Optimal Pick-up and Drop-off Locations for Regional Ridesharing

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Abstract

The increase of mobility needs will lead to an increase of the traffic volume generating an increase of traffic problems such as environmental pollution and congestion. This trend will continue over the coming years. Ridesharing offers an opportunity to counteract the effects. The performance of regional ridesharing concepts will be mainly a matter of an efficient handling of the pick-up and drop-off procedure. To determine the optimal pick-up and drop-off points a method is presented varying a series of pick-up and drop-off concepts for ridesharing trips. From the point of view of the operators, the readiness of the drivers to take detours, the readiness of possible passengers to access pick-up points and the effects of bundling are contradictory. In this area of conflict, a recommendation for action in the form of a compromise solution for all participants is derived from the results of this study.

Keywords

Ridesharing, Ridepooling, Ridematching, PUDO, Mobility as a Service, Mobility on Demand

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1 Introduction

Due to the steady growth in traffic, road traffic is reaching its capacity limits, especially during peak hours. According to forecasts, the traffic load will continue to rise in the coming years (*1–5*). The situation will thus continue to deteriorate and congestion hours will increase (*6*). It will become more and more problematic, especially in cities during rush hours.

There are different approaches to solve this problem. One possibility would be the expansion of roads. (*7*). However, this measure requires a high level of investment and available space. Further possibilities are demand-oriented approaches such as the introduction of time-based user charges (*8*) or Mobility as a Service (MaaS) concepts (*9–14*).

Ridesharing offers the possibility to adjust the supply to a flexible demand. In order to guarantee efficiency, traffic flows must be bundled. Since several road users travel a distance together, ridesharing represents a cost-effective alternative, which, if generally accepted and used, could trigger a considerable reduction of the traffic load (*15; 16*).

As a solution, ridesharing can serve as a kind of fine distribution supply of public transport in rural areas. Therefore, the already existing seat capacities of private cars can be used (*17, S.* 5). In addition, during off-peak periods ridesharing can complement public transport to ensure a reliable and flexible form of mobility. Ridesharing does not compete with public transport in this context, but complements it in terms of on demand mobility and in terms of inter- and multimodality. (*18*).

Ridesharing offers the benefits of reducing traffic and environmental impacts. With an average occupancy rate of approx. 1.5 people (*19*), almost every car on the road offers sufficient capacity to share the ride with other people. The problem: "Mobility behavior is a highly routine behavior" (*17*). A means of transport (here the car) is chosen until external circumstances such as extended travel times, lack of parking space or monetary restrictions necessitate a change in behavior (*20, S.* 17). The greatest challenge in providing an attractive and efficient service is to reach critical mass (*21*).

For long distance trips (> 100 km), ridesharing has already established itself as an alternative to public transport. Detours for picking-up or dropping-off passengers have only a minor influence compared to the duration of the journey.

In regional ridesharing (< 100 km), on the other hand, distances and travel times are shorter. Detours for picking-up and dropping-off passengers are more important and influence the performance of the system largely. The attractiveness of the system therefore closely depends on the speed with which the pick-up and drop-off points (PUDO) between driver and passenger are handled. Passengers expect the shortest possible entry and exit routes; ideally, they are picked up directly at the origin of the trip and dropped-off at their destination. The driver, on the other hand, as well as passengers already seated in the vehicle (occupants), want to drive as directly as possible to their destination. These diverging interests require optimization procedures taken into account by the empirical method explained below. The article arranges the interaction between the participants - drivers, occupants, passengers - and their willingness to accept detours in the form of a deviation of the optimal route and the willingness to accept routes to a nearby PUDO. The study does not analyze human behavior, but indicates under which conditions - number of people to be collected, willingness of drivers, passengers to accept detours - the average loss of time can be expected. Whether such a loss of time occurs, depends on the actual demand and the operator model. The classification of loss times helps to better assess the effects.

The investigation presented in the following is independent of the development of automated vehicles. It remains valid regardless of technological progress.

2 Method development

Fictitious ridesharing rides are used to determine the optimal PUDO concept. The rides are automatically generated. The investigation method is applied for different areas in order to exclude the specific influence of individual areas. Optimum conditions are assumed in this investigation to exclude the side effects of traffic jams, breakdowns, accidents or other delays. Besides the investigation is based on the assumption, that all passengers arrive punctually at the corresponding PUDO.

2.1 Indicator

Parameters help to classify the investigation. A distinction is made between driver-specific and passenger-specific parameters. They are called:

- Seating capacity: This is based on a vehicle with five seats. Consequently, the parameters for one to four passengers are determined.
- Travel time: Travel time of the driver with and without additional passengers. The journey time is measured per area, i.e. starting the moment the driver enters the area and ending the moment the driver leaves it.
- The travel time within an area therefore represents only a share of the total travel time. For the interaction between driver, occupants and passengers the effects in the study area are decisive.
- Level of access readiness: distance and time from the source of passengers to the PUDO in the range of 0 m, 50 m, 100 m, 200 m, nearest public transport stop, all passengers meet at a central location within the area.

