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An international review of experiences from on-demand public transport services

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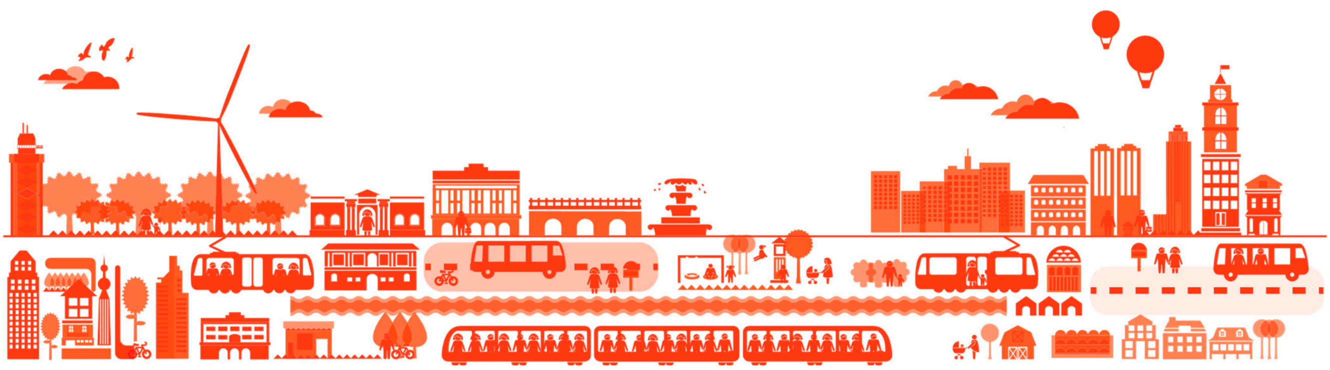

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Preface

At the moment, there is a great interest in new public transport solutions that take advantage of technological advances to better match demand and supply. Basically, this is based on the idea of demand responsive transport (DRT), which has developed since the 1970s. This report examines how some of these new on-demand services are configured and whether they have contributed to improving the efficiency of DRT.

The research has been carried out in the K2 funded project *Public transport on-demand? – Assessment of the potential for demand-responsive public transport services in Sweden.*

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Summary

The aim of this report is to contribute to develop knowledge about what the developments in positioning and smartphone technology bring to the table for the public transport sector.

The overarching question in the report is: can new technology improve demand-responsive transport (DRT)?

The cases analysed in this report were selected using a number of criteria to delimit the sample and distinguish the cases from "traditional" DRT and from ride-hailing services. A total of 35 different services were identified that met the criteria for what this report refers to as on-demand public transport. The identified cases are located in nine different countries and 23 different cities or regions, and includes services that have been or are operating in major urban areas, smaller towns, suburbs, semi-rural and rural areas. Nine services, most of which are subsidised by the public sector, have been analysed in more detail.

The comparison of the cases reveal differences and similarities concerning aspects such as vehicles and fleet sizes, and service partnerships. Different variants are also described regarding operational policies of the services. This includes origin-destination policies, areas covered by the services, where to pick up and drop off passengers, operating hours, booking method, time of booking, payment and pricing.

For the nine cases that are the focus of the report a comparison of patronage, productivity and production costs are also made. A main conclusion from this part of the study is that so far there is scant evidence that new technology improves the productivity of DRT. This suggests that new technology is no panacea for fixing the problems of DRT and the study shows that thus far, at least, on-demand public transport hardly represents a transport revolution.

1. Introduction

For decades, demand-responsive transport (DRT) has been highlighted as an opportunity to offer public transport in areas with low demand and for special purpose services (Mulley et al., 2012). However, experience shows that DRT is often expensive and fails to deliver the expected benefits because of barriers such as inadequate technology, mismatches between services and geographical conditions, lack of knowledge about users and various kinds of institutional barriers (Mulley et al., 2012; Davison et al., 2012). The breakthrough in "smart" mobile phones and the development of vehicle positioning systems and routing software has led to a renewed interest in DRT. Various attempts have been made in recent years to implement new public transport services that are distinct from "traditional" DRT. One difference is that these new services are often launched in an urban or metropolitan context, as opposed to a rural context. Another difference is that many services are aimed at the general public rather than focusing on special needs groups (e.g. DRT services for the elderly). A further difference is that DRT has traditionally been provided exclusively as a welfare service operated and paid for by the public sector. In contrast, more recent attempts have been initiated either solely by new private actors with the ambition of launching new services to make money from urban mobility, or through public-private partnerships between incumbents, such as public transport agencies, traditional public transport operators and new actors.

It has been argued that it is necessary for public transport agencies to offer flexible, demand-oriented public transport services as a means of competing with commercial ride-hailing services (e.g. Bay Area News Group, 2017). Thus, these services can be viewed as examples of how public transport actors become involved in innovation processes concerning Mobility as a service (Maas) concepts or at least attempts to improve their range of services by implementing "smart" technology. Several of these new services have been launched as an attempt by public transport actors to "Maasify" their range of transport services.

This report presents the results of a systematic review of experiences of recent and current attempts at using different types of flexible on-demand public transport services. Previous research on these type of services has typically been conducted as single case studies (e.g. Alonso-González et al., 2018; Sharmeen & Meurs, 2018). Some reports, such as Shaheen et al (2016) and the Eno Center for Transportation (2018), compare different cases, although these are typically confined to one national context. There is currently a lack of studies that attempt to gain a more general overview, comparing experiences across national boundaries, as well as multiple cases. The aim of this report is to contribute to developing knowledge about what improvements in positioning and smartphone technology have brought to the public transport sector. The overarching question posed in this report is: can new technology improve DRT?

The ambition of this report is to provide a snapshot in time of experiences of new technology-driven DRT service trials and services implemented from 2012 to 2018. The justification for this time frame is that it coincides with the smartphone revolution, as well as a general tendency for new mobility providers to enter the transport market. As will be shown in the presentation of cases, many new services have been launched over the last couple of years. At the time of writing, there are also multiple plans for new services. Thus, a lot of data presented in this report will inevitably be out of date at the time of publication. Additionally, as several of the studied cases have either been fully implemented by private actors or, in several instances, through partnerships between public and private actors, there are obstacles to obtaining data, for example, regarding issues that are considered sensitive from a business perspective. Nonetheless, the huge interest in launching new services highlight the importance of gathering and analysing as much data as possible about these new services.

The emphasis in this report is descriptive rather than analytical. Data on a large number of variables has been compiled (to the extent possible) describing service design and outcomes. Examples of variables include type of system, operating hours, geographical demarcation, type of vehicles, number of vehicles, as well as demand and operating costs. The analysis of much of this data is quite basic and generally attempts to identify patterns of similarities and differences across the cases. However, the concluding section of the report also includes a more analytical approach in an attempt to draw lessons from the studied cases.

1.1. Method

The data presented in this report have been compiled from various sources such as published secondary sources, including the Helsinki Regional Transport Authority (2016), Shaheen et al, (2016), Eno Center for Transportation (2018), VTA (2016) and RideCo, (2018). Apart from reports, other secondary sources have been used, including news items from online publications and information from the websites of service providers.

In some cases brief interviews were conducted. This includes Skype interviews with representatives of ViaVan, ArrivaClick and Padam. For Breng flex, a brief Skype interview was conducted with a representative of the consultancy firm Innotrans and personal correspondence via email was conducted with a representative of Gelderland Province. Also, personal meetings were held with Keolis Downer and Transport New South Wales.

An important part of the process has been participation in a workshop with representatives of Plustur in Oslo in November 2018. In addition, the preliminary results of the study have been presented in many different forums, including an UITP workshop in London in May 2018, a seminar in Perth in January 2019, a seminar at Monash University, Melbourne in February 2019, as well as various presentations in Sweden in 2018 and 2019.

The report is structured in three sections: The *Types of systems and services* section describes different aspects of the services, such as vehicles, fleet sizes and service partnerships. The *Operational policies* section describes different routing and scheduling policies, pick/up drop-off points, operating hours, booking and payment methods, including pricing and booking policies. These two sections are the most extensive part of the report. The *System performance* section includes data from cases for which information on the number of trips, revenue and production costs are available. As previously stated, there are considerable barriers to obtaining certain types of information, particularly information that is sensitive from a business perspective. This means that the cross-case comparisons are incomplete. The report closes with a *Discussion and concluding remarks* that distil some lessons from the studied cases.

