Indoor Robot Taxi Planning for a Heterogeneous Vehicle Fleet [IndoorRobotTaxieS]

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Contents

Executive summary

As autonomous driving technologies are advancing in a remarkable speed, real-world applications receive an observable traction in warehouse logistics, production and service sectors, especially after pandemic. Similarly, indoor mobility systems for personal micro/mid mobility are being roboticized especially in large complexes such as holiday resorts, hospitals, airports and exhibition centers with electric buggies, personal wheelchairs, small-size shuttles. Coordination of multiple transportation vehicles with possibly different capacity of motion and carriage becomes more critical when they are being operated automatically.

We at Ro Mobility aim to develop inherently safe autonomous robotic technologies that would integrate into already available indoor mobility applications and provide autonomy-as-a-service solutions even in crowded environments. We believe that with the introduced digitalization and autonomy, it would become possible to be ``smarter'' in the way classical Mobility solutions are being operated. With an ecosystem of applications (i.e., scheduling and planning) built around the provided autonomous behaviors, it would be possible to enable a Mobility-2.0 system: a safer, easier, reliable, and efficient capability for motion.

1 Context

Indoor person transportation, in large complexes such as holiday resorts, airports, recreation centers and exhibition centers, is managed by several driving personnel of buggies and experts directing the drivers to destinations and users. In addition to a fleet of generally same-type of equipment, in some cases, additional mobility options are being deployed for large groups (larger transportation vehicles such as small size shuttles) and/or individuals with special needs (such as electrical wheelchairs with an attendant). Moreover, it is generally the case for our focused application domains that there exist multiple locations of interest with varying numbers of passengers. In some cases, planning algorithm could additionally be parametrized based on time-critical and non-critical transportation requests (i.e. Passengers trying to catch their planes in airports). Planning which is currently performed manually through a coordinator can be automated with observable improvements in efficiency, sustainability and availability.

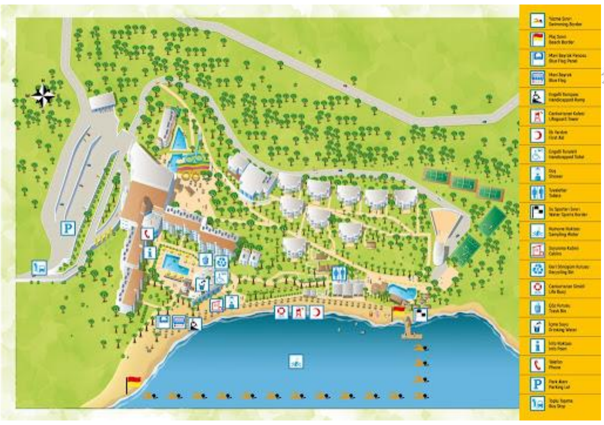

Fig.1 Magic Life Bodrum Holiday Resort Map

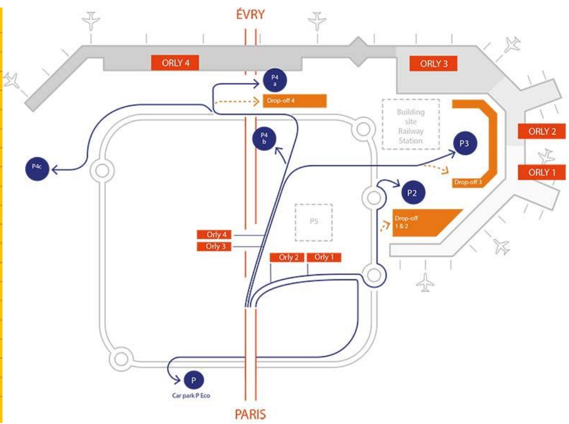

Fig.2 Istanbul Airport Map Sample

<u>Current Operations</u>

Current operations rely solely on either manual planning and direct communication between personnel or looping at pre-defined intervals. Operations are usually managed by reception personnel who directs buggy drivers to certain destinations based on the information exchanged between buggy driver and users/customers. Shuttles have fixed timelines independent from users/customers or providing service with the reservation through reception. In general, there is not a pool of requests for buggy services which can be optimized by a person/system.

<u>Current Operations Drawbacks</u>

Still in several occasions person transportation is managed by the fossil fuels only to avoid vehicle charging interval issues. Carbon emission and noise pollution are the leading drawbacks of this current solution among others. Even electrical vehicles in service driven by human and without an AI planning in place will cause inefficient use of personnel, vehicle and energy usage.