2.2 PUDO

A large number of possible PUDO are determined automatically in the study areas. The focus is on sufficient area coverage and concentration depending on the population density. From possible PUDO, actual entry points are later determined and combined with the number of passenger requests and the level of access readiness. Possible PUDO represent a simplification of all possible start addresses in each street and number.

In addition to possible PUDO at the lowest level of access readiness, (pick-up takes place at starting point), it is determined for each area which PUDO becomes a fictitious ridesharing stop. Care is taken to ensure that the access readiness of 50 m, 100 m, 200 m, the next public transport stop or all passengers meet at a central location is maintained. An example of an investigation area is the selection of possible PUDO shown in Figure 1.

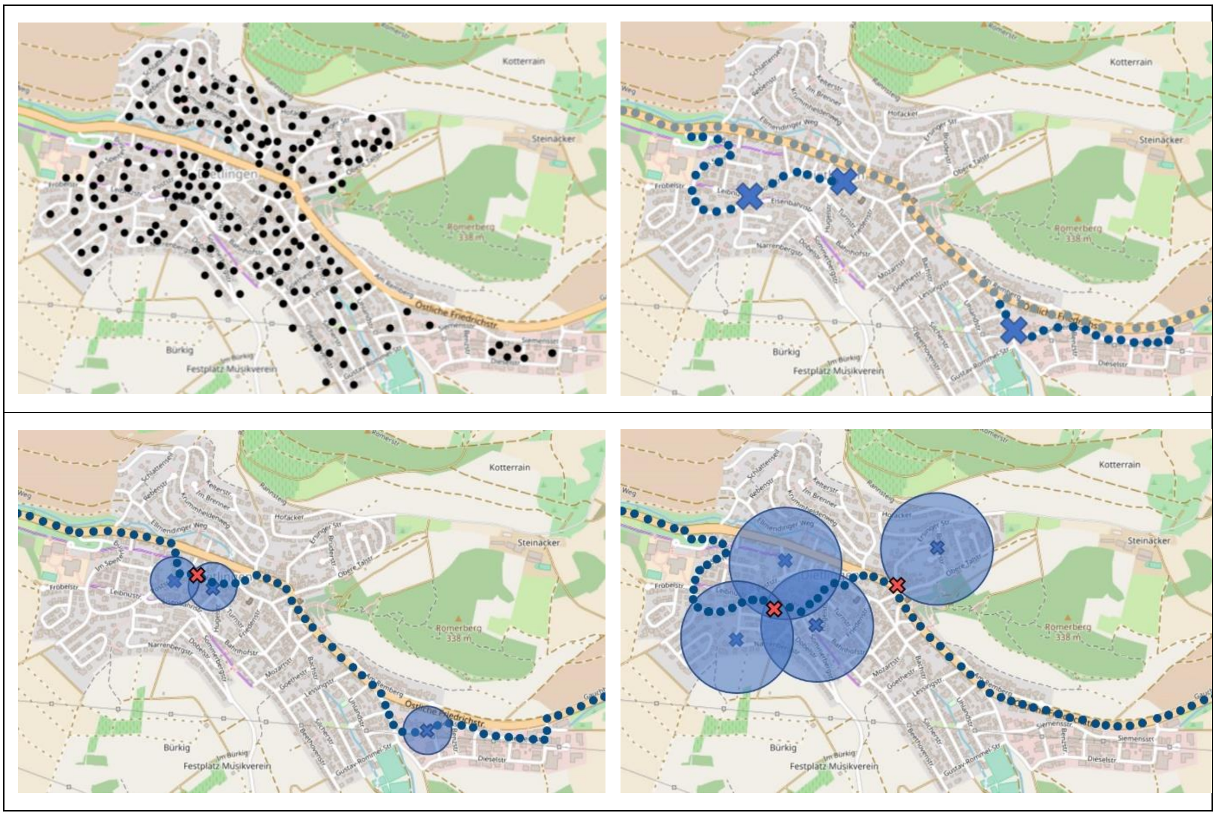

Figure 1 **Possible PUDO in a study area (top left) exemplary presentation of trip route for 3 passengers with direct pick-up at origin (top right), trip route with 3 passengers and access distance to pick-up point of 50 m (down left), trip route with 4 passengers that are waiting at two different PUDO and an access distance of 200 m (down right).**

With the stop-based ride-sharing system, a different number of PUDO are set up in the location. Analogous to this form of ride sharing, fictitious PUDO are also determined in each investigation area. Two criteria are defined for the selection of the points at which the PUDO are to be located. Firstly, the route should be optimized in such a way that the deviation from the driver's original route and thus the detour is minimized. Secondly, within a radius of 500 m direct distance, a PUDO must be accessible to almost every inhabitant. Figure 1 (down right) shows the PUDO selection based on a study area. In this case, two PUDO are necessary to cover the requested passenger trips. The grey dotted line shows the original route of the driver. The blue dotted line shows the detour if at least one passenger is waiting at each PUDO.

