Shared Mobility and Last-Mile Connectivity to Metro Public Transport: Survey Design Aspects for Determining Willingness for Intermodal Ridesharing in Athens

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Abstract. People living in peri-urban low-density areas may not choose the urban rail because they are hindered by the 'first/last mile' problem. The issue concerns poor bus feeder service to rail stations and/or congested Park&Ride facilities at respective intermodal hubs. Shared mobility in the form of carpooling is a viable alternative in connection to urban rail, especially when appropriate incentives and ridematching tools are effectuated. A multi-modal ride-matching app combining flexible (carpooling) and scheduled (rail and bus public transport) mobility is stipulated by the Horizon 2020 Ride2Rail project. Two intermodal hubs of urban rail along the 20 km-long corridor connecting the Athens basin with the Athens airport in Eastern Attica, Greece, are selected as a case study. The paper envisages the behavioural underpinning of combined rail-rideshare travel companion platform in the first/last mile context through the design of a SP experiment, as mode choice is concerned. All main access and egress modes of intermodal hubs are considered in the mode choice experiment, namely driving alone, using bus feeder, carpool driving and carpool riding. Tested parameters pertain particularly to incentive mechanisms increasing ridesharing to intermodal hubs, contextual preferences related to the trip purpose and perceived barriers of shared mobility.

Keywords: Carpooling · Metro · Shared mobility · Last-mile · Public Transport

1   Introduction

Rail Public Transport (PT) modal shares in peri-urban low density areas are often disappointing due to the 'first/last mile' (FM/LM) problem. This problem pertains to poor bus PT feeder services to/from rail PT stations and/or congested Park and Ride (P&R) facilities at the respective intermodal hubs which hinder access to rail PT stations either by PT or private cars. Shared mobility in the form of carpooling (being a form of ridesharing) is a viable alternative in connection to urban rail, especially when

appropriate incentives and ridematching tools are effectuated. Thus, carpooling may complement PT and amplify rail ridership.

A multi-modal ridematching app combining flexible (carpooling) and scheduled (rail, PT) mobility is stipulated by the EU H2020 Ride2Rail project; Ride2Rail consists of 17 partners including ATTIKO METRO of Greece. In the case of Athens, the project aims among others at reducing single-occupant car trips, car-kms travelled as well as GHG emissions. Two intermodal hubs of urban rail along the 20 km-long corridor connecting Athens basin with Athens International Airport (AIA) in Eastern Attica are selected as a case study. Having intermodal hubs as a shared trip end for a part of a journey increases the likelihood of congruent trip ends and successful ridematching.

The paper envisages the behavioural underpinning of combined rail-rideshare travel companion platform in the first/last mile context through the design (and conduct in a later stage) of a Stated Preference (SP) experiment, as mode choice is concerned.

All main access and egress modes at intermodal hubs are considered in the mode choice experiment, namely driving alone, using PT bus feeder, carpool driving and carpool riding. Tested parameters pertain particularly to incentive mechanisms increasing ridesharing to intermodal hubs, contextual preferences related to the trip purpose as well as perceived barriers of shared mobility.

The main objective of the paper is to enhance the understanding of travellers' decision using carpooling as the access or egress mode to/from intermodal hubs of urban rail. Another objective is to draft a suitable design for a SP experiment that will distil information about ridesharing behaviour. Revealed preference (actual) behaviour is influenced by habit, supply limitations or (uncontrolled) system effects, thus is more constrained into explaining factors impacting ridesharing.

Novel features of the paper refer to the design of the SP carpool experiment for a part - first/last mile - of an entire journey, namely the trip to/from an intermodal hub. The experiment being conducted at a region-wide level covers short-distance trips complementing the use of the (line-haul) PT mode. Based on the survey data, realistic (to the respondent) alternative mode usage scenarios are generated during the interview for use in the SP part of the survey. Discrete choice modelling will be used to analyse the data and several specifications are to be developed in a next phase to help explain the forces that impact ridesharing to intermodal hubs.

The paper is structured in 5 sections. Section 2 presents the relevant literature review, aiming to identify potential factors affecting the decision to become carpool driver or rider. Notional issues and the concept of dynamic ridesharing are described. An overview of the study area along with the underlying travel data and information is given in Sect. 3. Section 4 elaborates on the methodological issues concerning the field survey, the questionnaire structure, the sampling technique and the SP experimental design. The final section presents the next steps of this research and attempts an overview of the main points of this effort until now.

2 Literature Review

2.1 General

Ridesharing, and in particular carpooling, is an efficient mobility form which may fill service gaps to rail stations and other PT terminals. PT gaps are evident in low density areas. Affected communities have an interest to enhance low cost accessibility to trunk-haul lines (TCRP 2012).