As there is no AI planning used when there is a high demand in the first stop of the route, the shuttle may fill up at the first stop and have no room for users/customers at the second or third stops. On the other hand, shuttles may be operating mostly with zero-to-few passengers if there is a low number of users. Without an AI planning in service it is not possible to track real time location of the buggy and direct to customers accordingly to increase efficiency of the vehicles and decreasing the waiting time of users/customers.

Finally, the current solution has no automated control over electrical motor driven buggies battery status therefore charging intervals cannot be managed without causing any interruption to services. To conclude, since current operation of these multiples modes of transportation is non-digitized, there exists no formal definition and therefore no available framework for optimization.

2 Planning Application

In order to clarify the planning application in our use-case, a sample storyboard is provided below. Here a sample route is being serviced with two types of autonomous vehicles – a 4-seated buggy and an 8-seated shuttle. For the sake of this scenario, there exists a total of 12 passengers who requested transportation from the centralized network.

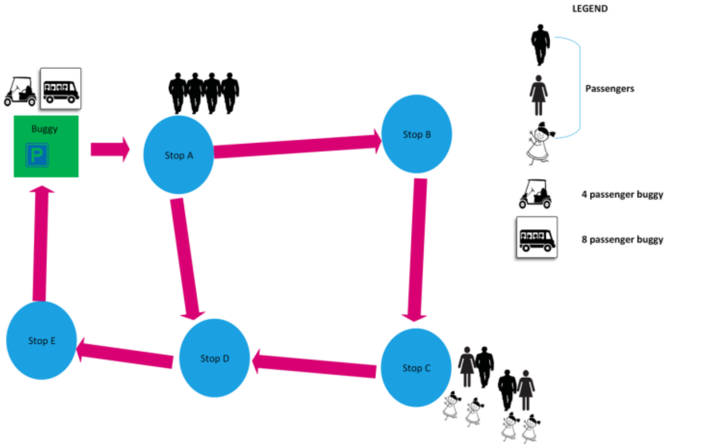

Fig. 3 A schematic representation of a sample vehicle route with actors

Considering a non-automated planning solution with manual decisions, it would be quite possible that the shuttle is sent based on fixed timelines without consideration of the real-time request or optimized routes. For example, as provided in Figure 4, 4 passengers are requesting a transportation from point A to point E and at the same time 8 passengers from point C to point E.

In current solution, 8-seated shuttle will start its journey from parking area to E, stopping in every destination and when it reaches the point C there will be no room for 8 passengers' group and they will have to wait for next shuttle. Moreover, the vehicle did not utilize the shorter route through stops A, D and finally E.

However, with planning in use, the 4-seated buggy will be sent to point A and 8-seated shuttle to point C right after the request to the centralized network, resulting in minimized waiting time of passengers, efficient use of shuttles and reduced load in traffic.

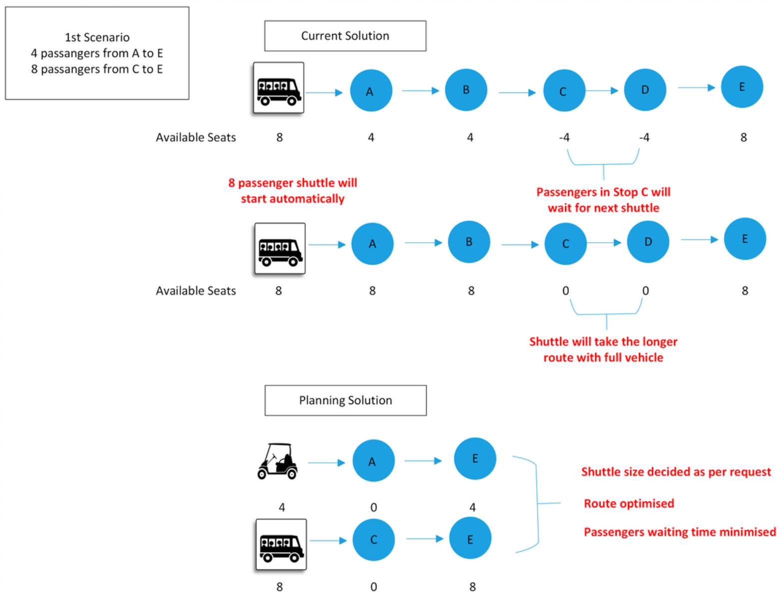

Fig. 4 Comparison of Current Solution and Solution with Planning

To summarize, with planning we intend to address the following key problems:

- low efficiency on vehicle usage,
- high level of manual decisions for driving and coordinating,
- low customer/user satisfaction

which can be measured with the observed positive outcomes on the:

- efficient use of vehicles
- reduced waiting time of users/customers (increased satisfaction)
- reduced traffic along the route

through the decisions the planner can provide on:

- the type of vehicle to utilize depending on the number of passengers, their possible unique requests (e.g., special needs)
- the optimized route based on user/customer requirements and additional temporal constraints
- charging intervals of vehicles
- operation interval for shuttles to minimize traffic and user/customer wait time

based on the data provided on:

- the number of passengers,
- the temporal and additional constraints (such as disability) provided by each user,
- the map of the environment,
- available vehicles and their capacity,
- battery-level of each vehicle,
- destination requests,

which is invoked at each new transportation request and on a cyclic manner for charging.

