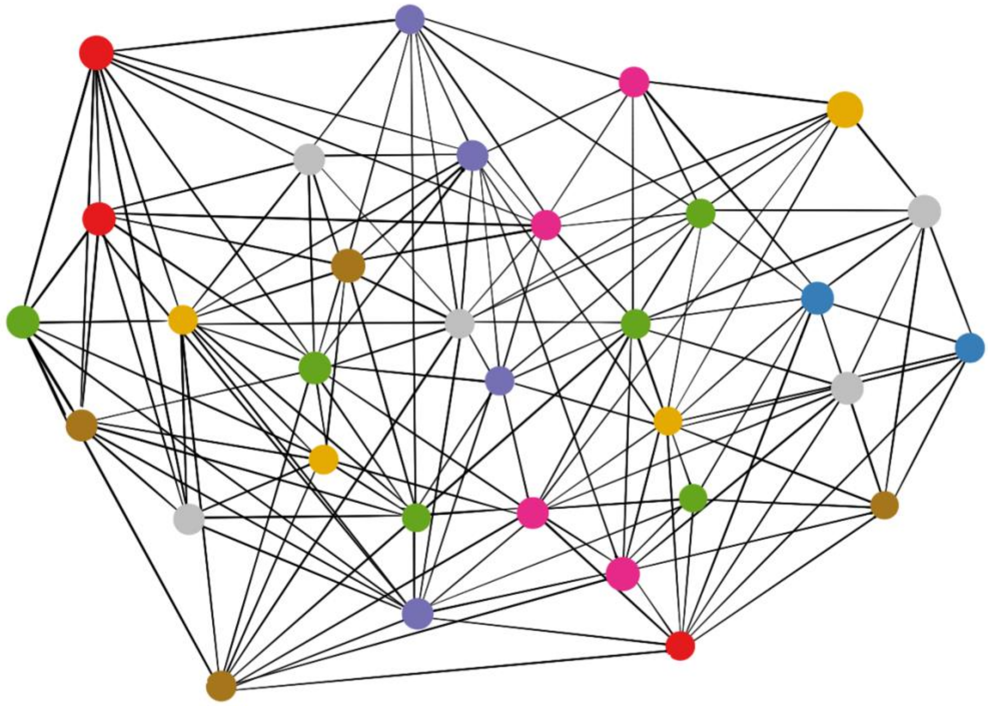
Integration of client choice in the transportation of clients to social care services



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Management Summary

Introduction: This research is focused on the optimisation of patient transportation. Specifically on the client allocation aspect of the transportation process of patients to social care services. Client allocation refers to the allocation of patients to certain care providers or timeslots within the system. Social care services refer to the assistance of people who are unable to independently arrange the care and support they need. This thesis aims to improve the quality perceived by the clients as well as the quality of the company's specifications. Effective transportation has been proven to have a positive effect on the quality of care provided to clients, hence, it has been selected as the focus point of this thesis.

Motivation for the research: The majority of research concerning patient transportation is focused on the optimisation of quantitative variables about the quality of the system concerning distance and time travelled, vehicles used, etc. That, combined with the rising demand for on-demand transportation, raises significant concerns about the quality of the transportation process perceived by the patients.

Research objective and research questions: This research aims to identify the trade-off between client choice (CC) and system efficiency in the field of patient transportation. Client choice refers to the ability of clients to choose between several care providers (CPs). The objective is to determine the most effective way to increase customer-based quality, without compromising on the technical efficiency of the system. To complete this objective, the following research questions have been formulated.

Main Research Question: "What is the trade-off between client choice and transportation costs in the client allocation phase of patient transportation?"

Sub-Questions:

1. What is the current strategy for allocating and transporting patients to care providers?
2. How is client choice known to be modelled in a DARP?
3. How should the client allocation model be constructed?
4. What is the performance of the strategies concerning the selected KPIs?

Approach: The context of the transportation system can me modelled as a Dial-a-ride problem (DARP). Because of the limited literature on client allocation models in a DARP, especially including the integration of client choice in the model, there was a liberty in the research approach. Initially, the variable that should be subject to client choice was decided. After the care provider (CP) was selected as the variable to be subject to client choice, the model was constructed. The case was modelled by using Integer Linear Programming (ILP). Three strategies for client allocation were constructed, in which the criteria for which care provider was subject to client choice differed, as well as the objective. The Shortest Distance Strategy populates Πi with the CPs closest to client i. The Availability strategy has the same objective but takes an extra variable, the availability of each client. For those two strategies, the objective is the distance between client and CP. The Rating strategy's objective is to minimise the product of the distance of a CPs to client i, and the CP's rating. The model optimises the timeslot(s) and care provider a patient is allocated to. Every strategy has four variants, distinguished by the number of care providers subject to client choice (2-4). Then, the results are assessed by using them as input to a routing algorithm that ultimately calculates the total time travelled.

Results: After several experiments, the three strategies and their variants were compared on the total time travelled. Besides the travel time, the standard deviation and a 97,5% confidence interval were

identified for every experiment. The table below presents the time travelled in minutes for all the variants of the three strategies.

Strategy	2 CPs	3 CPs	4 CPs	5 CPs
Shortest distance Strategy	25.505,2	25.309,0	25.206,4	25.134
Availability Strategy	25.421,4	25.396,6	25.196,2	**25.025,2**
Rating Strategy	25.630,6	26.081,8	25.962,0	25.582,8

The results show a negative correlation of CPs subject to client choice and time travelled. The only variant that opposes this conclusion is the variant of 2 CPs of the rating strategy. Likely, because of the random element implemented in the variable of the CP's rating, in the rating strategy. Every strategy's most efficient variant is the one with 5 CPs subject to CC. Additionally, the best-performing strategy is the Availability of 5 CPs subject to CC with a travel time of **25.025,2** minutes.

Outlook: Future research can be done on the effects of having other variants subject to CC. Timeslots and means of transportation (taxi, shared transportation, etc.) can be some of them. Additionally, there can be a more detailed measurement of perceived quality from the customers' and care provider's perspective. The impact of the quality of the system with the increase of the CPs subject to CC can be specifically determined.

Abbreviations

Abbreviation	Explanation
CP	Care provider
CC	Client Choice
NEMT	Non-Emergency Medical Transportation
PDR	Pick-up and delivery problem
DARP	Dial-a-ride problem
CD-DARP	Choice-driven Dial-a-ride problem
KPI	Key performance indicator
SLR	Systematic literature review
SDS	Shortest distance strategy
LP	Linear programming
ILP	Integer linear programming
MILP	Mixed integer linear programming
MPSM	Managerial problem-solving method

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Chapter 1: Introduction

In this chapter there will be an introduction to the scope, motivation, and context of the thesis. Section 1.1 definesIn section 1.1 the concept of social care, elaborates on the importance of effective transportation, and introduces the case context. In section 1.2 the problems of the situation will be analysed. Section 1.3 includes the research questions.

1.1 Case context

This thesis focuses on the improvement of the patient transportation process to social care services. To properly understand the current situation, a brief description of the social care landscape in the Netherlands will be introduced.

Currently, in the Netherlands, where the case study is focused, a decentralised system is in place for social care provision. The local governments are responsible for providing clients with social care (Dijkhoff, 2014). Based on the Social Support Act (WMO), municipalities are responsible for assisting people who are unable to independently arrange the care and support they need. Municipalities provide services like:

- coaching/companionship and day activities
- temporary respite for informal carers
- a place in sheltered accommodation for people with psychiatric disorders
- emergency shelters for victims of domestic violence (Ministerie van Volksgezondheid, Welzijn en Sport, 2022)

The Netherlands is known to be one of the states with the best healthcare system globally (Schneider et al., 2021). Bowers et al (2012), state that the patient transportation service is a crucial component of a healthcare system. Hence, it is vital to resolve any inefficiencies occurring in this process. Currently, route planning is solved by classical methods in the transportation sector (Tóth et al., 2024). Therefore, in more complicated routes, emphasis is given to the optimization of technical quality, as customer-based quality is often neglected. As technological advancements become more noticeable in the field of responsive and adaptive transportation, it is crucial to enhance the service quality of the process as well. Achieving that could lead to more efficient resource utilisation and substantial cost savings (Nasri et al., 2024).

Efficient client transportation is a feature vital for a healthcare institution thriving to provide effective care. In this research, the main focus will be on the transportation of patients to caregivers. This paper tackles a similar issue as the Master thesis of Feike Weijzen (2023), "Optimizing transportation of clients for social care services". In that research, Weijzen analysed the process of client transportation and came up with three possible solutions. One of them is the client allocation strategy. This option allocates the clients to other care providers if this is beneficial for the transportation routes (Weijzen, 2023). This research is based on the principles of this approach.

Client transportation is a feature that many organisations struggle with. Often, the patient cannot attend the social care institution by means of their own. This could be due to personal reasons, their condition, or any walking disabilities they may experience. The assessment of whether a client can arrange their own transport is done by a region, and it is not strict. In our case study from region X, around 400 of the approximately 1000 clients that receive care at the X region, have their transportation arranged by X. Currently, the clients can choose the caregiver they please. Consequently, long distances may have to be travelled to accommodate them. The efficiency of this process must be optimised so this feature remains a sustainable option for both the clients, X, and the caregivers.

This thesis focuses on optimising clients' transportation to their caregivers while maintaining or improving the quality of the service perceived by the clients. The quality of the process is analysed from a technical approach and a customer-based approach. The technical approach focuses more on company specifications, while the customer-based approach is occupied more with the quality perception of the client (Paquette et al., 2009). The way to include the customer-based approach is by incorporating client choice in the client allocation strategy presented by Weijzen (2023). Specifically, the effect of certain degrees of freedom within this context will be analysed and compared.

The reason the transportation aspect of the social care provision process has been selected is the immediate effect it has on the effectiveness and sustainability of social care, proven by literature. Kotval-K et al. (2020) state that there is a critical connection between transportation services and preventive healthcare attainment. Boyd et al. (2024) found that transportation is a significant factor for entering and remaining in treatment. Moreover, Razon et al. (2023) have deemed Non-Emergency Medical Transportation (NEMT) as a valued service essential to their ability to access health care. Even though the studies have a different target group than this thesis, the importance of efficient transportation can be translated in this case as well. In conclusion, inefficient NEMT causes suboptimal patient and staff experiences through complex advanced scheduling procedures, long waits and missed appointments (Lyons et al., 2021).

The problem of this thesis falls within the category of Pickup and Delivery Problems (PDP), and more specifically, Dial-A-Ride Problems (DARP). A solution to DARP requires balancing the trade-off between service quality (i.e. customer convenience) and economic perspective (Paquette et al., 2009). Therefore, integrating client choice would theoretically yield a more complete and accurate solution to this DARP. This report focuses on providing a patient allocation model that yields the most effective strategy for the DARP to use as input.

This section presents a stakeholder analysis of the patient transportation process within the X region. It is crucial to understand the interests and needs of each stakeholder to provide a suitable and viable solution for all.

1.1.1 Stakeholders

A brief stakeholder analysis will be implemented to understand the dynamics of the current situation properly. It is crucial to determine the interests of each actor in this process to identify the problems and determine a valuable solution for everyone involved. The three main stakeholders in the process of client transportation are the clients, the care providers, and the region of X.

Firstly, the clients are the most influential actors in this process. Besides the time and date of the appointment, they also choose the caregiver. Their main interest is to be transported to their selected caregiver, with as little delay as possible. If the routing or client allocation strategy is not sophisticated enough, there might be some extra time between the pickup times of patients. That would also result in a client spending more time than needed in the process.

Additionally, the clients are divided into two categories for their transportation; those who require light transport, and medium transport. Light transport refers to standard transportation. Medium transport is provided for clients who require extra supervision while travelling or have specific impairments that prevent them from being transported under normal conditions.

Another actively involved actor is the caregiver. The care providers are responsible for the transportation of the clients. They are compensated for the transportation per client. These fees do not take into account travelling distance. Therefore, if a client is located far away from the social care services facility, this is disadvantageous for the care provider (Weijzen, 2023). The caregivers' main interest in this process is ensuring clients make their appointments on time while minimising the distance travelled.

Lastly, the region is responsible for ensuring the quality and accessibility of care for those in need. Region X builds a strong relationship with the care provider to achieve these goals but is not in power to make policies. However, it can advise the municipalities regarding policies. The main interest of the region is ensuring care is accessible, of high quality, and that costs are maintained reasonably.

Currently, customers can pick the care provider they desire. Hence, the allocation strategy depends entirely on the patient's preferences. While this option enhances the customer-based quality of the system, the technical quality can be compromised. The patients have complete freedom to pick the care provider and timeslot, as long as it complies with the availability of the care provider.

1.1.2 Problem description

In this case, the main issue is the lack of optimised transportation of patients to their respective caregivers. However, an important feature that must be integrated is client choice. Specifically, the effect of certain degrees of freedom of client choice in the client allocation phase will be examined. Several properties can be subject to client choice.

The caregiver is the main actor who can be dependent on the client's choice. In this case, there is a reduction in the degrees of freedom a client has, as currently, the clients can choose whoever caregiver they please. By maintaining some degree of freedom, quality is balanced based on a technical approach and a customer-based approach.

One way to realize this idea, X will present the client with some possible care providers based on several criteria. Then, the client can decide on which one to choose. Alternatively, the client would present X with their preferred pickup time, and based on that, X would identify the caregiver whose location would provide the most cost-effective transportation.

1.1.3 Problem Context

In this section of the report, the main problems that occur during the process of patient transportation are listed. Those issues form the core problems of the situation. The motivation and explanation for selecting the core problems will be further explained in Section 1.2.2.

Transportation prices

Transportation costs are constantly rising for various reasons. Besides the routing optimisation aspect of the logistical process, other causes are the increase in fuel prices, shortage of raw materials, and other worldwide events such as COVID-19 and the war in Ukraine (CBS, "Pump prices motor fuels; location petrol station, type fuel," 2023). In this case, one of the main reasons for the increased transportation prices for the caregivers is that they are compensated per client they pick up, not considering the distance travelled.

Unmonitored client freedom

In the current strategy, the client can choose the caregiver they desire. This uncontrolled and unmonitored freedom the clients possess backfires in terms of cost efficiency for the caregivers. As the X compensates the caregivers by client transported and not by distance covered, the clients that are located far from the care providers are somewhat of an economic inconvenience.

Lack of planning collaboration

As of right now, the care providers are in charge of their clients' transportation. The carers' lack of coordination and centralised planning is evident in this approach and jeopardises the efficiency of the process. Also, the routing aspect of the transportation is not optimised. Combining that with the lack of collaboration, the efficiency of the process is severely compromised.

High absenteeism

High absenteeism has been a struggle for caregivers, especially after COVID-19 (CBS, "Gezondheid in coronatijd," 2023). In this case, there are two kinds of absenteeism, from clients and work staff. Employees of the care providers call in sick more often, needing more expensive staff for replacement. As far as client absenteeism, some of them do not show up to their appointments. The care providers are compensated by the time the client is present in their facility. This means that if a patient does not show up, the caregivers are not reimbursed for their investment in the planned appointment. Both aspects of absenteeism have a significant impact on the profitability of the care provider's businesses.

Lack of organised facility network design

The care providers involved in this context are individual organisations that do not cooperate. Hence, the location of each facility was not planned in a way that enables the most efficient transportation for clients. To have an organised facility network design the optimal location of facilities in a community, the number of facilities, their capacity, the number of their allocated clients, and their cost must be meticulously planned. In the case of X, some of those factors are not optimised, hence, the network is not as efficient as it could be.