The following three categories of PUDO are available for existing ridesharing systems:

- The passenger's flats represent an entry point that will be investigated in the course of the method. Different PUDO (possible start addresses) are randomly selected in the study area.
- The access readiness is increased, so that the passenger has to go 50 m, 100 m or 200 m to a suitable PUDO for the ride. There are several possibilities to determine a suitable point. If the address is in a one-way street, the passenger should go to the end of the street. This also applies to a dead end street or to an area with a reduced level of traffic. If a passenger can reach a larger road via a pedestrian walkway, this is the appropriate pick-up area. In the course of the method, the PUDO of the passenger is chosen in such a way that the

travel time for the driver is minimized. Consequently, if possible, two or more passengers will go to the same meeting point to reduce the stop waiting time.

- As the last method, a central PUDO is defined as the entry point. In order to determine the position of the central PUDO, two criteria are defined analogous to the selection of the stop-based PUDO. The entry point should minimize the average access times of the passengers. In addition, the detour for the driver should be as small as possible.

3 Study areas

The study areas are selected according to several criteria. On the one hand, the area should have as few interlocking roads as possible to the surrounding countryside, as well as one main road through the area. When selecting the areas, a balanced mix of urban, suburban and rural areas is taken into account. The study is based on the evaluation of six areas around Stuttgart. The total selection can be traced in (*22*).

4 Analysis

In order to determine the optimal PUDO and thus the best possible PUDO concept, the additional driving time of the drivers is compared with the average access time of the passengers. Both parties are assumed to be willing to compromise. A similar amount of time is assumed for the willingness to meet each other. The distance covered within a time unit differs considerably due to the speed. An average speed of 4.5 km/h for a pedestrian is assumed (*23–28*). The driving time of the drivers is derived from route information.

It turned out that only the stop-based PUDO and a central stopping point could be considered as PUDO if the additional driving time for drivers and occupants is to be kept to a minimum. The drivers' willingness to change the route choice is increased under the premise that more passengers meet at a central point. This ensures that the driver and the passengers can meet in an acceptable time and that the higher effort of the driver is rewarded with a higher collection density. Since an additional minute of access time for a pedestrian is assumed to be more strenuous, the additional driving time of drivers is increased in the case of a decision. The additional driving time of the driver should therefore correspond approximately to the access time of the passenger.

