Optimized Dispatching Algorithm for Taxi and Car Rental Services

[1]Abhay M Shalghar, [2] Manas M N

Department of Computer Science Engineering, R V College of Engineering, Bangalore 560098

Abstract: *This paper aims to develop an algorithm to automate and optimize dispatching strategies for Taxi and Car Rental Services. Here dispatching strategies include tackling the following problems: Route Planning, Minimizing the Waiting time of Customers, Assignment of agents for tasks, Optimizing Vehicle Travel Distance, Accommodating surge in Demand, and Minimizing cost to Stakeholders (Owners, Branch Operators, etc,.). The current Taxi and Car Rental services either don't focus on these dispatching strategies or use outdated algorithms for each and every strategy which makes them ineffective.The algorithm developed not only optimizes these decisions for the stakeholder but also automates the decision-making process for the above dispatching strategies. The algorithm is designed to take inputs from the Taxis/Cars and Rental stations and develop an optimized solution for any of the above problems. This algorithm is designed by taking into consideration the existing algorithms that are being used to solve some of the above problems and amalgamating them to improve efficiency and decision-making for each of the dispatching strategies.*

Keywords: **Dispatching Strategies; Stakeholders; Amalgamating**

1. INTRODUCTION

The need for efficient dispatching strategies in the commute industry is ever important due to their increased usage by the public. Taxi and Rental Car services often ignore the problems like Route Planning, Minimizing the Waiting time of Customers, Assignment of agents for tasks, Optimizing Vehicle Travel Distance, Accommodating surges in Demand, etc which leads to an increase in operational costs. This paper aims to develop an algorithm to provide proper dispatching solutions to the above problems and hence not only reduce operational costs to the stakeholders but make the commute process better for the customers. This project aims to study the existing solutions for each problem related to dispatching and come up with an amalgamation to provide a one-stop solution for efficient dispatching strategies. The main contribution is as follows: Developing an algorithm to take in specific parameters read from the Taxis/Cars and also from the Rental stations to make decisions about Routing, Driver assignment, Shift timings for Drivers, Optimizing waiting time, Reducing travel distance, etc. The algorithm covers most of the dispatching strategies in a single go and provides reasonable decisions that are optimum for the provider and the customer.

2. RELATED WORK AND RESEARCH GAP

Development of the algorithm needed a good understanding of the currently used techniques to counter the problems in dispatching. An in-depth study was done to know about the existing algorithms and their efficiency. [1] talks about the OSTF (Online taxi scheduling framework) algorithm which directs a taxi to the next nearest pick up from the current location which improves waiting time and the distance traveled. Also assigning the right drivers for pickup under time constraints is talked about in [2] which uses graph algorithms to find the right solution. A comprehensive approach has been proposed in [3] to reduce the waiting time. Genetic algorithms have also been proposed for route planning and tackling demand surges [4][5]. There has been an exploration into reducing the cruising distance without passengers [6-9]. There have been many mathematical studies and theorems for route planning and agent assignment [10-15]. These studies have acted as a stepping stone for building this algorithm and also provide a good view of the research gap in this space -

- None of the research done either doesn't consider the real world scenario or rather doesn’t have sufficient data to be possibly implemented in the real world.
- No single research has focused on all the concepts to implement an Automated Dispatch Tool like driver allocation, feasibility, reducing waiting time, least idle time, etc.
- The holistic view of customer expectations and characteristics has not been considered.
- None of the studies sees from a product point of view including actual agents, branches of taxi rentals, etc.
- None of the studies focus on the Shuttle, Tour concept as in the case of Manual dispatch Tool from a car rental standpoint.

3. OBJECTIVES

- Detailed study of the existing algorithms and techniques to improve dispatching strategies.
- Amalgamate the existing algorithms to cater to a wide range of dispatching strategies using a single algorithmic framework.
- Testing the algorithm locally for various use cases and also deploying in the real world to get a detailed feedback report.

4. METHODOLOGY

Preliminary study and understanding of the existing algorithms. This forms the basis for further work. Based on the study the scope of the research is defined. The study found that the critical dispatching problems include -

- Waiting Time - The time the customer has to wait to get the taxi/car rental service.
- Route Planning - The lack of this has a direct impact on the cost borne by the stakeholders and the company.
- Assigning Agents - Agents include the driver, the person delivering or picking up a car, etc. The optimal assignment of agents is critical to optimizing dispatching.
- Vehicle Travel Distance - This is the total distance traveled by the vehicle during a given task. Reducing this is essential to cut the company’s costs.
- Surge in Demand - This is a critical issue during peak traffic hours. Handling this will result in reducing the pricing for the customers.

