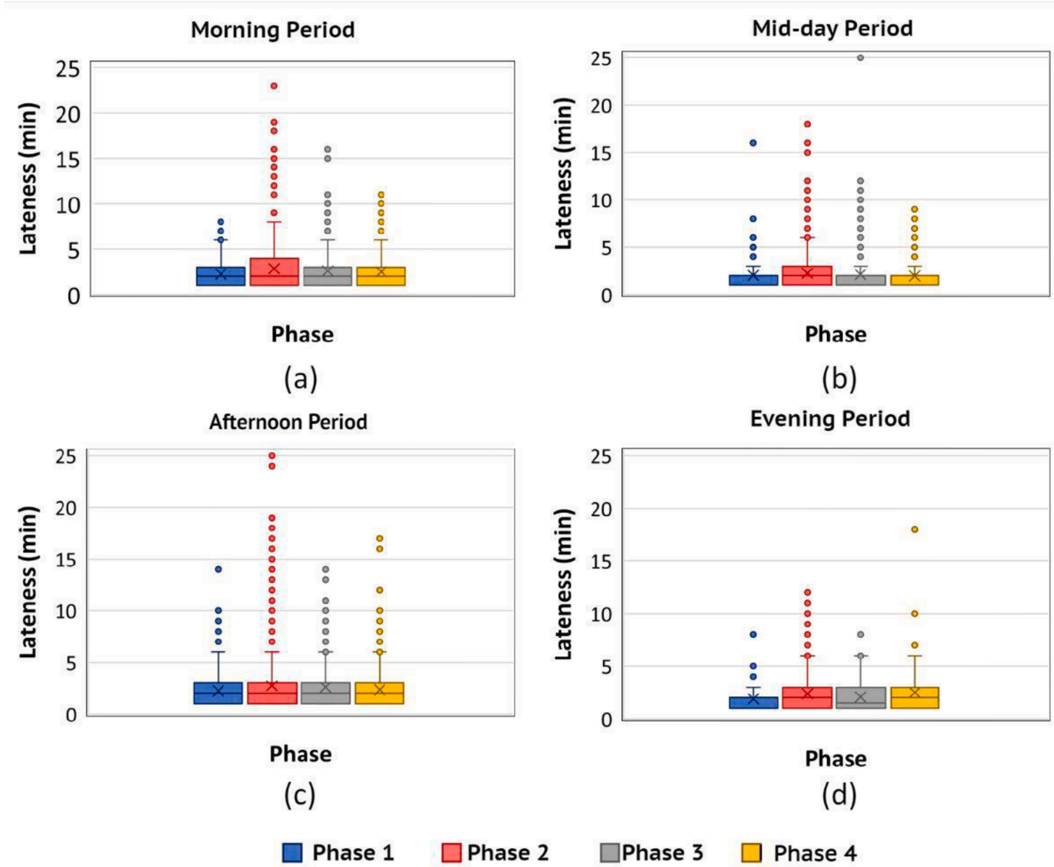

Fig. 12. Box and Whisker plots of pick-up lateness (minutes) for a) Morning period, b) mid-day period, c) afternoon period, and d) evening period.

distribution of trip density.

6.1.2. *Second level analysis results – trip characteristics changes*

The analysis of the distance length of requested trips revealed that their average is always around 5 km. Similar average distance was also observed for the DRT trips in Belleville (Sanaullah et al., 2021). Despite of the changes in service design, the differences between long and short trips seems largely unchanged from phase to phase. It is also worth relating that zonal diameter for both services was similar (approximately 8 km).

6.1.3. *Third level analysis results – Operational changes*

Regarding the DRT operation, it can be observed that the difference between shared and inferred trip time increased over time during the evening time periods. This phenomenon was not observed in Kutsuplus, in which the offered trip duration was comparable to private car for most of the trips (Haglund et al., 2019). It is noteworthy that there is a decrease to this difference for some time periods between phase 2 and 3. It follows the intuition that greater demand should lead to greater discomfort for DRT passengers, assuming all else remains equal (e.g., fleet size).

Focusing on the punctuality of service, low average earliness or lateness times show that the operator was operationally punctual most of the time. Similar results are reflected in other case studies (HSL, 2016; Alonso-Gonźalez et al., 2018). However, analysis reports earliness of the majority of trips.

If the assumption is that negative values are positively perceived by passengers, since they lead to lower total travel times than expected, this means that the service performed sufficiently most of the time. However, if we consider that lower travel time also means earlier drop-off times if pick-up time is punctual, it could be assumed that the negative values might displease some passengers who arrive earlier at activities that are associated with negatively perceived waiting times (e.g., waiting outside public buildings due to COVID-19 restrictions).