3 Impact

3.1 Business Impacts

In general, the proposed use-case stands on three major technological breakthroughs:

- Electrification of transportation vehicles reduces the cost of operation,
- Autonomous operation of vehicles enables digitalization of the system and reduces operation overheads, and
- Automated scheduling and planning further reduces the consumption, improves vehicle lifetime and user experience,

resulting in supporting the adoption of these technologies in the proposed sectors.

It is possible to extract the overall business impact through inductive reasoning, starting in a single application area, for example, Istanbul Airport which receives over 50 million passengers yearly. Currently, 25 buggies are being used for indoor transportation of passengers across more than 1 million square-meter closed-area. Approximating 0.05% of passengers utilize buggies to travel nets more than 20000 monthly uses with at least 25 personnel to operate the vehicles. With the proposed approach, it would be possible to reduce the personnel to 10% of the current capacity with planning and autonomous operations.

Moving on to the bigger picture; only for airport domain and considering 6 biggest airports in EMEA, only be 12 to 15 buggy driver personnel will be required in total instead of 150. With an average 2000 USD/month personnel cost resulting in around 3MUSD overall saving yearly. It should be noted that this projection does not include the reduced cost on coordinating personnel thanks to planning.

Finally, the proposed application and its impact on the improved user/customer satisfaction would further drive the adoption of the technology, resulting in increased use and revenue for the service provider.

3.2 Other Impacts

With the proposed use-case, positive environmental effects would be observed due to the reduced traffic and less idle use of transportation vehicles, as well as the encouragement of the use of electric vehicles since their charging cycle is automatically handled by planning. At a societal level, we expect an improvement in the use of personal and multi-people transportation vehicles so that elderly and disabled citizens can be more involved in the workforce and better utilize their recreational travels.

In general, indoor transportation provides a more controlled environment for the implementation of the suggested use-case: i) vehicles generally operates in predefined driving lanes with zero-to-none traffic effects (providing reliable travel cost assumptions for planning) ii) map of the environment is well-known and can be more frequently updated iii) driving behavior and properties are much less affected by external conditions (weather, sunlight) and iv) varying road conditions is non-relevant. Therefore, it provides a unique opportunity to show the efficacy of the proposed planning algorithm(s) and advance benchmarking efforts. However, lessons-learned during the scheduling and optimization of multiple heterogeneous vehicles with different capabilities would be really advantageous towards an urban mobility 2.0 concept where different elements of transportation in a city work in harmony-with each agent performing to the best of their capabilities.

4 Measures of Success

Applying AI-based planning techniques into the proposed use case would result in quantitative improvements in several key aspects of the process. Major positive outcomes would be reduced battery consumption, optimized route and scheduling of multiple vehicles and therefore improved user experience. Moreover, due to the digitalization and formal framework established within the proposed use-case, there would be considerable secondary effects and further impacts (e.g., enabling predictive maintenance, improved vehicle lifetime, and site-based optimization of the number of vehicles).

Energy consumption decrease of the facility for transportation: Optimized workflow with less idle use implies better power consumption for each vehicle at a facility. This necessitates the planning algorithm to provide correct plans and schedules – resulting in decreased consumption compared to the current manual operations. The quantitative improvements should be observed through the energy meters from the battery supply feeds of the facility.

The overall personnel cost difference for the service: By eliminating the need for an expert manual planner – and by autonomous operation of the shuttles - overall personnel cost would be decreased. This necessitates the planning algorithm to be complete in the sense that if there is a solution for planning and scheduling, it should be found even though it is not the optimal solution. The quantitative improvements should be observed through the accounting overhead services at the deployment facility.

Measured improved user/customer satisfaction: Improved routing and decreased wait times are expected to increase user/customer satisfaction with the service. This necessitates the planning algorithm to be respondent to user requests while providing an optimal solution for routing and scheduling. The performance of the planner can then be quantitatively and subjectively evaluated through measured user/customer satisfaction.

For all performance indicators, the planning would be queried at fixed intervals for charging, and per each new user request through the day.