According to Furuhata et al. (2013), *'Ridesharing'* refers to a mode of transportation in which individual travellers share a vehicle for a trip and split travel costs such as fuel, toll, and parking fees with others that have similar itineraries and time schedules. They consider informal carpools involving family members and related persons (e.g. friends, co-workers) as well as formal carpools involving unrelated persons (unknowns). A slightly different definition from ICARO project final report (ICARO 1999), states that '*Car-pooling* is at least two people riding in a car usually belonging to one of the occupants, whether one person always drives or the carpoolers alternate cars. Each member would have made the trip independently if the carpool had not been there. Driver and passengers know before the trip that they will share the ride and at what time they will be leaving. Professional and/or commercial vehicles are excluded'.

Carpooling is served by private cars for various trip purposes. In a US survey in Texas, 50% of carpool vehicles using High Occupancy Vehicle (HOV) lanes were carrying two or more occupants who were commuters (Li et al. 2007). However, other trip purposes may also be satisfied by the carpool mode such as recreation or shopping.

Ways of filling up mobility needs of people in low density areas are equivalent to solving the 'last-mile' problem in logistics terms. Thus, carpooling is a modal form which complements PT for short-distance rides. In contrast, long-distance carpools fully replace PT rides, thus deteriorating sustainability (Stiglic et al. 2018).

Environmental concerns (e.g. car-kms and GHG emission savings) are further reasons for promoting carpooling and ridesharing in general. Carpools reduce Single-Occupant (SOV) car trips leading both to road and parking decongestion. Less parking-search traffic and need for parking spaces are additional benefits. User concerns (e.g. minimization of car-kms, excess driving time and travel costs) are aligned in this respect with environmental concerns, demonstrating a win-win situation. Car-kms and tons of GHG emission savings as well as increases in car occupancy levels are prevalent KPIs from the *community* perspective. From the *user* perspective, appropriate KPIs pertain to excess driving time (delay), travel costs and comfort levels.

Ridersharing platforms and apps are more appropriate for the formation of formal carpools. Large employers' platforms or large trip generators mobility plans (e.g. universities, shopping malls, etc.), may also serve as carpool enabling mechanisms.

In the rail-rideshare context of peripheral low-density areas we distinguish:

- drivers and riders (passengers) opting to use the rail (carpool multimodality)
- drivers dropping off riders (passengers) at intermodal hubs and continuing by car to their final destination (carpool rider multimodality, 'Kiss&Ride' mode)
- both driver and rider completing their journey by carpool (carpool unimodality).

Only carpool multimodality contributes to the road and parking decongestion in the city centre.

Intermodal hubs are a critical component for promoting carpooling in a region. The rail-rideshare combination of intermodal hubs provides a ridematching advantage. The hubs as shared and fixed trip ends (but transfer points over the entire journey) enable shorter detours and less inconvenience for the carpool drivers, thus allowing more feasible ride matches than complete-journey carpools where both trip ends are variable. In case of long journeys, the proportion of trips with similar O-D pairings is small due to the distance friction. The tolerances for detour delays and walk time measure the spatial flexibility of the ridemates. Narrow departure time windows and schedule rigidity of the carpoolers are further limitations for ridematching. The temporal flexibility of ridemates (e.g. earliest possible departure time, latest possible arrival time) greatly impacts the ridematching success rate.

2.2   Factors Impacting Ridesharing Behaviour

Prominent factors in the literature having an impact on ridesharing behaviour are:

- *In-vehicle travel time*, perceived differently by carpool drivers and by (incidentally more relaxed) riders. According to Hunt and McMillan (1997), the relationship between the value of time of a rider and a driver for commuters is approximately 0.69.
- *Detour time*, i.e. delay of the carpool driver to pickup and drop-off the rider at a meeting point (home or out-of-home); excess driving time represents an inconvenience factor for the driver. The value of detour time to the value of direct travel time amounts about 1.4 for commuters (Hunt and McMillan 1997).
- *Walk time* of the rider to an out-of-home meeting point. The value of walking time to the value of in-vehicle travel time amounts about 1.8 in Athens (Spanos et al. 1997)
- *Travel cost* (normally shared equally among car poolers) includes - apart of fuel cost – toll cost and possibly parking cost. The latter is shared equally through the number of car occupants, if they are unrelated; in case of family members or friends, mostly the driver assumes the burden.
- *Type of relationship* between ridemates (family members, friends/co-workers, unknowns)
- *Availability of and waiting time for a Guaranteed Ride Home (GRH)* referring to riders. The value of GRH availability approximates the PT ticket fare for commuters (Hunt and McMillan 1997). Overall, a return trip outwards, must not be done with the inward driver too.
- Existence of HOVs which stipulate time savings to carpoolers by providing exclusive lanes for them.