Each of these problems required different algorithmic solutions. The first task was to find the most appropriate algorithm for each task individually.

To reduce the waiting time of the passengers a hybrid programming approach is adopted where the strengths of Integer Programming (IP) and Variable Neighbourhood Search (VNS) are combined to service a user with the nearest agent who is idle.

For route planning, a bunch of algorithms were tried like genetic algorithms, graph algorithms, and dynamic programming approaches. But the best result came by integrating genetic and graph algorithms as shown in Table 1. The accuracy is measured by simulating taxi orders across various regions in Vienna city and seeing the response which takes the least cost. The natural selection of the genetic algorithm and the mathematical approach of the graph algorithms give a perfect blend to get optimized route planning.

TABLE 1 . ALGORITHMIC ACCURACY

Algorithmic Accuracy	
Algorithmic approach	***Accuracy***
Genetic Algorithm	56%

Algorithmic Accuracy	
Algorithmic approach	***Accuracy***
Dynamic Programming	48%
Graph Algorithm	54%
Genetic + Graph	71%

For Assignment of agents Conflict-Based Min-Cost flow(CBM) algorithm is used which is originally used for optimal target assignment and pathfinding (TAPF) but with some minor changes it can be used for agent assignment. The CBM (Conflict-Based Min-Cost-Flow) algorithm is a hierarchical algorithm that optimally solves TAPF instances by combining ideas from anonymous and non-anonymous multi-agent path-finding algorithms. CBM assigns all agents in a single team to targets and plans their paths using a min-cost max-flow algorithm on a time-expanded network. CBM uses conflict-based searches to resolve collisions between agents in different teams.

Minimizing Vehicle Travel Distance includes minimizing cruise distance without passengers and also minimizing distance traveled between pickup and drop-off. There is an existing Genetic Algorithm with a branch-and-bound technique with a breadth-first search. And also the generic traveling salesman problem represents this problem in a simple manner. But a different approach had to be taken to solve this issue. A potential-cruising-distance performance evaluation model (PCD). After receiving a passenger, the algorithm recommends the current optimal route and updates both the capacity and the probability along the route. Doing this reduces idle travel distance. Table 2 shows the distance traveled idle between pickups with different approaches.

TABLE 2. ALGORITHMIC PERFORMANCE

Algorithmic Performance	
Approach	***Distance Traveled (km)***
Simple TSP algorithm	3.4
Genetic Algorithm	3
PCD	2.3

Surge pricing is essentially a market mechanism that aims to close the supply-demand gap. It is an essential tool for on-demand cab service providers to match supply and demand during peak times. It is a possible solution to the rider's 'no cab available' problem. It aids in increasing efficiency and increasing the number of rides available to the service provider. The surge in demand can be tackled by using each of the above approaches in a priority-based manner based on the given scenario.

The Algorithmic flow for the developed dispatching algorithm is shown in Fig 1. Here the algorithm takes in 13 different parameters as input which are taken from the transit vehicles and the branches that hold these vehicles. The parameters are sampled after testing with data provided by SIXT and can’t be disclosed due to IP rights. The algorithm then takes in a dispatching action which is provided by the user using the algorithm and based on that an optimal decision is made for the particular dispatching strategy.

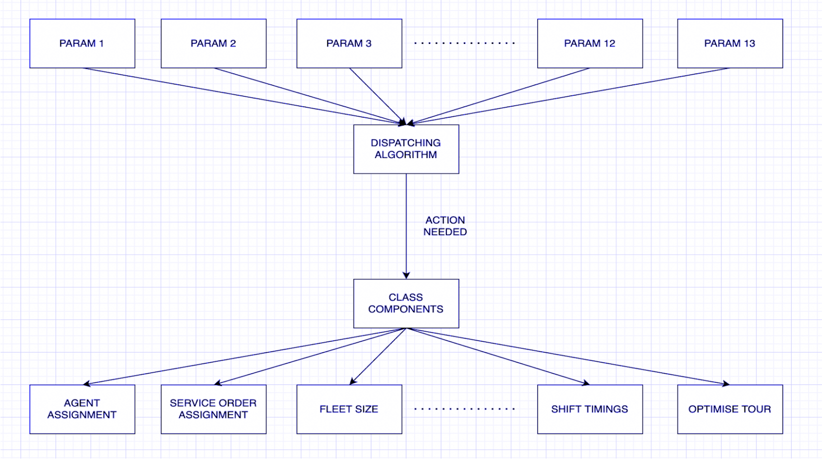

Figure 1. Algorithmic Flow

5. TESTING AND RESULTS

The algorithm developed has gone through two rounds of testing. The first testing was done locally using a simulator provided by SIXT which models real-life scenarios. Rigorous testing was done for the whole algorithm and also the individual components. The second round of testing included deploying the algorithm on the SIXT app used by a branch in Vienna for a span of 20 days.

