

# Service Design and Analysis of Autonomous Vehicles for Last-Mile Delivery

Master's Thesis of Alireza Harazi

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## Introduction

Research Question : Under what circumstances can autonomous vehicles become a component of transportation systems for last-mile delivery in the future?



Fig 1 : Autonomous Mobile Parcel Locker Concept for Last Mile Delivery

## Literature review

Following the research question, the concepts of last-mile delivery and mobile parcel lockers have been investigated. A summary of these literature reviews is presented in Figures 2 and 3.

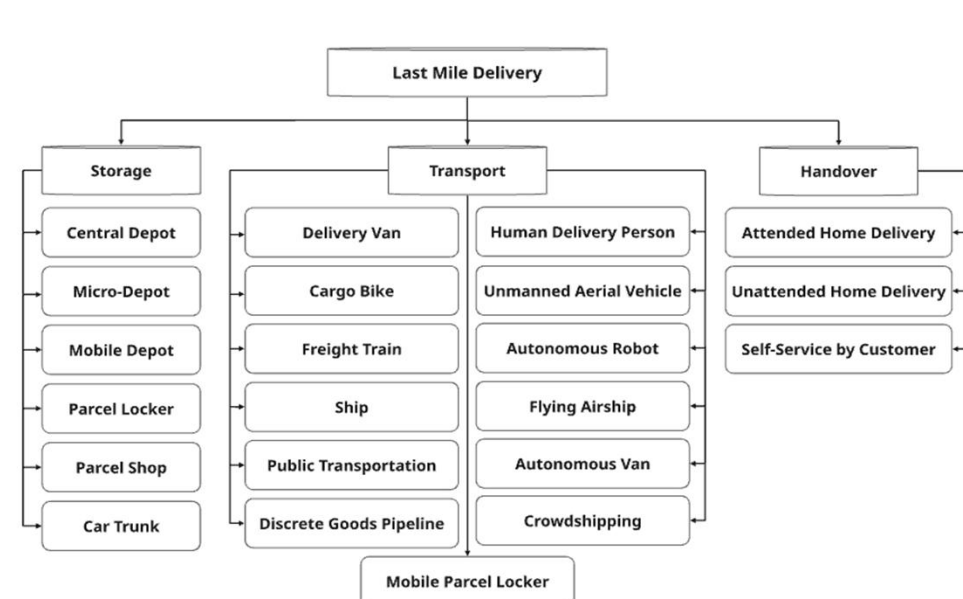


Fig 2 : Last-Mile Delivery Literature Review

Models	Objective
Mobile Locker Location Problem	Minimize fleet size
Mobile Parcel Locker Location and Route Optimization Problem	Minimize costs
Robust Optimization Problem under Stochastic Demands	Minimize costs
Autonomous Mobile Lockers Courier 2-Echelon Location Routing Problem	Minimize costs
Parcel Locker Service Design problem	Minimize costs
Mobile Parcel Lockers and cargo bikes Route and Location Optimization Problem	Minimize fleet size and travel distance
Heterogeneous Locker Location Problem	Maximize served customers
Mobile Parcel Locker Problem	Minimize fleet size, travel distance and service delay
Mobile Parcel Lockers routing problem under uncertain demands	Minimize costs
Integration of Mobile Parcel Locker Problem	Minimize costs
Mobile Home Delivery Parcel Locker Problem	Maximize served customers

Fig 3 : Autonomous Mobile Parcel Locker Literature Review

## Analysis of Amazon Dataset

To investigate the research question, a real-world delivery process used by Amazon was analyzed. A summary of this analysis is presented in Figures 4 and 5.