1.1.4 Action problem

In this case, the main issue that endangers the economic sustainability of this process is the costs that occur during patient transportation. The caregivers are responsible for the patient's transportation. When compensating them, the X does not take into the distances travelled per patient. This means that if a patient chooses a caregiver far from his pickup location, more costs will occur for the caregivers. If this process becomes unsustainable for the caregivers, more clients will miss their appointments or choose not to plan one at all.

Therefore, the action problem in this case is formulated as follows.

"The costs that occur for the caregivers during the transportation of patients to their facilities are too high for this process to remain sustainable".

The reason that this standard is set is to examine whether it is possible to preserve the same costs while integrating client choice. The reality is represented by the costs that are currently estimated that occurred for the care providers.

1.2 Problem cluster and motivation of core problem

1.2.1 Problem cluster

After identifying the most dominant problems of the case, it is crucial to determine the cause and effect of those problems. The most effective way to achieve this is by forming a problem cluster. The problem cluster is a powerful tool for mapping all the problems and their connections, as well as for determining the core problem.

To get insights into the issues the stakeholders face, it would be necessary to conduct qualitative data gathering methods. However, the scope of this report is too narrow to have the time and resources to conduct them. Hence, in forming this problem cluster, the scientific paper from Weijzen (2023) "Optimizing transportation of clients for social care services" will be used as the main data gathering source for this section. Weijzen's paper tackles a similar issue with this thesis, therefore, can be a valid source for the problem cluster.

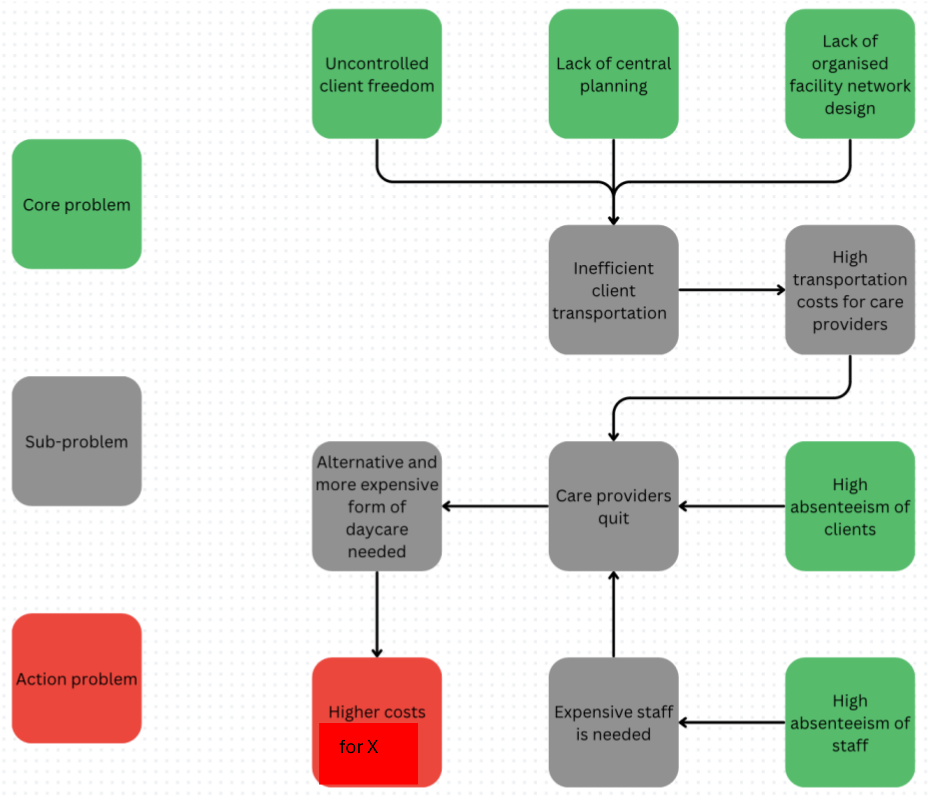

Figure 1. Problem cluster

1.2.2 Core problem

As presented in the problem cluster (Figure 1), the source of most problems is the uncontrolled freedom of clients, the lack of central planning, the lack of organised facility network design and high absenteeism. These problems do not have any direct cause themselves, hence they are suited for the core problem. Moreover, according to Heerkens et al. (2021), "The most important problem is whichever one whose solution has the greatest impact, at the lowest cost". Reorganising the facility network of the care providers would potentially yield significant results, however, it would be drastically more costly than addressing the other problems. Additionally, the problem of high absenteeism has more socially rooted causes, hence its solution would be outside the scope of this thesis.

Therefore, the core problems of this case are the uncontrolled freedom of clients and the lack of central planning. The reason there are two core problems is that the solution presented tackles both of them. By incorporating a centralised planning system that integrates client core problems are addressed.

The combination of those problems jeopardises the efficiency of the system, making the process of patient transportation economically unsustainable. As the care providers are responsible for financing the transportation of the clients, if there is no more economic benefit, it can affect the quality and sustainability of the care provided. Subsequently, whether the process becomes too costly, care providers will quit. That results in X being obligated to find an alternative form of care. That care is often more expensive, leading to more expenses for X.

1.3 Research questions

The research objective of this study is to examine the most effective way to incorporate client choice in the client allocation process within the context of transportation for clients of social care services in the X region.

Main Research Question: “What is the trade-off between client choice and transportation costs in the client allocation phase of patient transportation?”

To reach this objective and answer this research question, the following research questions have been formulated.

1. What is the current strategy for allocating and transporting patients to care providers?
   1.1. What degrees of freedom do the clients currently have?
   1.2. What is the performance of the current strategy in terms of technical and customer-based quality?

2. How is client choice known to be modelled in a DARP?
   2.1. What variables are known to be subject to client choice in a healthcare context, presented by literature?
   2.2. What is the assessment of that usage?
   2.3. How are those cases similar to the social care context?
   2.4. Can a similar strategy be applied in this research?

3. How should the client allocation model be constructed?
   3.1. How can client choice be modelled?
   3.2. What are the steps for the client allocation process?
   3.3. What are the KPIs that the strategies should be assessed on?

4. What is the performance of the strategies concerning the selected KPIs?

5. What are future recommendations for integrating client choice in a DARP?

After the research questions have been answered, the research will provide the following insights two insights. (1) an assessment of the implementation of client choice in this context. Insights must also be derived on whether it is cost-effective to implement client choice in a DARP. (2) provide X, as well as any other organisations with similar conditions, with the effects of implementing client choice in the client allocation process and the perception of service quality from the clients.

Chapter 2: Systematic Literature Review

This section of the report presents a systematic literature review (SLR). The SLR will aim to answer research question 2, and sub-questions 2.1, 2.2, 2.3, and 2.4.

2 How is client choice known to be modelled in a DARP?

The inclusion and exclusion criteria must be identified to effectively perform a systematic literature review. The criteria are generated based on the context of the research as well as based on language and relevancy factors and shown in Table 2.

Inclusion criteria	Exclusion criteria
Articles written in English	Does not consider service quality as a factor
In healthcare	
The paper must be published in a peer-reviewed or academic journal	

Table 2. Inclusion/Exclusion criteria for SLR

After determining the inclusion and exclusion criteria for the SLR, the key concepts for the review must be identified. The concepts displayed in Table 3 are part of the context of the research question that needs to be answered.

Key concepts	Broader concepts	Related terms
Dial-A-Ride Problem	VRP, Pickup and Delivery Vehicle Routing Problem, Vehicle Routing Problem with Time Windows, Patient transportation	Travelling Salesman problem, Demand Responsive Transport, Non-Emergency Medical Transport
Client choice	Choice driven	Enhanced service quality, Discrete choice model, User preference
Technical/Customer based quality	Service quality	

Table 3. Key concepts

Having determined the key concepts, the search started. The database selected to operate the SLR was Scopus.

Table 3 presents the search log of the SLR. In the search log the key findings of the research are displayed. The number of papers each string combination has generated and some comments about the effectiveness of the search are also shown.

Date	**Search String**	**Database**	**# of articles**	**Remarks**
8/06	TITLE-ABS-KEY ("Dial-A-Ride Problem")	Scopus	454	Many articles. Some insightful ones, however, most of them are not highly related to the problem. Good enough to understand what a DARP is. More specific strings required.

8/06	TITLE-ABS-KEY ("Dial-A-Ride Problem" AND (patient OR client) AND transportation)	Scopus	33	A lot more (or too) specific. Some very insightful articles (Martin et al., 2024, Molenbrunch et al., 2017).
8/06	TITLE-ABS-KEY ("Dial-A-Ride Problem" AND (patient OR client) AND transportation AND "service quality")	Scopus	3	Results narrowed down substantially. Not too many relevant information. Different direction required.
8/06	TITLE-ABS-KEY ("Dial-A-Ride Problem" AND "service quality")	Scopus	23	Integrating service quality shifted the focus to more customer-oriented solutions. A lot of relevant information about how to shift the service quality to a more customer-based approach.
8/06	TITLE-ABS-KEY ("Dial-A-Ride Problem" AND choice)	Scopus	10	This search yielded the most relevant article to date (Azadeh et al., 2022). Some other useful information on how incorporate user interaction in the modelling of DAR system.
8/06	TITLE-ABS-KEY ("Dial-A-Ride Problem" AND user AND choice)	Scopus	5	Same as previous search but more filtered information. Some more information about the modelling of the system is required.
9/06	TITLE-ABS-KEY ("Dial-a-ride" AND "linear programming" AND heterogeneous)	Scopus	5	Mostly what I have read already from previous searches.

Table 4. Search log

During the search, the main focal point was the DARP, hence, the string was present in all searches. The first string (TITLE-ABS-KEY ("Dial-A-Ride Problem") yielded only 454 results. Considering how generic the string was, the results were quite few. Therefore, it was best to keep the search strings as little sophisticated as possible. This was apparent in the third search when the results were narrowed down considerably.

Overall, the search yielded some insightful results. The following papers provided the most valuable information for the research.

Ho et al. (2018) conducted a literature review for DARPs in their scientific paper "**A survey of dial-a-ride problems: Literature review and recent developments**". They surveys the research developments such as technological and operational innovations since 2007. While it does not mention anything about incorporating client choice, it provides many valuable insights about the modelling and solution of DARPs based on their characteristics. What was concluded based on this information is that an exact solution often cannot solve DARP as they are NP-Hard problems. However, exact methods are known to work well in static settings, as is the situation in this thesis. Furthermore, it has been proved that DARPs with a heterogeneous fleet are solved more efficiently with a Generic Algorithm (GA). Overall, while this article did not have any particular information that can be directly applied to our research, it provided some valuable context around this, at the time estranged concept of DARPs.

Moreover, Ershadi and Shemirani (2021) designed a network of preventive healthcare facilities optimally based on client choice. The distinct difference between this article and research is that the article does not include any DARP model. However, the way they incorporated client choice in the modelling of the problem, can also be adapted to the problem in this research. They developed two models of probabilistic selection and optimal selection as different client choice for predicting and managing the preventive services networks. “In the probabilistic model, it is assumed that the client can choose every facility with a certain probabilistic, which increases with the degree of attractiveness of the facility. But in the optimal selection model, each client chooses only the most attractive facility for his/herself” (Ershadi and Shemirani, 2021). A similar model will need to be used in this research as well.

As mentioned previously, this research focuses on implementing client choice into a DARP. Based on the literature studied, the only model that achieves that is the Choice-Driven Dial-A-Ride Problem (CD-DARP). To the best of our knowledge, there is only one study implementing this model, the “Choice-driven dial-a-ride problem for demand responsive mobility service” (Azadeh, 2022). Although there are some differences between the context of each case, the main principle remains the same. The point of this research is to examine the effect of client choice in a DAR system. The factor that makes the CD-DARP model such a suitable option for this case is that it presents the service quality as a utility function. Figure 3 represents the timeline of the dynamic framework from Azadeh (2022). After the customer *n* has entered the system, a set of alternatives is generated based on his preferred pickup time and drop-off location. A set of assortments is generated based on the price settings of the alternatives and presented to the client to choose from. After the client has made their choice, the state of the system is updated (vehicle location and capacity).

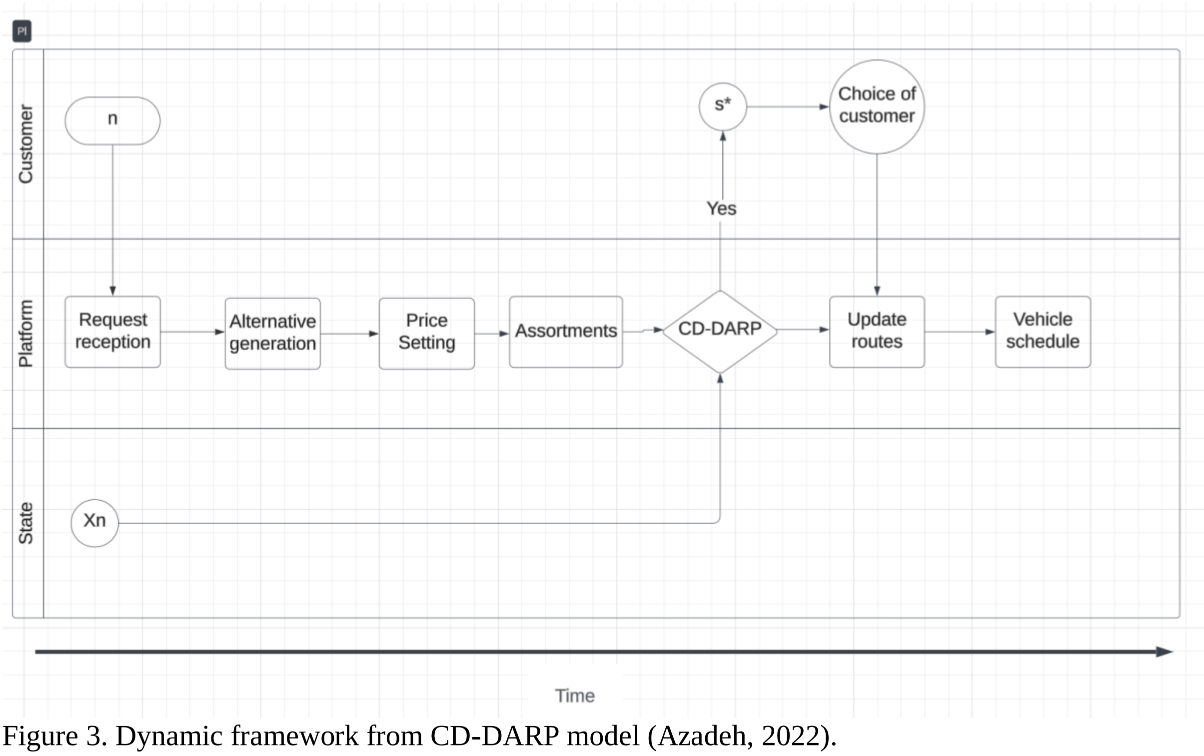

Figure 3. Dynamic framework from CD-DARP model (Azadeh, 2022).

The main principle remains the same for the case in this thesis as well. However, there are some key differences in modelling this situation. In our case, the caregiver will be subject to the client's choice. The following framework will be implemented. When the client enters the system, they present their pickup time and location. Based on those, the costs for transportation to each caregiver are calculated. The three caregivers with the lower costs will be presented to the client to choose from. After the client has made their choice, the state of the system will be updated.