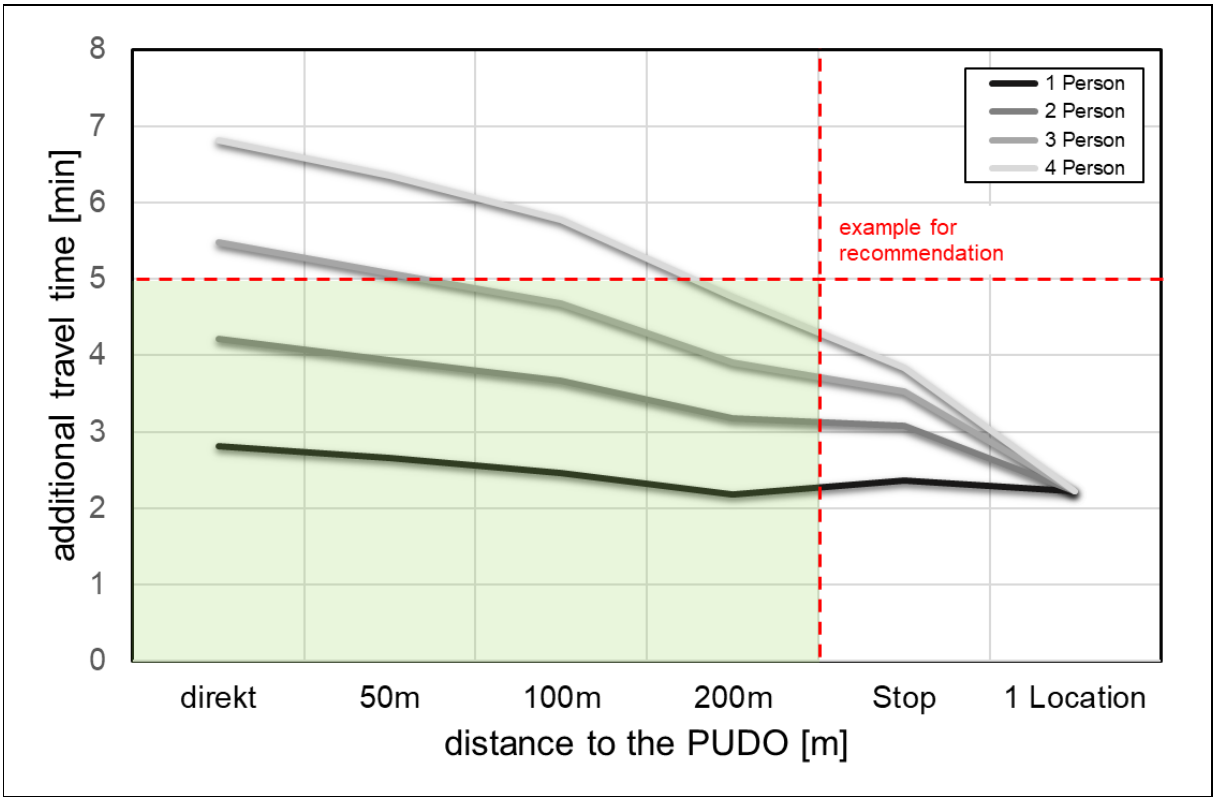

Figure 2 **Average loss time for drivers and passengers differentiated according to the level of access readiness**

Figure 2 shows the average loss time for drivers and passengers as a function of access readiness. The higher the number of people to be picked-up in the area, the longer the time lost. If many people want to get in directly at their specific starting point, the time lost increases. In contrast, the loss time is reduced if PUDO are bundled and several persons can be collected at one location. Each course stands for the number of persons. It has the highest loss time with a PUDO directly at the starting point of the passengers. The lowest loss time of the curves is reached with a central PUDO. This is the case because with increasing access width of the passenger, the detour for the driver becomes smaller. This minimizes the required stopping time. An exception is the transport of only one person. The loss times have a smaller effect here. The minimum additional travel time of the driver is reached at a boarding point of 200 m. In most cases, a PUDO can be reached directly on the driver's route with the access width. For the remaining scenarios, the minimum loss time is at a central point as PUDO.

Recommendation

Figure 2 shows an example of a recommended course of action. It is assumed that persons accept distances of up to 200 m to the PUDO (vertical red dotted line). Furthermore, the accepted loss time for driver and passengers is limited to 5 minutes (horizontal red dotted line). The green colored area represents the acceptance area between driver and passenger. The participants should meet within this area. In this example, one or two passengers can be picked up directly at the starting point. If the number of passengers rises to three or four, an access width of up to 200 m becomes necessary.

The definition of the boundaries is closely related to the operator concept and must always be considered in context. Figure 2 can be a first indication. The limits help to narrow down the standards and to balance the willingness of the drivers and of the passengers.

5 Conclusion

From the driver's point of view, performance is at its maximum if the additional travel time is minimized. For a passenger, the system is maximally efficient if the access width and the additional travel time is minimized. From the perspective of a ridesharing provider, the occupancy rate must be maximized in order to be profitable. In order to increase the overall performance, a compromise solution between all parties involved is necessary. Depending on how the optimization is decided, the different factors can be weighted and thus the performance of the system and the attractiveness for every party involved can be changed.

The aim is to find the optimal PUDO for the driver and passengers, depending on the number of passengers. This method is based on fictitious ridesharing rides for which different PUDO constellations are varied. In this context, parameters for different PUDO concepts are determined for the study areas. The number of one to four passengers is varied and compared. The object of the evaluation is a comparison of the access times of the passengers with the additional travel time of the driver.

The following recommendations for action can be summarized from the evaluations of all investigation areas of additional travel time of the driver, taking into account the access times of the passengers. If a carpool consists of only one driver and one passenger, the passenger should be picked up and dropped off directly at the starting point. For a carpool with two passengers, the PUDO is usually sufficient with an access width of 100 m for driver and passenger. If three or more passengers are picked-up, they should walk 200 m to reach the optimal PUDO.

The tolerances in time losses are a matter of the ridesharing concept of the corresponding operators. Tariffs are conceivable for which longer loss times can be accepted if the price falls accordingly. There can also be a kind of exclusive trip, for which a higher fee may be charged. In return, the direct route without additional passengers is guaranteed. Findings about this are already known from acceptance research (*29*) for driving services. Participants are generally prepared to accept detours. In principle, they are prepared to share the vehicle with other passengers if monetary incentives are created and the route for taking the passenger with them does not change significantly. This gives operators the flexibility they need.

There is still a need for investigation for the determination of optimal PUDO. The methodology should be extended to other research areas in order to determine whether there are deviations in access readiness.

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