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A conceptual model

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Opportunities for integration between Mobility as a Service (MaaS) and freight transport: A conceptual model

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ABSTRACT

This paper explores the potential integration of freight transport into a Mobility as a Service (MaaS) environment. MaaS is a user-oriented service concept providing door-to-door mobility solutions for people. It integrates services of multiple providers, enabling searching, booking, and payment through a single digital platform. Although MaaS is often presented as a great opportunity to increase the efficiency of the overall transport system, its application is constrained to passenger transport. The possibility of combining freight and passenger trips in MaaS might contribute to improving capacity utilization in passenger transport and to reducing freight movements in cities. The aim of the paper is to systematically explore the service models through which integration might take place and to qualitatively assess their potential impact. Based on a suitable conceptualization of what we called MaaS4PaF, i.e. MaaS for Passenger and Freight, we identify relevant logistics segments, propose service models and evaluate these from a multi-stakeholder and sustainability perspective. The analysis results in propositions about the fitness between on-demand freight and passenger systems combined in MaaS, as well as a related research agenda to further investigate the potential of this approach for future sustainable mobility.

1. Introduction

Transport systems are vital for city development, but they hamper city sustainability with substantial external costs particularly related to congestion, emissions, and road accidents (Holden, Banister, Gössling, Gilpin & Linnerud, 2020). Innovations brought by digitalization and new technologies are changing the way mobility is conceived with a growing trend towards its *servitisation*, leading to an integrated combination of products and services, i.e. "product-service systems" (Baines et al., 2007). Technological advances can have a fundamental role in guiding/enabling city activities and services. However, technology can be both a blessing and a curse for cities, exhacerbating undesired effects, if not adequately planned and managed (Dillman et al., 2021; Thomopoulos & Givoni, 2015). In the transition towards sustainable smart cities, it is important to envision innovative solutions to improve the efficiency and quality of services of city operations developed with the wider scope of sustainability (Bibri, 2018; Silva, Khan & Han, 2018).

In this context, "Mobility as a Service" (MaaS) is emerging as a personalised user-oriented platform that unifies the creation, purchase, and delivery of door-to-door passenger transport solutions integrating traditional and innovative modes of transport with the overall aim to reduce private car ownership (Kamargianni, Li, Matyas & Schäfer, 2016; Wong, Hensher & Mulley, 2018). The use of MaaS potentially benefits both the demand and the supply of transport services. The main benefit for users would be to have a customizable service that encompasses all the available transport options and provides seamless door-to-door and on demand transport solutions. On the other side, the attractiveness of MaaS for transport operators would be related to the critical mass of users and the potential network effect it could have by providing integrative solutions that could enlarge the catchment areas of some transport services. In this respect, public transport is often considered as the backbone of MaaS, complemented by shared and mobility on demand (MoD) services that should serve a first- or last-mile connection to other modes (Giuffrida, Le Pira, Inturri & Ignaccolo, 2020; Scheltes & Correia, 2017; Shaheen & Chan, 2016). This is expected to be the main field of application of electric and automated vehicles in the near future (Liang,

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Correia & van Arem, 2018; Wang, Correia & Lin, 2019). Following the concept of "collaborative consumption" (Wong et al., 2018), shared mobility is the shared use of a vehicle or a ride, enabling users to have a short-term access to transport modes on an "as-needed" basis. MaaS users "can use a single account and booking interface to access a broad range of transport modes, none of which the customer owns" (NSW, 2018). The concept, therefore, implies a shift from a culture based on vehicles' ownership to one based on sharing assets and services. However, even if it is a highly debated topic, MaaS applications are still not a fully-fledged reality. Many questions are being posed about its feasibility, but most importantly about its potential to bridge the gap between smart and sustainable transport, and the promise to reduce private car ownership (Mulley, 2017; Pangbourne, Mladenović, Stead & Milakis, 2020). Recently, research has started to address the conditions under which MaaS would be a truly sustainable solution for cities (Hörcher & Graham, 2020; Storme, De Vos, De Paepe & Witlox, 2020).

The focus so far has been only on passenger transport services. Freight transport has been often overlooked when considering urban mobility and transport planning, partly due to a general lack of knowledge and data regarding freight activities and its many stakeholders (Le Pira et al., 2017). Urban freight transport is facing many changes thanks to technological innovations and consumer involvement in supply chains enabling collaborative strategies and new business models (Tavasszy, 2020). E-commerce is a representative case, rapidly evolving and consolidating new habits and new logistics segments, like e-grocery and instant deliveries (Marcucci, Gatta, Le Pira, Chao & Li, 2021). In 2020, we have witnessed a strong increase worldwide with more than three in four consumers buying items on the internet (Statista, 2020). The growth of the last year has been substantial, most probably linked to the restrictions posed by the COVID-19 pandemic. The impact on the logistics sector is remarkable. In this respect, logistics innovations may lead to efficiency improvements, but for policy-makers also resilience, environmental impacts, and social sustainability are relevant.

In the advent of new transport scenarios in cities, the coexistence of passenger mobility and urban freight as two different ecosystems poses challenges to policy-makers, who are called upon to help tackle negative transport externalities. One important solution direction, potentially contributing to reducing transport externalities and improving logistics reliability and efficiency, is the integration of freight and passenger transport services (Hu et al., 2020). Given new technological advances allowing more interconnections among people and the possibility of sharing assets and services, integration becomes a promising concept for future transport scenarios based on digitalization and pervasive use of mobility platforms. In this respect, partial integration has been investigated recently through systems like crowdshipping (i.e. involving any citizen for freight deliveries) and cargo hitching (i.e. using the spare capacity of vehicles to carry goods), at a conceptual level (Marcucci, Le Pira, Carrocci, Gatta & Pieralice, 2017) and with pilots and proofs of concept (Alho et al., 2020; Pietrzak, Pietrzak & Montwiłł, 2021; Van Duin, Wiegmans, Tavasszy, Hendriks & He, 2019). According to Authors' knowledge, there has been no research, however, on their comprehensive integration with MaaS as a fundamental, overarching concept for passenger transport services. The critical mass of MaaS users and the variety of services included could be useful to perform some legs of the logistics chain, by taking advantages of vehicles' spare capacity, thus reducing the overall impact freight deliveries have on city sustainability and liveability, increasing the efficiency for transport operators and resulting in a more customizable and cheaper service for users.

Considering that the impact of MaaS systems on transport in cities is still uncertain, combining freight shipments with passenger trips is a promising addition to the MaaS business model that could help on the one side to reduce the number of freight vehicles, and thus kilometres travelled, and related externalities; on the other side, this could also contribute to a more efficient use of passenger transport services and modes, opening new opportunities for the transport sector, and increasing the overall city resilience. In this respect, in the "new normal" envisioned for transport services after the COVID-19 pandemic, we could expect "some light goods movement that can be picked up by underemployed Uber drivers and also by Community Transport" (Hensher, 2020). Considering the travel habit changes brought by the pandemic with an increase in teleworking and online educational activities (de Vos, 2020), the restrictions posed on public transport due to the need of social distancing (Jenelius & Cebecauer, 2020), and the increase in e-commerce demand and related freight deliveries, it becomes interesting to understand how the increased spare capacity of passenger trains/buses could be used to transport freight. This is applicable both in the short term to the emergency settings we are experiencing due to the current pandemic, and to a longer term considering the expected long lasting impacts and changes that it will brought (e.g. an increase of teleworking). Integrating passenger and freight transport services in MaaS would lead to an increase in the resilience of the overall transport system.