Focusing on pick-up and drop-off, phase 2 was often times associated with greater uncertainty on whether the passenger will be picked up as promised. The deviations were fairly low most of the time, with the exception of some outliers. It is interesting to note that morning time periods observed the least outliers throughout the service trajectory. Regarding the promised and performed pick-up time (lateness), the morning time difference increases over time, whereas the afternoon time period remains stable. The opposite trend was observed during evening time periods.

6.2. *Implications for practice*

The followings are the implication for practice for urban DRT implementation in future:

This urban DRT pilot was implemented in a multi-modal area offering integrated mobility services. Since HSL services have received international recognition for high quality (HSL, 2018), it could be implied that the local commuters also have high standards and expectations from transport services. However, it is noted here that service was not integrated with existing HSL and Whim MaaS platform for ordering and payment of the ride. Such integration could complement with existing mobility ecosystem. Moreover, only smartphone-enabled platform in English language was provided in an area of mostly Finnish and Swedish speakers. Thus, DRT operators should keenly focus on the context of the service area while designing the service.

The developed framework is helpful in looking at both diverged and converged pictures of the service trajectory. The daily time scale presenting a diverged cross-sectional picture can help practitioners in

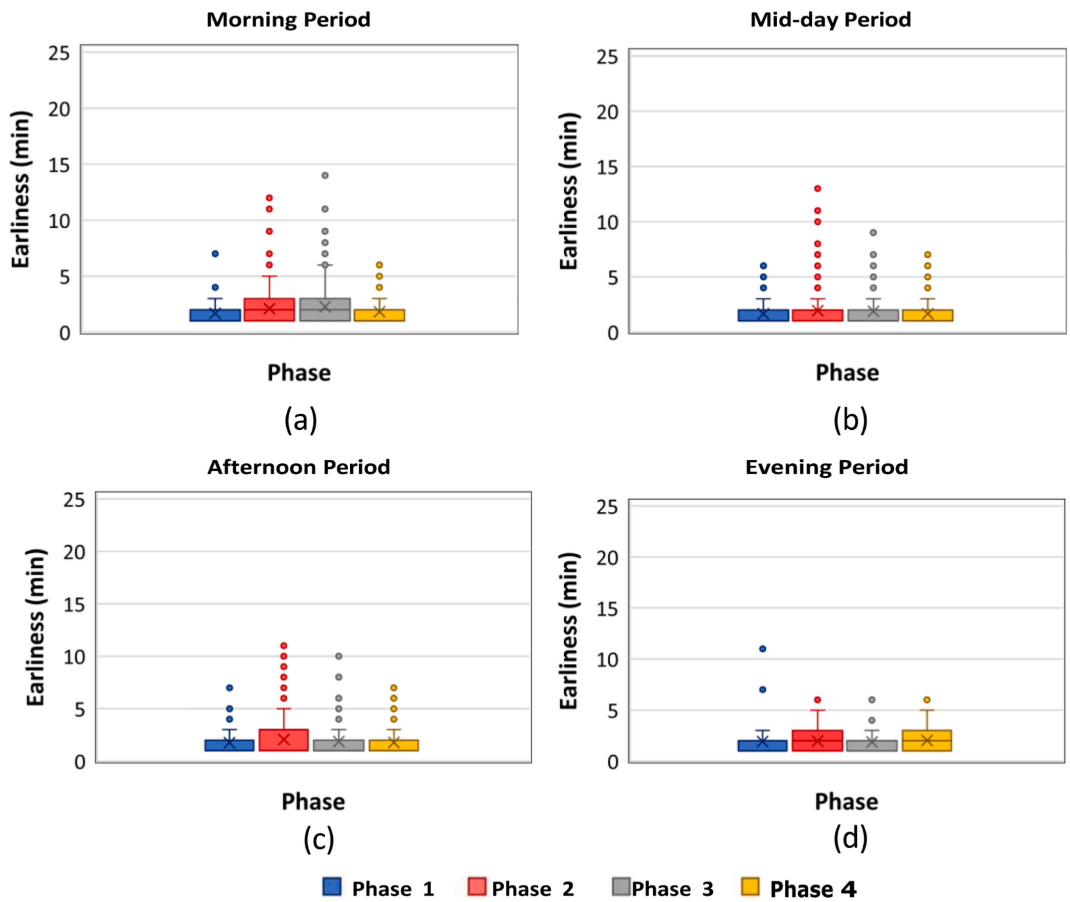

Fig. 13. Box and Whisker plots of pick-up earliness (minutes) for a) Morning period, b) mid-day period, c) afternoon period, and d) evening period.

making service supply-related decisions. On the other hand, a converged longitudinal picture at phase level can be helpful in understanding the dynamics of the service trajectory changing over time. However, longitudinal analysis can not efficiently help in separating the impact of a certain change over the system.