Some key points have been noted to summarise the findings of the SLR. First, there is a lack of research about the inclusion of client choice in a DARP or, generally, any transportation system. Although that made the initial parts of the research somewhat time-consuming, ultimately, it proved to give the research some critical liberty. Even though the efforts of the researcher to identify an article with a similar context as this thesis, not many (if any) scientific papers were found. Besides the article from Azadeh et al. (2022), there are no other articles that incorporate client choice in a DARP, to the best of our knowledge. In that article, the authors decided to have the timeslots subject to client choice. However, the key difference between this article and this thesis is the objective value selected for the two researches. Azadeh et al. (2022) have the price as an objective value. Every timeslot is associated with a different price assortment. Hence, the comparison of different timeslot selections can be immediately compared. Because of the data available for this thesis, having insight into how the price is influenced by different variables was outside the scope of the analysis. The data available for this research will be further analysed in Section 4.1. Ultimately, that proved to be the deciding factor on the decision to have the caregiver as the variable subject to client choice.

Chapter 3: Mathematical model

In this chapter, the mathematical model will be introduced. An overview of the model, well as an introduction of the three strategies will be presented in section 3.1. Section 3.2 elaborates on the details of the model, and the reasoning of the selection of ILP. Section 3.3 explains the data context of the case study.

3.1 Model Overview

Subsection 4.1 presents an overview of the mathematical model of the case. The three strategies derived from this model will also be analysed.

Below, the mathematical model is presented. The case is modelled by using Integer Linear Programming (ILP). The argumentation as to why ILP is most suitable for this case, as well as details about the properties of the ILP, are presented in section 4.2.

The most important point from the model is the set Π. Π contains the care providers available for the client to choose from. The different criteria as to how Π is populated is the point of difference between the three different strategies that will be presented in subsections 4.1.1, 4.1.2, and 4.1.3.

The constraints are formulated to simulate real-life criteria and limitations that occur during the process of patient transportation.

Sets:

- C: Set of clients (*i*)
- G: Set of caregivers (*j*)
- T: Set of time slots (*t*)
- $\Pi_i \subseteq G$: Set of care providers available for client i

Parameters

- Q_{jt}: Capacity of care provider j in timeslot t
- D_{ij}: Distance between client i and care provider j
- R_{ij}: Ranking of care provider j for client i based on proximity or distance*rating (for the Rating strategy)
- $Match_{ij} \in \{0,1\}$: 1 if care provider j can provide the care client i needs, and their insurance matches
- $demand_i$: Number of time slots client i needs to be allocated to a care provider
- A_i: Availability of client i (1)
- r_j: Rating of care provider j (2)

Decision Variables

- $x_{ijt} \in \{01\}$: Binary variable that is 1 if client i is assigned to caregiver j in time slot t, and 0 otherwise.
- $y_{ij} \in \{01\}$: Binary decision variable, where $y_{ij} = 1$ if i is assigned to care provider j, and 0 otherwise

(1), (2) Those variables are not used in every strategy, but only in their respective one. More information about their properties can be found in section 4.3.

Objective Function

Minimize the total weighted distance based on the rank of the caregivers:

$$min \sum_{i \in C} \sum_{j \in \Pi_i} \sum_{t \in T} D_{ij} * R_{ij} * x_{ijt} \quad (1)$$

Constraints

1. Demand Constraint (Ensures each client is assigned exactly their demand):

$$\sum_{j \in G} \sum_{t \in T} x_{ijt} = \text{demand}_i \quad \forall i \in C \quad (2)$$

2. Capacity Constraint (Ensures caregiver's capacity is not exceeded in any time slot):

$$\sum_{i \in C} x_{ijt} \leq Q_{jt} \quad \forall j \in G, t \in T \quad (3)$$

3. Matching Constraint (Ensures a caregiver can only serve clients they can provide care for):

$$x_{ijt} \leq Match_{ij} \quad \forall i \in C, j \in G, t \in T \quad (4)$$

4. Single Care Provider Per Time Slot for Each Client:

$$\sum_{j \in G} y_{ij} = 1 \quad \forall i \in C \quad (5)$$

5. Linking Constraint Between x and y (Ensures that if any x_{ij}=1, then y_{ij}=1):

$$\sum_{t \in T} x_{ijt} \leq y_{ij} * demand_i \quad \forall i \in C, j \in G \quad (6)$$

6. Binary constraint (Enforces x_{ij} and y_{ij} as binary variables):

$$x_{ijt} \in \{0, 1\}, \quad y_{ij} \in \{0, 1\}, \quad \forall i \in C, j \in G, t \in T \quad (7)$$

3.1.1 Shortest Distance strategy (SDS)

The goal of the SDS is to solely minimise the travelling distance of the system. The objective function embodies that. Πi is populated by the CPs that are closest to client i. They are then ranked by distance for the client to choose from.

3.1.2 Rating strategy

The strategy “Rating system” differs from the basic model regarding how the Π is populated. In this model, a random rating (1-5) is generated for each CP.

Then, the product of the rating and distance is calculated for each client. Π is then populated with the CP with the smallest product.The Sets, Parameters, decision variables, and constraints remain the same. However, the objective function is slightly altered. It is updated to the following;

Objective function for the Rating strategy:

$$min \sum_{i\in C} \sum_{j\in \Pi_i} \sum_{t\in T} D_{ij} * R_{ij} * x_{ijt} * r_j$$

3.1.3 Availability strategy

The Availability strategy takes an extra variable, the availability of each client, as input. When entering the system, each client presents their availability in timeslots. Then, the care providers that have the capacity to match the availability criteria are ranked by distance, and the closest populate Π.

Table 7 presents an overview of the three different strategies. For every strategy, the CPs populating Π must match the care type and insurance of the client. Also, all strategies improve the customer-based quality of the current system, however, the table compares the two types of quality of the strategies.

Strategy	How Π is populated	Technical/Customer-based quality
Basic	Π is populated with the CPs closest to client i.	The strategy mainly aims to optimise the technical quality.
Availability	Π is populated with the CPs closest to client i. Also, the client's availability must match the CP's capacity.	The strategy mainly aims to optimise technical quality. However, the inclusion of the availability constraint shows more consideration in the customer-based quality as well.
Rating	Π is populated with the CPs that have the smallest product of rating and distance.	The strategy mainly aims to optimise the customer-based quality. The rating variable significantly improves the attention to customer-based quality as the quality of care provided is part of the objective function.

Table 7. Key difference between three strategies

3.2 CP subject to client choice

The main aim of the mathematical model is to set a foundation for a solution that assigns a patient to a care provider in a certain time slot throughout the week. The model is constructed as an integer linear programming (ILP) problem. The main reason for selecting ILP to solve this problem is because of how the objective function of ILP embodies the aim of this model. In this case, there is a clear aim to minimise the costs of the process. The nature of the objective function in linear programming allows the researcher to accurately target and monitor the objective value of the system. Specifically, the goal is to minimise costs, hence travelling time. This can be expressed as a linear objective function. Moreover, constraints on insurance coverage, care type matching, and time slot assignments can all be expressed as linear inequalities or equalities.

Linear programming has been used in many cases in the field of transportation. LP models of the Travelling Salesman Person have been introduced by Öncan et al. (2009), Matai et al. (2010), Roberti and Toth (2012) and Cacchiani et al. (2020), amongst others. Additionally, allocation models are known to be solved by MILP. Hammam et al. (2024), use MILP to optimally allocate EV charging stations within a highway. Additionally, Karthikeyan and Potluri (2024) utilise MILP for both the allocation and routing part of their research. The focus of the paper is route planning for transporting patients within the hospital. MILP is used to allocate fairly the transport jobs by formulating optimization constraints with bounds for satisfying the secondary objectives.

As with any linear programming model, it has sets, parameters, variables, constraints, and an objective function. Below, an overview of the model is displayed. The sets contain the clients (C), the care providers (G), and the timeslots in a week (T). There are 296 clients, 27 care providers, and 12 timeslots in a week (two per day, Monday-Saturday), hence each set is limited to these numbers.

Another important component of the system is Π. Π is the set containing the CPs subject to client choice for a specific client. The quantity, as well as the criteria for how the subset populated, is the main difference factor between the different strategies and their variants. It is a crucial part of the system as the CPs that are available to the client can dictate the quality of service as well the efficiency of the system. Different priorities are mirrored on Π.

Three strategies were created to compare a diverse array of results. Initially, the simplest version of the model was constructed. This can be observed in two details of the model. First, Π is populated by care providers closest to each patient. This selection has been made to minimise the distance travelled for each client as much as possible. However, if emphasis had been placed more on the customer-based quality of the system, more freedom would have been given to the client. This approach was investigated by establishing a rating system for each care provided. The combination of distance and this rating system will provide a solution that combines the optimisation of both customer-based and technical quality.

3.3 Data context

The data used in the model contains information about the clients and care providers. Firstly, the clients' locations, type of care needed, and demand were provided for this research. Then, the care providers' location, type of care provided, and capacity per timeslot were used. The distance for every location is also provided. Lastly, for variations of the model that will later be explained, a random availability was generated for every client and a random rating from 1-5 for every care provider.

After carefully analysing the theoretical perspective, the mathematical model is constructed. The case of the care provider being subject to client choice is examined. The client will provide their location, demand (how many appointments per week), care type and insurance. Similarly, the caregivers provide their location, care type, insurance they work with, and capacity per time slot. Lastly, the distance from every client to all the caregivers is calculated. The model will use as input the data mentioned above to provide a complete solution to the problem. This data was provided by region X and has been anonymised to protect the privacy of the clients. The solution will include the care provider and timeslot that is most suitable for each client.

Tables 5 and 6 present an overview of the data that has been used to generate the results for the clients and CPs respectively.

Variables	Provided or generated	Description
Type of care and insurance	Provided	2-3 worded abbreviation combining the insurance type care variables (e.g. XXX)
Location	Provided	Generalised area code (e.g. AreaXXX).
Demand	Provided	How many times the patient required care per week.
Availability	Generated	Random timeslots the patient is available during the week.

Table 5. Data attributes of Client data

Variables	Provided or generated	Description
Type of care and insurance	Provided	2-3 worded abbreviation combining the insurance type care variables (e.g. XXX)
Location	Provided	Generalised area code (e.g. AreaXXX).
Capacity	Provided	The capacity the CP has each timeslot.
Rating	Generated	A random number 1-5 indicating the rating of each CP (1 being the best).

Table 6. Data attributes of Care provider data

Chapter 4: Results

The methodology and analysis of the results will be presented and assessed in this section of the report. The experimental setup is displayed in section 5.1. Sections 5.2 and 5.3 show the analysis and discussion of the results.

4.1 Experimental setup

There are three main strategies (Basic, Availability, and Rating). Each strategy has four variants. The variants are differentiated from each other by the number of CP that populate Π. Every strategy will be assessed by having 2-5 available CPs for the client to choose from. By examining those cases, there will be a definitive establishment of how different degrees of client freedom affect the efficiency of the model. The KPI that will be used to assess those variants is the total time travelled (in minutes).

The methodology for generating the quantitative results for each strategy begins with the solution of the ILP. After solving the ILP, a client allocation strategy is created, assigning the clients to the most appropriate CPs.

The assessment of those results will be done by using them as input into an algorithm that ultimately provides the routing strategy of the system. The transportation planning algorithm creates an initial solution, followed by an ALNS algorithm that optimises that solution. The principles of simulated annealing are employed to determine whether this new solution is accepted as the new solution. The researcher did not develop the transportation planning algorithm but was provided by their supervisor. Also, the algorithm is similar to the one developed by Weijzen (2023) in his thesis, "Optimizing transportation of clients for social care services".

The results were produced using 300 iterations and five repetitions Then, the mean of the five repetitions is calculated. That is the objective value for that timeslot. In order to calculate the time travelled within a week for each strategy, the objective values for the twelve timeslots are summed.

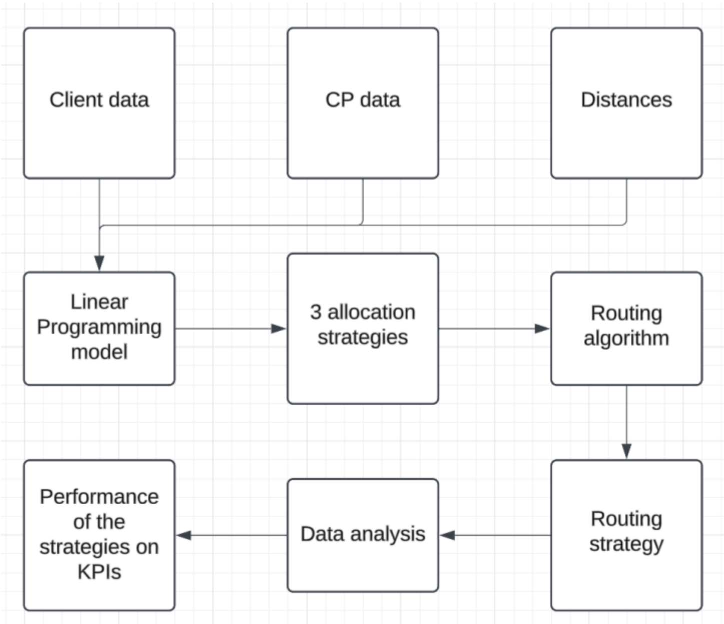

Figure 4. Overview of the result generation, application, and assessment

4.2 Result analysis

Initially, the goal was to make sure the results were stable and consistent. The timeslots were analysed individually. The performance of every variant's timeslot was assessed across all repetitions. To have consistent results on a weekly level, it was necessary to make sure the results were consistent on a timeslot level. The mean and standard deviation of every variant's timeslot's travel time were calculated. Based on the mean, the standard deviation and the sample size (the repetitions), a 97,5% Confidence Interval (CI) was created for each timeslot, as well as for the whole week. A 97,5% CI was selected because of the small sample size used in this case. The purpose of creating a CI was to ensure the number of outliers was kept to a minimum.

As seen in Appendix A, some objective values are outside the CI. Small sample sizes (n=5) are known to be more variable, which could lead to more data points falling outside the CI. Additionally, the data points outside the CI might be outliers, which are extreme values that do not follow the general trend of the data. Such outliers could result from the randomness aspect of the ALNS.

The performance of every variant will also be compared with a benchmark value of having a fixed CP. The CP selected will be the one closest to the client's location. Ideally, the benchmark would be the travelling time of the current strategy, however, the data required to calculate this value is not available. Hence, the benchmark value is **25.299,1**. This value is calculated from the Basic strategy. By having only one CP available for client choice, the closest CP is always allocated to every client.

Figures 4-6 display the comparison in performance of the variants of each strategy. In all three cases, the variant with the five CPs available performed the best. Also, it is important to note that in two (Basic and Availability) of the three models, there is a negative correlation between the degrees of freedom and time travelled. The exception to that is the variant of the Rating strategy with two CPs available to client choice. In that case, the objective value of that variant (Rating2 - 25.630,6) is smaller than that of the variant with three (26.081,0) and four (25.962,0) CPs available for client choice.