Olsson et al. (2019) carried out a meta-analysis of 18 recent studies on carpooling and calculated effect sizes of 20 different factors. Their results indicated a very weak influence of socio-demographics on carpooling. Influential are fuel costs and economic benefits as well as socio-psychological factors and attitudes, such as desire for socializing or lack of trust and loss of privacy. Policy incentives and situational factors

(e.g. area density, PT service level) are also drivers of carpooling. Interestingly, issues such as 3rd party liability insurance or driving behaviour have not been considered. Buliung et al. (2009) estimated in the Greater Toronto Hamilton Area in Canada that the number of carpool platform users within 1 km of the place of residence increases significantly the odds of starting to carpool through the platform; potential match locations in excess of 3 kms have a little impact on carpooling. This important finding is an advice to embrace suburban municipalities and raise at the neighbourhood level the awareness of the ridesharing platform.

Effective policy incentives for carpooling seem to be preferential parking for carpooling vehicles as well as discounted parking fees. Another incentive is the granting of free PT tickets or even taxi ride to provide the GRH stimulus (Menczer 2007). A certain factor is the ridematching transaction cost, dependent on the design features of mobile apps. Relevant socioeconomic characteristics pertaining to carpool propensity are home location, age, gender, household size, number of household cars over number of driver licenses, schedule flexibility, activity constraints, mode currently used (inertia) as well as current direct–trip characteristics

2.3 P&R Facilities

It is well known that parking constraints in central urban destinations generally increase the PT share (Morrall and Bolger 1996), which is also true for the Athens case (Polydoropoulou et al. 1998). However, referring to peri-urban areas close to trip origins, Merriman (1998) provided evidence that increases in the capacity of parking-constrained suburban rail stations increase rail ridership. Depending on time period and other variables, the author observes that system-wide between 0.75 and 1.5 additional boarders are associated with an additional parking space. Nevertheless, expansion of parking capacity is cost-intensive and detrimental to a sustainable transit-oriented development around stations. A smarter way to increase rail ridership without expanding parking capacity around suburban stations is to increase ridesharing to P&R hubs. Such an option was studied in Thessaloniki, Greece in 1997, as part of the ICARO project demo case combining carpool use, the implementation of an HOV lane and the provision of a P&R facility (ICARO 1999). The study findings indicated consistently that an increase in carpooling use is achieved when additional measures such as preferential parking for car poolers are taken.

2.4 Dynamic Ridesharing

Dynamic ridesharing is facilitated by ride matching platforms and apps. ICARO project examined, 20 years ago, one of the first real-world carpool matching centres established in co-operation with individual companies in Brussels, Belgium. The ultimate aim was to promote carpooling and to encourage employees to put carpooling into practice. A matching index was devised in a ridematching platform allowing the pairing of carpool drivers with prospective passengers based on trip and person characteristics. Apart from the trip characteristics of the prospective ridemates, other specific requests from both sides were taken into account when calculating the index. According to the project findings,

a carpool matching service could be part of a larger transport co-ordination centre. PT operators could also be involved in matching prospective carpoolers ICARO (1999).

Another such initiative is the Carpool Zone app which is part of the Smart Commute programme started in 2005 in Toronto Area (GTHA) in Canada (Buliung et al. 2009). The specific programme encourages commuters to explore various commuter options like carpooling, teleworking, transit, cycling, walking or flexible work hours. Some 50 major employers work with local authorities to offer customized commuter services.

Today, technology with mobile apps and GPS-enabled devices allow easier ride-matching. Dynamic ridesharing apps match ride offers of drivers as Travel Service Providers/TSPs (supply-side) and requests of riders as passengers (demand-side). Such apps reduce the transaction costs of ridematching and facilitate carpool formation (Amey et al. 2011). There is evidence that they increase the willingness to rideshare (Lee et al. 2016). Blockchain technology is a trust-building mechanism envisaged by the RIDE2RAIL project to enhance ridesharing with unknowns.

Dynamic ridesharing is predisposed for single, non-recurring trips, unsteady work time or shift work. However, commuters with recurring trips may also use a platform to establish a more stable carpool and eventually share driving in turn (platform as a networking tool for carpool acquaintanceship). It is noted that social or recreation trips typically exhibit a higher than 2.0 car occupancy rate, whereas commuting trips a lower than 1.2; thus, promoting carpooling among commuters seems to be a more efficient strategy. Rideshare platforms need an initial phase to stabilize. It is common to incentivize early adopters to gain a sufficient driver-to-rider ratio and a critical mass of offers and requests. A minimum success rate for ridematching is a condition for potential participants to continue using the platform.