1.2. Overview of on-demand services

The cases analysed in this report were selected using a number of criteria to delimit the sample and distinguish the cases from "traditional" DRT and from ride-hailing services. First, a temporal delimitation was introduced in order to only include tests or actual services in operation or that were commissioned from 2012 or later. Technical delimitations, for example, required that journeys had to be bookable via a smartphone application or a web page and that the system relied on automatic real-time matching of supply and demand (not only manual dispatch). Two delimitations concerning service design characteristics were also added: the services had to be accessible to the general public (not special services only) and should be targeted at shared trips.

Completed	Ongoing
Kutsuplus: Helsinki (FI)	Via as TNC (NY, Washington DC, Chicago) Via in partnership with cities (US): Arlington TX, West Sacramento CA; (US) ViaVan: London (UK), Amsterdam (NL), Berlin (DE) Via in partnerships with operators: **ArrivaClick** (**Sittingbourne**, Liverpool), PickMeUp (Go-Ahead Group, TRP Group/Oxford Bus Company) (UK)
Bridj: Boston, Washington DC, **Kansas City** (US)	Flexigo – Paris (FR)
VTA flex: San José	**Résa'Est (FR)**
RideCo: Go Connect, Milton (CA)	**Breng flex: Nijmegen, Arnhem, Molenhoek (NL)**
Slide: Bristol (UK)	**Plustur: North Jutland (DK)**
Sydney: Inner West Wetherill Park (Bridj/Transit systems) (AU)	New South Wales, Greater Sydney area, (AU), 11 ongoing trials (and one completed, Inner West Wetherill Park): • Bankstown (Punchbowl bus company) • Carlingford and North Rocks (Hillsbus) • Central coast (Community transport central coast) • Eastern suburbs (Bridj/Transit systems) • Manly (Rideplus/Transdev) • Edmonson park (Interline bus services) • Macquarie Park, **Northern Beaches (Keolis Downer)** • Illawarra region (Premier motor services) • Sutherland Shire (Transdev)

Table 1 Overview of identified cases per December 2018. Cases in bold are the focus of the report.

While these selection criteria worked reasonably well in terms of distinguishing from traditional DRT, the demarcation against ride-hailing services such as Uber and Lyft were more difficult. As will be shown in the report, this is partly because some of the major players like Via and RideCo that are currently experiencing rapid growth have very similar business models and operate much in the same manner as ride-hailing companies. From the criteria presented above, the emphasis on shared trips is the only one that arguably distinguishes between what the report refers to as on-demand public transport and ride-hailing. However, since several ride-hailing companies also offer shared services, the criteria presented above does not strictly exclude ride-hailing. Thus, the selection of cases is somewhat arbitrary. However, it could be argued that there is a distinction between a primary emphasis that targets shared trips, which would then be what defines a service defined as on-demand public transport, and ride-hailing services, which do not generally have this focus, but may offer shared services.

Table 1 provides an overview of the relevant services that meet the established selection criteria. The highlighted cases are the cases that will be the focus of the report. The reason for emphasising some identified cases and not others is primarily the availability of data.

Table 1 describes the situation in December 2018, and includes cases defined as completed and ongoing. This includes cases in nine different countries located in 23 different cities or regions. Table 1 includes a total of 35 different services that have been or are operating in major urban areas, smaller towns, suburbs, semi-rural and rural areas. However, out of all the cases included in the review, Plustur in Denmark is the only one that clearly targets the classic DRT territory of a rural, low demand context. However, this overview of cases should not be considered exhaustive. The review has undoubtedly missed many completed or ongoing services. Despite its shortcomings, this overview is an attempt to increase the opportunity to make comparisons between different types of services in different types of contexts.

Some services were deliberately excluded as they failed to comply with the selection criteria. This includes the RideCo service at Changi Airport, Singapore, which was launched in 2018. This is an on-demand service for transporting employees at a company at the airport to/from their homes all over Singapore to/from four terminals at Changi Airport. As this service is not available to the general public it was excluded from the overview. Another service involving RideCo in Singapore, Go Shuttle Plus, allows passengers to pre-book a seat on a shared vehicle. This service will not be included in the study as it was launched in late 2018 and it was not possible to compile data for the overview. The interviews and meetings with various organizations also showed that there are many trials in the pipeline. Thus, the situation will look considerably different when this report is published.

Completed cases include both temporally limited technical trials and services launched with the intention of becoming permanent but which were discontinued for various reasons, e.g. Kutsuplus (2012–2015), VTA Flex (2016), RideKC: Bridj (2016–2017), RideCo: Go Connect (2015–2016), Slide Bristol (2016–2018), Sydney Inner West/Wetherill Park (2018).

The ongoing cases in Table 1 show that the company Via accounts for a high volume of the cases, either through its main company (New York, Washington DC, Chicago), through its subsidiary company ViaVan (Berlin, London, Amsterdam) or in partnerships with cities (e.g. US: Arlington TX, West Sacramento CA, UK: Milton Keynes) or incumbent public transport operators (Arriva Click/Sittingbourne, Liverpool; PickMeUp with the Go-Ahead TRP Group/Oxford Bus Company).

The company Padam is, or was, involved in various trials, including Slide (Bristol, UK) together with RATP Dev, which was discontinued in 2018. Padam, in conjunction with Transdev, also operate the Flexigo service in an area to the west of Paris. Another ongoing trial is the Résa´Est service east of Orléans in conjunction with Orléans Métropole (Padam, 2019).

Between December 2017 and March 2018, twelve different trials commenced in the Greater Sydney metropolitan area. These trials involved partnerships between various companies.

Other ongoing cases include Breng flex (NL), serving areas around the cities of Arnhem, Nijmegen and Moelhoek, which was launched in December 2016, and Plustur (DK), servicing the Northern Jutland area, which was launched in 2018. Both Breng flex and Plustur are examples of public transport incumbents that are developing their own solutions.

Of the 35 identified cases in Table 1, nine cases have been selected for a deeper analysis. These include both completed and ongoing cases which are in focus in the report. That the nine cases briefly described briefly below are the focus of the report means that these cases will figure in all the different parts of the report. They are also are eligible for more qualified analyses concerning comparisons of systems' performance metrics, for example. However, throughout the report, references will also be made to the other 26 identified cases, although the intention is not to compare these cases in the same way that the nine selected cases were compared. The nine cases in focus will be highlighted in bold text in the tables throughout the report.

1.2.1. Cases in focus in the report

Completed:

Kutsuplus, Helsinki, Finland, has been described as "… the world's first fully automated, real-time demand responsive public transport service" (Helsinki Regional Transport Authority, 2016, p.1). The trial was launched in 2012 and the service was open to the general public from 2013–2015. The service area covered central areas of the city and some surrounding suburbs.

Go Connect, greater Toronto metropolitan area, Canada, was a one-year trial launched in March 2015. Go Connect was a first/last-mile service transporting suburban commuters to and from a metro station in Milton, a municipality some 70 km outside of Toronto. The objective of the trial was to improve access to the local metro station. Milton, which has around 110,000 residents, was selected for the pilot because of congestion and parking issues at the metro station (RideCo, 2018).

RideKC: Bridj, Kansas City, USA, was a year-long trial launched in March 2016. The trial was aimed at transporting commuters between a downtown and suburban area outside the city (KCATA, 2016).

VTA Flex: San Jose, USA was a six-month trial launched in January 2016 operating in a 5.5 square mile area of North San Jose. This was the first trial in the Bay Area using automated real-time public transport (VTA, 2016).

Ongoing:

Breng flex is a service operated by Dutch public transport provider Connexxion (Shaarman & Meurs, 2018). The first pilot was launched in December 2016 and Breng flex currently operates in three service areas around the cities of Nijmegen, Arnhem and Molenhoek.

In February 2017 in the UK, transport operator Arriva launched the *ArrivaClick* service in Sittingbourne, a city of some 40,000 inhabitants, around 70 km southeast of London.

The *Résa'Est* service has been operating in the outskirts of the city of Orléans, France, since April 2018. This service was launched in order to update and replace an existing demand-responsive service using traditional dial-a-ride technology (Padam website, 2019).

Plustur was launched in January 2018 to augment the existing demand-responsive transport services in North Jutland, Denmark. The service is part of the regional transport authority's strategy to improve accessibility in the rural parts of the region.