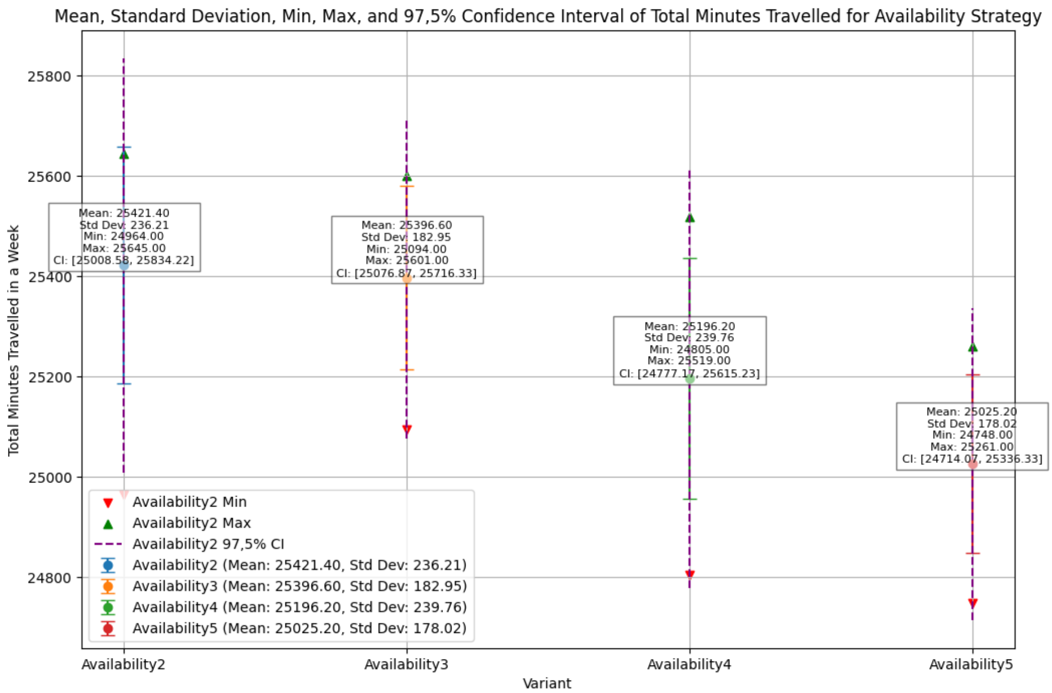

Figure 5. Availability variants weekly time travelled and important metrics.

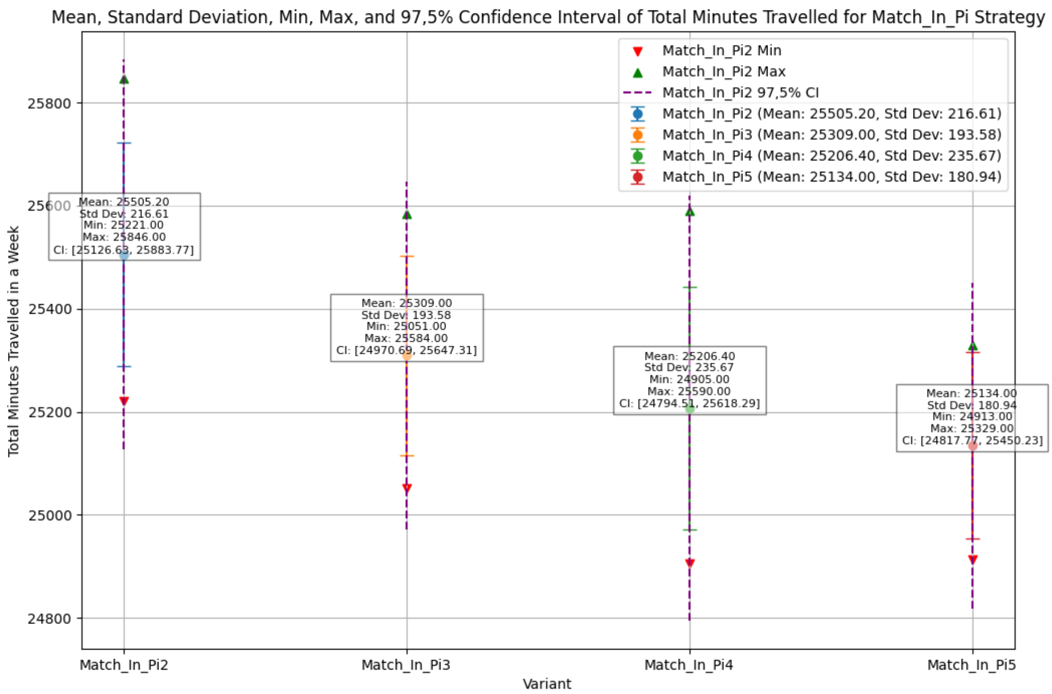

Figure 6. Basic strategy variants weekly time travelled and important metrics.

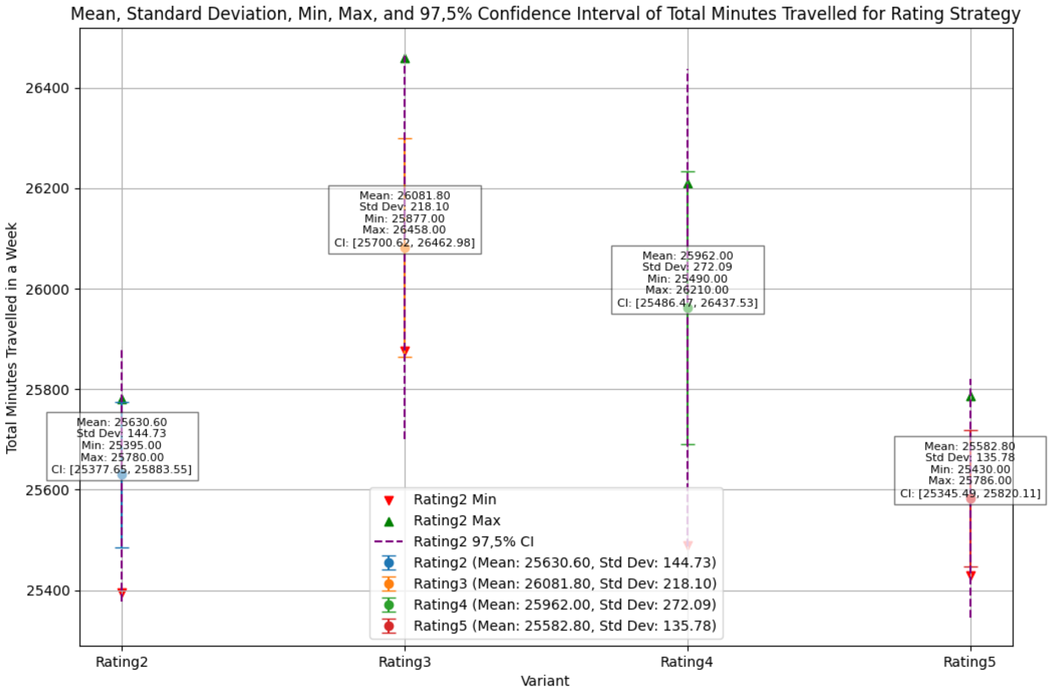

Figure 7. Rating strategy variants weekly time travelled and important metrics.

Figure 8 displays the comparison between the best-performing variants from each strategy. The strategy with the overall less time travelled is the Availability with five CPs subject to client choice strategy. This variant's objective value is 25.025,2. Additionally, the Basic's and Availability's best variants have a smaller objective value than the benchmark set (25.299,1). Rating5 has a higher objective value, which can most likely be because of the integration of the rating factor in the objective function of the model. In contrast with the other two strategies, the Rating strategy incorporates a variable that represents the customer-based quality of the system. Hence, it is expected that the technical quality is slightly compromised.

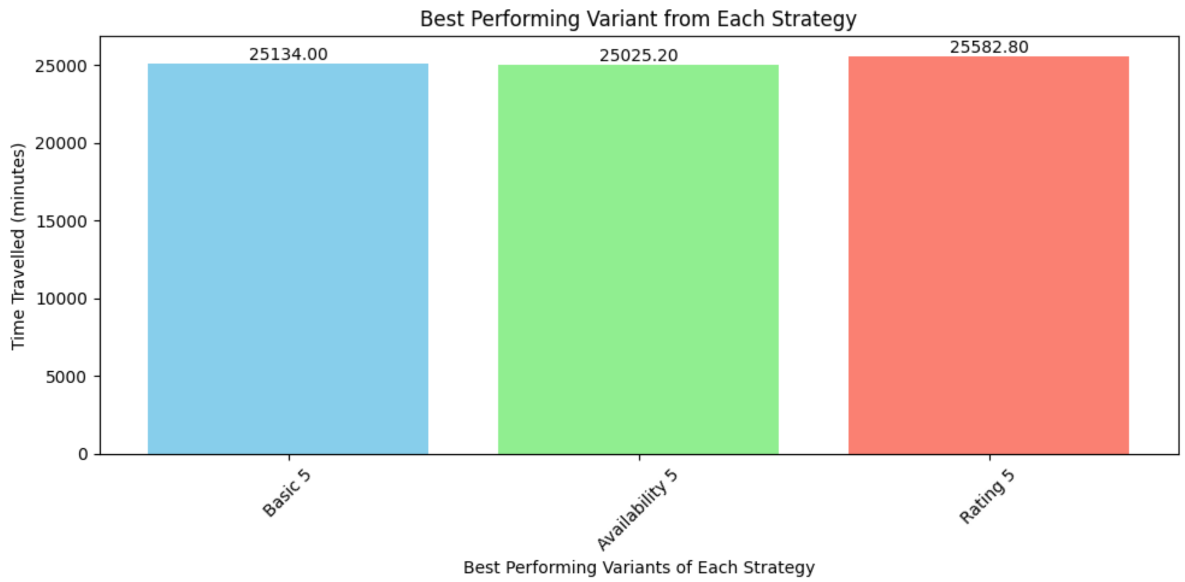

Figure 8. Best performing variants of each strategy

4.3 Discussion of results

The results presented provide significant insight into the relationship between the effectiveness of the model and the degrees of freedom of client choice. Each graph depicts the mean, standard deviation, and 97.5% confidence interval (CI) of total travel times for variants within the Availability, Basic, and Rating strategies. These metrics enable the assessment of the performance of each variant as well as the variability across different strategies.

The Availability strategy shows a clear pattern of decreasing travel times throughout the different degrees of freedom. This indicates that Availability5 is the most efficient variant, achieving the lowest travel time and suggesting better performance and an optimised client allocation strategy. The standard deviation values indicate varying levels of performance amongst the repetitions. However, Availability 5 has a relatively lower standard deviation, which implies more consistent performance compared to other variants.

The Basic strategy shows a similar correlation between the travel times and degrees of freedom, with Basic 5 having the lowest mean value. The standard deviation for the strategy variants is comparable across all the models, which suggests that the level of variability in performance is relatively similar. The confidence interval lines are relatively close, indicating the observed differences in performance between these variants might not be highly significant. Nonetheless, the decreasing trend in mean values suggests an improvement in performance as the variant number increases.

The rating strategy shows some inconsistency in the pattern of negative correlation between the degrees of freedom and mean travel times. Rating 2 has the second smallest mean out of the variants, behind only Rating 5. This shows that the performance of the strategy is more volatile compared to the others. That would make sense however, as it is the only strategy that the CPs available for client choice are not solely selected based on the distance between them and the client. Hence, other variables could affect the objective value, the main one being the rating of the CPs. A high CP rating could affect the technical quality of the system, as it could potentially prioritise them over a CP closer to the client. However, that would increase the customer-based quality of the system.

An important conclusion from the results is that the most time-efficient strategy combines some aspects of customer-based quality as well. The Availability strategy lets the client present their availability and assigns them to a timeslot within that availability. In contrast with the two other strategies, where the client was assigned to the timeslot that was the most suitable for the objective function of the model.

Additionally, the strategy with arguably the most attention to customer-based quality, the Rating strategy, is not considerably less effective than the others, marking only a 2% increase in time travelled. This strategy embodies better real-life scenarios where patients consider the quality of care as important as the time or distance travelled.

A recommendation for future research would be to combine the Availability and Rating strategy. The model would consider the availability of each client as well as the quality of care every CP provides. By combining both of those strategies, the customer-based quality of the system would increase, while its technical quality would not potentially decrease by much, if not at all.

4.4 Critical reflection

In this paragraph, a critical reflection of the analysis will follow. The key points and decisions will be reflected, based on the results, as well as the theory supporting them.

Firstly, the main decision for the research was to have the CP subject to client choice. The reasoning behind this was the lack of research made investigating this situation. The papers that include some form of client choice in a transportation context have the timeslot, mean of transportation, or type of care subject to CC. Ultimately, the improvement in travel time with the increase of CPs available proves that this decision was towards the right direction.

Then, a point this research could further improve is to maximise the KPIs that the client allocation results were assessed from. Currently, the only performance index in the result assessment is travel time. As the routing algorithm that calculates the travel time was provided by the researcher's supervisor, it was outside the scope of this research to make any modifications. For further investigation, the travelling distance, vehicles used, and satisfaction rates by the customers, are all important KPIs that could be considered. Within the scope of this research, it was not possible to do so. Moreover, it would be beneficial if the value optimised in the objective function of the ILP was present as a KPI in the final result assessment. That would provide some clarity and continuity in the research. In section 4.1, the ILP model is introduced. The objective value in that model is the travelling distance. However, the KPI that the results of the ILP are judged is the travelling time.

Lastly, another point this research could be further elaborated on is the repetitions completed in the routing algorithm. Currently, five repetitions occur for every timeslot. This resulted in some objective values being outside the 97,5% CI set by the researcher. However, some of them are outliers, meaning that the value is extremely outside the bounds of expected and logical. Hence, these values should mostly be ignored. The Availability and Rating strategies show more consistent results than the basic strategy, which is somewhat unexpected. The two former strategies have an element of randomness (random availability and rating), hence, were expected to provide the most inconsistent results. Nevertheless, the research could potentially benefit from more repetitions to stabilise the results and increase precision. However, the goal of this research is to identify the relationship between degrees of freedom of client choice and technical efficiency. This research has indicated a negative correlation between those variables.

Chapter 5: Conclusion

This thesis investigates the impact of various degrees of freedom of client choice on the transportation of patients to social care providers. The research aims to improve the customer-based quality of the system while also increasing the technical efficiency. The motivation for the research was the concerns of financial sustainability for the current strategy of the X region. A strategy that was proposed by another paper was to allocate the clients to the CP closest to them. This research aims to find a balance between them by including both technical and customer-based variables in the objective function.

In the literature, there were not many similar contexts present. An SLR was performed to ensure that that was indeed the case. The main question that the SLR aimed to answer was how client choice was known to be modelled in a DAR system. CC was hardly ever investigated within the context of client transportation. That provided some critical liberty to the research. After the CP was selected as the variable for CC, the ILP model was introduced. The ILP was a client allocation model that allocated all patients to a suitable CP and timeslot. It took into consideration all of the real-life constraints the context of the research has set. The objective function was to minimise the distance travelled. Three variations of the model emerged. Hence, the three strategies; Basic, Availability, and Rating strategy.

The key factor that differentiates these models is the criteria upon which CPs are available for CC. The Basic model provides the client with the CPs closest to them. The Availability model introduces a new variable, the availability of the client. The variable contains randomly generated timeslots for every client. The added constraint of the model is that the capacity of the CP must match the client's availability. Lastly, the Rating strategy integrated the quality of care provided by adding the rating of CPs as a variable. Each CP has a rating of 1-5 (1 being the best) randomly generated. Then, the CPs available for the client are those with smaller products of rating and distance. Each strategy had four variants, based on the number of CPs available for the client to choose from, from 2-5.