2.5   SP Experiments and Carpooling

SP experiments with hypothetical trade-off games have been used in a few studies of carpooling choice behaviour. All concern entire journeys from initial trip origins to final destinations. Experiments for the propensity to participate in carpooling schemes as a driver or as a rider have shown the importance of, inter alia, working schedule flexibility, weather conditions and perceived rider vs. driver profile respectively (Tahmasseby et al. 2016). Correia and Viegas (2011) merge together carpool drivers and riders in the form of a single alternative to driving alone/with family. Higher willingness to carpool characterises younger persons and lower income people. A highly positive and significant Alternative Specific Constant (ASC) represents an unexplained preference for carpooling. Trust-building was intended through the formation of car clubs. Focusing on the home to work trip towards city centre, Van der Waerden et al. (2015) asked car drivers in an SP experiment to choose between driving alone and carpooling, in a similar setting of Correia and Viegas (2011). Most influential was the flexibility of working hours, time and cost variables.

In the SP experiment of Ciari and Axhausen (2012), respondents choose among car, PT, carpooling as driver and carpooling as rider. The experiment is conducted at a nation-wide level in Switzerland covering trips longer than 10 kms, thus carpool alternatives antagonize PT mode by design. The in-vehicle Value of Time (VoT) of the

carpool passengers is higher than the VoT of the carpool driver and the latter is higher than that of the single driver. Pertaining to the carpool rider, the value of walk time is 16% higher compared to the in-vehicle VoT. A contextual preference for carpooling was associated with work as trip purpose.

With respect to Greece, an SP experiment took place in Thessaloniki, two decades ago, in the framework of the EU ICARO project (ICARO 1999; Papaioannou and Georgiou 2001). Thessaloniki is inhabited by almost one million people and PT services are provided by buses only. The survey goal was to determine the percentage of persons willing to carpool under specific circumstances from home to work during the morning peak. The survey covered a specific area as home origins and the city centre as work destinations. Attributes in the SP games included the total journey time by car with and without the existence and use of an HOV lane by car poolers, the trip cost and the occupancy rate. A fractional factorial design of 9 combinations was employed instead of the full SP design of 27 combinations. Trip time and cost values were taken as % of the respective average figures. Surveyed persons had to make a choice between a hypothetical option and the revealed one (paired choice). VoT figures for carpool drivers and riders were obtained, showing that there is a ratio of 1.56 between these two categories. Survey findings indicated that 5% of those asked are willing to carpool as riders for a 17 min. journey (3.5 km) provided they would save 60% of their initial trip cost and they would also reduce their journey time by 25%. Parking search time savings were not explicitly mentioned but they were taken as part of the overall journey time.

3   Case Study
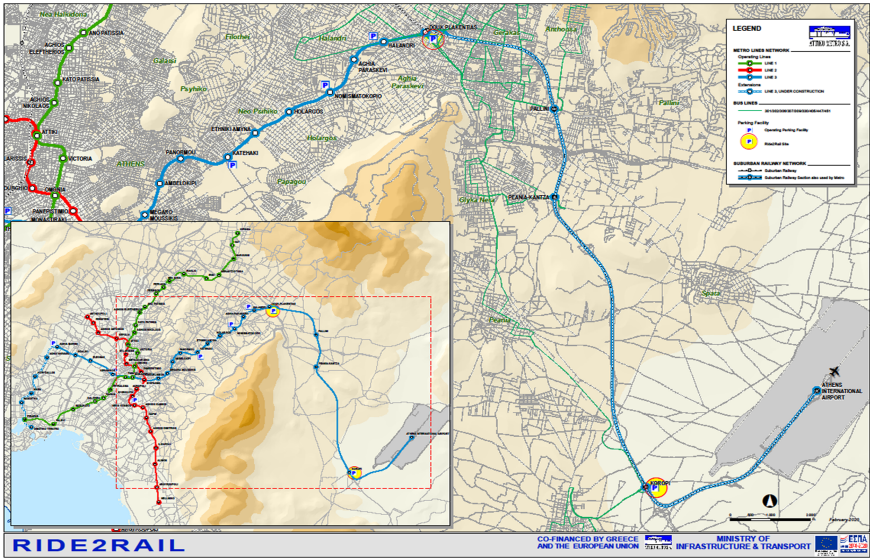
3.1   Study Area and Background Information

The study area of this research is the catchment zone of the 20-km long air-rail corridor between "Doukissis Plakentias" and Athens Airport rail stations along "Attiki Odos" toll road. This area comprises territories of five (5) municipalities with low population densities compared to the core centre of the Athens municipality (Table 1).