The *Northern Beaches* trial in Sydney, Australia, was launched in November 2017 to supplement the public transport network in the north-western suburbs along the coast. The key idea with this service is to feed passengers to the B-Line bus service (a high-quality bus service with frequent departures to the CBD).

2. Types of systems and services

This section of the report contains data describing various case attributes, such as differences and similarities concerning types of vehicles and fleet sizes, geographical context and service partnerships.

2.1. Vehicles and fleet sizes

Here, data on the type and number of vehicles in the different cases are provided. As shown in Table 2, in most cases smaller vans and minibuses, ranging from 5 to 17 seats, are used. In one case, VTA Flex, larger 26-seat buses were used. The Breng flex fleet comprises both minibuses and passenger cars. Most of the systems use a limited number of vehicles, ranging from 3 to 16, although Table 2 also shows that no data are available for some of the services. Many services emphasise the level of comfort and that their vehicles are new and feature luxury seats, Wi-Fi and charging points. This indicates that as well as offering flexible services, an additional selling point for many of the services appears to be a higher standard compared to conventional public transport services. Below, some brief comments are provided on each case.

Case	Type of vehicle	Number of vehicles
Kutsuplus	Minibus (9 seats)	15
RideKC: Bridj	Minibus (14 seats)	12
VTA Flex	Bus (26 seats)	6
Via	Typically Mercedes shuttle (normally 6 seats, but a range of different vehicles are used)	N/A
ArrivaClick (Sittingbourne)	Minibus (12 seats)	5–6
ArrivaClick (Liverpool)	Minibus (15 seats)	12
PickMeUp	Minibus (17 seats)	8
Plustur	N/A	N/A
Go Connect	Minibus (5 seats)	14
Breng flex	Minibuses (8 seats, wheelchair accessible) and electric cars (3 seats).	16 (8 minibuses and 8 cars).
Résa'Est	Minibus (6 seats)	3
Northern Beaches	Minibuses, cars	8
Hillsbus	Minibus (10 seats)	4
FlexiGo	Minibus (17 seats)	7
Slide	Minibus (8)	16

Table 2 Type and number of vehicles in the different cases. Sources provided in the text below.

Kutsuplus: Field testing of the Kutsuplus service with real passengers started with three vehicles. The fleet was expanded to 10 vehicles within a couple of weeks of the trial and a maximum of 15 vehicles were used at the peak of the service. Vehicles could typically accommodate nine passengers and there was extra space for a pram or a foldable wheelchair (Helsinki Regional Transport Authority, 2016).

RideKC: Bridj: In the trials in Kansas City, 12 buses (of which two were wheelchair accessible) with 14 seats were used (Eno Center for Transportation, 2018).

VTA Flex: The pilot project in San José used six retired 26-seat community buses, re-commissioned for the trial. According to an evaluation these vehicles were not well-suited to a dynamic response service due to their large size (VTA, 2016).

Via: Concerning Via and its different business partnerships such as ViaVan and ArrivaClick, the total fleet size will not be disclosed for reasons of business confidentiality. According to information from Via, it has several thousand registered drivers in New York, Washington DC and Chicago. Via's business model in these cities is basically a Transport Network Company (TNC) that is similar to other ride-hailing services such as Uber and Lyft, the difference being the emphasis on shared rides (also see, for example, TLC factbook, 2018 for evidence of a higher level of shared rides).

In *BerlKönig*, the system launched by ViaVan in September 2018, an initial fleet of 50 vehicles was deployed. By November 2018, the fleet size had increased to 80 vehicles and the terms of the contract allow for up to 300 vehicles (Via, 2018).

ArrivaClick: The service in Liverpool (launched in September 2018) initially operated with six vehicles. By November, 12 vehicles with a 15-seat capacity were being used and there are plans to operate up to 25 vehicles by the summer of 2019. The service in Sittingbourne operates with 5–6 minivans (12 seats) (personal correspondence, ArrivaClick, 2018).

PickMeUp: According to PickMeUp's website, its minibuses can accommodate up to 20 people, with 17 seated and three standing (or 14 seated, three standing and one wheelchair). (PickMeUp, 2019)

Plustur: Plustur is operated by Nordjyllands Trafikselskab, (the regional PTA). The service is included as part of an extensive range of DRT services (called Flextrafik). The regional PTA has a total of 1,400 vehicles at its disposal for all DRT services. Thus, it is not possible to define the number and types of vehicles used for the Plustur service (Nordjyllands Trafikselskab, 2018).

Go Connect: The service used five to seven minibuses in order to offer a waiting time of under 10 minutes. RideCo sourced a pool of 14 vehicles and drivers from a local commercial transportation company in order to keep five vehicles in operation. The local transportation company offered licensed and insured vehicles, as well as drivers (RideCo, 2018).

Breng flex: Currently, a fleet of 16 vehicles is being used including eight minibuses running on "green gas" (produced from biomass) and eight electric cars.

Keoride/Northern Beaches: A fleet of eight vehicles, both shuttle vehicles and passenger cars, are being used. The Northern Beaches trial is a partnership with GoGet, a car-share company that supplies the vehicles (personal correspondence with Keolis Downer, 2019).

2.2. Service partnerships

The service partnership for the reviewed cases can be described in the two different categories shown in Table 3. The first category is *Commercial services*. The main characteristics of these systems is that they are not subsidised by tax money. An example of this are the services operated by Via in New York, Washington DC and Chicago. These services are examples of standalone systems, i.e. operations are not integrated with the public transport system through contracts or partnerships, for example. As for other Transport Network Companies (TNCs) such as Uber and Lyft, Via does not own vehicles. However, drivers can lease or rent vehicles at special rates through Via (personal correspondence, ViaVan, November, 2018).

Commercial services	Subsidised services
Bridj (Boston and Washington DC) Via (NYC, Washington DC, Chicago) PickMeUp (Oxford Bus company) **ArrivaClick** (Liverpool, **Sittingbourne**) Slide (Bristol)	**Kutsuplus,** Via (Arlington, West Sacramento) **Go Connect** **RideKC: Bridj** ViaVan (BerlKönig) **Northern Beaches (and the other Sydney trials)** **Résa'Est** Flexigo **VTA Flex** **Plustur** **Breng flex**

Table 3 Commercial and subsidised services.

Another business model for Via and its subsidiary ViaVan (a partnership between Via and Mercedes-Benz Vans) is to partner with local transport actors. Examples of this include partnerships with public transport operators (e.g. ArrivaClick (Liverpool, Sittingbourne and PickMeUp (Oxford). Here, Via provides the tech platform (app/vehicle routing equipment) and the transport operators perform the service (Interview ArrivaClick, 2018, Interview ViaVan, 2018). The Slide service (Bristol) was based on a similar partnership between Padam and RATP Dev (personal correspondence, Padam, 2019). As can be seen in Table 3, only one of the commercial services are in focus in the report. This demonstrates that obtaining information about these services is difficult because of business confidentiality.

The second category is *Subsidised services*. This includes many different types of partnerships between public and private actors. Many of the services are conducted as trials and typically rely on public sector funding, vehicles and drivers from transport operators and technology platforms developed by other actors.

One example that illustrates a seemingly quite typical set up is Kutsuplus, which was funded by HSL (the regional transport authority). HSL was also responsible for service design and defining the requirements specifications for partners and subcontractors (including transport operators, telecom system vendors, software and hardware development companies). Local transport operators (taxi and bus companies) provided the vehicles, information system infrastructure and drivers. Ajelo, a software company, developed core control and service systems and programmed passenger and driver information systems, and also implemented and maintained databases (including geographic data) and payment solutions (Helsinki Regional Transport Authority, 2016)

For the RideKC: Bridj Pilot, the Kansas City Area Transportation Authority (KCATA) and Bridj worked together to identify service areas and design the project. The pilot was financed by KCATA and the vehicles were operated by KCATA employees. Bridj supplied the system infrastructure, software and in-vehicle hardware and Ford supplied the vehicles (Eno Center for Transportation, 2018).

In Go Connect, Metrolinx – a public transit agency in the Greater Toronto Area (GTA) – partnered with RideCo (a software company) and Milton Transit (the local transit authority) to plan, launch and operate the service. Funding was from public sources (RideCo, 2018).

The Via services in Arlington and West Sacramento are run in partnerships between Via and the cities. Here, Via provides the technology platform for ordering trips and automated routing, vehicles, drivers and operates the service, which is paid for by the cities (personal correspondence, ViaVan, 2018).