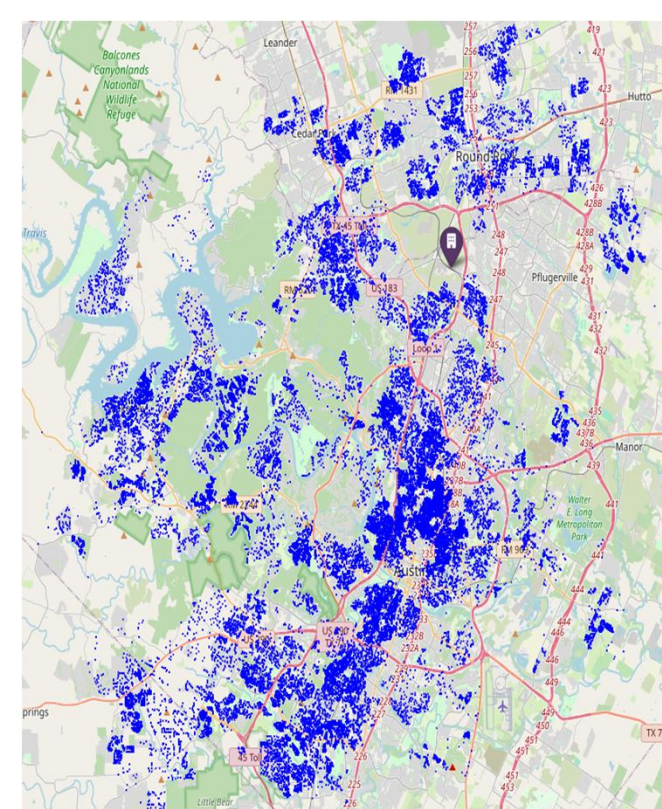


Fig 4: Illustration of the depot and demands in the case study.

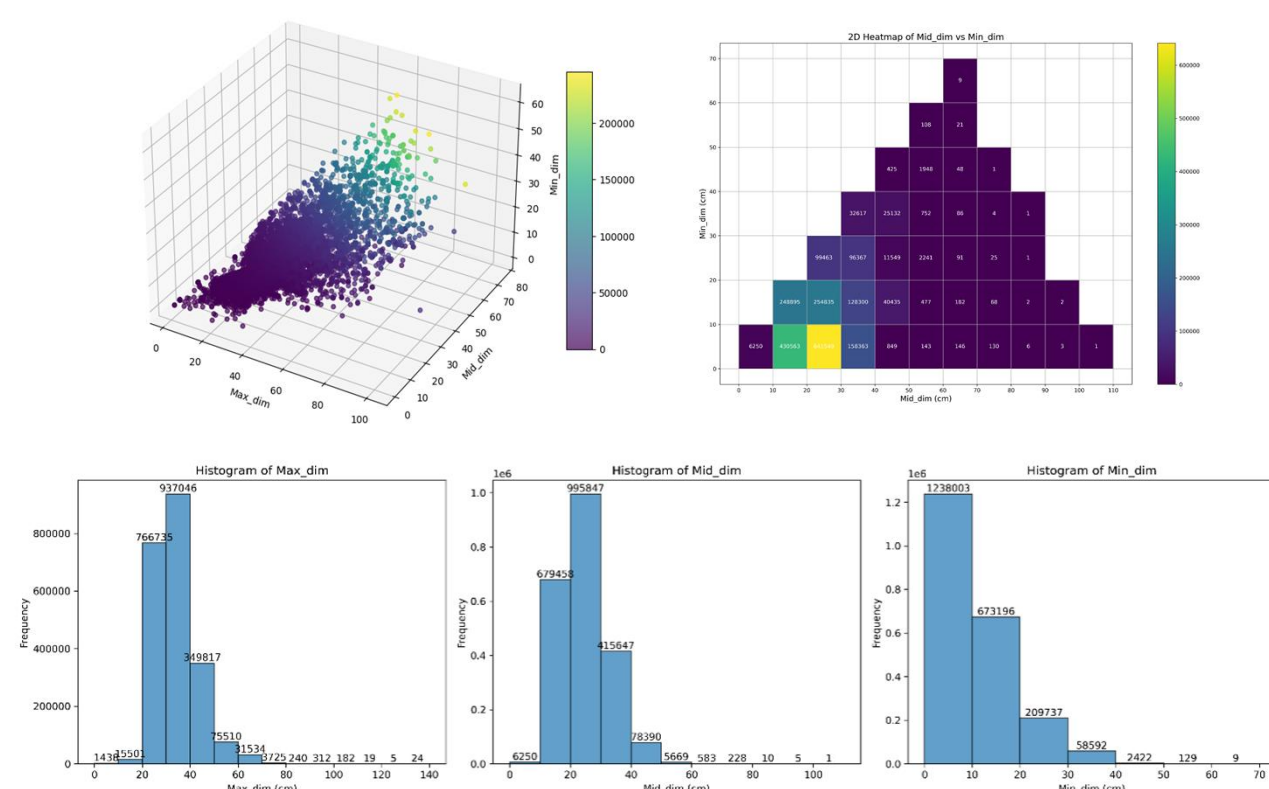


Fig 5 : Dimensional Analysis of Package Sizes and Locker Design

## Service Scenarios

According to the analysis of Amazon's last-mile delivery, different service scenarios have been defined, and a summary of them is presented in Figure 6.