Table 1. Demographic & travel demand features of municipalities represented in the study area

Municipality	Total area (km^2)	Population	Population density (inh/km^2)	24 h travel demand	PT share (%)
Athens	39	664,046	17,026.8	1,491,531	78
Vrilissia	3.9	30,741	7,882.3	64,142	32
Penteli	36.1	34,934	967.7	27,051	27
Pallini	29.4	54,415	1,850.9	66,088	30
Paiania	53.2	26,668	501.3	28,833	27
Koropi	102	30,307	297.1	57,712	26

The spatio-temporal distribution of the inward travel demand refers to morning peak (MP) trip productions of the five municipalities directed to the centre of Athens; the outward demand pertains to afternoon peak trip productions from the centre to them. Metro and suburban rail PT services connect Doukissis Plakentias (DP) station with the airport as well as three (3) intermediate stations, namely: "Pallini", "Kantza" and "Koropi" (KR). Hub selection criteria refer to varying parking characteristics, distance from the CBD, rail service level and suburban vs extra-urban land use. Along this corridor, DP and KR stations were selected as intermodal hubs for accommodating last-mile ridesharing trips (Fig. 1). DP suburban station is regarded as the gate to the main city of Athens while KR extra-urban station is the last stop before the airport, and it is located 13 kms south of DP. Both metro and suburban rail services are offered towards Athens and airport from KR and DP hubs. Inwards service level at DP, with a combined headway of 4 min, is comparatively higher to that at KR featuring a combined headway of 12 min. (Table 2). Thus, it is expected that some travellers living closer to KR may divert to the better serviced DP hub to catch the train.

Fig. 1. Athens metro network and intermodal hubs (in yellow) (Source: ATTIKO METRO) (Color figure online)

In the selected corridor setting, using urban rail to reach a central destination is typically faster than using the car, the radial arterials being persistently congested. The PT share of Athens' trip attractions (Table 1) is an evidence in this respect.

The following bus lines (Table 3) comprise the bus feeder routes of the two intermodal hubs. Boarding figures for morning period and 24 h are also provided. Nights and weekends seem to be very suitable periods for dynamic ridesharing as a

Table 2. Rail service level in the selected intermodal hubs

Metro/suburban rail station	Morning peak headway (minutes)			Span of service		Morning peak boardings	
	Met.	Sub	Comb	Metro	Suburban	Initial	Transfer
Doukissis Plakentias	5	20	4	05:30–24:00 (02:00)[a]	06:00–23:00	2,009	692
Koropi	30	20	12	06:30–23:30	06:00–23:00	91	287

[a]Fridays and Saturdays

feeder mode to the (sub)urban rail featuring a high service level. The net effect is a higher rail utilization in low traffic periods through an otherwise suppressed demand.

Table 3. Bus feeder services and boardings recorded in the selected intermodal hubs

Metro/suburban rail station	Bus line	MP headway (min)	Span of service	Destination	Boardings	
					MP	24 h
Doukissis Plakentias (DP)	301	45	05:00–23:00	Pallini-Penteli	109	1,298
	302	35	05:00–23:45	Pallini	364	4,333
	306	35	05:30–22:30	Pallini	372	4,429
	307	40	06:15–23:30	Pallini-Paiania	287	3,417
	405	35	05:30–23:30	Vrilissia-Penteli	260	3,095
	447	30	05:30–23:00	Vrilissia	176	2,095
	451	30	05:30–23:30	Vrilissia-Penteli	371	4,417
Koropi (KR)	309	30	05:00–23:30	Koropi	321	3,821
	330	45	06:00–21:30	Koropi	319	3,798

Both stations are equipped with P&R facilities which could encourage carpooling for multimodal travellers. Table 4 shows their main features. Note that in DP's P&R station, due to parking charges, there is a low to middle utilization rate.

At DP hub, the P&R operator leases the land from the Metro's owner (ATTIKO METRO). Average parking duration is in the range of 6–8 h. There is no strict parking enforcement in the area, thus resulting to intense parking spillover and lower parking demand at the facility. Parking availability is typically quite good. At KR station, the

Table 4. P&R facilities features in the selected intermodal hubs

Metro/suburban rail station	Area (m^2)	Capacity	Fees per hour
Doukissis Plakentias (DP)	15,200- paved	630 spaces	0.5€ (up to 12 h per day, 7 days a week)
Koropi (KR)	6,100- unpaved	300 spaces	Free

parking lot is saturated every workday during morning peak period. Furthermore, spillover parking of about 300 additional cars is noticed on a regular basis.

3.2 Survey Method and Instruments

The method adopted for data collection is the controlled experimentation based on the choice between alternative hypothetical scenarios (travel options). This is because carpooling is a rather infrequent modal choice in practice. The Stated Preference (SP) technique is particularly effective in this respect (Louvière et al. 2000). This technique forces the respondents to trade off among conditions regarding specific attributes.

The chosen survey instrument is combined with revealed preference (RP) queries about the actual behaviour (i.e. the actual journey) to contextualize the hypothetical scenarios. The use of mobile devices for conducting SP interviews enables the interactive generation of realistic alternative scenarios. SP experiments explicitly acknowledge user preferences for carpooling.