The trials in Sydney are funded by Transport New South Wales as part of a transport system innovation programme. All the trials are financed via six-month contracts with the option to renew contracts upon completion of the trial period (personal correspondence, Transport NSW, 2019). The various trials in the Sydney metropolitan area are delivered through partnerships between various transport operators. This includes transport companies such as the Punchbowl Bus Company, Hillsbus, Community Transport Central Coast, Premier Motor Services, Transdev, Keolis Downer and Transit Systems Australia. The Northern Beaches trial is delivered through a partnership between Keolis Downer and GoGet (car sharing company) and the Keoride app is powered by the Via system (personal correspondence, Keolis Downer, 2019).

Breng flex is funded by Gelderland Province (Sharmeen & Meurs, 2018) and operated by Transdev using the tech platform from the defunct Dutch ride-hailing company, Able. Plustur is funded by the region of Northern Jutland and is operated as part of the Flex traffic provided by the regional PTA (Personal correspondence with Northern Jutland regional PTA, 2018).

3. Operational policies

In the following sections some key operational policies of the cases are described. This includes similarities and differences between the cases concerning routing and scheduling, pick-up/drop-off points, operating hours, booking, payment and pricing.

3.1. Routing/scheduling

All of the reviewed cases can be described as demand-responsive services that allow for flexible routes and on-demand schedules. This means that users can request shared vehicles and vehicles are re-routed to pick up the passenger in real time. In many cases routes are fully flexible and adjusted in real time, although operational policies can vary. Below, four different variants are described concerning origin-destination policies and the area covered by the services.

Figure 1. ArrivaClick service area in Sittingbourne, Source: ArrivaClick, (2019)

3.1.1. Free floating within a continuous area

In numerous cases, operational policies allow for many-to-many origin – destination relationships within a specific geographic area. See, for example, fig 1. showing the area coverage of the ArrivaClick service in Sittingbourne. Kutsuplus, VTA Flex, all Via powered systems, Breng flex and Résa'Est are all examples of cases with a similar free-floating routing/scheduling policy. Trips can typically be ordered from anywhere to anywhere within the operational area.

3.1.2. Fixed destination or origin

Another variant of the routing/scheduling policy is exemplified by Go Connect, which provided transport between homes in a suburban area and a metro station. For this system the origin-destination operational policy can be described as many-to-one, or one-to-many, where the metro station is either the destination (in the morning) or the origin (in the evening). See fig. 5 on p. 17. The Northern Beaches trial in Sydney employs a similar approach where three stops for the B-line services (a bus route connecting the northern suburbs and the city centre) are either destination or origin. A key benefit of this system is the high frequency of the B-line service, with departures every five minutes during peak hours. This means that there is no need to arrive at a specific time at the B-line stations, since transfer waiting times are very short. This makes the optimization of routes and the ability to respond to new requests easier (personal correspondence, Keolis Downer, 2019).

3.1.3. Combination of free floating and fixed destination or origin

The Flexigo system in Evelines, some 35 km west of Paris, utilises an operational policy that combines the two different approaches described above. During commuting hours, three metro stations in the area function as fixed destinations (in the morning) and fixed

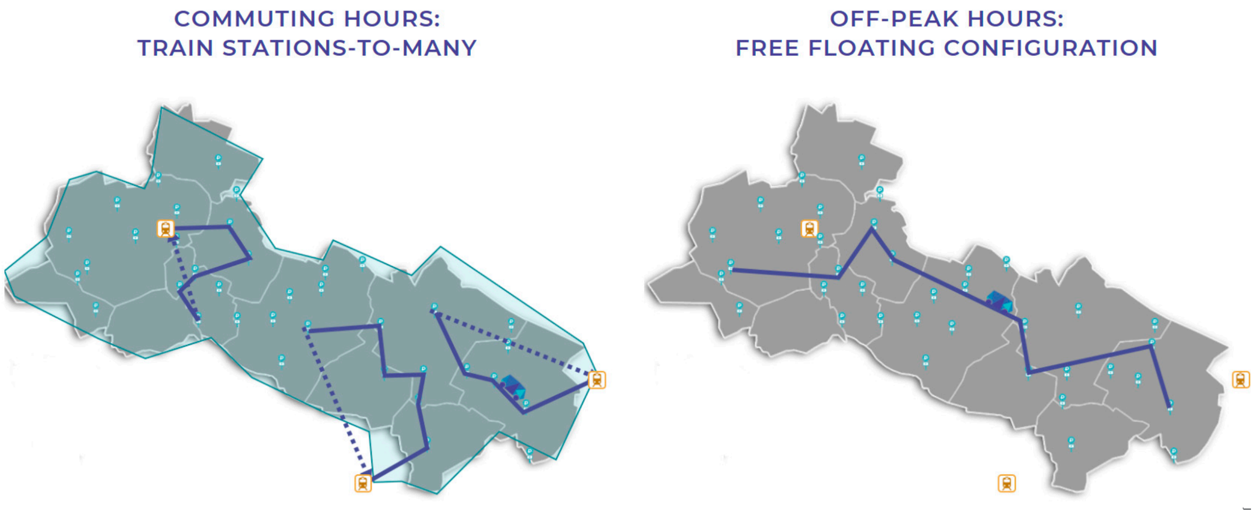

Figure 2. Flexigo, Evelines Routing/Scheduling policies, Source: Padam, (2019)

origins (in the afternoon). In the morning, it is critical to ensure that passengers arrive on time to reach their connecting train and this is a key parameter for accepting or declining trip requests. For the rest of the day, the system operates with a free-floating routing/scheduling policy. See fig. 2.

3.1.4. Zone-to-zone structure

Whereas the cases described above all operate in one continuous area, Bridj (Boston, Washington DC and Kansas City) offered a service that utilised a zone-to-zone structure, as illustrated in figure 3. In Kansas City, this idea was implemented in its purest form in the commuter service. Here, a set of vehicles departed from residential areas towards the CBD in peak morning traffic. The software re-routed vehicles on the way to pick up customers. In the evening, the flow was reversed. So while this service was still demand driven and flexible, the operational policies ensured that there was a strong uni-directionality of origin-destination patterns (Eno Center for Transportation, 2018).

Figure 3 Zone-to-zone structure of RideKC:Bridj, Source: KCATAT, (2018)

A similar approach is employed in the Bridj/Transit systems Australia trial in the Eastern Suburbs in Sydney, where the key idea is to take passengers to and from a ferry wharf in the morning and afternoon. The Keolis Downer trial in Macqure Park, Sydney, also utilises a zone-to-zone structure, where the zones form an inner and an outer ring.

3.2. Pick-up/drop-off points

Different cases have made different choices regarding where to pick up and drop off passengers. Three main variants have been identified: door-to-door service, physical stops and virtual stops. Door-to-door services function as a taxi where users are allowed to order trips between two specific addresses. Virtual stops are defined here as locations for pick-up/drop-off that are not marked at a street level, i.e. there is no specific sign indicating where the vehicle will stop. There are different varieties of virtual stops, which are described in more detail below. However, typically, the user requesting a trip will be asked to walk to a location to rendezvous with the vehicle. Physical stops are defined here as traditional bus stops, or other physical signs that indicate the location for picking up or dropping off passengers.

As can be seen in Table 4 below, virtual stops are most common and door-to-door services were only an option in two of the cases. Some services allow a combination of variants.

Further details are provided below on how different cases handled the issue of entering and leaving the vehicles.

Case	Door-to-door service	Physical stops	Virtual stops
Kutsuplus			x
RideKC: Bridj			x
FLEX		X	
Via			x
ArrivaClick			x
PickMeUp			x
Plustur		X	
Go Connect	X	X	x
Breng flex		X	x
Rideplus			x
Northern Beaches	X	X	x

Table 4. Variants of pick-up and drop-off points.

3.2.1. Virtual stops

For the Kutsplus service, hundreds of virtual bus stops were photographed and defined in the Helsinki metropolitan area. "In principle, any safe and feasible location within the road network can be defined as a virtual bus stop" (Helsinki Regional Transport Authority, 2016, p. 16). The system directed the passenger to the nearest virtual bus stop.