After the ILP solves the allocation, they are assessed by being used as input into a routing algorithm. That algorithm, ultimately, calculates the travelling time of a timeslot. Following, those values were assessed on stability, consistency and accuracy by constructing confidence intervals for every timeslot, and later, for the whole week. The objective values of the timeslots in a week are summed, and these values are compared with each other to identify the optimal strategy. Further, the values are compared to the benchmark value. This benchmark value is the travelling time in a week while every client has a fixed CP, the one closest to their location.

The best-performing strategy proved to be **the Availability with five CPs available** with a travelling time of 25.025,2 minutes. Moreover, this research indicated the degrees of freedom of client choice are negatively correlated with travelling time. The only exception was the Rating strategy with two CPs available, which had a smaller travelling time than the variant of the same strategy with three and four CPs available. To conclude, integrating client choice in the client allocation process of a patient transportation system improved the technical and customer-based quality of the system.

5.1 Outlook and Recommendations

This section outlines a brief summary of findings, considerations for future application, and some recommendations for future research.

Although this research did not have the goal of providing managerial recommendations to an organisation, several insights can be gained for similar issues. The thesis aimed to identify the trade-off between customer-based and technical quality in the client allocation process of a DARP. Three strategies were developed. Each one had emphasis on different types of quality (Shortest distance, Rating), with one emphasising on both (Availability). Their technical quality was assessed by travelling distance. In contrast, the customer-based quality by the degrees of freedom a client has in the process, as well as some other variables in the mathematical model (rating and availability). After analysing the results of that model, a negative correlation between the two types of qualities was indicated.

The validity of the results was then assessed by calculating the standard deviation and confidence intervals of their performance. Even though there were some outliers and some cases proved to be quite inconsistent, the majority of repetitions were within the acceptable confidence interval.

However, the validity of the research is not fully assured. The internal validity is achieved, but the external validity remains inconclusive. Internal validity, as stated by Patino and Ferreira (2018), refers to how the observed results represent the truth in the population we are studying. The results, as mentioned in section 5.3, have remained consistent and true. Hence, internal validity is established. External validity asks the question of whether the study results apply to similar patients in different settings or not (Patino & Ferreira, 2018). In this case, the results are dependent on several different factors such as insurance and government policies, care provider capacities, client preference, etc.. Hence, scaling the results to different contexts does not reassure the same results. For future application, all those factors must be considered before applying the methods of this research.

Moreover, for future applications, the reccomendation would be to integrate client choice of some form into the context of a patient transportation system. However, it is important to consider the sociopolitical, and insurance-policy landscape of the system. After the model has been adapted to those modifications, one, or a combination of the strategies mentioned could have significant benefits in the performance of the system in the two types of quality. Additionally, it is crucial for an organisations to clarify the spcific goals of their intervention. The type of quality that is aimed to be improved should be identified. Then, a strategy should be picked based on that selection and the association between strategy and type of quality mentioned previously in this section.

Some recommendations for future research would include the following points. (1) Analysing how the strategies presented in this research affect care provider behavior. In this research the client's preferences were mainly the driving force of decision making. However, this may lead to the care providers overworking, alternating their schedule, or generally affect them in a harmful way. Interviews, questionnaires, or any other quality data gathering tool could be applied to investigate what affect would the application of the results of this research would have on the care providers of the region. Then, the results could be confirmed, altered, or maybe even disregarded completely.

(2) The costs of the process, and how the strategies affect them could be implemented in the research. The costs are a crucial KPI for all stakeholders involved (clients, CPs, region). Hence, integrating the costs in the mathematical model could have significant benefits. It could be in a form of objective function or/and constraint. Having the transportation costs as the objective value of the ILP could potentially increase the urgency of the research. Currently, the assumption that shorter travelling distance and time correlate to less travelling costs. Eliminating that assumption and directly linking the strategies to the costs could emphasize the urgency of the research for future applications.

(3) The assessment of the results indicated a negative correlation between the degrees of freedom of client choice and the objective value for technical quality. The degrees of freedom have been limited to a maximum of five CPs subject to client choice. By applying this logic, having more CPs for the client to choose from, could increase the performance even more. On the other hand, there could a specific number of CPs that is optimal, and after that, the performance deteriorates. All that could be investigated more in future research.

(4) Combining the Availability and Rating strategy could create a solution that merges the best of the types of quality. The Availability strategy performed best in the technical quality assessment. On the other hand, the Rating strategy implements more the customer-based quality, as the quality of care provided is part of the objective function. Creating a strategy that has the availability of the clients and rating of CPs as a variable, could combine the performance of the two strategies in their respective type of quality.

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Appendices

Appendix A: Objective values outside the Confidence intervals

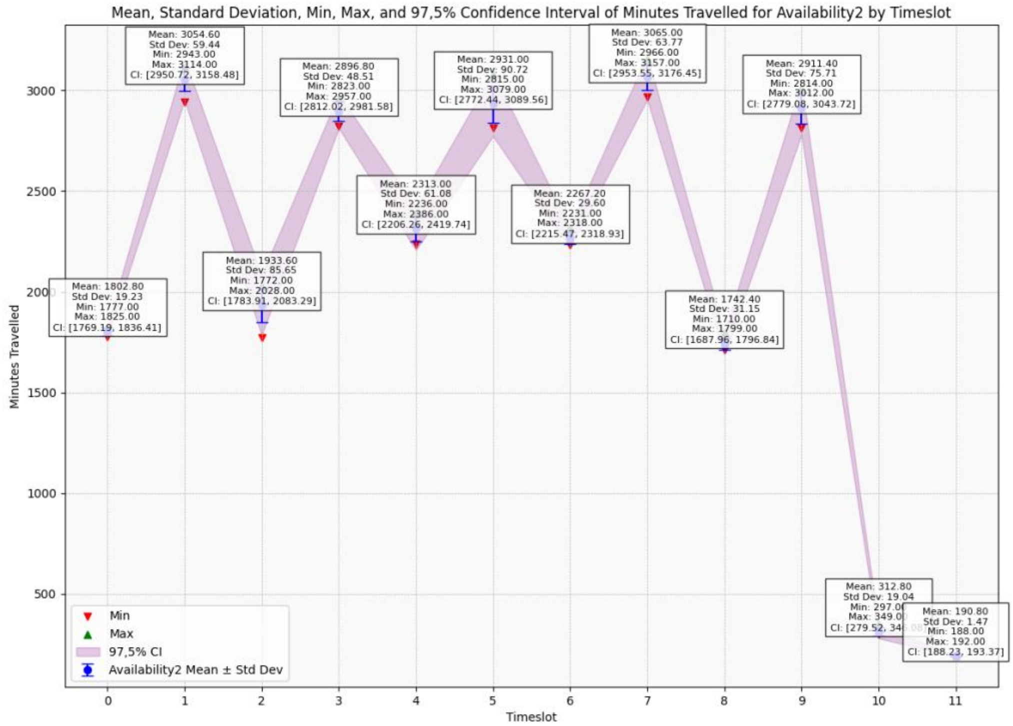
Rating2 has no values outside the CI.
Rating3 has no values outside the CI.
Rating4 has no values outside the CI.
Rating5 has no values outside the CI.
Total number of values outside the CI: 0
Rating2 Timeslot 0 has no values outside the CI.
Rating2 Timeslot 1 has no values outside the CI.
Rating2 Timeslot 2 has values outside the CI: [2188.0]
Rating2 Timeslot 3 has no values outside the CI.
Rating2 Timeslot 4 has no values outside the CI.
Rating2 Timeslot 5 has no values outside the CI.
Rating2 Timeslot 6 has values outside the CI: [1847.0]
Rating2 Timeslot 7 has no values outside the CI.
Rating2 Timeslot 8 has no values outside the CI.
Rating2 Timeslot 9 has no values outside the CI.
Rating2 Timeslot 10 has no values outside the CI.
Rating2 Timeslot 11 has no values outside the CI.
Rating3 Timeslot 0 has no values outside the CI.
Rating3 Timeslot 1 has values outside the CI: [2627.0]
Rating3 Timeslot 2 has no values outside the CI.
Rating3 Timeslot 3 has no values outside the CI.
Rating3 Timeslot 4 has no values outside the CI.
Rating3 Timeslot 5 has values outside the CI: [3241.0]
Rating3 Timeslot 6 has no values outside the CI.
Rating3 Timeslot 7 has no values outside the CI.
Rating3 Timeslot 8 has values outside the CI: [1782.0]
Rating3 Timeslot 9 has values outside the CI: [3067.0]

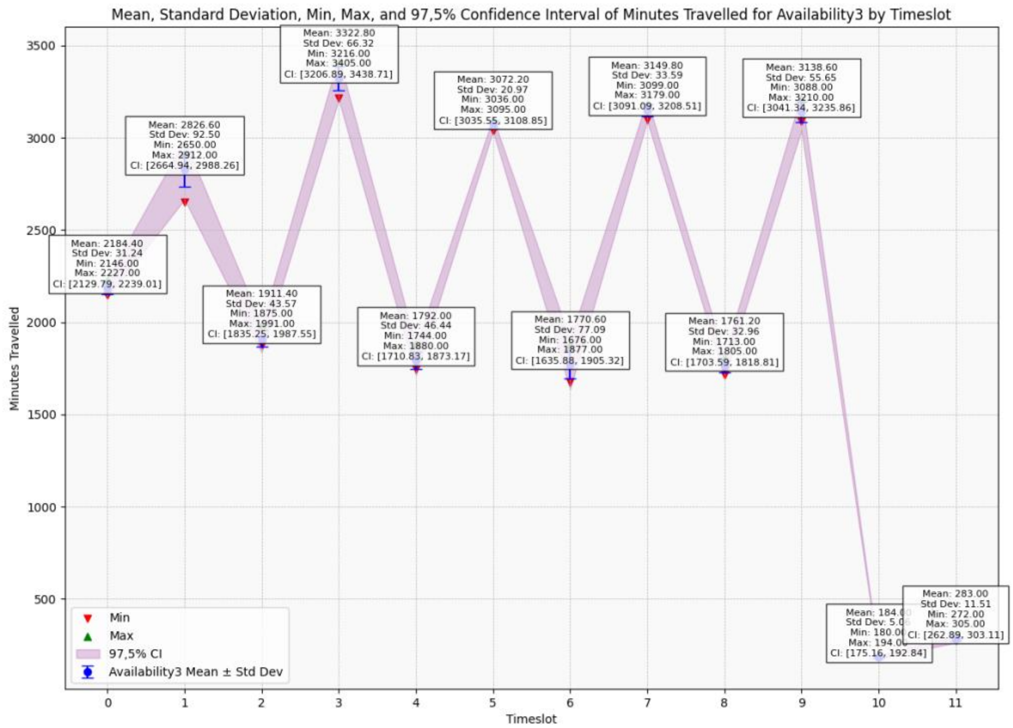
Rating3 Timeslot 10 has no values outside the CI.
Rating3 Timeslot 11 has no values outside the CI.
Rating4 Timeslot 0 has no values outside the CI.
Rating4 Timeslot 1 has no values outside the CI.
Rating4 Timeslot 2 has no values outside the CI.
Rating4 Timeslot 3 has no values outside the CI.
Rating4 Timeslot 4 has no values outside the CI.
Rating4 Timeslot 5 has no values outside the CI.
Rating4 Timeslot 6 has no values outside the CI.
Rating4 Timeslot 7 has values outside the CI: [3510.0]
Rating4 Timeslot 8 has values outside the CI: [2425.0]
Rating4 Timeslot 9 has values outside the CI: [3165.0]
Rating4 Timeslot 10 has no values outside the CI.
Rating4 Timeslot 11 has no values outside the CI.
Rating5 Timeslot 0 has no values outside the CI.
Rating5 Timeslot 1 has no values outside the CI.
Rating5 Timeslot 2 has no values outside the CI.
Rating5 Timeslot 3 has no values outside the CI.
Rating5 Timeslot 4 has no values outside the CI.
Rating5 Timeslot 5 has values outside the CI: [3160.0]
Rating5 Timeslot 6 has values outside the CI: [2142.0]
Rating5 Timeslot 7 has no values outside the CI.
Rating5 Timeslot 8 has no values outside the CI.
Rating5 Timeslot 9 has no values outside the CI.
Rating5 Timeslot 10 has no values outside the CI.
Rating5 Timeslot 11 has values outside the CI: [196.0]
Availability2 has values outside the CI: [24964.0]
Availability3 has no values outside the CI.
Availability4 has no values outside the CI.
Availability5 has no values outside the CI.
Total number of values outside the CI: 1
Availability2 Timeslot 0 has no values outside the CI.
Availability2 Timeslot 1 has values outside the CI: [2943.0]
Availability2 Timeslot 2 has values outside the CI: [1772.0]
Availability2 Timeslot 3 has no values outside the CI.
Availability2 Timeslot 4 has no values outside the CI.
Availability2 Timeslot 5 has no values outside the CI.
Availability2 Timeslot 6 has no values outside the CI.
Availability2 Timeslot 7 has no values outside the CI.
Availability2 Timeslot 8 has values outside the CI: [1799.0]
Availability2 Timeslot 9 has no values outside the CI.
Availability2 Timeslot 10 has values outside the CI: [349.0]
Availability2 Timeslot 11 has values outside the CI: [188.0]
Availability3 Timeslot 0 has no values outside the CI.
Availability3 Timeslot 1 has values outside the CI: [2650.0]
Availability3 Timeslot 2 has values outside the CI: [1991.0]
Availability3 Timeslot 3 has no values outside the CI.
Availability3 Timeslot 4 has values outside the CI: [1880.0]
Availability3 Timeslot 5 has no values outside the CI.
Availability3 Timeslot 6 has no values outside the CI.