The computer-assisted questionnaire to be used for the combined RP/SP survey consists of three main parts. The first one pertains to the travel behaviour of the respondent, capturing in this way the current preferences of the trip makers and the characteristics of the on-going journey. The second part includes questions about the socioeconomic features of the respondent and his/her household. The third part pertains to the SP of the respondents. Specific questions in the survey form aim at capturing the interviewees' potential attitudinal and behavioural changes under different circumstances. This part also includes the SP cards to be presented to the interviewees. Combinations of presented options with different attribute values/levels in the form of game cards are chosen in a semi-dynamic way by the survey software to reflect the real trip and person characteristics corresponding to each person.

3.3 Sampling Method and Sample Size

The population to be sampled comprises intermodal hub users at the two stations who make the first/last part of their journey by one of the following modes:

– Public Transport Feeder bus, falling in one of the bus lines of Table 3
– Driving Alone (SOV) and parking at or outside the designated P&R facility
– Driving with one passenger and parking at or outside the designated P&R facility
– Riding a car as passenger; car is parked at or outside the designated P&R facility

Trip makers who are dropped off/picked up by a family member or friend are not included in the targeted sample, since the alternative travel options are deemed inferior to the current ones. In other words, these trip makers will be most likely non traders. A point to be explored is whether current car drivers and riders from different households who share a car but do not share the travel costs, will consider formal carpooling as a potential travel option either as drivers or as riders and under which conditions.

Target respondents are people above the age of 18, i.e. persons eligible to drive. Furthermore, the respondents' population is categorised into two main groups according to their main trip purpose, namely commuting and other purpose. Business trips are not considered. The sampling procedure does not include by design car drivers being in need of their car during the day. Users of company cars are excluded from the survey. It is assumed that car trips shorter than 2 kms (i.e. about 5 min) are not worth of the carpool coordination effort, case that will be checked through the survey instrument.

According to the ATTIKO METRO transportation model developed in the Metro Development Study, approximately 39% of the road-side travellers' access/egress the two intermodal hubs of DP and KR by bus feeder and 61% by car/taxi. However, it is expected that the population of respondents will access or egress to a higher percentage by car; at least one third of the retrieved P&R users will be drawn from cars with an occupancy of 2 or more, also including non-household members, thus enriching the carpool share. Pertaining to the existing users of bus feeder lines, the intention is to promote the carpool alternative when the bus service is either not available (night) or very thin (weekend). Especially for aged persons (being at risk of social isolation) or persons without driver's license in low density areas, carpooling is a value alternative.

The travel options considered in the SP survey are four: PT Bus (PTB), Drive Alone (SOV), Drive with other passengers (HOV) or carpool driver (CPD) and riding a car as passenger (PAS) or carpool rider (CPR). The travel options will appear as triplets or pairs on the game cards, meaning that the respondent will have to choose one option among the current one and the alternative options, each time a game card is presented to him. The following travel choice sets shown in Table 5 will be investigated.

Table 5. Travel choice sets to be examined

	Travel option 1 (actual)	Travel option 2	Travel option 3
Choice set 1	PT feeder bus	Carpool driver	Carpool rider
Choice set 2	Car driver (SOV)	Carpool driver	Carpool rider
Choice set 3	Car driver (HOV)	–	Carpool rider
Choice set 4	Car passenger*	Carpool driver	–

* Conditions to be met: licence holder & car available and work purpose

The sampling method chosen is the one used for choice-based surveys (similar to quota sampling). A minimum sample size should be reached for each group in the population to ensure reliable findings. By combining the current travel modes for the

first/last part of the inward or outward trip and the trip purpose we end up with 8 groups.

A minimum number of 60 valid questionnaires per group are deemed adequate for the research purposes. This threshold strongly depends on the number of game cards to be presented to each interviewee. Considering that 8 choice games with alternative travel options will be shown to each interviewee, 480 observations per group will be reached. The proportion between inward and outward trips will be locked up after the completion of a pilot survey. Table 6 shows the groups to be surveyed and the indicative sample size for each hub location and trip purpose. The targeted sample for other purposes is slightly higher than the one for commuting, to account for wider variation.

Table 6. Sample size per population group, intermodal hub location and trip purpose

Intermodal hub	Doukissis Plakentias				Koropi				Total
Trip purpose	Travel mode								
	PT bus	Car			PT bus	Car			
		SOV driver	HOV driver	Rider		SOV driver	HOV driver	Rider	
Commuting	35	35	30	35	35	35	35	35	**280**
Other	40	40	40	40	40	40	40	40	**320**
Total questionnaires	**75**	**75**	**75**	**75**	**75**	**75**	**75**	**75**	**600**
Expected valid questionnaires	**60**	**60**	**60**	**60**	**60**	**60**	**60**	**60**	**480**

3.4 SP Design

The RP part of the questionnaire reports values on current trip characteristics to the intermodal hubs, as well as socioeconomic features of travellers (e.g. car ownership level, number of driver licenses, PT travelcard holding, distance home - bus stop, employment status, work time flexibility). A research hypothesis is that people in households with fewer cars than drivers are more prone for carpooling. Current values are used as seeds to calculate attribute values for the SP part of the questionnaire. Attitudinal responses rule out carpooling as alternative filter for non-traders.