Via defines itself as a "corner-to-corner service". This means that the actual pick-up location may differ from where the passenger requested to be picked up. According to Via's website, this means that the passenger will often be directed to the street corner closest to the requested pick-up location. This may sometimes involve walking a few blocks from the requested point of origin, and the same applies at the destination. According to Via, this operational policy is important in order to ensure that travel times are comparable to those of a taxi, even with multiple pick-ups (Via, 2019a). The virtual pick-up locations on street corners are sometimes defined by addresses and sometimes by the names of businesses. The app counts down the minutes to the arrival of the vehicle and the passenger is sent a text message when the vehicle is two minutes away and again when it arrives (Via, 2019b).

Similar approaches are employed in other Via powered systems, such as ArrivaClick and PickMeUp. The platform used by Transdev in the Rideplus service in Manly, Sydney also uses such an approach, as did the RideKC: Bridj service. Here, passengers could input their pick-up and drop-off locations within the service area. The smartphone application provided directions to pick-up locations within roughly a five-minute walking distance of the passengers place of origin. (Eno Center for Transportation, 2018)

3.2.2. Physical stops

For VTA FLEX, "Several hundred FLEX stops, marked with a special sidewalk decal, were used as designated pick-up and drop-off locations throughout the FLEX area" (VTA, 2016, p. 3). Locations were selected with consideration to passenger safety and operational efficiency.

Plustur: Trips are ordered from an address to a bus/train stop, or from a bus stop/railway stationto an address (see figure 4). However, the actual location of the pick-up and drop-off of passengers at their origin or final destination may be a mobility hub. A mobility hub is a pre-defined location where different mobility options should be available. In rural areas, mobility hubs in their most basic form are often just a post with a sign signalling that this is the location for boarding or alighting a Plustur. In the more central areas of the region the mobility hubs are typically public transport nodes, with multimodal access, park & ride facilities, and sometimes access to rideshare vehicles, bike-share systems, etc.

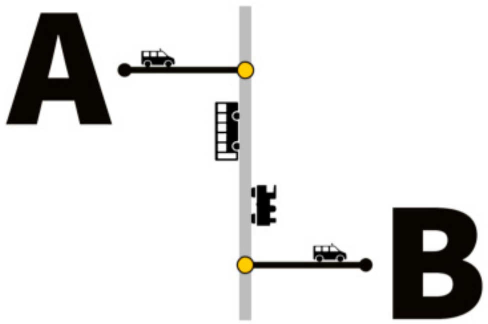

Figure 4 Plustur

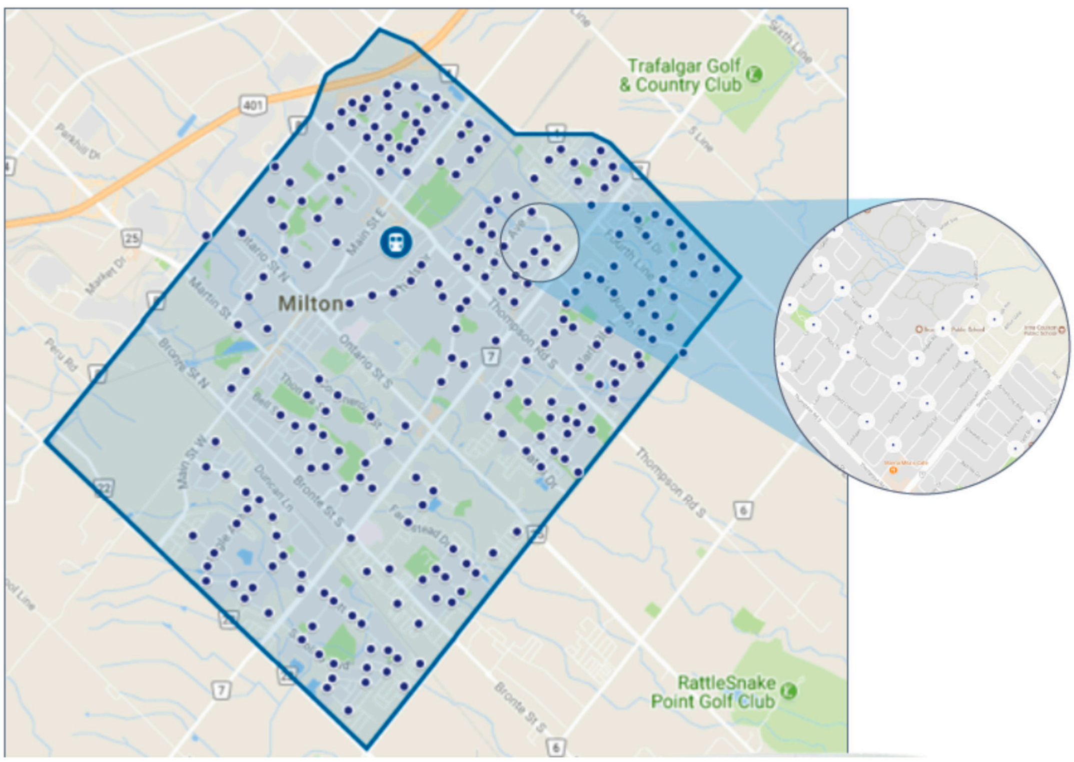

Figure 5 The 240 virtual stops and the metro station in the Go Connect service area, Source: RideCo, (2018).

3.2.3. Combinations

For the Go Connect service, 240 virtual stops were defined within the service area, from where trips to and from the metro station (a physical stop) could be ordered (see figure 5). The location of the virtual stops ensured that passengers were less than a three-minute walk from their homes. The virtual stops were typically located at street signposts, or close to post boxes at intersections. The service also included the option for passengers to be picked up or dropped off at their home addresses (RideCo, 2018).

The Northern Beaches trial employs a similar approach, where passengers can either be picked up at home, or at a "designated point of interest within the service area". Passengers are then dropped off at the nearest of the three B-line bus stations. Depending on where a passenger is within the service area, the system will automatically designate one of the three stations as the destination (Personal correspondence, Keolis Downer, 2019).

Breng flex is described as a bus-stop-to-bus-stop service. There are a total of 225 stops in the network, which include most of the bus stops in the cities, and some additional virtual bus stops, such as retirement homes (Sharmeen & Meurs, 2018).

3.3. Operating hours

As can be seen in Table 5, different cases have explored various options concerning the systems'.operating hours. The services provided by Via in major cities in the USA and

Case	Hours
Kutsuplus (from August 2014)	Mon–Fri 06.00–24.00
RideKC: Bridj	Mon–Fri 06.00–22.00 and 15.00–19.00
FLEX	Mon–Fri 17.30–20.30
Via NYC, Washington DC, Chicago	24/7
Via Arlington, TX	Mon–Fri 06.00–21.00, Sat 09.00–21.00
Via West Sacramento, CA	Mon–Fri 07.00–22.00, Sat 09.00–22.00
ViaVan BerlKönig, London, Amsterdam	24/7
ArrivaClick, Liverpool	Mon–Sun 06.00–20.00
ArrivaClick, Sittingbourne	Mon–Sat 06.00–22.00
Plustur	Depending on general PT system operating hours
Go Connect	Mon–Fri 06.00–08.30 and 16.45–20.25
PickMeUP	Mon–Fri 06.00–1100, Sat 07.00–12.00, Sun 09.00–21.00
Breng flex: Arnhem/Nijmegen	Mon–Fri 06.30–24.00, Sat 07.00–24.00, Sun 09.00–24.00
Breng flex: Molenhoek	Mon–Fri 07.00–19.00, Sat 10.00–16.00
Résa'Est	Mon–Fri 06.15–19.00, Sat 07.00–19.30
Northern Beaches	Mon–Wed 06.00–22.00, Thu & Friday 06.00–23.30, Sat 07.00–23.30, Sun 07.00–21.30
Macquire Park	Mon–Fri 06.00–10.00 and 15.00–19.00

Table 5 Operating hours, Sources: various websites and reports

Europe operate around the clock. In certain cases, somewhat more limited services are or were offered in smaller cities (e.g. Kutsuplus, Flex, RideKC: Bridj and Go Connect) on weekdays only, whereas other cases such as Breng flex, ArrivaClick and PickMeUp offered a varying level of service at weekends.

Some of the cases, for example, RideKC: Bridj, Flexigo, Go Connect and Macquire Park specifically targeted commuters and their operating hours have been designed to meet their needs. For example, in Go Connect, the operating schedule was aligned with the first departing train in the morning and the last returning train in the evening (RideCo, 2018). Similarly, RideKC: Bridj operated a morning and afternoon service but provided direct access, without public transport transfers, between residential areas and the Central Business District (CBD) of Kansas City.