Earlier, authors proposed to combine freight transport into MaaS systems as an additional service via the involvement of logistics service providers, drawing on past pilots that have attempted this connection (König, Eckhardt, Aapaoja, Sochor & Karlsson, 2016; Pangbourne, Stead, Mladenović & Milakis, 2018). Others explore the adaptation of the MaaS concept to freight transport ("Freight as a Service"), adopting the same perspective of promoting sharing instead of ownership (Monios & Bergqvist, 2020). However, no study so far explores how the demand for different types of freight deliveries could be matched with the supply of several service providers available in MaaS and the related impact on sustainability. In this respect, these two worlds are very different and complex to match. While freight services using single passenger services (like crowdshipping or cargo hitching) only consider the freight perspective, MaaS is fully focused on the passenger services perspective. Therefore, it is of utmost importance to consider both perspectives at the same time if one wants to fully explore the feasibility, costs and benefits of adding freight to MaaS and its likely impact on existing business models of transport operators. Besides, MaaS has not a well outlined application context so far. It is often proposed for urban trips, but its potential has also been explored for suburban and rural areas and for national/international trips (Aapaoja, Eckhardt, Nykänen & Sochor, 2017). In this respect, freight could be potentially included in MaaS in each of its implementation. Based on it, the results could vary. The urban context would be interesting to focus on, both because cities are the ideal places where to first implement MaaS due to the high population density and variety of transport modes (Aapaoja et al., 2017), and since urban freight transport is one of the most cost-intensive activities of the supply chain and has a big impact on city sustainability and liveability (Gevaers, Van de Voorde & Vanelslander, 2011).

The research objective of this paper is therefore to analyse the *feasibility and sustainability benefits of integrating freight with passenger transport in a MaaS environment*. To this purpose, a framework for an extended version of MaaS including freight, which here we call "MaaS for Passenger and Freight" (MaaS4PaF), is proposed, and different schemes to perform such integration are presented and evaluated, based on the involvement of multiple MaaS actors, including passenger users. A first evaluation of the potential of MaaS4PaF is thus made from a logistics and a MaaS perspective, considering the potential sustainability impact. The analysis performed can give useful insights and unveil opportunities and barriers for the full exploitation of the MaaS4PaF concept.

The remainder of the paper is organized as follows. Section 2 reviews the literature related to MaaS concerning transport integration and MoD (2.1), and freight innovation, especially linked to the growing on-demand logistics market (2.2). This paves the way for the definition of MaaS4PaF, which is introduced in Section 3. Based on a conceptualization of MaaS4PaF, relevant logistics segments are identified and possible configurations proposed (3.2), resulting in different service combinations and models (3.3). This is qualitatively evaluated adopting a multi-stakeholder perspective in Section 4, by defining different stakeholders, related goals and criteria (4.1). Results are presented and discussed in Section 4.2. Section 5 concludes the paper, with suggestions about the fit between on-demand freight and passenger systems in MaaS, as well as a related research agenda.

2. Literature review

2.1. MaaS towards transport integration and MoD

There is no unique definition of MaaS (Jittrapirom et al., 2017). For the research objective of this paper, we define it as:

a user-oriented integrator of transport services enabling searching, booking, and payment through a single digital platform for door-to-door customized trips.

The essence of MaaS in such definition is represented by the concept of integration. Integration can refer to different aspects. Sochor, Arby, Karlsson and Sarasini (2018) propose a topological approach for the analysis of MaaS integration concepts, distinguishing between (1) no integration; (2) integration of information; (3) booking and payment integration; (4) integration of the service offered, including contracts and responsibilities; and (5) integration of societal goals. Some authors also highlight that bundling of mobility services is typically seen as the next step after the full integration of operations, information and payments, although this sequence is not necessarily followed in practice (Reck, Hensher & Ho, 2020).

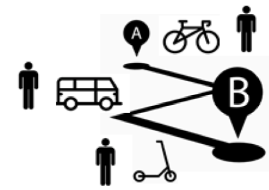
An important role is assumed by the integration of different transport services available via a single platform. They can go from scheduled public transport to MoD services, from publicly operated services to privately owned transportation network companies (TNCs), like Uber or Lyft. MoD services are important in complementing the existing public transport network by serving as a first- or last-mile connection (Shaheen & Chan, 2016) or as a stand-alone service. In the latter case, this implies that they could also serve as a substitute for public transport (Liu, Bansal, Daziano & Samaranayake, 2019). Privately-owned vehicles are usually excluded from MaaS, since the final aim should be to make it more attractive to use MaaS services instead of owning a car (Mulley, 2017). However, this dogma is often questioned, as recent research shows. Storme et al. (2020) point to the complexity of the relationship between MaaS use and car ownership and suggest that MaaS should be considered as complementary rather than in substitution to a private car. Even if in principle it may reduce the car ownership of MaaS subscribers, it may imply additional trips given the very low marginal fare thanks to the subscription, and bigger use of the private car by non-MaaS users because of the crowding of transport services by MaaS users (Hörcher & Graham, 2020). Based on this, we suggest that in a broader view of MaaS each service and mode could be used according to its optimal range with a complete sharing of assets and vehicles. If one adopts this perspective, then also private vehicles could be considered as part of MaaS trips, e.g. if they allow using public transport where there is no other first- last- mile connection with it. Table 1 summarizes the main transport services and modes that could be used for multimodal trips enabled by MaaS.

The promise to reduce car ownership is directly linked to the one of making transport more sustainable. However, there is growing evidence that MaaS (and MoD) does not always decrease emissions in a city, but can increase the use of space with the introduction of new vehicles that do not always use their capacity optimally causing many idle vehicles (e.g. ridehailing services), and may introduce new social exclusion problems, e.g. linked to transport digitalization (Pangbourne et al., 2018).

Besides questioning the MaaS role in reducing car ownership and its

Table 1
Passenger transport services and modes for multimodal trips enabled by MaaS.

Transport service/mode	Multimodal trip (example)
Scheduled public transport	*Metro/Heavy Rail, Light Rail/Rapid Bus, Bus*
On-demand public transport	*On-demand bus, Microtransit*
Carsharing	*Station-based or free-floating; fleet-operated or peer-to-peer*
Ridehailing/ ridesharing	*Ridehailing (peer-to-peer and TNC) and Shared ridehailing, Conventional or shared taxi, carpooling, vanpooling*
Micromobility	*Bikesharing, scooter sharing, private bikes, private scooters*
Motorized private transport	*Car, motorcycle*



unintended consequences, many open issues prevent its full implementation and make the gap between research and practice still high.[1] Polydoropoulou et al. (2020) elaborated on possible MaaS barriers and enablers by evaluating three case studies according to four criteria, related to: *Infrastructures* (integrated payments, open application programming interfaces - APIs), *Hard Institutions* (regulations e.g. related to fares, security concerns), *Soft institutions* (acceptability, trust between operators), and *Capabilities* (need for transport investments). Results show that regulations, non-standardized APIs, and required investments could be barriers for MaaS, while trust and cooperation between MaaS actors could be considered as key enablers.

The caveats open up new opportunities to explore alternative MaaS models with the inclusion of new actors that could be beneficial for the overall transport system sustainability. Given that MaaS could be considered as an integrator of different services, it is interesting to understand if it could be matched with freight transport. The paper aims to help fill this gap by exploring this concept with the overall aim to increase city sustainability. In the following, we elaborate on the freight perspective of city mobility, concerning MaaS.