The results of the various tests for individual dispatching strategies have been elaborated in the below figures -

- Waiting Time

Average Waiting Time (in mins)	
Without Algorithm	15.8
With Algorithm	9.6

Fig 2. Average Waiting Time

- Route Planning

Cost Incurred between Trips (in euros)	
Without Algorithm	4.3
With Algorithm	3.5

Fig 3. Cost Incurred between Trips

- Agent Assignment

Agent Idle Time (in mins)	
Without Algorithm	19.3
With Algorithm	12

Fig 4. Agent Idle Time

- Vehicle Travel Distance

Vehicle Cruise Distance (in km)	
Without Algorithm	5.1
With Algorithm	3.2

Fig 5. Vehicle Cruize Distance

- Surge in Demand

Surge pricing (in percent)	
Without Algorithm	14.5%
With Algorithm	7%

Fig 6. Surge Pricing

The individual results clearly show the reduction in average waiting time, reduction of the cost incurred due to better route planning, reduction of agent idle time by assigning agents in an optimal manner, reduction in vehicle cruise distance without passenger,s and reduction in surge pricing due to better handling of resources during rising in demand.
Now comparing the overall algorithm performance in local testing and after deploying compared to the old approach in Fig 7. This shows how better it is in using the algorithmic approach over the traditional approach using simulator parameters.

Algorithmic performance	
Local Tests	34%
Deploy and Test	27%

Fig 7. Algorithmic Performance

This clearly shows the functional performance increase using the developed dispatching algorithm.

6. CONCLUSION

The Dispatching algorithm developed in this paper caters to a wide range of dispatching strategies. With the ever-growing dependency on taxis and car rentals, it has become difficult for the stakeholders to meet the increasing demands. This algorithm is a way to make optimal strategies based on the parameters obtained from the transit vehicle and the branch itself so that it satisfies the customer's needs and also be cost-efficient for the stakeholders. This algorithm uses different approaches for solving different dispatching problems like Dynamic programming, Graph algorithms, etc. as discussed above to provide efficient and optimal decisions. While the focus is on providing a stop solution the efficiency of the individual tasks has not been compromised.

Further enhancements can be done by trying different combinations of algorithms to provide a further boost to the decision-making ability of the algorithm and its accuracy. If feasible, machine learning techniques can be used to provide a predictive approach based on the previous data, but first, the current approach has to be implemented on a wide scale and data must be collected. This algorithm will become a start towards optimizing dispatching strategies for the specific domain of transit systems.

Acknowledgments

I would like to express my sincere gratitude to my guide, Prof. Manas M N for his continuous support and guidance throughout this research.

I would also like to thank SIXT, the first and most influential international car rental company in the world - with over 100 years in the business - a trusted reputation as a global leading car rental provider for helping me to get in-depth knowledge into taxi and car rental services. This organization also helped me get the relevant data and also testing the algorithm in real scenarios.

REFERENCES

[1] Nguyen Van, S., Vu Thi Hong, N., Pham Quang, D., Nguyen Xuan, H., Babaki, B., and Dries, A., Novel online routing algorithms for smart people-parcel taxi sharing services, ETRI Journal 44 (2022), 220–231. https://doi.org/10.4218/etrij.2021-0406

[2] Xijun Zhang , Qirui Zhang, Zhanting Yuan, Chenhui Wang, and Lijuan Zhang, The Research on Planning of Taxi Sharing Route and Sharing Expenses, Mathematical Problems in Engineering Volume 2020, Article ID 6348578, 9 pages https://doi.org/10.1155/2020/6348578

[3] 3. Aloisio, Alessandro and Mkrtchyan, Vahan, Assigning tasks to agents under time conflicts: a parameterized complexity approach, https://doi.org/10.48550/arxiv.1904.09246

[4] 4. Mohammad Ansari Esfeh, S. C. Wirasinghe, Saeid Saidi & Lina Kattan (2021) Waiting time and headway modeling for urban transit systems – a critical review and proposed approach, Transport Reviews, 41:2, 141-163, DOI: 10.1080/01441647.2020.1806942

[5] 5. N. Shanmugasundaram, K. Sushita, S. Pradeep Kumar, and E.N. Ganesh, Genetic algorithm-based road network design for optimizing the vehicle travel distance, International Journal of Vehicle Information and Communication Systems 2019 4:4, 344-354

[6] 6. J. Xu, R. Rahmatizadeh, L. Bölöni and D. Turgut, "Taxi Dispatch Planning via Demand and Destination Modeling," 2018 IEEE 43rd Conference on Local Computer Networks (LCN), 2018, pp. 377-384, doi: 10.1109/LCN.2018.8638038.