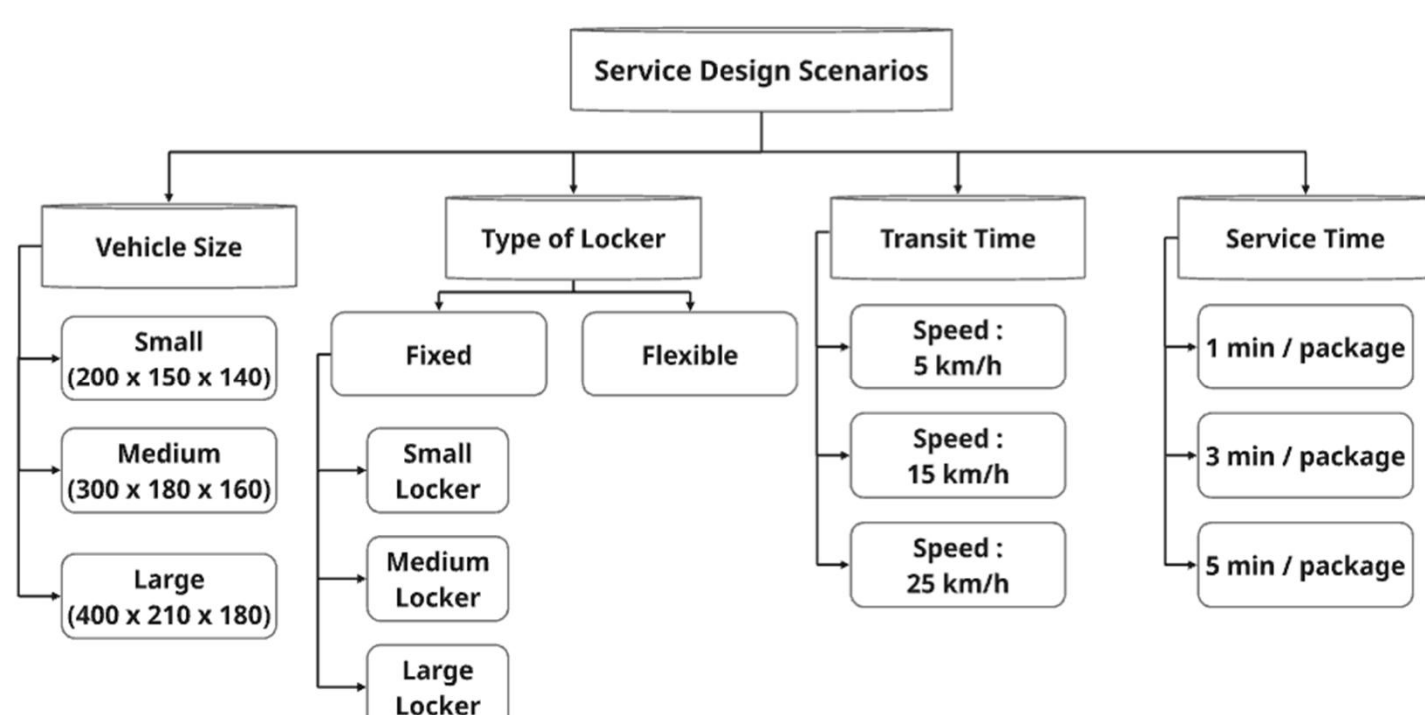


Fig 6 : Service Scenarios of Autonomous Vehicle Delivery Systems

## Service Analysis

The layout of fixed lockers has been determined based on the statistical analysis of the packages, with an example presented in Figure 7. Based on this analysis and the dimensions of the vehicles, the locker layout has been designed, and packages are assigned to lockers, as illustrated in Figure 8. After the assignment, routing is performed by solving the Traveling Salesman Problem (TSP), as shown in Figure 9.