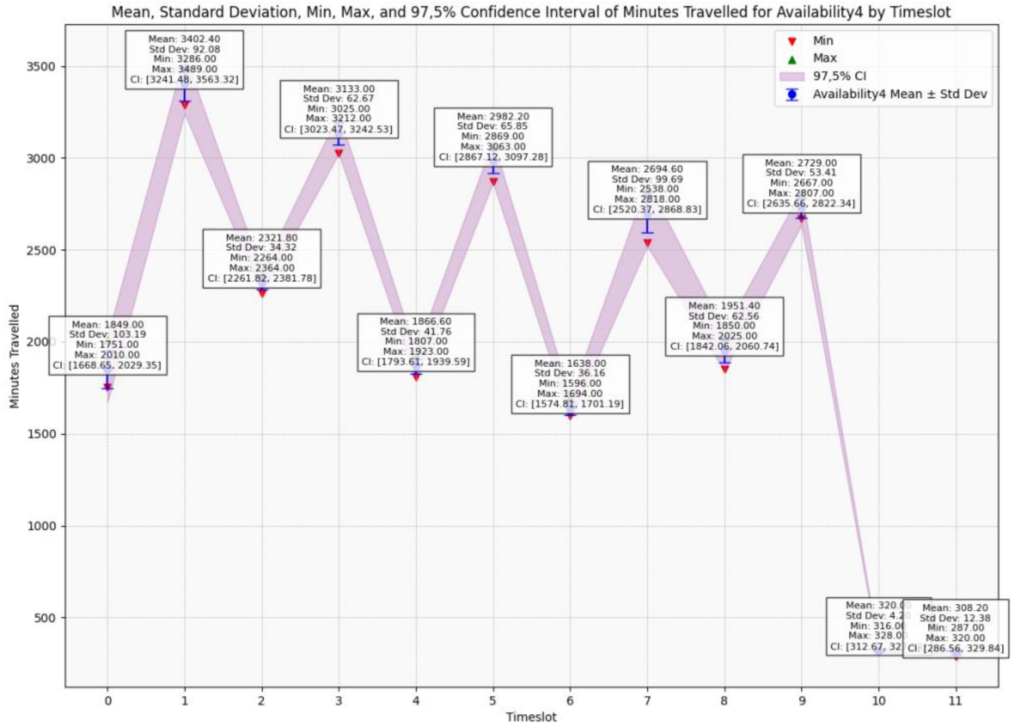
Availability3 Timeslot 7 has no values outside the CI.
Availability3 Timeslot 8 has no values outside the CI.
Availability3 Timeslot 9 has no values outside the CI.
Availability3 Timeslot 10 has values outside the CI: [194.0]
Availability3 Timeslot 11 has values outside the CI: [305.0]
Availability4 Timeslot 0 has no values outside the CI.
Availability4 Timeslot 1 has no values outside the CI.
Availability4 Timeslot 2 has no values outside the CI.
Availability4 Timeslot 3 has no values outside the CI.
Availability4 Timeslot 4 has no values outside the CI.
Availability4 Timeslot 5 has no values outside the CI.
Availability4 Timeslot 6 has no values outside the CI.
Availability4 Timeslot 7 has no values outside the CI.
Availability4 Timeslot 8 has no values outside the CI.
Availability4 Timeslot 9 has no values outside the CI.
Availability4 Timeslot 10 has values outside the CI: [328.0]
Availability4 Timeslot 11 has no values outside the CI.
Availability5 Timeslot 0 has values outside the CI: [1808.0]
Availability5 Timeslot 1 has values outside the CI: [3068.0]
Availability5 Timeslot 2 has values outside the CI: [1940.0]
Availability5 Timeslot 3 has values outside the CI: [2611.0]
Availability5 Timeslot 4 has values outside the CI: [2023.0]
Availability5 Timeslot 5 has values outside the CI: [2758.0]
Availability5 Timeslot 6 has no values outside the CI.
Availability5 Timeslot 7 has no values outside the CI.
Availability5 Timeslot 8 has values outside the CI: [1551.0]
Availability5 Timeslot 9 has no values outside the CI.
Availability5 Timeslot 10 has values outside the CI: [670.0]
Availability5 Timeslot 11 has no values outside the CI.
Match_In_Pi2 has no values outside the CI.
Match_In_Pi3 has no values outside the CI.
Match_In_Pi4 has no values outside the CI.
Match_In_Pi5 has no values outside the CI.
Total number of values outside the CI: 0
Match_In_Pi2 Timeslot 0 has no values outside the CI.
Match_In_Pi2 Timeslot 1 has values outside the CI: [2733.0]
Match_In_Pi2 Timeslot 2 has no values outside the CI.
Match_In_Pi2 Timeslot 3 has no values outside the CI.
Match_In_Pi2 Timeslot 4 has no values outside the CI.
Match_In_Pi2 Timeslot 5 has no values outside the CI.
Match_In_Pi2 Timeslot 6 has values outside the CI: [2114.0]
Match_In_Pi2 Timeslot 7 has values outside the CI: [3052.0]
Match_In_Pi2 Timeslot 8 has values outside the CI: [1536.0]
Match_In_Pi2 Timeslot 9 has no values outside the CI.
Match_In_Pi2 Timeslot 10 has no values outside the CI.
Match_In_Pi2 Timeslot 11 has no values outside the CI.
Match_In_Pi3 Timeslot 0 has values outside the CI: [2308.0]
Match_In_Pi3 Timeslot 1 has no values outside the CI.
Match_In_Pi3 Timeslot 2 has values outside the CI: [2341.0]
Match_In_Pi3 Timeslot 3 has no values outside the CI.

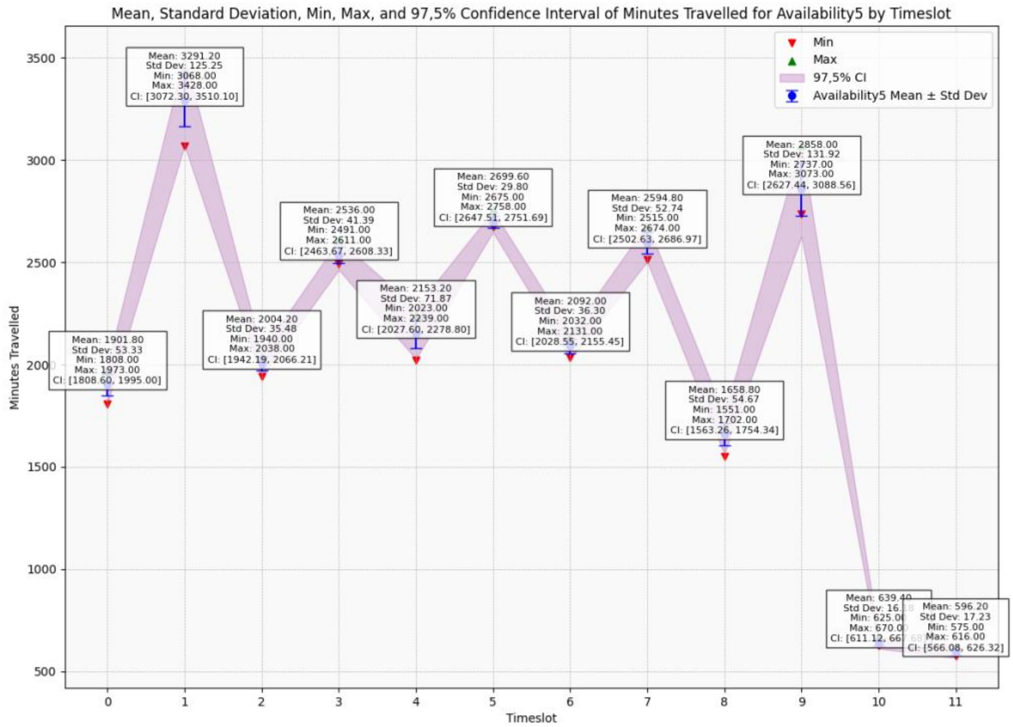
Match_In_Pi3 Timeslot 4 has no values outside the CI.
Match_In_Pi3 Timeslot 5 has values outside the CI: [2257.0]
Match_In_Pi3 Timeslot 6 has values outside the CI: [1965.0]
Match_In_Pi3 Timeslot 7 has values outside the CI: [3448.0]
Match_In_Pi3 Timeslot 8 has no values outside the CI.
Match_In_Pi3 Timeslot 9 has values outside the CI: [2870.0]
Match_In_Pi3 Timeslot 10 has no values outside the CI.
Match_In_Pi3 Timeslot 11 has no values outside the CI.
Match_In_Pi4 Timeslot 0 has values outside the CI: [1859.0]
Match_In_Pi4 Timeslot 1 has no values outside the CI.
Match_In_Pi4 Timeslot 2 has values outside the CI: [2271.0]
Match_In_Pi4 Timeslot 3 has values outside the CI: [3091.0]
Match_In_Pi4 Timeslot 4 has values outside the CI: [1479.0]
Match_In_Pi4 Timeslot 5 has no values outside the CI.
Match_In_Pi4 Timeslot 6 has values outside the CI: [2286.0]
Match_In_Pi4 Timeslot 7 has no values outside the CI.
Match_In_Pi4 Timeslot 8 has no values outside the CI.
Match_In_Pi4 Timeslot 9 has values outside the CI: [3305.0]
Match_In_Pi4 Timeslot 10 has values outside the CI: [357.0]
Match_In_Pi4 Timeslot 11 has no values outside the CI.
Match_In_Pi5 Timeslot 0 has no values outside the CI.
Match_In_Pi5 Timeslot 1 has no values outside the CI.
Match_In_Pi5 Timeslot 2 has no values outside the CI.
Match_In_Pi5 Timeslot 3 has no values outside the CI.
Match_In_Pi5 Timeslot 4 has values outside the CI: [2593.0]
Match_In_Pi5 Timeslot 5 has no values outside the CI.
Match_In_Pi5 Timeslot 6 has no values outside the CI.
Match_In_Pi5 Timeslot 7 has no values outside the CI.
Match_In_Pi5 Timeslot 8 has no values outside the CI.
Match_In_Pi5 Timeslot 9 has no values outside the CI.
Match_In_Pi5 Timeslot 10 has no values outside the CI.
Match_In_Pi5 Timeslot 11 has no values outside the CI.

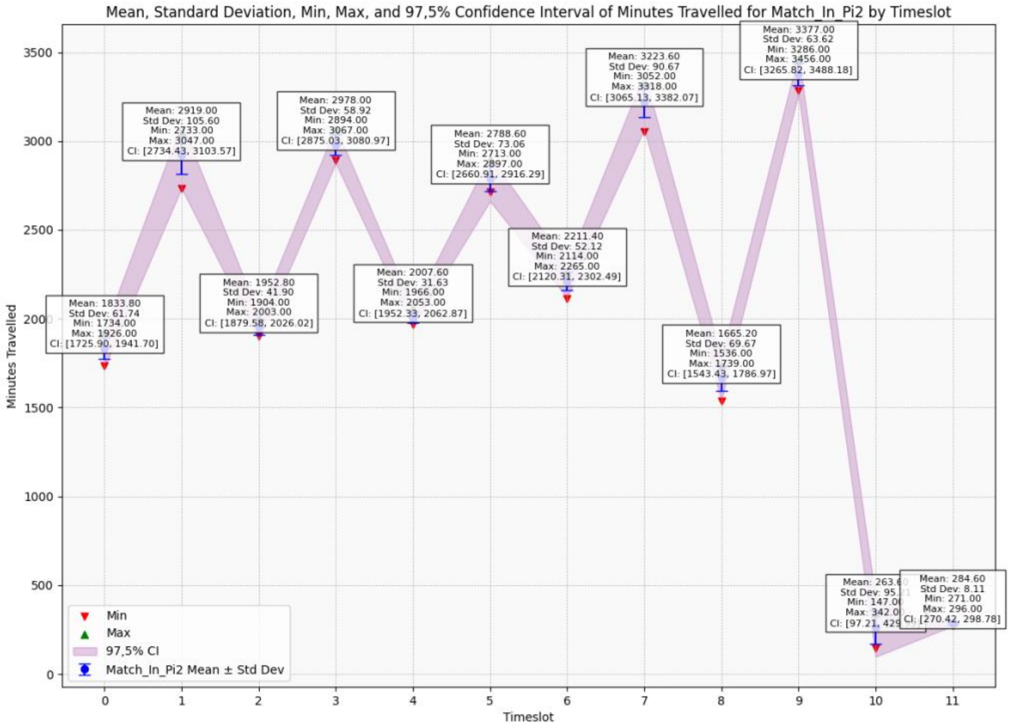
Appendix B. Mean, standard deviation, and CI of all strategies per timeslot