Plustur is a special case as it can only be ordered using the public transport planner in conjunction with a bus or train journey. Thus, the service is only available whenever the public transport system is operating.

3.4. Booking method

Case	Website	SMS	Smartphone application	Phone call	Searchable in public transport planner
Kutsuplus	x	x			
RideKC:Bridj			X		
FLEX			X	x	
Via			X	x	
ArrivaClick			X		
PickMeUp			X		
Plustur			X		x
Flexigo			X	x	
Résa'Est	x		X	x	
BerlKönig			X		x
Go Connect	x		X	x	
Breng flex			X	x	x
Northern Beaches	x		X	x	

Table 5 Different way of booking trips in the studied cases.

As can be seen in Table 6, the various cases display a range of booking methods. The most common method is to search and book trips via a smartphone application. Kutsuplus is an exception as a prototype smartphone application was developed but never offered to customers. Kutsuplus also stands out as it is the only system that allowed trips to be ordered via SMS. This option was introduced after criticism that only internet users could access the service. However, it transpired that only 3% of trips were ordered via SMS. (Helsinki Regional Transport Authority, 2016). A common way of addressing this issue in other cases has been to introduce the option to order trips via phone. This was, for instance, the case for FLEX where the RideCell application was complemented by a customer service centre. Requests by phone were handled by service centre who entered the request in the RideCell application system. For the first month after the launch of the Go Connect service the smartphone application included a "call the operator" feature, which was staffed during hours of operation. This became an effective way of collecting real-time feedback on the service, concerning, for example, virtual stop location issues or negative feedback. The "call the operator" feature was disabled once the service had been fine-tuned based on early passenger feedback (RideCo, 2018). Other services such as Breng flex, Flexigo and Résa'Est have opted for permanent call centres.

It is noticeable that only a few of the cases, Plustur, Breng flex and BerlKönig, have suggests there are significant barriers to integration with the general public transport system.

3.5. Time of booking

As can be seen in Table 7, there is a degree of variation between cases with regards to when bookings can be made. Key to this issue is the balance between real-time requests and the possibility of making bookings in advance. In some cases the choice appears to be a deliberate part of the service design, while in other cases it is a consequence of technical limitations of the specific technology platform being used. Below are some brief comments on the policies of some of the studied cases.

Case	Less than one hour before departure	More than one hour before departure	The day before departure (or earlier)
Kutsuplus	X	x	
RideKC: Bridj	X		x
FLEX	X		
Via	X		
ArrivaClick	X	x	x
PickMeUp	X		
Plustur		x	x
Go Connect	X	x	x
Breng flex	X		
Resa'Ést	X	x	x
Northern Beaches	X	x	x

Table 6 Different approaches to booking times.

For Kutsuplus, real-time requests were always an option and the predetermined categories used included: now, 5 minutes, 10 minutes, and others. Some difficulties were encountered in combining bookings made in advance with real-time requests. Thus, bookings close to the time of departure were favoured (Helsinki Regional Transport Authority, 2016).

RideKC: Bridj offered the option to book in real time or up to 24 hours in advance. The service in Sydney's Eastern Suburbs allowed bookings to be made from 10 minutes up to 48 hours in advance.

The Co Connect service allowed for variation in the time of booking, both in advance and in real time. Over two thirds of passengers chose to book their morning trip the day or evening before travel. In the afternoons, almost two-thirds of users booked their trips from the station to home at the last minute, after they had caught a specific train and were more certain about when they would arrive at the station (RideCo, 2018).

For the ArrivaClick services in Sittingbourne and Liverpool, the Via platform has been tweaked to allow for pre-schedule requests as far as one month in advance. Pre-schedule requests are currently limited to a maximum of five per 30-minute time frame (this can be adjusted in the event of service growth). Once five requests have been placed in a specific 30-minute time frame, requests are capped, notifying users that pre-schedule requests for this day and time are not possible. Pre-schedule requests are not actual bookings and this is something that has been difficult to explain to passengers (personal correspondence with ArrivaClick, 2018).

The Northern Beaches trial, which also uses the Via platform, allows for both real-time requests and advance bookings weeks ahead. The Padam platform, used in Résa'Est, for example, also allows for both advance bookings and real-time requests.

FLEX was purely an on-demand service. RideCell's software could not accommodate both pre-scheduled and on-demand requests (VTA, 2016).

The Via services in New York, Chicago, Washington DC and BerlKönig, for example, operate an on-demand service only, as does Breng flex, which has no advance booking option. Maximum waiting time is set to 20 minutes. Journeys that cannot be made within this time framewill not be accepted (Alonzo-Gonzales et al., 2018). A similar approach is employed in PickMeUp, which allows journeys to be booked up to 20 minutes in advance.

The outlier among the cases here is Plustur, where trips must be booked no later than two hours in advance.

3.6. Payment methods

The most common payments solution is via a smartphone application (see Table 8) on which passengers must register a profile and link a credit card. It has been noted that only a few systems (e.g. Breng flex, Northern Beaches, Macquire Park) allow payment using public transport smart cards.

Case	Smartphone application/credit card	Public transport smart card	On board payment
Kutsuplus	X		
RideKC:Bridj	X		
FLEX	X		
Go Connect	X		
Via	X		
ArrivaClick	X		
PickMeUp	X		
Résa'Est	X		
Plustur	X		
Breng flex	X	x	x
Northern Beaches	X	x	
Macquire Park	X	x	

Table 7 Payment methods.

In addition to the three options in Table 8, Kutsuplus also allowed payment through the passengers' mobile phone subscriptions. Breng flex allows multiple options. Users can pay in advance via the smartphone app or on the vehicle using their debit cards or national travel cards (Sharmeen & Meurs, 2018).

For the FLEX system, the ambition to integrate the FLEX payment system with the public transport smart card (the VTA Clipper Card) was stifled by technical and administrative challenges.

3.7. Pricing

The pricing strategies of the different cases vary. Some cases (see Table 9) adopted a dynamic approach to pricing, while other cases applied fixed prices. With a couple of exceptions (discussed below), the general approach to pricing can be described as "less expensive than a taxi, more expensive than a bus". Some brief comments on the approaches in the different cases are provided below.

In Kutsuplus, dynamic pricing was introduced to steer demand from peak hours. A 20% discount was applied to trips ordered between 10.00 and 14.00. Similarly, FLEX also applied a dynamic pricing model with lower off-peak pricing (USD 2.00) and higher prices (USD 3.00) during peak commute hours.

Kutsuplus' dynamic pricing model also comprised three different service classes where passengers could choose between paying more for a faster journey (with less deviations to pick up new passengers) and a lower price for a slower journey. A typical Kutsuplus journey was priced at EUR 5.70 (Helsinki Regional Transport Authority, 2016, p. 16).

For Via's services, pricing strategies appear to differ between cities, but typically include a dynamic, distance-based component. For example, in New York the fare is based on the length of the trip and fares start at USD 3.95. There is also an option to buy 1-week and 4-week passes (allowing up to four shared trips per day), which will lower the per trip fare (Via, 2019c).

For ArrivaClick, fares start at GPB 1.00 and are based on the length of the trip. Prices may vary depending on time and day of travel. Two types of commuter passes are available in both cities: one which allows two trips per day and another which allows unlimited journeys. The commuter passes that offer unlimited journeys are more often used for different types of trips, such as leisure travel or picking up/dropping off children. In Liverpool, trips to and from the airport are also quite common. In Sittingbourne, discounted fares for the elderly are offered (personal correspondence, ArrivaClick, 2018).

The GoConnect system applied another dynamic approach based on the willingness of passengers to walk to or from a virtual bus stop, or whether they preferred a door-step service. This relates to how far the passenger is willing to walk. GoConnect had two different prices: CAD 1.45 for hub pick up, i.e. passengers are expected to walk to/from a virtual stop, or CAD 1.95 for the door-step service, i.e. passengers are picked up/dropped off at home (RideCo, 2018).

Case	Dynamic	Flat
Kutsuplus	X	
RideKC: Bridj		x
FLEX	X	
Go Connect	X	
Via	X	
ArrivaClick	X	
PickMeUp		x
Plustur		x
Breng flex		x
Northern Beaches	X	
Eastern Suburbs		x

Table 8 Pricing strategy of different cases.