The attributes presented in the PT (bus feeder) and SOV alternatives are constant among alternatives, i.e. variable attributes are presented only for the carpooling alternatives (driver, rider). Note that driving alone a car or using bus feeder is conditioned by car availability or PT service availability respectively. Carpooling depends not only on car availability but also on the willingness to share a car.

Based on existing knowledge from the international bibliography, issues of interest in this research refer to the:

– Value of Guarantee Ride Home (GRH) utility
– Value of Detour Time disutility; max. excess time (5-10 min. in the given setting), driver-relevant
– Value of utility for carpooling household members (vs friends vs unknown persons)
– Value of Wait Time (for GRH) disutility
– Value of Walk Time disutility; riders are more prone to carpool when picked up at home; max. threshold of walk time to meeting point (5 min. in the given setting), rider-relevant
– Parking Cost share with non-household members and resulting parking cost savings
– Value of additional riders' disutility (for non-household members)
– Value of different vs same gender of ridemates (dis)utility
– Value of Dynamic Ridesharing Platform (in)convenience (dis)utility

The attributes selected to form the utility functions for the discrete choice models to be constructed along with the levels that will form the different values for the game cards are presented in Table 7. In total 6 attributes will be studied in the SP survey and the resulting discrete choice models. Three of them (travel cost, travel time and flexible carpool schedule) will receive three value levels (L, M, H), whereas the other three (i.e. preferential parking, meeting point and GRH) will receive two levels. The first four alternatives refer to the current existing travel options as recorded by the RP survey. The other two refer to the travel options under investigation through the SP survey.

Travel time is specified as an alternative-specific attribute and the travel cost as a generic variable. Depending on transport mode, travel time consists of different components such as in-vehicle time, parking search time, walking time, etc. (see notation after Table 7). Separate specifications are considered, referring to riders being household members or non-household members respectively. In the former case it is expected that carpooling with household members is a utility for the driver, in the latter case a disutility. The GRH insurance for carpool riders unsuccessfully requesting a carpool driver pertains either to a PT ticket voucher once a week or to a taxi ride 6 times a year (for a ride up to 15 kms when a bus feeder is not available within 40 min. or more).

The reference value for each attribute per travel option is as follows:

– For the current option is the one obtained from the RP survey or from the AM transportation model (e.g. travel time between a location and the intermodal hubs, travel distance, travel cost based on distance, parking cost, etc.)
– For carpool travel options it is calculated by taking into account the initial reference values as previously described and then by properly adjusting for the new conditions. For instance, for the 'carpooling driver' option, the travel cost obtained from the survey is increased to account for any detour required to pick up the carpool rider and then is divided by two, since the total travel cost is equally split among the travellers. An assumption is made that most carpools will include two ridemates only. Similarly, the reference travel time for this option is increased by the detour extra time for the driver and the walk plus the wait time for the rider.

Table 7. Trip attributes and attribute levels for current and carpooling travel options

Alternative (Travel Option)	Attribute	Reference Source/Value	Variations		
			L	M	H
PT Bus (PTB)	Travel Cost (ticket)	0 €	n.a.	#	n.a.
	Travel Time (WLT + IVT + WLK + WAT[a])	TM[c]		#	
Drive Alone (SOV)	Car Travel cost (fuel + parking)	TM[c]	n.a.	#	n.a.
	Travel Time (IVT + PST)	TM + RP[b]		#	
Drive not alone (HOV)	Travel Cost (fuel + parking)	RP	n.a.	#	n.a.
	Travel Time (WAT + IVT + WLK + WAT[a])	TM[c]		#	
Car Rider (PAS)	Travel Cost	0 €	n.a.	#	n.a.
	Travel Time (IVT + WLK + WAT[a])	TM[c]		#	
Carpool Driver (CPD)	Travel cost (fuel + parking)	½ Car Cost	-25%	#	+25%
	Travel Time (IVT + DTT +PST)	TTT + 5 m	#	+20%	+40%
	Preferential Parking	-		Yes	No
	Flexible Schedule (1h, 3h, 12h)	-	12 h	3h	1h
Carpool Rider (CPR)	Travel cost (fuel + parking)	½ Car Cost	-25%	#	+25%
	Travel Time (WAT + IVT + WLK+PST)	TTT + 10 m	-30%	#	+30%
	Meeting Point (home, Out of home)	-	HM	-	OHM
	Flexible Schedule (1h, 3h, 12h)	-	12h	3h	1h
	GRH (1 PT ticket/week, 6 taxi rides/year)	-	PT	-	Taxi