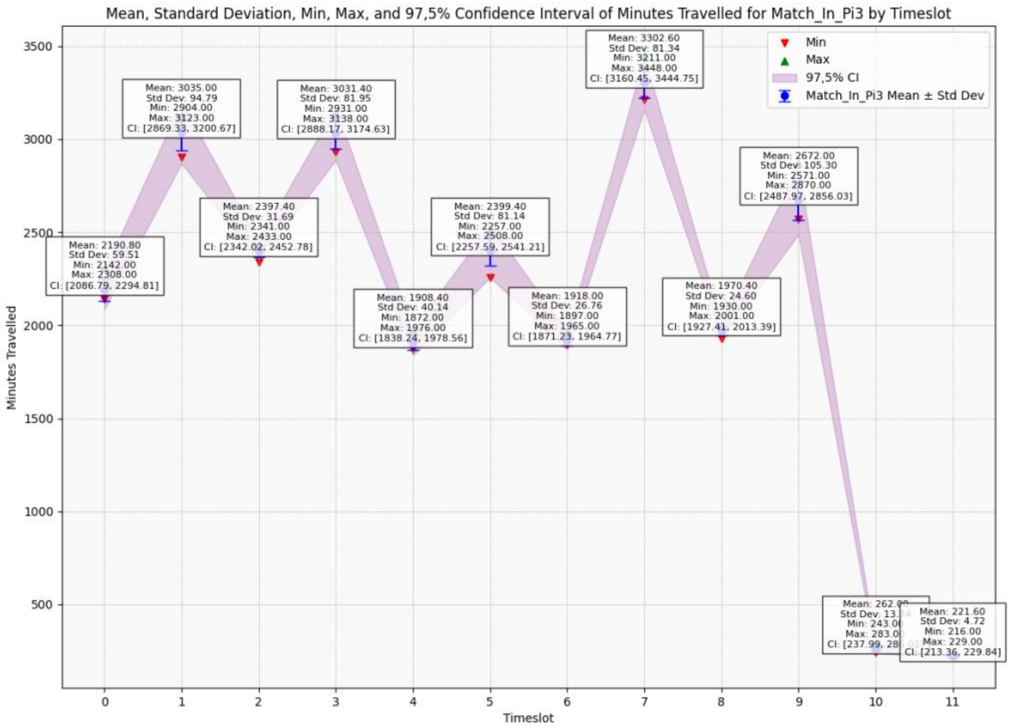


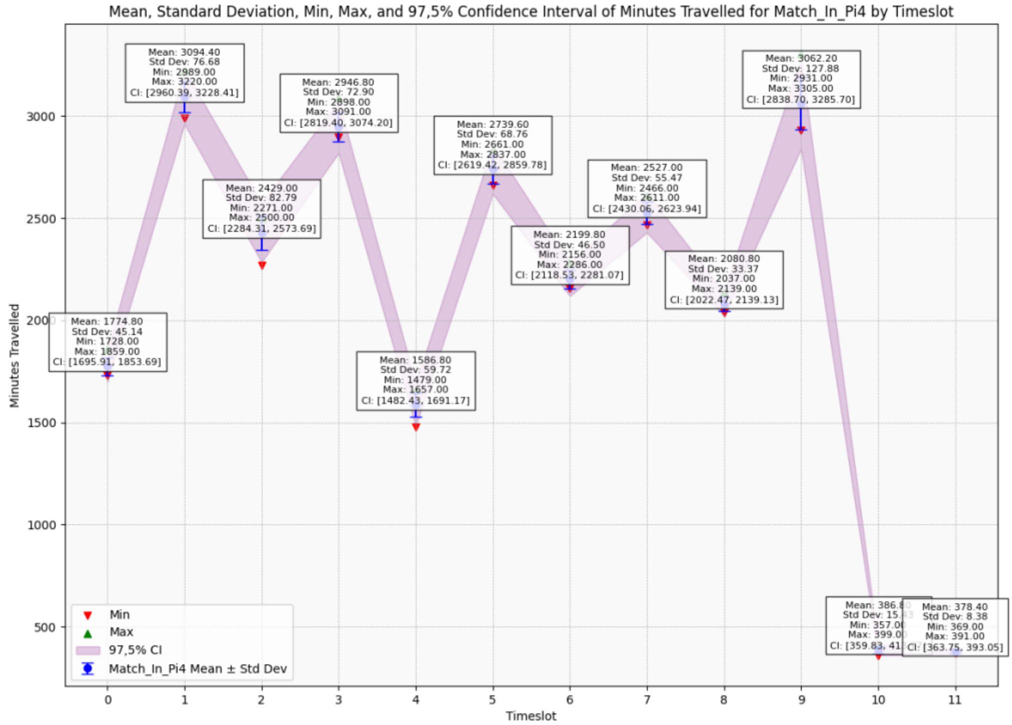


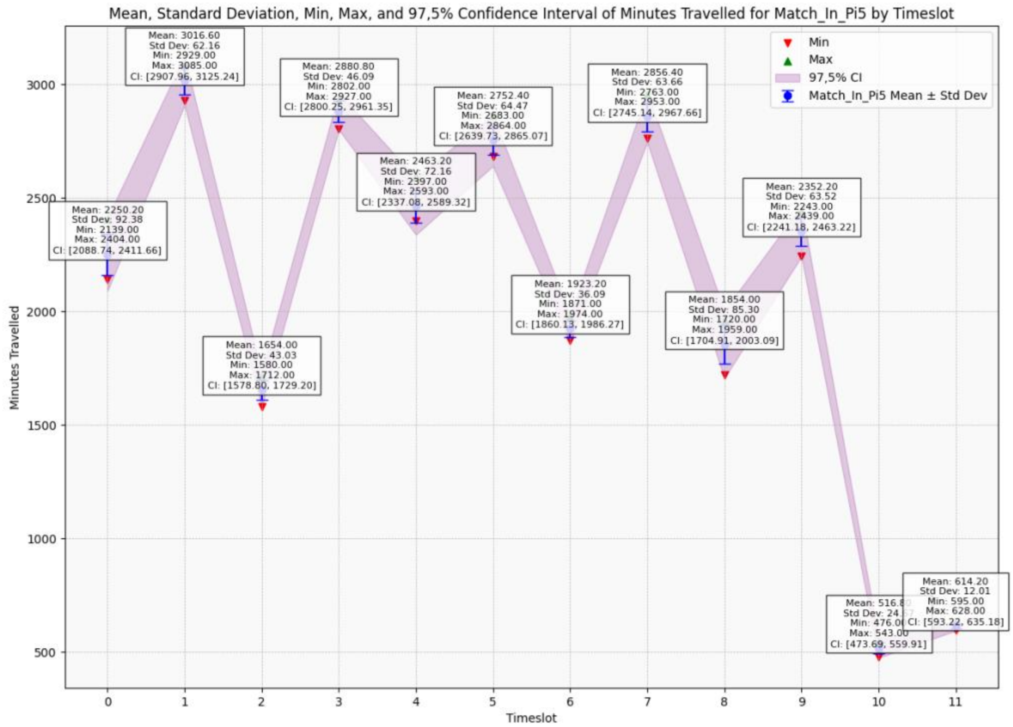

Mean, Standard Deviation, Min, Max, and 97,5% Confidence Interval of Minutes Travelled for Availability4 by Timeslot
Min
Max
97,5% CI
Availability4 Mean ± Std Dev
Minutes Travelled
Timeslot
Mean: 1849.00 Std Dev: 103.19 Min: 1751.00 Max: 2010.00 CI: [1668.65, 2029.35]
Mean: 3402.40 Std Dev: 92.08 Min: 3286.00 Max: 3489.00 CI: [3241.48, 3563.32]
Mean: 2321.80 Std Dev: 34.32 Min: 2264.00 Max: 2364.00 CI: [2261.82, 2381.78]
Mean: 3133.00 Std Dev: 62.67 Min: 3025.00 Max: 3212.00 CI: [3023.47, 3242.53]
Mean: 1866.60 Std Dev: 41.76 Min: 1807.00 Max: 1923.00 CI: [1793.61, 1939.59]
Mean: 2982.20 Std Dev: 65.85 Min: 2869.00 Max: 3063.00 CI: [2867.12, 3097.28]
Mean: 1638.00 Std Dev: 36.16 Min: 1596.00 Max: 1694.00 CI: [1574.81, 1701.19]
Mean: 2694.60 Std Dev: 99.69 Min: 2538.00 Max: 2818.00 CI: [2520.37, 2868.83]
Mean: 1951.40 Std Dev: 62.56 Min: 1850.00 Max: 2025.00 CI: [1842.06, 2060.74]
Mean: 2729.00 Std Dev: 53.41 Min: 2667.00 Max: 2807.00 CI: [2635.66, 2822.34]
Mean: 308.20 Std Dev: 12.38 Min: 287.00 Max: 320.00 CI: [286.56, 329.84]

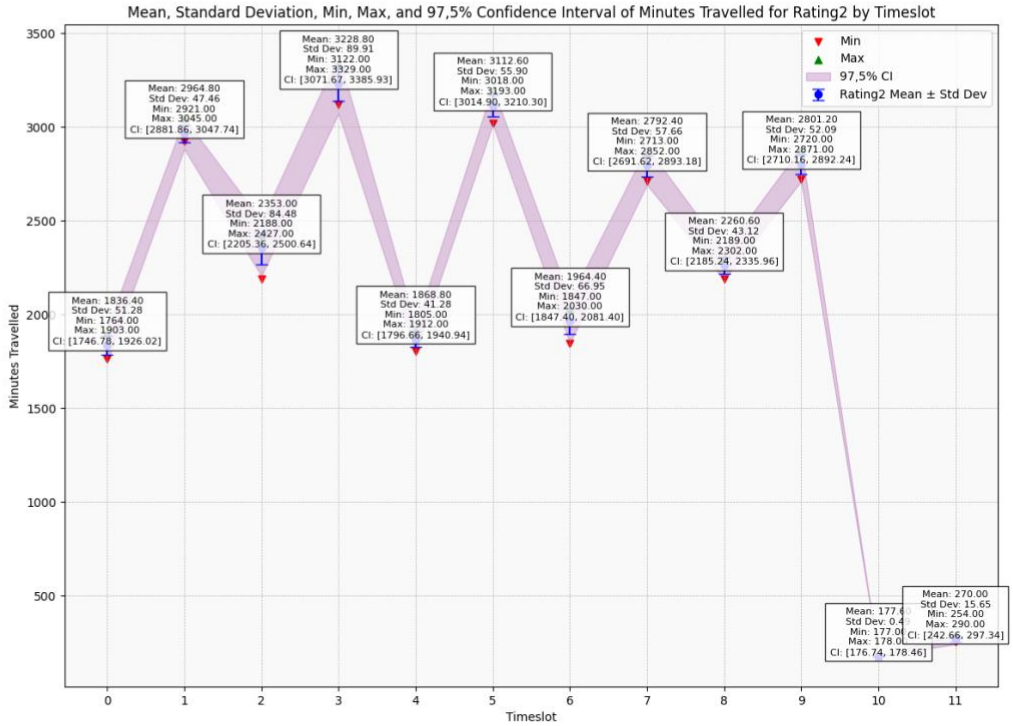

Mean, Standard Deviation, Min, Max, and 97,5% Confidence Interval of Minutes Travelled for Availability5 by Timeslot
Min
Max
97,5% CI
Availability5 Mean ± Std Dev
Minutes Travelled
Timeslot
Mean: 1901.80 Std Dev: 53.33 Min: 1808.00 Max: 1973.00 CI: [1808.60, 1995.00]
Mean: 3291.20 Std Dev: 125.25 Min: 3068.00 Max: 3428.00 CI: [3072.30, 3510.10]
Mean: 2004.20 Std Dev: 35.48 Min: 1940.00 Max: 2038.00 CI: [1942.19, 2066.21]
Mean: 2536.00 Std Dev: 41.39 Min: 2491.00 Max: 2611.00 CI: [2463.67, 2608.33]
Mean: 2153.20 Std Dev: 71.87 Min: 2023.00 Max: 2239.00 CI: [2027.60, 2278.80]
Mean: 2699.60 Std Dev: 29.80 Min: 2675.00 Max: 2758.00 CI: [2647.51, 2751.69]
Mean: 2092.00 Std Dev: 36.30 Min: 2032.00 Max: 2131.00 CI: [2028.55, 2155.45]
Mean: 2594.80 Std Dev: 52.74 Min: 2515.00 Max: 2674.00 CI: [2502.63, 2686.97]
Mean: 1658.80 Std Dev: 54.67 Min: 1551.00 Max: 1702.00 CI: [1563.26, 1754.34]
Mean: 2858.00 Std Dev: 131.92 Min: 2737.00 Max: 3073.00 CI: [2627.44, 3088.56]
Mean: 596.20 Std Dev: 17.23 Min: 575.00 Max: 616.00 CI: [566.08, 626.32]


Mean, Standard Deviation, Min, Max, and 97,5% Confidence Interval of Minutes Travelled for Match_In_Pi2 by Timeslot
Minutes Travelled
Timeslot
Min
Max
97,5% CI
Match_In_Pi2 Mean ± Std Dev

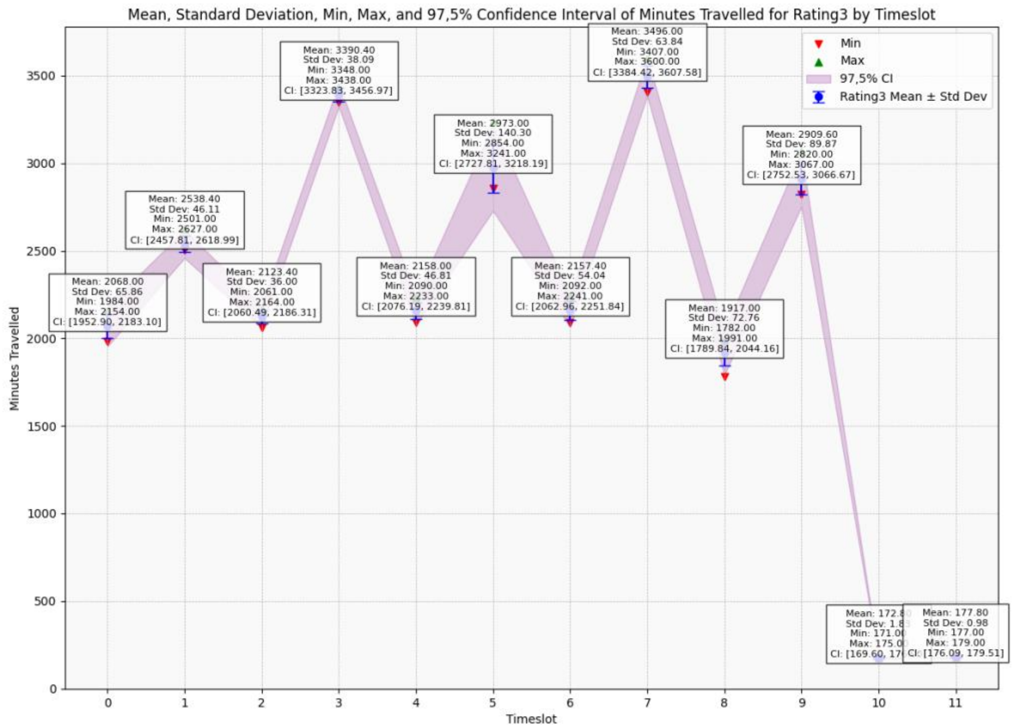

Mean, Standard Deviation, Min, Max, and 97,5% Confidence Interval of Minutes Travelled for Match_In_Pi3 by Timeslot
Minutes Travelled
Timeslot
Min
Max
97,5% CI
Match_In_Pi3 Mean ± Std Dev


Mean, Standard Deviation, Min, Max, and 97,5% Confidence Interval of Minutes Travelled for Match_In_Pi4 by Timeslot
Minutes Travelled
Timeslot
Mean: 1774.80 Std Dev: 45.14 Min: 1728.00 Max: 1859.00 CI: [1695.91, 1853.69]
Mean: 3094.40 Std Dev: 76.68 Min: 2989.00 Max: 3220.00 CI: [2960.39, 3228.41]
Mean: 2429.00 Std Dev: 82.79 Min: 2271.00 Max: 2500.00 CI: [2284.31, 2573.69]
Mean: 2946.80 Std Dev: 72.90 Min: 2898.00 Max: 3091.00 CI: [2819.40, 3074.20]
Mean: 1586.80 Std Dev: 59.72 Min: 1479.00 Max: 1657.00 CI: [1482.43, 1691.17]
Mean: 2739.60 Std Dev: 68.76 Min: 2661.00 Max: 2837.00 CI: [2619.42, 2859.78]
Mean: 2199.80 Std Dev: 46.50 Min: 2156.00 Max: 2286.00 CI: [2118.53, 2281.07]
Mean: 2527.00 Std Dev: 55.47 Min: 2466.00 Max: 2611.00 CI: [2430.06, 2623.94]
Mean: 2080.80 Std Dev: 33.37 Min: 2037.00 Max: 2139.00 CI: [2022.47, 2139.13]
Mean: 3062.20 Std Dev: 127.88 Min: 2931.00 Max: 3305.00 CI: [2838.70, 3285.70]
Mean: 378.40 Std Dev: 8.38 Min: 369.00 Max: 391.00 CI: [363.75, 393.05]
Min
Max
97,5% CI
Match_In_Pi4 Mean ± Std Dev

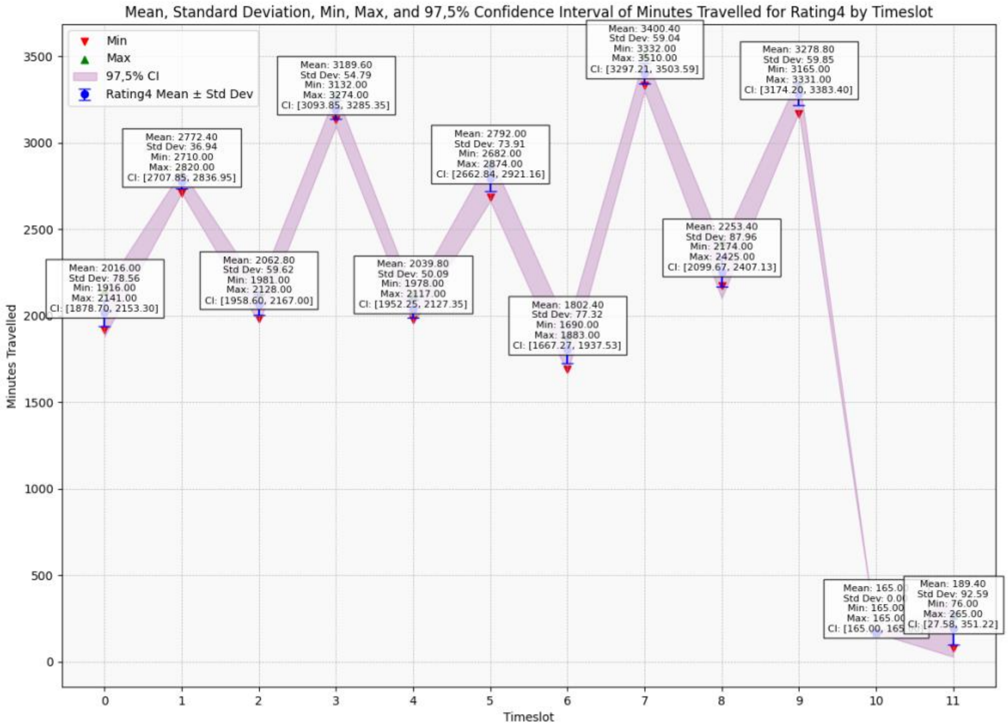

Mean, Standard Deviation, Min, Max, and 97,5% Confidence Interval of Minutes Travelled for Match_In_Pi5 by Timeslot
Minutes Travelled
Timeslot
Mean: 2250.20 Std Dev: 92.38 Min: 2139.00 Max: 2404.00 CI: [2088.74, 2411.66]
Mean: 3016.60 Std Dev: 62.16 Min: 2929.00 Max: 3085.00 CI: [2907.96, 3125.24]
Mean: 1654.00 Std Dev: 43.03 Min: 1580.00 Max: 1712.00 CI: [1578.80, 1729.20]
Mean: 2880.80 Std Dev: 46.09 Min: 2802.00 Max: 2927.00 CI: [2800.25, 2961.35]
Mean: 2463.20 Std Dev: 72.16 Min: 2397.00 Max: 2593.00 CI: [2337.08, 2589.32]
Mean: 2752.40 Std Dev: 64.47 Min: 2683.00 Max: 2864.00 CI: [2639.73, 2865.07]
Mean: 1923.20 Std Dev: 36.09 Min: 1871.00 Max: 1974.00 CI: [1860.13, 1986.27]
Mean: 2856.40 Std Dev: 63.66 Min: 2763.00 Max: 2953.00 CI: [2745.14, 2967.66]
Mean: 1854.00 Std Dev: 85.30 Min: 1720.00 Max: 1959.00 CI: [1704.91, 2003.09]
Mean: 2352.20 Std Dev: 63.52 Min: 2243.00 Max: 2439.00 CI: [2241.18, 2463.22]
Max: 543.00 CI: [473.69, 559.91]
Mean: 614.20 Std Dev: 12.01 Min: 595.00 Max: 628.00 CI: [593.22, 635.18]
Min
Max
97,5% CI
Match_In_Pi5 Mean ± Std Dev