2.2. Freight innovations and the growth of on-demand and collaborative logistics

Freight transport is in an unprecedented season of changes. Technological innovations like digitalization, automation and consumer involvement in supply chains are transforming the shipping industry (Tavasszy, 2020). The last-mile sector is especially witnessing many innovations both from the demand and supply side. They are promising since last-mile logistics is one of the most cost-intensive activities of the supply chain and it is becoming one big concern of policy-makers, given its negative impact on sustainability (Pronello, Camusso & Rappazzo, 2017). This is especially true at the urban level, which is usually characterized by scarce knowledge and heterogeneous stakeholders, interacting, and often competing (Le Pira et al., 2017). Innovations in last-mile logistics are diverse and can be categorized into six groups (WEF, 2020): vehicle change, secure delivery, customer movement,

[1] While MaaS-like platforms are rapidly emerging in many countries with many different business models, we are still far from a full implementation of this concept at its most advanced level (Cruz and Sarmento, 2020).

consolidation, last-leg change, delivery environment. Some of them are already in use today (see e.g. parcel lockers or electric vehicles), while others are expected to be developed in the next few years (e.g. trunk delivery,[2] load pooling, or goods tram), or in a longer time horizon (e.g. automated vehicles or robots). Freight and passenger integration is seen as a promising solution for the last-mile distribution towards load consolidation and asset sharing. In particular, according to ALICE's Roadmap towards zero emissions logistics 2050 (ALICE, 2019), this integration could be performed via crowdshipping, implying "recruiting citizens to serve as couriers using their private vehicles to pick up and drop off parcels along routes they are taking anyway", or by using public transport modes like "underground freight trains during non-operating hours or even combining freight and public transport in a way that does not affect current schedules". The Transport Capacity Sharing phenomenon is rapidly growing, following the sharing economy paradigm, as testified by many platforms that help to match shippers and carriers in an effort to optimize freight operations towards fewer empty kilometres and lower shipping times (Van Duin et al., 2019). This is in line with the concept of "Freight as a Service" (FaaS): "similar to Mobility as a Service, this is a business model whereby on-demand and ridesharing concepts formulate different procedures for the supply of goods to customers which are accessed through a single account and booking interface" (NSW, 2018).

Crowdshipping is a widely debated topic. Its sustainability is strictly linked to the non-dedicated nature of the delivery, and its success to the acceptability both from the supply (crowdshippers) and demand-side (Marcucci et al., 2017; Rai, Verlinde, Merckx & Macharis, 2017). In principle, it is promising since it can help to reduce the distance travelled by vehicles by taking advantage of already planned trips. Crowdshipping with commuting cyclists has been tested in an experiment in The Hague, showing that it is possible to increase logistics performance with a small burden for crowdshippers (Lin, Nishiki & Tavasszy, 2020). Gatta, Marcucci, Nigro, Patella and Serafini (2019) propose a crowdshipping service in Rome based on the use of mass transit by commuters, which would imply emission savings, but also public incentives to reach economic sustainability.

The use of public transport to carry freight is also known as cargo hitching, i.e. an unassisted delivery service where cargo can hitch a ride on a passenger vehicle, or even people can hitch a ride on a freight vehicle. The business model analysis of a cargo hitching experience in the Netherlands concluded that integrating passenger and freight transport is a promising approach (Van Duin et al., 2019). However, it is necessary to develop a sustainable business model to guarantee its success. Also, new MoD solutions could be used to integrate passenger and freight transport (Wang & Yang, 2019). Shaheen and Chan (2016) discuss the possibility of sharing of a delivery ride via courier network services that could be a peer-to-peer (P2P) delivery or a "privately-operated" ride and courier service. More in detail, a P2P delivery service implies that any individual performs a delivery with his/her vehicle or with a shared one, similarly to crowdshipping. Paired on-demand passenger ride and courier services are performed by private operators, i.e. TNCs, which can carry both passengers and freight at the same time or in different moments.

None of the above efforts considers opportunities for integration of freight and passenger rides within a MaaS environment. While attractive in principle, this integration is not trivial, given the differences between the two systems, and thus it is worthy to be investigated. Some authors have dealt with freight inclusion in a MaaS environment, but there is no study exploring its feasibility in detail. In particular, König et al. (2016) see MaaS as an ecosystem composed of four levels, i.e.: (1) public and regulatory; (2) transport and logistics service provider (i.e. the supply side); (3) mobility service (i.e. the MaaS operator); (4) "flexible mobility market" (i.e. the demand side). They put logistics services on the supply side as an additional service. However, there is no clear definition of *who* can perform the logistics service nor any reference to freight and passenger transport integration.

Our main contribution, therefore, is that we develop a framework for this integrated treatment of passenger and freight services from a MaaS perspective and considering the sustainability perspective as well. We develop the design of the system in the next section.

3. Framing integrated passenger and freight services into MaaS

A conceptual and business framework is needed to systematically explore passenger and freight integration in MaaS. The MaaS4PaF proposition is based on an identification of possible service combinations that could perform the integrated passenger and freight service, for multiple delivery networks and logistics segments. We build this up in the following subsections.

3.1. Overall MaaS4PaF conceptualization

The MaaS4PaF system is logically found by enumerating the options for the passenger and freight transport service systems (see Fig. 1):

(1) Logistics ecosystem: a basic ecosystem is composed of shippers, i.e. anyone that sends goods by any form of conveyance (from Merriam-Webster's dictionary), and of freight transport operators, i.e. those who perform the delivery of freight providing a service to shippers. They are usually professional carriers who provide logistics services by using a fleet of vehicles. The relation between shippers and carriers can be regulated by agreements (1a in Fig. 1) and, in some cases, it can be enabled using digital platforms (1b in Fig. 1). Examples are represented by the Accenture Logistics Platform and GoShare. Other examples are crowdshipping platforms that match informal carriers with individuals asking for some freight delivery. This applies both to specific logistics segments, like food delivery (e.g. Deliveroo, Glovo) or general freight (e.g. Nimber, Piggybee).

(2) MaaS ecosystem: according to Kamargianni and Matyas (2017), a MaaS business ecosystem "comprises of a wide range of stakeholders including public authorities, public and private transport operators, data providers, IT companies, ticketing and payment service providers, telecommunications, financing companies, institutions, passenger associations, etc.". In a basic framework, the MaaS ecosystem is composed of the MaaS platform (i.e. the MaaS operator) that can be public or private (like Whim), by passenger users who ask for a door-to-door transport service, and by passenger transport operators, i.e. a plethora of service providers that can be conceived in MaaS (e.g. public transport operators, shared mobility companies, TNCs). They provide a service to passengers via the MaaS platform.

(3) Cooperative MaaS + freight ecosystem: in this first instance of cooperation, we assume that freight transport operators can join the MaaS platform as done with any other logistics platforms. The added value of choosing the MaaS platform instead of any other logistics platform would be the greater number of users that are likely to use it, either by asking for a passenger or a freight trip. This is the approach envisioned by those who claim that freight transport could be added to MaaS as an "additional service" (König et al., 2016). Besides, TNCs could propose their transport service for freight delivery, as already done by Uber with UberEats or UberFreight.

(4) Integrative MaaS4PaF ecosystem: the full integration of passenger and freight transport occurs when every MaaS actor can become a carrier while doing his/her daily transport activities. The matching between the demand and supply is done by the

[2] See the Volvo In-car Delivery allowed by a partnership between Volvo and Amazon (https://www.volvocars.com/us/own/additional-choices/in-car-delivery)