# denotes reference value. For current travel options it is obtained either from available data or from RP survey; for carpool options it is calculated as shown in the respective cells

[a] Different for each Intermodal hub   [b] Respondent specific

[c] TM: ATTIKO METRO (AM) Transportation Model

WLT: Walking Time   PST: Parking Search Time   TTT: (Total) Travel Time
IVT: In Vehicle Time   DTT: Detour Travel Time   WAT: Wait Time

Emphasis is posed on non-household members and unknowns who are the main focus group of the RIDE2RAIL app. Equal sharing of parking cost as well as of fuel and toll cost is the typical case, especially with unknowns.

Based on the number of attributes to be examined and the number of attribute levels, the total, the number of possible combinations in the SP game sets will be $3^3*2^1*3^3*2^2 = 5,832$. This figure represents the full factorial SP design. A fractional factorial, facing satisfactorily the main effects, would result to 24 combinations, which are far too many to be negotiated by the interviewees. For this reason, it has been decided to split these 24 combinations into 3 blocks. Each block should be treated by 15 to 20 respondents (FSGV 1996). A random selection special routine, developed in R software language (R Core Team 2013), returned the 3 * 8 combinations.

The Tables 8, 9 and 10 below present the 8 combinations per block for the carpool driver and carpool rider travel options.

A pilot survey which is part of the overall survey planning will help standardizing the survey instrument and test the complexity of choice situations. It will also indicate whether the survey can be completed on site. An alternative scheme of intercepting potential respondents will be tested, asking for contact details and cooperation and continuing with a same day online SP experiment for the given journey.

Table 8. SC game cards - block 1

CPD attributes				CPR attributes				
a1	a2	a3	a4	a1	a2	a3	a4	a5
H	L	L	M	H	H	L	L	L
H	M	H	H	M	H	M	M	L
H	M	H	H	H	L	L	H	L
H	H	H	M	M	H	M	H	L
H	M	L	H	M	H	M	H	L
L	M	L	H	H	L	L	M	H
L	L	L	L	M	L	M	M	H
L	L	H	M	M	H	M	M	H

Table 9. SC game cards - block 2

CCPD attributes				CPR attributes				
a1	a2	a3	a4	a1	a2	a3	a4	a5
H	M	H	L	H	L	L	L	L
M	M	H	H	M	H	L	M	L
L	M	L	M	M	L	M	M	L
L	L	H	M	H	L	M	M	L
M	M	H	L	H	L	H	M	L
M	L	H	M	H	H	L	H	L
H	M	H	L	H	L	H	L	H
M	L	H	M	H	L	M	M	H

Table 10. SC game cards - block 3

CPD attributes				CPR attributes				
a1	a2	a3	a4	a1	a2	a3	a4	a5
M	L	H	L	H	H	L	L	L
H	L	H	L	M	L	M	L	L
M	M	H	H	M	H	H	L	L
L	H	H	L	M	L	H	H	L
H	M	L	H	M	L	H	L	H
H	M	H	M	H	L	H	M	H
H	M	L	H	M	L	L	H	H
H	M	H	H	M	L	L	H	H

4   Further Steps and Outlook

Further steps in this research include pilot survey, full survey execution, data analysis, model specification, model estimation and algorithmic use in the RIDE2RAIL transit-rideshare app to be developed. The generalized costs of carpool drivers and riders for the given setting will be compared.

Carpool infrastructure (e.g. preferential parking) is an essential means to promote ridesharing. The RIDE2RAIL consortium makes arrangements to undersign collaboration agreements with locally affected municipalities and P&R providers aiming at the promotion of ridesharing during the pilot phase of the project. Pure tangible incentive mechanisms are foreseen in this respect. P&R managers providing dedicated carpool lots should benefit from a municipal tax exemption. Thus, municipalities are incentive providers for P+R operators and the latter are sponsors for carpoolers respectively. Carpool lots will be branded by an effective signage and marking and will be used as meeting points for outward carpool trips.

The Athens pilot, which shall test the RIDE2RAIL platform, will recruit control and experiment groups among SP respondents with enroute meeting points or relatively close home locations.

The discrete choice models which will be developed will be used for testing specific policies regarding the travellers who can combine carpooling access/egress to the Metro/Suburban rail intermodal hubs. The policies to be tested will pertain mainly to:

- Value of providing preferential parking at a discounted fee and close to the rail platform. The value depends on the magnitude of parking cost and walk time coefficients
- Value of providing a GRH for carpool riders
- Value of providing a carpool matching service for drivers and riders

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