A phase-based perspective provides an additional way to understand the changes in service trajectories in relation to the changes in service operation. However, other changes such as external factors can be used depending upon the need and available data sources. An example of an external factor could be a change in network infrastructure and the consequent change of traffic conditions affecting DRT service performance.

Phase-based analysis of DRT service provides a concept of phase-based implementation of the service. Phase-based implementation means thinking about several weeks or months, to determine the service milestones. For example, as findings from previous studies suggest (Gilibert et al., 2019; Executive et al., 2004), the largest portion of the urban DRT service is leisure trips. During winter, weather becomes extremely cold, the Christmas and new year holiday period in Finland cause potential loss of DRT trips for leisure and outdoor activity trips. Therefore, the practitioners can plan for the upcoming transition dates in advance.

Managerial decisions play an important role in providing better service quality (Jokinen et al., 2019). In this pilot, taxi drivers were contracted to operate DRT service without any training. Driver training can contribute to providing a better quality service. Therefore, DRT implementation in future should try to focus on managerial decisions that can contribute to the perceived service quality.

An emerging urban DRT service in a well-functioning mobility setup implies challenges with habituation and shifting demand from their existing modal choices. Implementation of a service with a predefined six months of operation could possibly influence the will of potential users to give up their private vehicles (Helsinki Regional Transport Authority, 2022). Therefore, practitioners should inspect the duration of the pilot and length of the phases while planning of a DRT service.

7. Conclusion

This study investigates an urban DRT pilot in the Helsinki Capital Region (HCR), Finland, during 2019–2020. During the pilot, several changes were made in the service design. This pilot has also experienced changes in service usage levels over time. This research aimed to contributes to the larger need for longitudinal understanding of DRT using trip data. As this pilot has been implemented in an urban area with already diverse set of mobility services. Therefore, this study provides extensive service area background and service implementation context.

The research framework has developed the concept of phase-based time- scale to understand the service trajectory of DRT service over time. The study uses key changes in service design to develop phases. Each phase in this study represents a time period within pilot duration without considerable service design changes. In addition to inter-phase analysis, each phase is further analyzed for intra-phase analysis. Intra-phase analysis is based on daily time periods. Research studies inter-phase and intra-phase changes at a three-level analysis of service parameters.

Analysis shows the complementary role of the urban DRT to fixed transport services and indicates challenges for efficient coordination. Study provides a set of additional factors for further understanding of the service trajectory. Lastly, study recommends that future research efforts should develop and test different timescales using additional data sources to understand service trajectories over time.