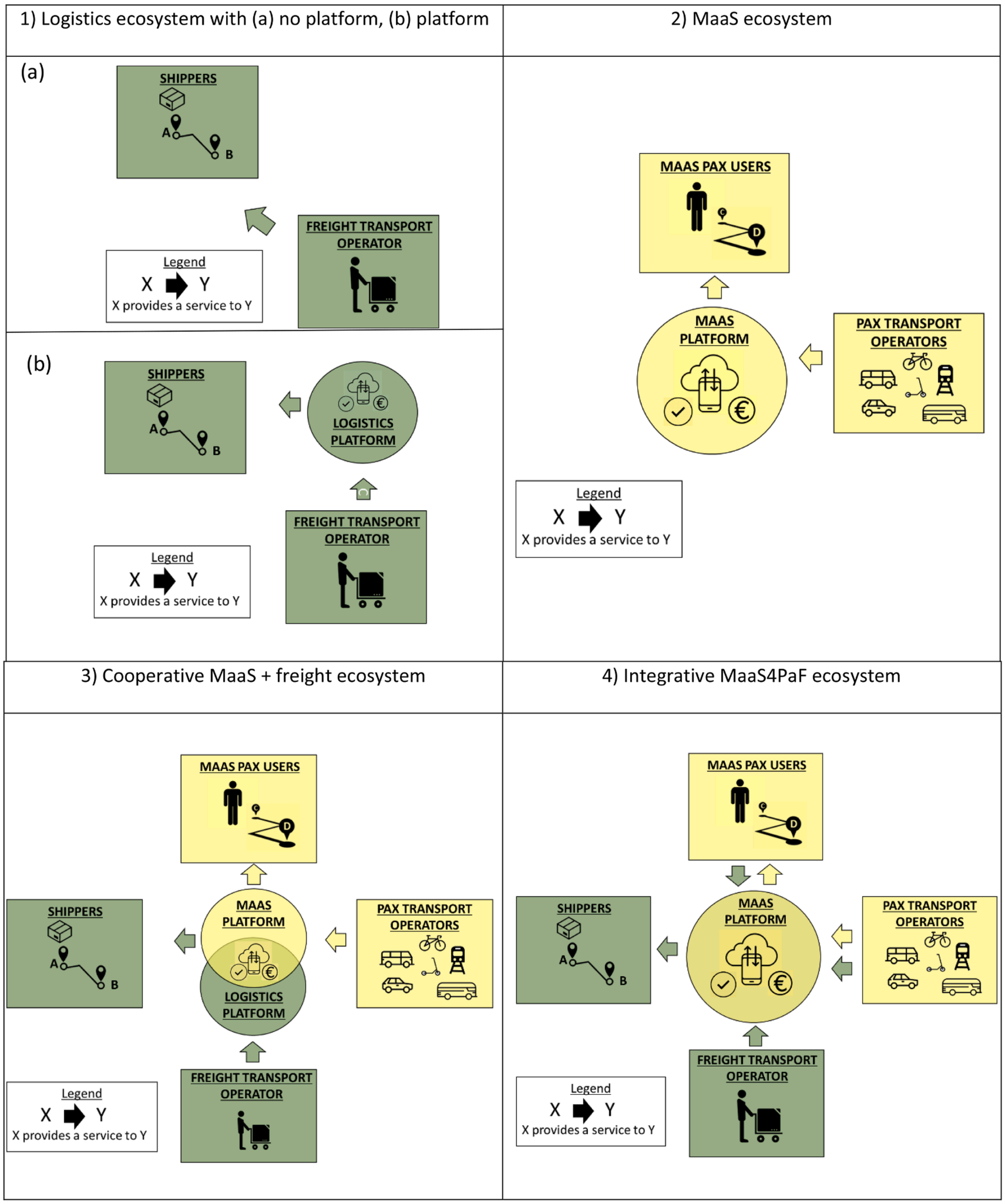


Fig. 1. MaaS4PaF conceptualization (arrows indicate the provision of a service from one actor to another).

platform and can consist of an integrated passenger and freight trip. It could be performed by passenger (PAX) users performing their trips and/or by passenger transport operators (PTO) sharing their spare capacity to perform the delivery trip and/or by freight transport operators (FTO) who have spare capacity. In principle, it would be possible for a freight vehicle to carry a passenger.[3] However, apart from regulatory problems (e.g. authorizations to carry people) that need to be overcome, they are usually not suitable to carry passengers. Therefore, we will leave out this option and focus on freight inclusion in passenger (or freight) trips. A multimodal trip involving different MaaS carriers is in principle possible as in the traditional MaaS scheme.

[3] This has been practiced in emergency situations, after a passenger service breakdown, and also in the leisure travel segment.

MaaS4PaF extends the current MaaS model by adding new actors and services related to logistics. Based on the definition of MaaS provided in Section 2.1, here we define the MaaS4PaF concept as:

a user-oriented integrator of passenger and freight transport services enabling searching, booking and payment through a single digital platform for door-to-door customized trips. The users are both passengers and shippers, and those who perform the delivery (i.e. *MaaS carriers) could be passengers, passenger transport operators, and freight transport operators.*

In this concept, the MaaS platform acts as the mediator between the demand (both passengers and shippers) and the supply. Passengers that usually are the demand of MaaS, asking for a passenger transport service, can become the supplier of a delivery service. Similarly to the traditional MaaS, once the shipper places an order of freight to be delivered from A to B, the MaaS platform evaluates the potential carriers (and their combinations) to be considered as candidates for the door-to-door delivery. Real-time geographic data and optimization algorithms are needed to provide adequate solutions. Based on the availability of different carriers, the MaaS platform can propose a set of solutions to the shipper, based on the expected travel time and cost.

3.2. Alternative service configurations

In this subsection we develop a service architecture by systematically considering the possible service combinations that can lead to an integrated service. MaaS4PaF architecture can be defined based on the steps needed to perform combined trips with the involvement of several carriers. They result in different logistics chains from the shipper to the final receiver (i.e. a door-to-door delivery from A to B), with the involvement of one or multiple MaaS carriers that have the responsibility of the delivery. They can be PAX, FTO and PTO. PTO can be divided into two categories, i.e. public transport (PT), and ridehailing/sharing services (RHS), as reported in Table 1, including flexible mobility services like TNCs, peer-to-peer and taxi services, and also on-demand public transport. Fig. 2 shows the different logistics chains:

I one-step chain: only one MaaS carrier is responsible for the door-to-door delivery. This automatically excludes PT, since the delivery cannot be fully unaccompanied and, most likely, PT would not allow door-to-door trips.

II Two-step chain: two MaaS carriers are responsible for the delivery. This means that the MaaS platform evaluates the potential combination of – already booked or scheduled – trips, and/or asks MaaS carriers for their availability to perform a leg of the delivery. As in the previous scheme, this type of solution cannot include unaccompanied deliveries by PT.

III Multi-step chain: all MaaS carriers could potentially be involved in the delivery by sharing their spare capacity. A part of the delivery could also be performed via PT, in an unaccompanied way. It is also possible that the delivery is performed by the same type of carrier (e.g. FTO), but by different agents, involving multiple responsibilities.

The different chains result in different service combinations. In particular, we have three options for the one-step chain, six for the two-step chain and sixteen options for the multi-step chain (excluding repeated cases like PAX+RHS/RHS+PAX). They are shown in Fig. 3.

It is worthy of note that while in principle all these combinations are possible, this may not apply to all logistics segments of on-demand deliveries. To streamline the analysis, the three chains will be examined concerning their suitability to provide the delivery service to different logistics segments, mainly differentiated by the size of the freight and the required delivery time, based on the classification by WEF (2020). They can be divided into parcels (small and light packages) and freight (>32 kg), and into deferred/time-definite (arrival some day or at specific day/time) and same day/instant deliveries (arrival on the same day or in few hours), which is usually applicable to parcels, resulting in three main typical logistics segments:

(a) parcel size and same-day/instant deliveries: e-grocery, same-day/instant e-commerce, food delivery, urgent document/item delivery;
(b) parcel size and deferred/time-definite deliveries: normal/express e-commerce, small-scale business-to-business (B2B) shipping, consumer-to-consumer (C2C) shipping;
(c) freight size and deferred/time-definite deliveries: B2B (e.g. store delivery), business-to-consumer (B2C) and C2C shipping.

In the following, the potential execution of MaaS deliveries with the three logistics chains is discussed with respect to their suitability to perform deliveries for different types of freight and lead times.

3.2.1. One-step chain

In the one-step chain, a shipper places an order from A (shipper's location) to B (receiver's location) at a certain time. The MaaS platform evaluates the potential matching between the origin and destination (OD) of the delivery and any other trip/carrier available in the platform.

Taking advantage of the critical mass of passengers users, matching could be found by looking at the OD of passengers, provided that: a small detour is probably needed to perform the delivery, that the delivery time window is compatible with the passenger trip, and that the freight to be delivered is a small package of low weight (i.e. a parcel). In this regard, user attractiveness (e.g. in terms of discounts on the trip) should overcome the burden of carrying the parcel. It would be possible to propose customized solutions based on user profile and preferences, inferring on the utility perceived and the probability to accept the delivery request. Especially in the case of multimodal trips implying the use of micromobility services, it is unlikely that passengers can carry more than one small parcel.