For the flexible lockers, the layout is derived by solving the Bin Packing Problem, with an example illustrated in Figure 10.

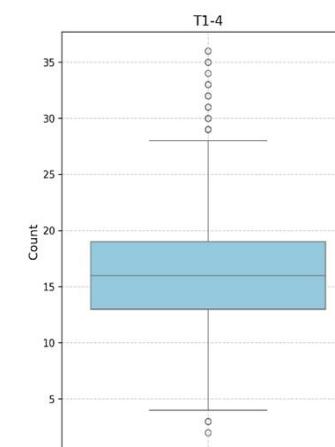


Fig 7 : Statistical Analysis of Lockers

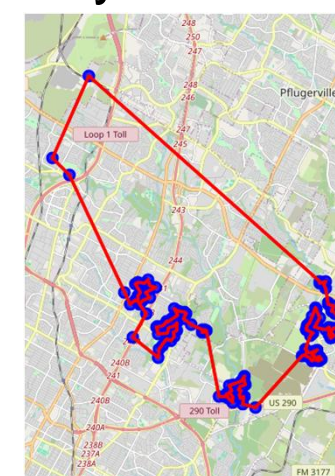


Fig 9 : Route Optimization

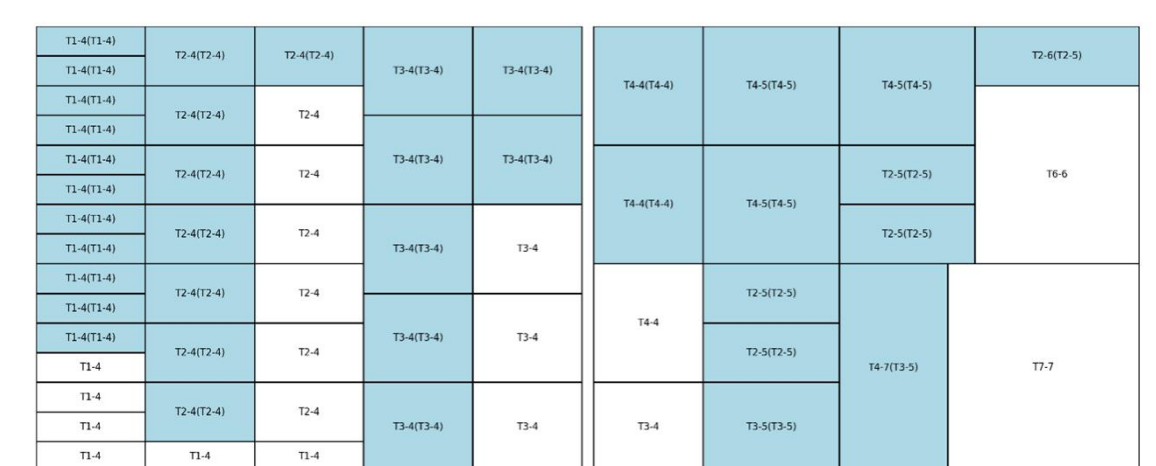


Fig 8 : Layout of Fixed Lockers in AVs

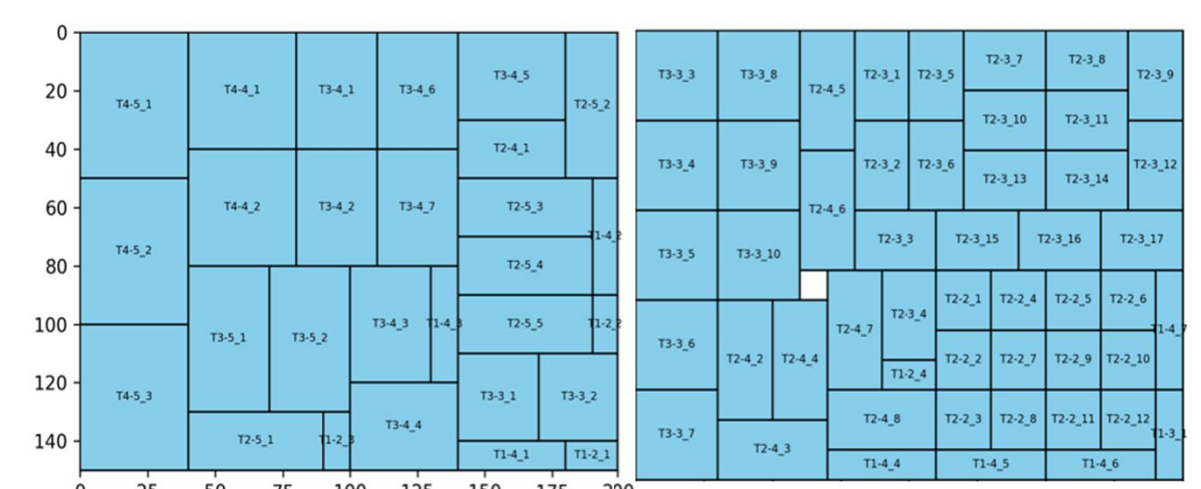


Fig 10 : Layout of Flexible Lockers in AVs

## Service Evaluation

The results of the analysis showed that autonomous mobile parcel locker services will require more vehicles compared to delivery by drivers. This aspect is illustrated in Figure 11. The analysis also revealed that a combination of low vehicle speed and long service duration leads to significantly poor results, while improving these factors considerably enhances performance. These aspects are presented in Figures 12 and 13. Additionally, the results showed that AVs with flexible lockers are economically justifiable, while AVs with fixed lockers are only economically viable for small layouts. This aspect is illustrated in Figure 14.