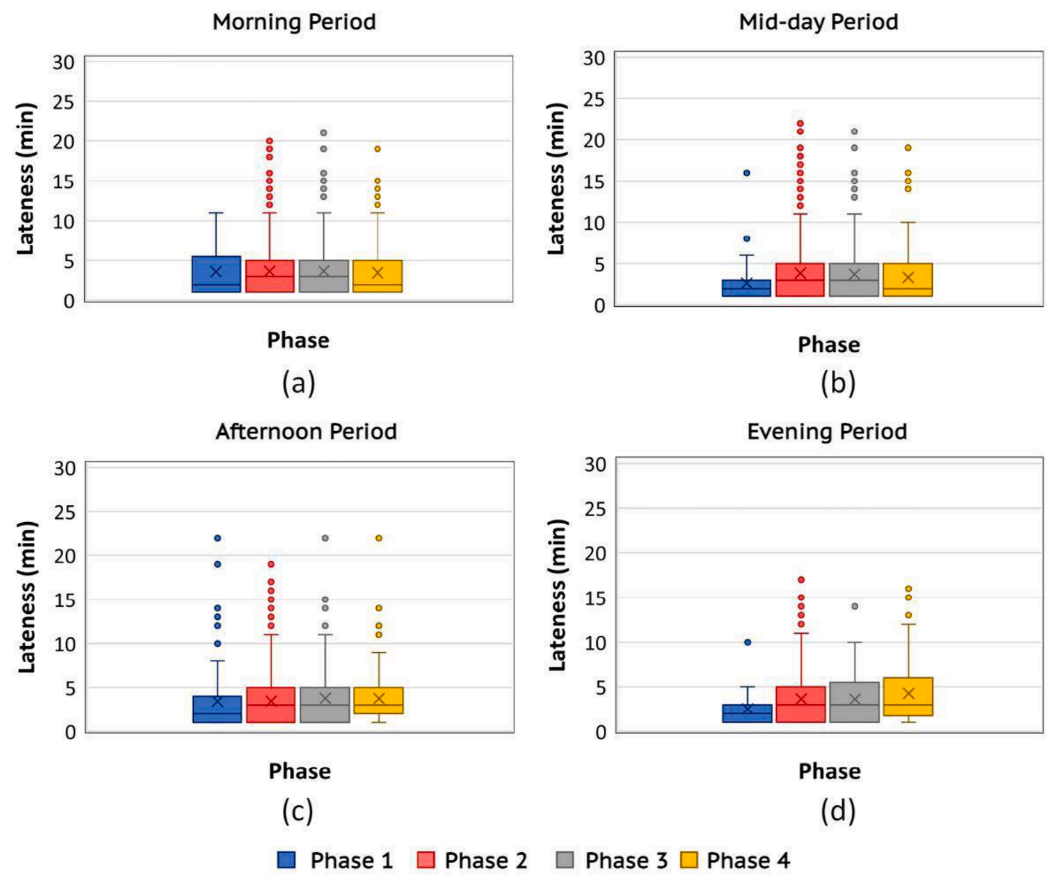

Fig. 14. Box and Whisker plots of drop-off lateness (minutes) for a) Morning period, b) mid-day period, c) afternoon period, and d) evening period.

7.1. Contribution to scholarly knowledge

This study contributes to the need for further understanding of DRT services on longitudinal scale, while also recognizing service trajectory changes across multiple levels (Sharmeen and Meurs, 2019). In particular, some of the previous studies have some indication of the need to understand the service trajectory from a phase-based perspective (Jokinen et al., 2019; Zhou et al., 2021). However, these studies have not thoroughly developed the phases and longitudinally analyzed the complete service trajectory incorporating all of the significant changes. The research continues the path of those initial studies. This case study develops a phase-based framework by introducing the concept of transition date and deepens the analysis by providing multiple levels of the analysis. The study also provides a thorough and extensive pilot implementation setup and service area background which offers valuable insights on planning and operating future DRT services, that is not discussed to great extent in literature so far. Moreover, this case study shows the potential of phase-based approach even with the limited data sets. Lastly, case study also adds to larger the need for more DRT studies based on empirical trip data.

7.2. Study limitations

The lack of actual routing data is the main limitation of this research, since this is considered proprietary data by the operator. Lack of the data prohibited the evaluation of some the trip characteristics such as occupancy. Similarly, the analysis relies on individual trip requests without information of passenger identification and demographics. In addition to the level of details about the trip, approximately 2000 trips (11.3 % of the total trips) made by weekly travel pass are not included in the available data. Due to the data limitations, study does not incorporate the data for various types of discounts such as Viapass discount, Espoo first ride activation discount, IsoOmena €1 ride promotion, final 2 weeks of 2 euro flat rate and proactive follow-up discount given in the process of phase development.

The Saturday operation introduction is not considered here as the motivation of travel on weekdays can be different than weekends. However, it is apparent that it leads to the great drops of usage that are met seasonally in the graph after November 4. Besides, it agrees with public transport usage trends that weekends are in general associated with lower demand for commuting (Sanaullah et al., 2021). The days corresponding to holiday season (i.e., December 21st to January 6th) have been removed since they are considered special days.

Operational times of the service were also changed during the service operation. As experienced in (Sanaullah et al., 2021), trip motivations and characteristics on weekend can vary compared to weekday trips. As this analysis framework does not include weekend operation and therefore a different operational time for Saturday is not considered as a transition date for phasing.

Finally, it is our knowledge that there were changes in the marketing approaches during the pilot. However, due to the lack of information about the detailed marketing strategy, it was not considered as a level of analysis.

7.3. Future research directions

Besides the contribution of the findings themselves, this study also opens up several new pathways for future research. Besides adhering to the scientific excellence criteria, these future studies should also aim to enable the stakeholders to make informed decisions on improving both DRT service design and implementation conditions.