Some examples of flat rates include RideKC: Bridj, where trips were priced at USD 1.50, the same as the local bus fare. The Plustur system applies a flat rate of DKK 22.00, which is paid in addition to the price of the trip using "normal" public transport (since Plustur cannot be ordered as a standalone service). Breng flex also operates on a flat rate of EUR 3.50 per person per trip. (Sharmeen & Meurs, 2018).

PickMeUp charges GPB 2.50 regardless of journey length. An additional charge of GPB 2.50 applies between 21.00 and midnight on Saturdays. An additional GPB 2.50 may be charged if the PickMeUp journey is made on a route where the Oxford Bus Company already operates bus services from the requested pick up point to the destination (PickMeUp, 2019).

4. System performance metrics

When considering the potential of new technology to improve the performance of DRT systems, the number of trips, or other productivity and efficiency metrics, such as passengers per revenue hour, cost per trip, or farebox recovery, are very significant. It is well known that traditional DRT is expensive to operate (see, for example, TCRP, 2008 for an overview of production costs of various systems), but there may also be arguments for accepting this higher cost due to the improved service DRT offers to users, for example, the ambition to increase accessibility.

A key question in this report is whether technological progress has improved the functionality and productivity of DRT. More specifically, this begs the question of whether the proliferation of smartphones, advances in positioning technology and the development of platforms that enable interaction between transport users and transport providers mean that new forms of DRT perform better than "traditional" DRT (e.g. dial-a-ride systems). A full comparison between all the cases would require access to comparable data for each case regarding production costs and farebox recovery. Because such data are not available for all cases, the main metric in focus here will be the number of trips and passengers per revenue hour. Passengers per revenue hour can be regarded as being a key measure and the single most important metric of DRT productivity since it "… captures the ability of the DRT system to schedule and serve passenger trips with similar origins, destinations, and time parameters, using the least number of in-service vehicles and revenue hours" (TCRP, 2008, p.58).

In some cases, more detailed information on economic metrics is available. These cases will be discussed in section 4.3.

4.1. Daily patronage

Here, the available data of patronage in different services have been compiled. Depending on the availability of data, the metric used for describing patronage may vary between services. The ambition is to provide data on daily patronage, where possible.

For Kutsuplus in 2015, at the peak of the service, nearly 100,000 trips were made, amounting to approximately 385 passengers/day (Helsinki Regional Transport Authority, 2016).

RideKC: Bridj had a total of 1,480 trips during the one-year trial, amounting to approximately 11 passengers/day. (Based on data from the Eno Center for Transportation, 2018.)

For VTA Flex, a total of 2,714 trips were made during the six-month trial, amounting to approximately 21 passengers/day (VTA, 2016).

Go Connect had around 13,000 passengers during the one-year trial, corresponding to approximately 84 passengers per day (RideCo, 2018). According to RideCo (2018), the levelling out at 84 passengers/day was due to budget restrictions in the trial, which restricted the possibility of booking trips from month eight of the trial. In order to meet the increasing demand, an extension of the service was required, but this was not possible with the available budget .

The ArrivaClick service in Sittingbourne had around 250 passengers/day in November 2018 (personal correspondence, ArrivaClick, 2018).

In Resà'Est, a consistent and quite significant increase in daily patronage was experienced for the first six months of the trial. Compared to the existing conventional DRT service that had been replaced by Resà'Est, patronage increased by approx. 60% during this period. The original system had around 50 passengers/day and Resá'Est had around 80 passengers/day (Keolis, 2018).

In the Northern Beaches trial, average daily patronage between September 2018 and March 2019 was approximately 327 passengers/day (author's own processing of data from Transport for New South Wales).

In addition to the figures presented above is a claim by Via that it provides one million trips/month in New York, Chicago and Washington DC. Via also claims to have provided more than 50 million trips since it was launched in New York in 2013. (Via, 2019d)

In some of the cases it appears that patronage was considerably lower than what was expected before the trials were launched.

For Go Connect, a memorandum written by the Town of Milton (2015, p. 11) stated that around 66,000 passengers were expected during the trial. Thus, the 13,000 passengers who actually used the service are a far cry from the numbers that were expected. The same memorandum also revealed that the outcome for the Go Connect service was actually lower than a previous service that operated in the evenings, where three manually dispatched shuttle buses provided commuters with trips from the metro station to home. Here, daily patronage was 114 passengers/day.

Plustur's objective was to reach 50,000 passengers in the first year of operations. However, for the first nine months of service, patronage was less than 300 passengers/month, or approximately 10 passengers/day (source: Nordjyllands Trafikselskab, 2018)

For Breng flex, Sharmeen & Meurs (2018) contend that about 60% of the initial target of 600 trips per day has been met (refers to Arnhem & Nijmegen). This would correspond to approx. 360 trips per day. According to personal correspondence with a representative of Gelderland Province, the situation in 2019 is that 450 trips are made per day, carrying approximately 550 passengers. This figure also includes the service in Molenhoek.

4.2. Passengers per revenue hour

In order to compare the productivity of a selection of the cases (for which data is available) and to compare productivity with a traditional DRT service, the following definition of productivity has been adopted: Productivity = total passenger trips/total revenue hours. Total revenue hours equal the vehicle revenue hours of each system. Vehicle revenue hours are defined as the hours when the vehicles are in revenue service (i.e. the time when a vehicle is available to the general public and there is an expectation of carrying passengers). More specifically, passengers per revenue hour has been calculated as follows: number of passengers per month/operating hours per month x number of vehicles used.

Given the available data, this provides a consistent way of making comparisons between the different systems. It also provides a way of making comparisons with traditional DRT services where a previous study of 34 systems in various contexts in the US found that productivity ranged from 1.28 to 4.7 passengers/revenue hour (TCRP, 2008, p. 61). This study included small and large urban DRT systems, some of which were open to the general public and some which had limited eligibility. The best performance (4.7 passengers/revenue hour) was achieved by DRT systems open to the general public in small urban areas (defined as cities with a population ranging from 50,000 to 200,000 inhabitants) (TCRP, 2008).

Case	Passengers/month	Revenue hours/month	Passengers/revenue hour
Kutsuplus	8,333	5,700	1.5
RideKC: Bridj	123	2,057	0.06
FLEX	452	1,993	0.2
Go Connect	1,083	759	1.4
Résa'Est	2,077	1,024	2
ArrivaClick	4,583	1,733	2.6
Northern Beaches	9,816	3,891	2.5
Breng flex	16,500	8,297	2

Table 9 Passengers per revenue hour.

The figures in Table 10 show some differences compared to the published sources. For example, Helsinki Regional Transport Authority (2016) states that for Kutsuplus, 25.7 trips/vehicle/day were made in 2015. This amounts to approx. 1.8 trips/vehicle hours (fig. 9a, p. 14). Thus, the figure from Helsinki Regional Transport Authority (2016) is higher compared to the calculations in Table 10.

The same applies to VTA Flex, for which the official report from the Valley Transit Authority concluded that the trial resulted in 0.4 boardings/revenue hours (VTA, 2016).

RideCo maintains that the Go Connect trial achieved 4.2 passengers per vehicle hours from month eight and onwards (RideCo, 2018). This is a substantial difference compared to the figures presented in Table 10. The same data on patronage have been used for the calculations in Table 10 but there is no information in RideCo (2018) about how vehicle hours have been calculated. The figures in Table 10 are based on an average fleet size of five vehicles (the figure on average fleet size is based on RideCo, 2018).

It can also be noted that the figures in Table 10 are based on monthly patronage which, in turn, is calculated based on the total patronage for the duration of a specific trial, or a whole year for certain services. Since patronage during the trials typically takes a while to build up, the results in Table 9 are likely to be low estimates in several cases. For example, patronage for January 2019 in the Northern Beaches trial indicates that passengers/revenue hours were approx. 2.9. For RésaEst, passenger/revenue hours for September 2018 were approx. 3.5.

It should also be noted that the figures for revenue hours/month are based on the assumption that the entire vehicle fleet (Table 2) was used throughout the operating hours of the services, (described in Table 5), unless otherwise stated, as in the case of Go Connect. The average vehicle fleet could differ from the figures in Table 2. If every vehicle is not operational at all times during operating hours, the figure for revenue hours/month in Table 10 would be lower. Consequently, passengers/revenue hours would be higher. Thus, achieving more accurate calculations on productivity would require data on average fleet sizes for each case.