The MaaS platform can also check the potential matching with RHS. Similarly to passenger transport, the platform could inform available

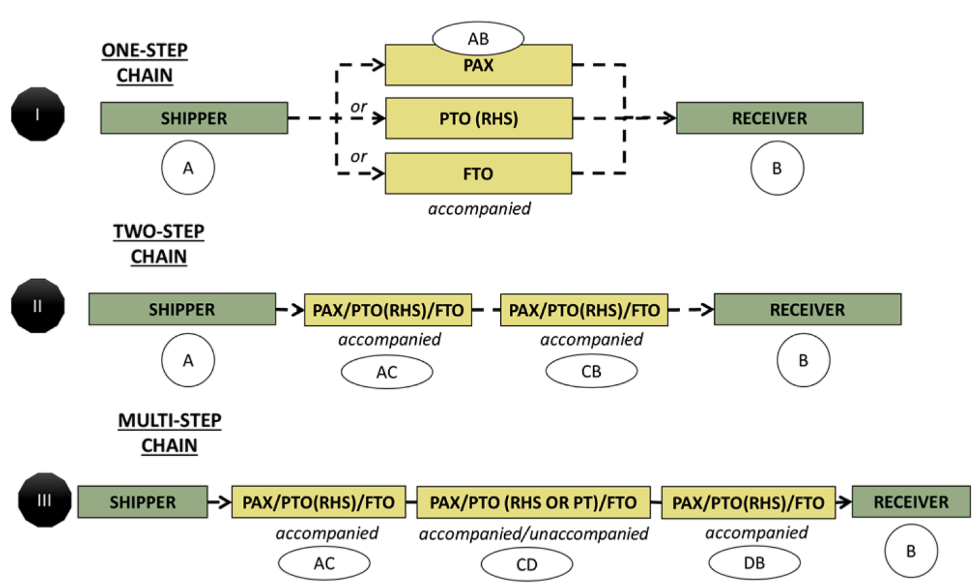


Fig. 2. MaaS4PaF logistics chains.

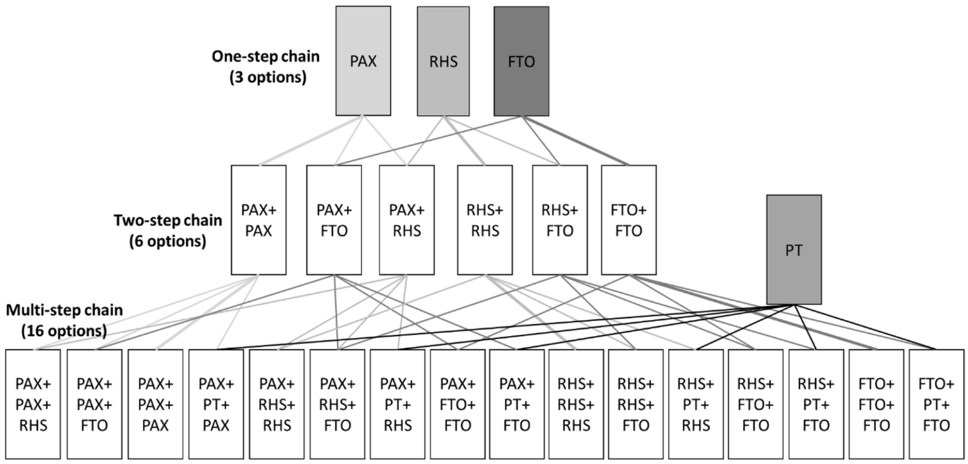


Fig. 3. MaaS4PaF service combinations.

drivers of the possibility to perform a delivery service. This can substitute a passenger trip (in case of no matching between ODs), and it could be applicable for parcels of higher volume or groups of parcels to be delivered at the same destination. Paired passenger ride and courier services are most likely to be performed for instant deliveries of parcels with (passenger and freight) requests that are dynamically generated via the platform. For dedicated deliveries, one should consider the attractiveness of carrying a freight instead of a person. Therefore, it is more likely that drivers decide to carry bigger parcels (or groups of parcels) if the price of the delivery is higher with respect to a small parcel and it could do it both for instant or time-definite deliveries.

Finally, the platform could also find a match between the freight OD and available FTO. Delivery of small packages would be attractive only if they match already scheduled trips with a small detour, especially if they are instant ones, while larger freight (not only parcels) could be considered more attractive, but knowing it with a higher notice that would allow the PTO to organize the deliveries in good time (time-definite deliveries).

To sum up, deliveries of parcels could be performed in principle by all MaaS carriers. While for passengers and FTO it is important to consider the detour needed from their already scheduled trip, for RHS services it is also important to understand the advantages of transporting parcels together with (or instead of) passengers. Time-definite delivery of parcels would be more efficiently performed by passengers who book their trips in advance or by FTO with some spare capacity during their planned deliveries, while freight of larger volume and weight are likely to be carried only by FTO.

3.2.2. Two-step chain

In the two-step chain, once the shipper places an order from A to B, the MaaS platform evaluates all the potential combinations with different MaaS carriers according to the shipper's delivery time preference. This process should be similar to the one adopted for users asking for a passenger trip, where the MaaS platform evaluates the possible mode combinations and proposes the best solution(s).

A match could be found by coupling an already existing passenger trip with the origin close to A and the destination in an intermediate node C, with a RHS or, in principle, a FTO trip with an *already scheduled* stop in C or close to C, and that could deliver the freight to B (final destination). Naturally, coordination is fundamental to avoid time loss, especially for instant deliveries, while logistics facilities like parcel lockers or micro-hubs are needed for time-definite deliveries. In the case of passenger involvement, it would be more likely to combine a delivery of small parcels of low weight and volume rather than those of higher volume and weight.

A combination of MaaS carriers is thus possible for different logistics segments, but it is more likely that parcel deliveries are performed by multiple passengers, single passengers in combination with RHS (e.g. a passenger leaving the parcel in a ride-sharing vehicle where the freight delivery will continue) or with FTO (e.g. using parcel lockers), while bigger (or a group of) parcels could be efficiently delivered by RHS and FTO (using parcel lockers or micro-hubs). Also in this case, deliveries of larger freight could be performed only by multiple FTO. Instant deliveries would be more difficult to be performed with respect to same-day/time-definite ones if one involves more carriers.

3.2.3. Multi-step chain

In this last case, once the shipper places the order from A to B, the MaaS platform evaluates all the potential combinations given the available MaaS carriers that "gravitate" near A or B, and the PT services that could be used to perform a leg of the delivery.

The MaaS platform could find a match between a passenger performing a trip aligned with the origin of the freight to be delivered (A), and leaving it in an intermediate stop coinciding or being close to a PT stop or station. In this case, the PT service should be of high frequency and reliable so that the user won't have to wait too much to drop off the parcel. Certainly, it would be easier to perform such a transport for passengers of a mass transit service that would go to the station in any case. In the case of FTO or RHS involvement, it would be easier to pick up the parcel/freight from a PT service that does not have a separate entrance/exit like a metro. Using PT would be easier if combined with two passenger trips using PT, one performing the first leg from the origin of the parcel to the departure PT stop/station, and the other performing the last leg from the arrival stop/station to the final destination.

A combination of multiple MaaS carriers that does not involve PT is still possible, e.g. with passengers leaving a parcel in the vehicle of a TNC, or an FTO picking up a parcel from a parcel locker where a passenger or a TNC dropped it off. In the multi-step chain, investments in logistics infrastructures would be important and greater than in the previous cases. With good scheduling, it would be possible to combine freight with PT and with FTO, which could be applied for time-definite delivery of large freight. In general, with the multi-step chain, it would be difficult to perform instant or same-day deliveries. The shift from one agent to the following one should be as smooth as possible, and this could be guaranteed if there is a decoupling between the freight arrival/departure from an intermediate node, e.g. by providing a diffused network of parcel lockers or micro-hubs.