[7] 7. Billhardt, H.; Fernandez Gil, A.; Ossowski, S.; Palanca Cámara, J.; Bajo, J. (15-0). Taxi dispatching strategies with compensations. Expert Systems with Applications. 122:173-182. https://doi.org/10.1016/j.eswa.2019.01.001

[8] 8. Z. Luo et al., "Dynamic Taxi Service Planning by Minimizing Cruising Distance Without Passengers," in IEEE Access, vol. 6, pp. 70005-70016, 2018, doi: 10.1109/ACCESS.2018.2881419.

[9] 9. Jihang Zhang, Minjie Zhang, Fenghui Ren and Weicheng Yin, Aden Prior, Claudio Villella, Chun-Yu Chan. 2018. Enable Automated Emergency Responses Through An Agent-Based Computer-Aided Dispatch System. In Proc. of the 17th International Conference on Autonomous Agents and Multiagent Systems (AAMAS 2018), Stockholm, Sweden, July 10–15, 2018, IFAAMAS, 3 pages.

[10] 10. Ma, Hang and Li, Jiaoyang and Kumar, T.K. Satish and Koenig, Sven, Lifelong Multi-Agent Path Finding for Online Pickup and Delivery Tasks, International Foundation for Autonomous Agents and Multiagent Systems 10.5555/3091125.3091243

[11] Erfan Rahimian, Kerem Akartunalı, John Levine, A hybrid Integer Programming and Variable Neighborhood Search algorithm to solve Nurse Rostering Problems, European Journal of Operational Research, Volume 258, Issue 2, 2017, Pages 411-423, https://doi.org/10.1016/j.ejor.2016.09.030.

[12] 12. Miao, Fei and Han, Shuo and Lin, Shan and Wang, Qian and Stankovic, John and Hendawi, Abdeltawab and Zhang, Desheng and He, Tian and Pappas, George J., Data-Driven Robust Taxi Dispatch under Demand Uncertainties, https://doi.org/10.48550/arxiv.1603.06263

[13] 13. Ma, Hang and Koenig, Sven, Optimal Target Assignment and Path Finding for Teams of Agents, International Foundation for Autonomous Agents and Multiagent Systems, 10.5555/2936924.2937092

[14] 14. M. Maciejewski, J. Bischoff and K. Nagel, "An Assignment-Based Approach to Efficient Real-Time City-Scale Taxi Dispatching," in IEEE Intelligent Systems, vol. 31, no. 1, pp. 68-77, Jan.-Feb. 2016, doi: 10.1109/MIS.2016.2.

[15] 15. X. Zhan, X. Qian and S. V. Ukkusuri, "A Graph-Based Approach to Measuring the Efficiency of an Urban Taxi Service System," in IEEE Transactions on Intelligent Transportation Systems, vol. 17, no. 9, pp. 2479-2489, Sept. 2016, doi: 10.1109/TITS.2016.2521862.

[16] 16. N. Sathya and A. Muthukumaravel, A Review of the Optimization Algorithms on Traveling Salesman Problem, Indian Journal of Science and Technology, Vol 8(29), DOI: 10.17485/ijst/2015/v8i1/84652, November 2015

[17] 17. Delling, Daniel, Route Planning in Transportation Networks: From Research to Practice, Association for Computing Machinery , 10.1145/3274895.3282802

[18] 18. Thomas Liebig, Nico Piatkowski, Christian Bockermann, Katharina Morik, Dynamic route planning with real-time traffic predictions, Information Systems, Volume 64, 2017, Pages 258-265, https://doi.org/10.1016/j.is.2016.01.007.

[19] 19. L.. Grigoriev, A. Kostogryzov, A. Tupysev, Automated dispatch control; problems and details of modeling., IFAC Proceedings Volumes, Volume 46, Issue 9,2013,Pages 1123-1127, https://doi.org/10.3182/20130619-3-RU-3018.00385.

[20] 20. Daniel Delling, Andrew V. Goldberg, Thomas Pajor, and Renato F. Werneck, Customizable Route Planning in Road Networks, Transportation Science 2013 51:2, 566-591