First pathway for future research includes further implementation of

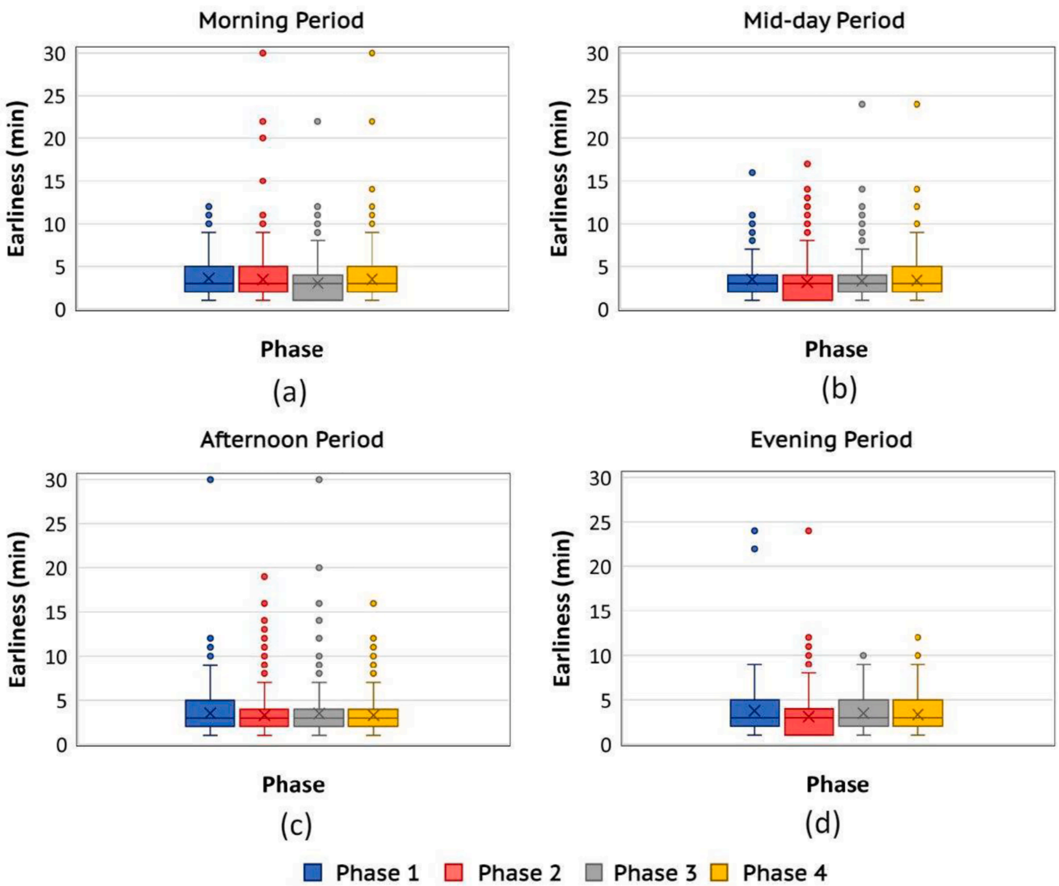

Fig. 15. Box and Whisker plots of drop-off earliness (minutes) for a) Morning period, b) mid-day period, c) afternoon period, and d) evening period.

MLP framework for case study analysis, such as those implemented in other transport studies (Torrisi et al., 2023; Medina-Molina et al., 2022; Bruno, 2022). These studies would have to rely on mixed methods, using both quantitative and qualitative data (e.g., stakeholder interviews). Moreover, these future studies should pay special attention to the analysis actor roles within the ecosystem and broader phenomena of governance and political culture in a particular context (Olin and Mladenović, 2023).

Second, since the analysis of this study relies on trip data, future studies should use other data sources to deepen the analysis. For example, those future studies should use marketing data or user behavior and evaluation data collected either automatically through service app or through dedicated questionnaires (Haglund et al., 2019). Moreover, subject to the availability of detailed data sources that help in identifying the user IDs and vehicle routing, future studies should develop additional indicators to study the service trajectory, such as additional measures of spatial coverage, among others.

Third, in this study, phases are developed based on service usage in connection to service design. Thus, there is a need for further development of phases based on different criteria and different time scales. Alongside with the previous aspect, future studies should also focus on investigating the role of pilot duration and phase duration.

Finally, there is also a need for a systematic review of previous urban DRT services. Such as review would help to understand how and to what extent various service attributes, service area context, information of the mobility ecosystem and service implementation setup are analyzed in various urban DRT case (De Vos and El-Geneidy, 2022; Wee and Banister, 2016). In this regard, applying MLP framework can be useful to understand the dynamics and interplay of various factors, such as in previous reviews of other topics (Geels, 2011; Geels, 2002).

CRediT authorship contribution statement

Muhammad Atiullah Saif: Conceptualization, Methodology, Software, Investigation, Formal analysis, Writing – original draft, Visualization, Data curation, Writing – review & editing. **Charalampos Sipetas:** Conceptualization, Methodology, Software, Formal analysis, Investigation, Writing – original draft, Visualization. **Milos Mladenovic:** Conceptualization, Methodology, Investigation, Supervision, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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