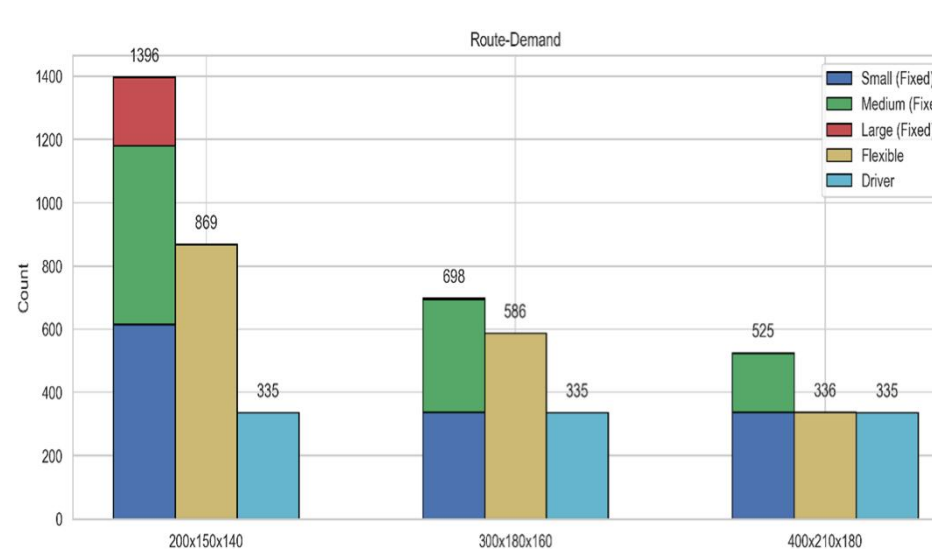


Fig 11 : Number of Vehicles

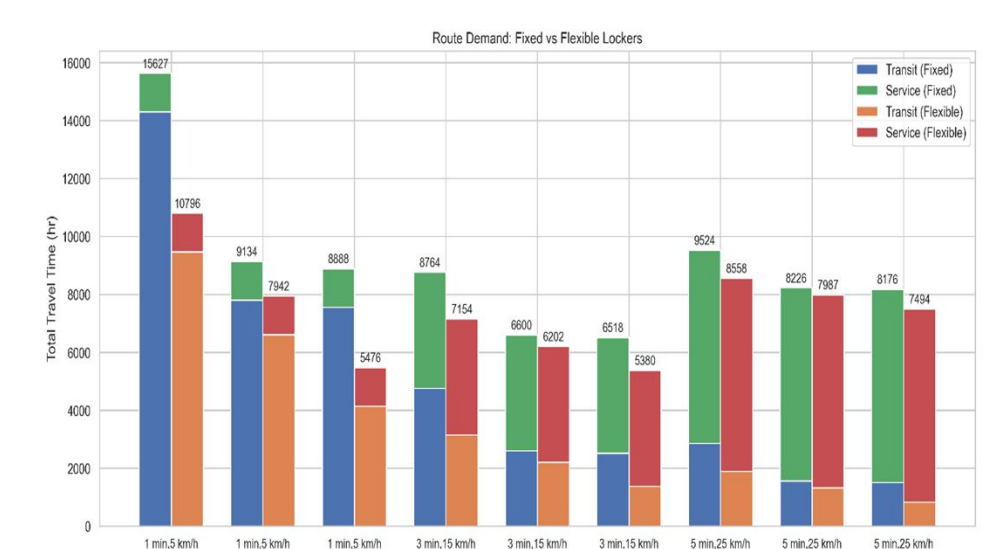


Fig 12 : Travel Time Components in Different Delivery Systems

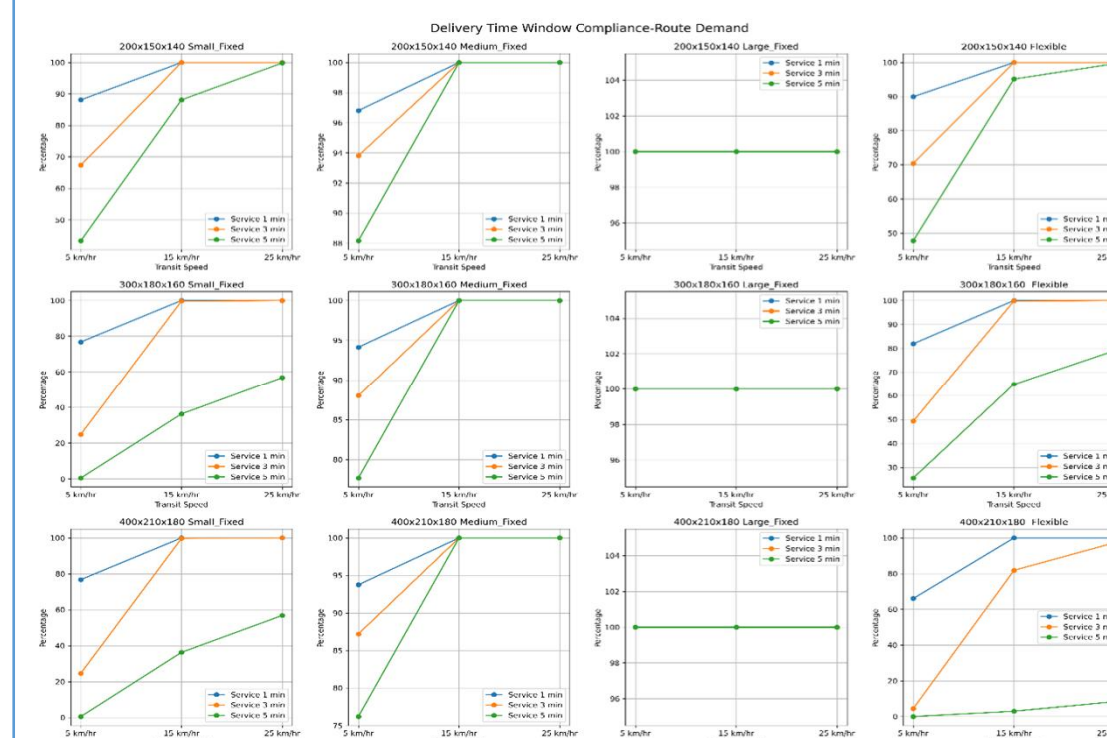


Fig 13 : Time Window Compliance

Service Type	Fixed Locker			Flexible Locker	Driver
	Small	Medium	Large		
200 x 150 x 140	0.57	1.62	14.42	0.73	0.98
300 x 180 x 160	0.41	1.19	87.83	0.52	
400 x 210 x 180	0.33	1.03	101.18	0.4	

Fig 14 : Operational Cost in Different Delivery Systems

## Conclusion

The performance of autonomous mobile parcel locker delivery depends on several factors, including vehicle speed, vehicle size, service time duration, the geographic distribution and density of customers, demand volume, and the locker type and layout within the autonomous vehicles.

Overall, autonomous mobile parcel lockers offer a promising solution to improve last mile delivery by increasing flexibility and reducing costs.