With these caveats in mind, the figures presented above indicate quite a substantial variation in terms of productivity. If the metrics in Table 10 are compared with the benchmark range of 1.28–4.70 passengers/revenue hours in TCRP (2008), it can be concluded that, in certain cases, productivity has been below that of traditional DRT. None of the studied cases perform higher than 4.2 (based on RideCo, 2018). Thus, from a productivity perspective, there is no indication that the cases in this study perform better than traditional DRT. There are probably multiple explanations concerning productivity outcomes in each individual case, although it would be reasonable to conclude that implementing new technology is, in itself, no guarantee of success.

4.3. Production costs

Naturally, production costs are very interesting, not least since high production costs are an acknowledged weak point of DRT. However, available data on production costs in the cases in focus in this report are limited and have only been possible to retrieve for a limited number of the subsidised services. The available data includes Kutsuplus, RideKC: Bridj, FLEX, Go Connect and Breng flex. The metrics used in the various reports are not fully comparable. Thus, the account below should be treated with a degree of caution. What is clear is that the available data show that production costs are still a key issue.

For Kutsuplus, net income from 2012–2015 was MEUR -7.9 MEUR. The cost/trip (operating costs, services purchased, personnel expenses, other expenses, depreciation/total number of trips) in 2015 amounted to approx. EUR 35.00 per trip and ticket revenue averaged EUR 5.07 per trip (Helsinki Regional Transport Authority, 2016). The cost of the service was the key reason for the decision to discontinue the service at the end of 2015.

RideKC: Bridj and FLEX, which both had very low rates of productivity (see Table 10), also performed very badly in terms of production costs. For RideKC: Bridj, costs have been estimated at approx. USD 1,000 per trip (Eno Center for Transportation, 2018). For FLEX, operating costs averaged USD 200/passenger and farebox recovery was approximately 1% (VTA, 2016). Needless to say, the poor performance of these cases was the reason for discontinuing the trials.

Go Connect had a total budget of CAD 150,000 for the one-year trial. According to Ride Co (2018), results throughout the test period corresponded to a cost recovery of 39%. This can be contrasted with the cost recovery of 24% of the fixed route bus service that was replaced by Go Connect during the trial. The net cost per trip for Go Connect was CAD 5.71, compared to CAD 7.28 for the fixed route bus service (RideCo, 2018). While this sounds promising, it should be noted that a key reason for the better performance of the Go Connect service compared to the fixed route bus service is probably the limited operating hours. The fixed route bus service operated throughout the day, while Go Connect only operated during the morning and evening peak hours.

The Breng flex service is funded as part of a concession and paid for via a lump sum which, for 2017, was MEUR 2.00. For 2018, the cost of the second year was MEUR 2.7 and for 2019 the cost is estimated at MEUR 2.5 (personal correspondence, Gelderland Province, 2019). Based on the figures for daily patronage presented in 4.1, this would mean that the cost per passenger would correspond to approximately EUR 12.00. This figure assumes that the daily average patronage (550 passengers) will be consistent throughout 2019 and result in a total of 200,700 passengers in 2019. There is clearly a great deal of uncertainty in such assumptions. No data are available on the actual costs of operating the service. Thus, the figures should be considered highly indicative, although there is no reason to assume that production costs for Breng flex are substantially lower. Indeed, the high cost of the service means that Gelderland Province is re-evaluating the service for 2020 (Personal correspondence, Gelderland Province, 2019).

5. Discussion and concluding remarks

The aim of this report has been to contribute to develop knowledge about what the developments in positioning and smartphone technology bring to the table for the public transport sector. The overarching question posed in the report was: can new technology improve DRT?

The review identified a substantial number of services that meet the criteria for what this report refers to as on-demand public transport. There are examples of both subsidised and commercial services and, because of the availability of data, the report has focused on subsidised services. Typically, these services have been implemented as trials lasting for a limited period. Breng flex is currently the subsidised service that has been operating for the longest period. The commercially operated Via services in North America have been operating for even longer.

Few of the cases have been implemented in "classic DRT territory", i.e. in a rural, low-demand context. It appears that many of the recent or ongoing trials have been carried out in urban contexts, with some of the identified cases, such as Via and Kutsuplus, being implemented in major urban areas. Many of the identified cases are attempts to improve public transport services in low density, low-demand peripheral urban or semi-rural areas.

The types of vehicles and fleet sizes vary. In most cases, fleet sizes are quite small, ranging from four vehicles to 16 vehicles. Also, typically, smaller vehicles (buses, and passenger vans) are used.

Four categories of routing/scheduling policies were identified in the identified cases: free floating within a continuous geographical area, fixed destination or origin, combination of free floating and fixed origin or destination, and a zone-to-zone structure. The services also utilised either physical or virtual stops.

A key operational policy of many new systems is that passengers are asked to walk to a nearby location to be collected. This could suggest a barrier to merging services with special needs services for the elderly where the primary purpose of DRT is to collect people from their homes so that they don't have to walk to a bus stop. Breng flex, Go Connect and Northern Beaches are interesting cases with regards to dealing with this issue as they all provide door-to-door services.

Operating hours vary across cases with some of the commercial services in the major urban areas operating around the clock, while other services aimed at commuters operate during peak hours only.

All but one of the cases in the study allow bookings to be made via a smartphone application. The one exception (Kutsuplus) is probably attributable to the fact that this case was implemented at quite an early stage. Many of the cases also allow booking via other means, e.g. online or by phone. The study identified different approaches to handling real-time requests and pre-bookings.

There are only a few cases in the study where payment is integrated with the general public transport system, for example, enabling payment using public transport smart cards. Additionally, there are also few examples of systems that are integrated with general public transport systems (e.g. searchable in a public transport planner). Thus, it can be argued that most cases in this study operate as standalone systems, in which links to, and integration with, other forms of public transport are limited.

The different pricing strategies employed in the various cases showed that some services opted for flat pricing, while others opted for dynamic pricing models. In general, most cases aim for a pricing segment that can be defined as less expensive than a taxi, more expensive than a bus.

However, the most important result of the analysis in this report is that, thus far, there is scant evidence to suggest that any of these design features play a crucial role with regards to patronage and productivity. There are no indications that technology is a game changer for improving DRT to any significant extent. A benevolent interpretation of the comparison of productivity (expressed as passengers per revenue hour) between the reviewed cases and traditional DRT indicates that, in some cases, there may be some incremental gains. However, there are also examples of cases in which productivity was lower than traditional DRT. This suggests that new technology is no panacea for fixing the problems of DRT and the study shows that thus far, at least, on-demand public transport hardly represents a transport revolution. This is not to say that services based on new technology cannot play an important role, but rather that the evidence to date indicates very modest results when focusing on improving the productivity of DRT systems.

Nonetheless, the study has identified some interesting niches that could be fruitful to further explore. One such example is Résa'Est, where existing DRT services were upgraded with new operational policies and improved technology, making it more convenient to use. Here, quite significant increases in patronage have been achieved compared to the previous system. Another trial that also shows some promise is Northern Beaches in Sydney, where the idea is to provide a feeder service to the fixed route bus network.

Go Connect highlights the importance of policy context and the purpose of services. In this example, one reason for implementing the trial was a Park & Ride facility at full capacity. The results of the trial indicate that the on-demand service could facilitate more efficient land use in conjunction with the metro station. If this service alleviated the need to build additional parking spaces at the station it could be argued that this is a good example of why it could be important to look beyond a strict focus on production metrics. Freeing up space for other types of use than parking close to a station could have a substantial economic value. However, it could also be argued that improving existing fixed route bus services by offering more frequent services could produce the same outcomes at a lower cost.

Another issue raised by Alonso-González et al. (2018) concerns the effect on accessibility. DRT services could significantly affect accessibility for certain groups of people who live in low density areas that are genuinely hard to service using fixed route public transport. In this type of context, it could be politically justified to accept a costly DRT system if it provides clear improvements in accessibility for those people in the population who have limited access to transport compared to the present situation. Here, it becomes important to consider what investment in fixed route public transport compared to a DRT service will actually achieve in terms of quality for the users.

The debate about whether it is better to spend money on DRT solutions rather than improving the fixed routes first will undoubtedly continue. The results of the study presented in this report emphasise that, thus far, there is scant evidence to suggest that new technology and on-demand services have resulted in any significant improvements in DRT in terms of productivity.

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