3.3. MaaS4PaF market segments and service models

Service combinations in MaaS4PaF can be classified according to various market segments considering different shipment sizes (from parcels to freight), and lead times (from instant to time-definite deliveries). As a result of the previous section, we assume that parcels can be carried by all MaaS carriers, big parcels by PTO and FTO, and large freight only by FTO. Besides, it is reasonable to think that instant deliveries (delivery time of a few hours) could be performed by one single MaaS carrier (one-step chain), while for same-day deliveries it would be possible to involve two different carriers (two-step chain) and a combination of more carriers could be considered for time-definite deliveries (multi-step chain). This will lead to different options to perform the deliveries with more possibilities for parcel deliveries and less for freight, especially for time-definite deliveries using the multi-step chain (see Fig. 4).

Here, it is also interesting to look at the level of integration between passenger and freight transport that can be achieved through different service combinations. If we assume that a full integration implies no (or a very small) detour from the original trip, then we could say that:

- in the one-step chain, involving passengers in the delivery implies a full integration, while FTO could only combine MaaS freight deliveries with other freight (not passengers), implying no integration. RHS could carry passengers and freight at the same time (full integration) or only freight (no integration), resulting in an intermedium level of integration;
- in the two-step chain, involving two different passengers would imply a full integration. A high level of integration could be reached by involving first a passenger performing a trip (usually with multiple modes), and then a RHS, while a low level could be achieved by involving passengers together with FTO, or RHS with FTO; combining two RHS would imply an intermedium level of integration, while no integration with passenger transport is achievable with FTO involvement only;
- finally, in the multi-step chain, out of all the possible combinations, the ones mainly involving passengers and PTO (both PT and RHS) allow obtaining good levels of integration between passenger and freight transport, higher if we consider only PT and passengers. If FTO are also involved in the delivery, lower levels of integration would be reached, and no integration if they are the only MaaS carriers involved.

These results are summarized in Fig. 5 where the different levels of integration are qualitatively reported in a graph with the x-axis representing the logistics chains and the y-axis the levels of integration

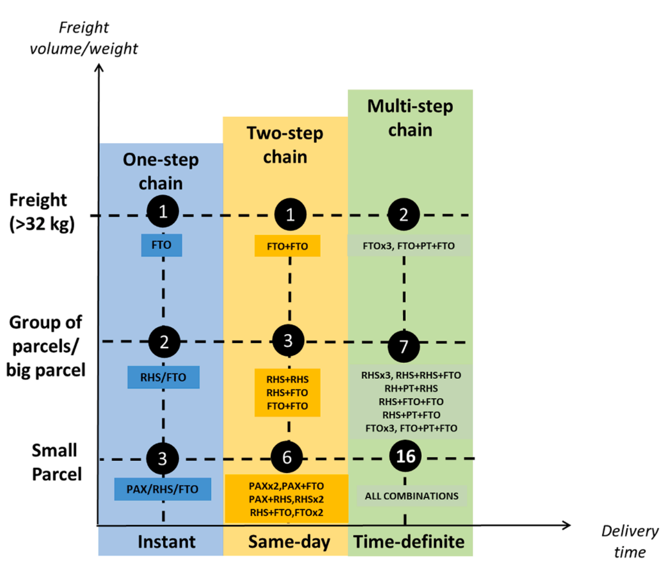


Fig. 4. MaaS4PaF service combinations according to market segments (numbers inside dots represent service combinations).

between passenger and freight transport.

If we look at the size of freight, a main finding is that the level of integration could have an inverse relation to shipment size. This is because passengers are more prone to carry parcels, and there are many options that allow a high level of integration with passenger involvement. This complies with the principle that smaller shipments are relatively expensive and will seek alternative shipping opportunities to economize on transport costs. Integration between passenger and freight transport is especially achievable involving passengers for instant deliveries, passengers and RHS for same-day deliveries, and PT for time-definite deliveries. E-grocery and food delivery are good candidates for passengers and RHS (or a combination of both), as well as instant e-commerce, while same-day/time-definite e-commerce and C2C shipping can be performed by multiple carriers (two-step and multi-step chains) preferably using PT for a leg of the delivery. RHS are good candidates to perform deliveries of bigger parcels (or groups of parcels) and this could allow reaching an intermediate level of integration, especially if we consider the possibility of using PT for a leg of the delivery. On the contrary, B2B, B2C, and C2C deliveries of larger freight are more suitable to be performed by FTO alone or in combination with RHS (two-step chain) and PT (multi-step chain). Naturally, deliveries of large freight performed only by FTO imply no integration between passenger and freight transport corresponding to the “cooperative MaaS + freight” concept presented in Section 3.1, i.e. an additional service in the traditional MaaS.

In conclusion, the potential for passenger and freight integration in MaaS seems feasible through different combinations of services and shipments, with more possibilities related to parcels than to larger freight.

Next, we find we can synthesize the propositions in three basic service clusters by focusing on (1) the main MaaS carrier involved in the delivery and (2) the level of integration between passengers and freight that can be achieved. We arrive at the following clusters (see Fig. 6 for the related stylized representation):

(1) PAX-driven MaaS4PaF/ full integration: this is the case of small parcel deliveries that can be performed either by a single passenger, multiple passengers or a combination of passengers with PT implying multiple responsibilities and a full integration of passenger with freight transport;
(2) PTO-driven MaaS4PaF/ intermediate integration: this usually applies to deliveries of more than one parcel or bigger parcels that can be performed in an accompanied way (by RHS) or for some legs in an unaccompanied way (by PT), by a single carrier or in combination with other MaaS carriers; this typically implies an intermediate level of integration between passenger and freight transport, since some of the deliveries may be performed by RHS without carrying passengers, or a leg of the delivery could be performed by an FTO;
(3) FTO-drivenMaaS4PaF/ low integration: this concept implies the main involvement of FTO and low to zero integration between passenger and freight transport, if the delivery is performed in combination with other carriers, or only by FTO. This can apply to large freight, e.g. using PT for a leg of the delivery, but even to parcels, e.g. in combination with passengers or RHS.

Since MaaS4PaF aim is to integrate freight with passenger transport in the logic of reducing the negative impact transport activities have on city sustainability, one could conclude that the first two service models are most prone to achieve this. However, it is important to understand that these may not be the most feasible in economic terms as the attractiveness of concepts for different actors will vary. In the following, therefore, a qualitative evaluation is performed by looking at different actors’ (private) perspectives, but also looking at the overall sustainability from a public perspective.

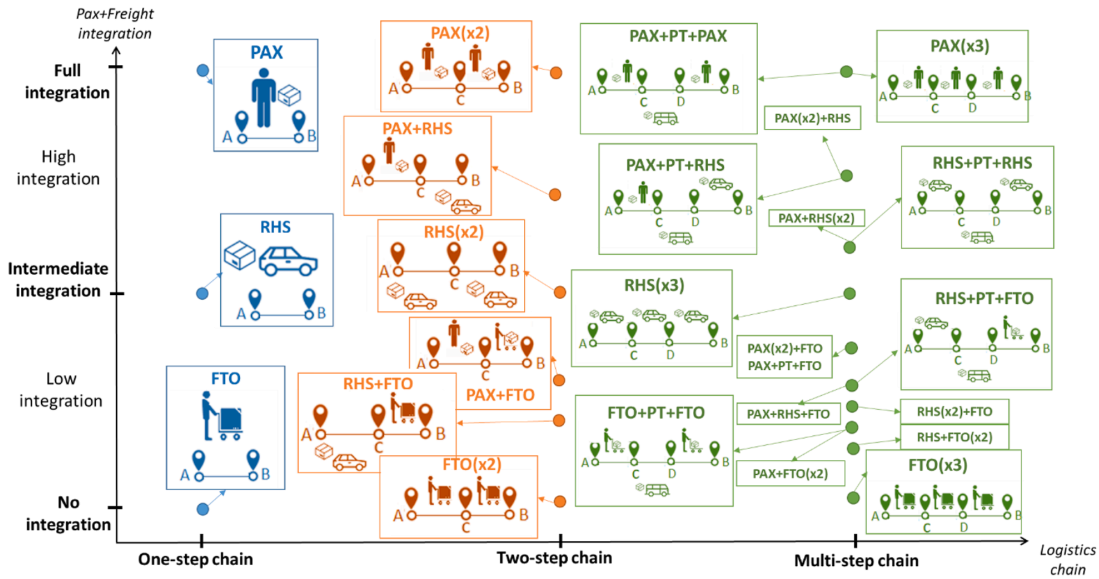


Fig. 5. Possibilities of freight and passenger integration in MaaS4PaF.

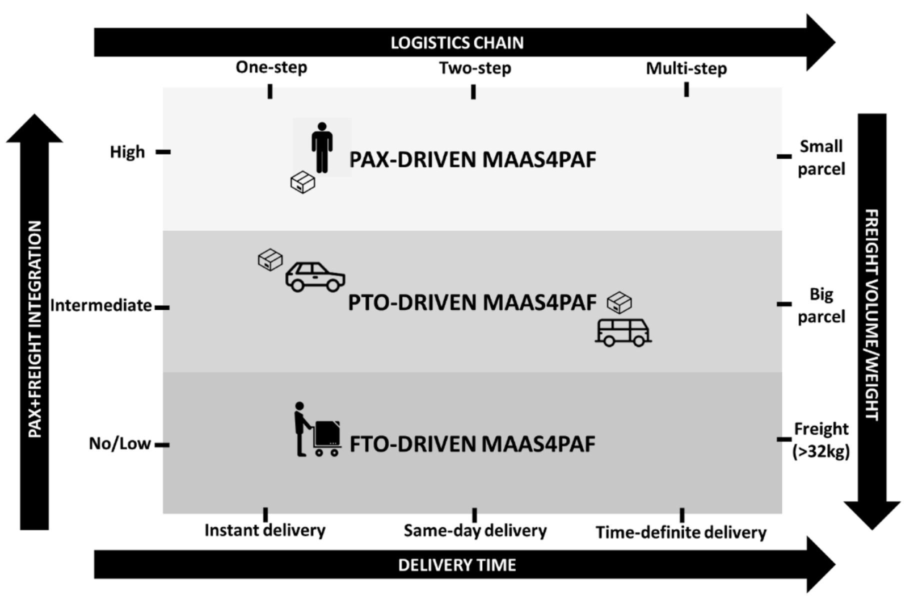


Fig. 6. MaaS4PaF service models.

4. Multi-stakeholder MaaS4PaF evaluation

The evaluation of the service models identified above is done by a systematic analysis of their potential impact on stakeholders' goals and specific criteria.

4.1. Stakeholders and their goals and criteria

MaaS4PaF potential success is strictly linked to the attractiveness of this service for the actors of its business ecosystem. This includes shippers, the MaaS operator (that could be public or private), and MaaS carriers. Besides, in order to specifically take into account the overall sustainability, a fourth actor is included, representative of a societal point of view, i.e. the government. Even if it may not have any specific role in MaaS4PaF deployment, it can foster or hinder its implementation based on the expected sustainability impacts. From relevant literature (Jittrapirom et al., 2017; Gatta et al., 2019; Polydoropoulou et al., 2020; Tavasszy, 2020; WEF, 2020; Bruzzone, Cavallaro & Nocera, 2021), the goals of actors have been defined, together with multiple criteria of evaluation. The goals and criteria of the MaaS stakeholders are summarized in Table 2.

4.2. Evaluation

For a preliminary qualitative assessment, service models are evaluated by indicating if they are expected to have a low/high positive or negative impact on each stakeholder's criterion. Results are graphically summarized in Fig. 7.

Delivery service price is a common criterion to all MaaS actors since it is at the core of their business models. In principle, the price assigned to the delivery should be linked both to the type of delivery (instant deliveries would cost more than the time-definite ones) and the quality of the service, which depends on the carrier(s) who perform it. FTO in general can assure a higher service quality as professional transport

Table 2
Goals and criteria of MaaS stakeholders related to the implementation of MaaS4PaF in its three service models.

Stakeholder	Goal	Criterion	Definition
MaaS shipper (and receiver)	Having the goods delivered in the right condition by the requested deadline at the lowest cost	Price	The price of the delivery charged by the MaaS operator
		Quality assurance	Condition of the goods, delivery reliability, flexibility
MaaS operator	Running a profitable business with an attractive service for users and service providers	Efficiency	Lowest costs possible, infrastructure, regulation
		Service attractiveness	Quality of service in line with proposition, number of platform's users and service providers, data
		Price	The price of the delivery charged by the MaaS operator
MaaS carriers	Making a profit as a carrier	Feasibility of service requirement	Capability to perform the service
		Efficient execution	Lowest detour possible
		Price	The price of the delivery charged by the MaaS operator
Local government	Making the city liveable while fostering a thriving economy	Environment	Local emission reduction due to reduced travelled distance (responsible for air and noise pollution)
		Equity	Increase in accessibility and social inclusion thanks to a cheaper, faster and pervasive service
		Economy	Investment on logistics infrastructures to perform MaaS deliveries (micro-hub, parcel lockers, UCCs)
National government	Correcting market failures while guaranteeing good services for citizens	Environment	Global emissions (GHG) reduction responsible for climate change
		Equity	Guarantee worker protection against exploitation
		Economy	Governance, harmonization of platforms and services

Fig. 7. MaaS4PaF models qualitative evaluation for MaaS actors (top figure) and for the government (bottom figure) (smiles of different sizes represent the expected positive or negative (small or high) impact; highlighted boxes represent preferred models).

companies; the same cannot be said for passengers who act as informal carriers, and for RHS who are focused on doing another job (carrying passengers), while PT reliability would highly affect the delivery reliability. In other words, if we assume that the MaaS operator assigns a higher price to deliveries led by FTO, and a decreasing price from RHS and PT to passengers, then shippers should find the PAX-driven or PTO-driven MaaS4PaF more attractive. Besides, while PTO would be paid for the delivery, passengers can be remunerated also with incentives and discounts on their trips.

For shippers, a compromise between the lower price of informal carriers and the higher quality assured by FTO has to be found when evaluating the attractiveness of the different solutions. In principle, FTO would assure a higher service quality, compensating the higher price, while the opposite is likely to occur with the PAX-driven model. However, a PTO-driven MaaS4PaF with the involvement of passengers and with RHS where drivers provide different freight and passenger services would be a good solution in terms of price and quality for MaaS shippers (e.g., Uber).

For the MaaS operator, the lower price assigned to PAX-driven deliveries would make it preferable compared to the other two options, while, of course, the opposite would apply to MaaS carriers. Besides, the MaaS operator should invest in PAX-driven MaaS4PaF since it can also be beneficial in terms of efficiency and service attractiveness. The efficiency gain relates to the fact that the service is offered with the lowest additional costs possible (the passenger carriers are already users of the platform). There can be efficiency gains in the case of FTO-driven MaaS4PaF as well, since FTO are usually professional carriers and there is no need to strongly intervene on the regulatory framework, whilst the same does not apply to PTO-driven MaaS4PaF because of the regulatory and infrastructure barriers that there can be, especially for PT (Polydoropoulou et al., 2020). In terms of attractiveness, the three options are considered equally desirable from a MaaS operator perspective, since they can assure a quality of service in line with proposition (especially FTO), and increase the number of platform's users and service providers and the data managed by the platform.

From the point of view of MaaS carriers, the least attractive concept seems to be the PAX-driven one. This is because of the low price/remuneration of the passenger-shipper, and the low capability to perform the service – as for PTO – with respect to FTO. However, in terms of the efficient execution of the delivery, it is easier for the MaaS platform to match freight with passengers implying the lowest detour possible (due to a critical mass of passengers using the platform), while the same cannot be said for FTO, who need to adjust their schedule according to the on-demand request coming from the MaaS platform. The case of PTO is mixed since it can imply RHS performing dedicated trips for the delivery (resulting in inefficiency and pollution) or RHS combining passenger with freight trips or PT perfectly matching passenger with freight trips. In principle, it can be assumed that a quite good degree of efficiency in terms of the detour needed is achievable with PTO-driven MaaS4PaF.

If we look at the government's perspective, PAX-driven and PTO-driven service models should be preferred in terms of expected environmental benefits. This is because they allow a good level of integration between (already occurring) passenger trips with freight trips, implying a reduction of the travelled distance for freight deliveries, which benefits the environment. This applies to both governmental perspectives since they can contribute to reducing local and global emissions. While in principle also an FTO-driven solution could be used to optimize the on-demand deliveries by combining them with already occurring freight trips, the expected benefits are likely to be higher with the other two solutions. A fast and above all cheaper delivery service is likely to be guaranteed by the first two service models contributing to increased equity from a local government perspective. Conversely, worker protection, which can be considered as an equity concern of the national government, is a hot topic especially when it involves non-professional carriers (see e.g. the protests against Deliveroo[4]). In this respect, involving mainly professional carriers would prevent this negative impact. Finally, from an economic sustainability perspective, a local government may need to invest to promote these types of deliveries with dedicated logistics infrastructures, and this is more likely with passenger and PTO involvement than for FTO (FTO are likely to already use logistics infrastructures to perform their deliveries). As an example, in the multi-step chain involving passengers, PT, and RHS, a ubiquitous network of parcel lockers should be provided to guarantee a secure stopover of the freight between each step of the delivery. However, also in the case of FTO it should be understood how the system would work by using logistics infrastructures that are usually not shared by multiple operators. From a national government perspective, the most difficult option to implement would be PTO-driven MaaS4PaF, implying governance issues, in particular a need for regulations and harmonization.

To summarize, a MaaS operator should primarily invest in PAX-driven and FTO-driven solutions, given that they can be the less expensive (to implement) and the most attractive for MaaS shippers. However, adequate incentives need to be given to the carriers involved (especially passengers), otherwise, they won't find it attractive to participate in the delivery service. Involving primarily PTO would entail some initial difficulties, especially related to the infrastructure and regulatory barriers.

A local government would be more interested in promoting the PAX-driven and PTO-driven service models, since they can be beneficial for the environment and equity, even if they may require higher investments in logistics infrastructures to perform the integration. A national government should prefer the PAX-driven service model, while the PTO-driven one could imply stronger barriers for its implementation. Conversely, the FTO-driven service model could have benefits in terms of worker protection and governance (representing equity and economy), but they are expected to be lower than the environmental benefits of the PAX- or PTO-driven service models.

These results point to the need for further research to investigate the feasibility and attractiveness of different MaaS4PaF configurations. These will be discussed in the next final section of the paper.

5. Discussion and conclusions

MaaS is a promising concept for the future of transport systems based on digitalization and integration. In this paper, we explored the integration potential with freight transport by introducing the MaaS for passenger and freight - MaaS4PaF - concept. In principle, this integration could benefit both systems. By defining MaaS4PaF actors and services, we analysed different service combinations in relation to various logistics segments, and proposed three main service models, based on different levels of freight and passengers integration and the main MaaS carrier involved, resulting in solutions driven by (1) passengers, (2) passenger transport operators or (3) freight transport operators. While from the point of view of freight and passenger integration the first and the second ones should be preferred, a qualitative evaluation from different MaaS stakeholders' perspectives suggests that there is no single solution and that each of them could have pros and cons.

From the analysis performed, it is possible to elaborate on opportunities and barriers for MaaS4PaF implementation. The main conclusion is that there are more opportunities by involving passengers and passenger transport operators in the delivery of small freight, i.e. parcels. This could benefit some growing sectors like e-commerce, and specific segments, like e-grocery or food delivery, requiring fast deliveries. Taking advantage of the critical mass of MaaS users, it would be possible to optimize (already existing) passenger and freight trips with the minimum detour possible. This would allow to reduce the impact of freight activities on cities, increase city resilience by offering additional services (Hensher, 2020) and MaaS attractiveness with new services and opportunities for users (Mulley, 2017). Besides, instead of excluding private transport from MaaS in the effort of reducing car ownership (Pangbourne et al., 2020), it could be good to include private vehicles in MaaS and promote their efficient use (e.g. by carrying goods while travelling for other purposes).

In the case of TNCs involvement, it is likely that including the possibility to carry freight will lead to fewer idle vehicles and better use of vehicle capacity, which is one of the issues with MaaS and MoD, i.e. the dilemma between competition or cooperation between public transport and MoD services (Liu et al., 2019). Using public transport for freight deliveries would be beneficial since it allows to combine freight with passengers with no detour. However, some existing MaaS barriers, mostly related to regulations and infrastructures (Polydoropoulou et al., 2020), could be exacerbated and new ones may emerge due to the inclusion of freight, e.g. security concerns. Including freight transport operators in MaaS would open up other opportunities for freight transport optimization, but with fewer possibilities of integration between passenger and freight transport and a lower expected impact on

[4] https://www.bbc.com/news/business-37053348

sustainability, if compared with the other options. However, impacts and opportunities also depend on the market size of different logistics segments. If the logistics of large freight is important, then freight transport operators' involvement in MaaS could be desirable to improve its efficiency; if e-commerce is predominant, then passenger and passenger transport operators are more suitable.

There are several operational issues that need to be addressed for future real implementations of MaaS4PaF. One important aspect is the reliability of the service, which strongly depends on the ability of the MaaS platform to find *ad-hoc* customized solutions for shippers, which in turn depends on the reliability of the MaaS carriers involved. A review/feedback mechanism of the performance of the different agents involved in the delivery should be included in the process.

Coordination and the interchange process are also fundamental in the case of involvement of more agents, especially for fast deliveries. This issue has been addressed by Lin et al. (2020) with respect to a crowdshipping experiment performed by multiple commuting cyclists. In particular, they considered the waiting time (to pass the parcel) as an indicator of the level of intrusiveness of the crowdshipping service for the commuters involved.

Security is another concern of deliveries involving multiple heterogeneous agents. According to Le, Stathopoulos, Van Woensel and Ukkusuri (2019) trust, safety and security are key factors for crowdshipping services and they are related both to the demand and to the supply. This includes damages to the freight and the concern to share information, as well as worries from the crowdshipper's side about hazardous or illegal products. According to the Authors of the study, some crowdshipping platforms include a basic insurance package and give the possibility to customers to decide if they want to pay more for an additional protection.

Finally, a deeper analysis of the most suited logistics segments for this type of service should be explored more in detail, by looking not only at the size of the freight and the time of the delivery, but at the freight type (e.g. perishable/non-perishable goods).

Apart from these operational issues, the exploratory nature of the paper brings some limitations, which point the way for follow-up research. Open issues relate to the need for quantitative validation of the framework and the expected impacts on MaaS business models and city sustainability. Interviews with stakeholders could be used to assess the viability of business models, while modelling would be required to assess magnitude of impacts. Co-operation problems could be addressed by multi-stakeholder multicriteria analyses or gaming approaches (Kourounioti and Tavaszzy, 2020). Simulation models, like agent-based models, would be suitable to reproduce the negotiation between different agents at a microscopic level and to test the service requirement of MaaS to perform the match between passenger and freight. Stated preference surveys could be used to investigate the preferences and willingness to pay of different MaaS actors (Gatta et al., 2019). Finally, proofs of concept would allow testing it in realistic scenarios, e.g. via pilot demonstrations.

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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