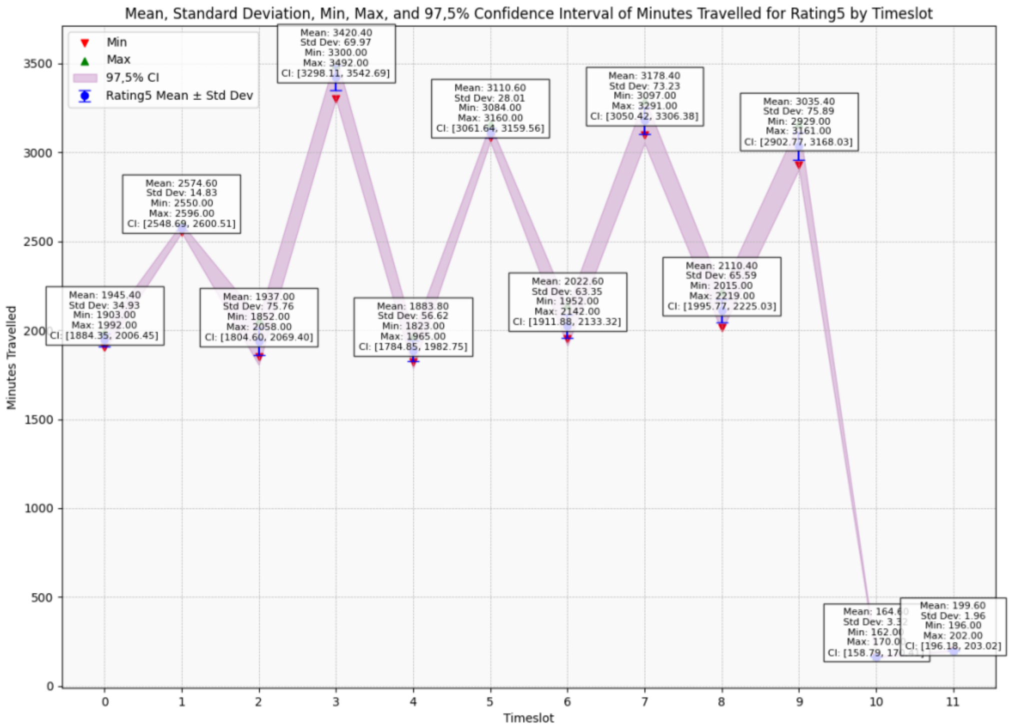
Mean, Standard Deviation, Min, Max, and 97,5% Confidence Interval of Minutes Travelled for Rating2 by Timeslot
Minutes Travelled
Timeslot
Min
Max
97,5% CI
Rating2 Mean ± Std Dev
Mean: 1836.40 Std Dev: 51.28 Min: 1764.00 Max: 1903.00 CI: [1746.78, 1926.02]
Mean: 2964.80 Std Dev: 47.46 Min: 2921.00 Max: 3045.00 CI: [2881.86, 3047.74]
Mean: 2353.00 Std Dev: 84.48 Min: 2188.00 Max: 2427.00 CI: [2205.36, 2500.64]
Mean: 3228.80 Std Dev: 89.91 Min: 3122.00 Max: 3329.00 CI: [3071.67, 3385.93]
Mean: 1868.80 Std Dev: 41.28 Min: 1805.00 Max: 1912.00 CI: [1796.66, 1940.94]
Mean: 3112.60 Std Dev: 55.90 Min: 3018.00 Max: 3193.00 CI: [3014.90, 3210.30]
Mean: 1964.40 Std Dev: 66.95 Min: 1847.00 Max: 2030.00 CI: [1847.40, 2081.40]
Mean: 2792.40 Std Dev: 57.66 Min: 2713.00 Max: 2852.00 CI: [2691.62, 2893.18]
Mean: 2260.60 Std Dev: 43.12 Min: 2189.00 Max: 2302.00 CI: [2185.24, 2335.96]
Mean: 2801.20 Std Dev: 52.09 Min: 2720.00 Max: 2871.00 CI: [2710.16, 2892.24]
CI: [176.74, 178.46]
Mean: 270.00 Std Dev: 15.65 Min: 254.00 Max: 290.00 CI: [242.66, 297.34]



Mean, Standard Deviation, Min, Max, and 97,5% Confidence Interval of Minutes Travelled for Rating3 by Timeslot
Minutes Travelled
Timeslot
Min
Max
97,5% CI
Rating3 Mean ± Std Dev
Mean: 2068.00 Std Dev: 65.86 Min: 1984.00 Max: 2154.00 CI: [1952.90, 2183.10]
Mean: 2538.40 Std Dev: 46.11 Min: 2501.00 Max: 2627.00 CI: [2457.81, 2618.99]
Mean: 2123.40 Std Dev: 36.00 Min: 2061.00 Max: 2164.00 CI: [2060.49, 2186.31]
Mean: 3390.40 Std Dev: 38.09 Min: 3348.00 Max: 3438.00 CI: [3323.83, 3456.97]
Mean: 2158.00 Std Dev: 46.81 Min: 2090.00 Max: 2233.00 CI: [2076.19, 2239.81]
Mean: 2973.00 Std Dev: 140.30 Min: 2854.00 Max: 3241.00 CI: [2727.81, 3218.19]
Mean: 2157.40 Std Dev: 54.04 Min: 2092.00 Max: 2241.00 CI: [2062.96, 2251.84]
Mean: 3496.00 Std Dev: 63.84 Min: 3407.00 Max: 3600.00 CI: [3384.42, 3607.58]
Mean: 1917.00 Std Dev: 72.76 Min: 1782.00 Max: 1991.00 CI: [1789.84, 2044.16]
Mean: 2909.60 Std Dev: 89.87 Min: 2820.00 Max: 3067.00 CI: [2752.53, 3066.67]
Mean: 177.80 Std Dev: 0.98 Min: 177.00 Max: 179.00 CI: [176.09, 179.51]



Mean, Standard Deviation, Min, Max, and 97,5% Confidence Interval of Minutes Travelled for Rating4 by Timeslot
Min
Max
97,5% CI
Rating4 Mean ± Std Dev
Minutes Travelled
Timeslot
Mean: 2016.00 Std Dev: 78.56 Min: 1916.00 Max: 2141.00 CI: [1878.70, 2153.30]
Mean: 2772.40 Std Dev: 36.94 Min: 2710.00 Max: 2820.00 CI: [2707.85, 2836.95]
Mean: 2062.80 Std Dev: 59.62 Min: 1981.00 Max: 2128.00 CI: [1958.60, 2167.00]
Mean: 3189.60 Std Dev: 54.79 Min: 3132.00 Max: 3274.00 CI: [3093.85, 3285.35]
Mean: 2039.80 Std Dev: 50.09 Min: 1978.00 Max: 2117.00 CI: [1952.25, 2127.35]
Mean: 2792.00 Std Dev: 73.91 Min: 2682.00 Max: 2874.00 CI: [2662.84, 2921.16]
Mean: 1802.40 Std Dev: 77.32 Min: 1690.00 Max: 1883.00 CI: [1667.27, 1937.53]
Mean: 3400.40 Std Dev: 59.04 Min: 3332.00 Max: 3510.00 CI: [3297.21, 3503.59]
Mean: 2253.40 Std Dev: 87.96 Min: 2174.00 Max: 2425.00 CI: [2099.67, 2407.13]
Mean: 3278.80 Std Dev: 59.85 Min: 3165.00 Max: 3331.00 CI: [3174.20, 3383.40]
Mean: 189.40 Std Dev: 92.59 Min: 76.00 Max: 265.00 CI: [27.58, 351.22]



Mean, Standard Deviation, Min, Max, and 97,5% Confidence Interval of Minutes Travelled for Rating5 by Timeslot
Min
Max
97,5% CI
Rating5 Mean ± Std Dev
Minutes Travelled
Timeslot
Mean: 1945.40 Std Dev: 34.93 Min: 1903.00 Max: 1992.00 CI: [1884.35, 2006.45]
Mean: 2574.60 Std Dev: 14.83 Min: 2550.00 Max: 2596.00 CI: [2548.69, 2600.51]
Mean: 1937.00 Std Dev: 75.76 Min: 1852.00 Max: 2058.00 CI: [1804.60, 2069.40]
Mean: 3420.40 Std Dev: 69.97 Min: 3300.00 Max: 3492.00 CI: [3298.11, 3542.69]
Mean: 1883.80 Std Dev: 56.62 Min: 1823.00 Max: 1965.00 CI: [1784.85, 1982.75]
Mean: 3110.60 Std Dev: 28.01 Min: 3084.00 Max: 3160.00 CI: [3061.64, 3159.56]
Mean: 2022.60 Std Dev: 63.35 Min: 1952.00 Max: 2142.00 CI: [1911.88, 2133.32]
Mean: 3178.40 Std Dev: 73.23 Min: 3097.00 Max: 3291.00 CI: [3050.42, 3306.38]
Mean: 2110.40 Std Dev: 65.59 Min: 2015.00 Max: 2219.00 CI: [1995.77, 2225.03]
Mean: 3035.40 Std Dev: 75.89 Min: 2929.00 Max: 3161.00 CI: [2902.77, 3168.03]
Mean: 199.60 Std Dev: 1.96 Min: 196.00 Max: 202.00 CI: [196.18, 203.02]

Appendix C: Research design and Problem-solving approach

The main purpose of this research is to establish the effect the degree of client freedom has on the efficiency of the client transportation process. In other words, to establish a relationship between the degrees of freedom and the performance of the process on certain KPIs. As per Saunders et al. (2018), "Studies that establish causal relationships between variables may be termed explanatory research". Therefore, this research can be considered explanatory.

To achieve this research's aim, there must be a collaboration between several participants and the researcher. These participants, also known as research subjects, will provide valuable information and data for research purposes. The research subjects in this case are the care providers and clients within the X and the organisation of X. The care providers will offer information about the current costs of client transportation, and the details of the supply chain of this operation. The clients will set a benchmark for the quality provided during their transportation to the caregivers. As a purpose of this research is to expand the quality of this process, their perception of the quality served is highly relevant to the validity of the result. Lastly, the X can supply details about the restrictions, policies and limitations currently in place during the process (number of vehicles and personnel available, budget for the process etc.).

To gather all the information mentioned in the previous paragraph, qualitative and quantitative data-gathering methods will be employed. Qualitative methods will be used to obtain data about the state of the process and its participants. The number of clients, the pickup locations, the caregiver location, and others are some of the information that will be gathered by quantitative research methods. Qualitative research methods will be used for various reasons during this research. Firstly, the quality of the process is a variable that is best measured by the clients themselves. Preferably, questionnaires will be used to determine how the clients perceive the quality of the service being proposed during this study. Furthermore, qualitative research methods will be utilised to get insight into how to solve this type of problem. Researching similar problems and analysing their solutions, studying ways to solve these problems are all qualitative research methods that are relevant in this case.

After the data is gathered, it needs to be analysed. To properly analyse data, first defining it is necessary. The numerical data presented by this research is mostly the performance of the solution on certain KPIs. These KPIs are not yet determined but may include the costs, the number of vehicles, the time of stay of a client in the process, and others. All of them are forms of ration data. The categorical data includes information such as the type of service a client requires, the type of care each caregiver provides, and others. This information will mostly be used in deriving results, not as much as in the analysis and presentation of data. Therefore, only the numerical data will be analysed in this research. Also, it is important to note that the numerical variables will be the point of comparison for the strategies with each degree of freedom.

Most of the studies for DARP have their results presented in tables. A table is an effective way to demonstrate the results of a study like this as it allows the researcher to include many variables in one figure. That way, different strategies are assessed and compared directly on certain KPIs. Additionally, a line graph could also be an effective way to present the results of this study. According to Saunders et al. (2018), a multiple-line graph is the most optimal way to compare the trends for two or more variables so that intersections are clear. One axis could represent the degrees of freedom, and the other a certain KPI.

Even though, the innovative part of this research, as it is only the second study to examine the effect of client choice in a DARP, it has some limitations. Firstly, as it examines quality in the service sector, it is impossible to guarantee that the results would have the same effect on every client. Subjectivity is most apparent in this case. Some clients could value different aspects of service.

Within the context of this research, an implication could be that a client would be emotionally connected with their caregiver. Forcing the client to have another provider, would damage the quality perception of the client. Therefore, extensive qualitative research methods have to be employed to determine the effect a solution will have on the clients. Unfortunately, the scope of this research does not allow for such extensive research methods.

Moreover, some assumptions will have to be made. To protect the privacy of the clients, their exact addresses will not be used in this research. Also, the shortest route will be a metric very frequently used in this research. However, the shortest route is not always the fastest. More assumptions will be made throughout this thesis, it is not certain that they will not affect the validity of the research. Nevertheless, if the researcher is aware of the assumption being made and the influence it will have on the results, there is no threat to the value of the research.

Problem-solving approach

The perspective that will be adopted in this research is the Managerial Problem-Solving Method (MSPM). MPSM is a problem-solving method developed by Heerkens (2021) and it is a blueprint the research follows to derive reliable and accurate results. It is divided into seven phases, listed in the figure below. A feature that made the MPSM suitable for the research is the possibility of combining a systematic and creative approach. Heerkens (2021) states "The MPSM is not stringently rigid, but a framework for you to fill in as you need". The creative approach will be needed to formulate solutions, as for such a complicated issue, the systematic approach would not produce the most optimal results.

Figure 2. MPSM phases

The problem approach is the second phase of the MPSM, and in this case, the most important. Most of the concepts, perspectives and terminologies, were encountered for the first time in this research. Hence, a sophisticated problem-solving approach will be formulated for each research question. The main aim of a problem-solving approach should be to prepare the researcher for the problem-solution process (Heerkens, 2021). After the core problems have been identified, the solution can start to be formed. However, it is crucial to determine the researcher's required knowledge to tackle the issue at hand. Therefore, the problem-solving approach will include the following activities.

1. Research on similar problems and how they were approached
   1.1. VRPs
   1.2. DARP
   1.3. Choice Driven DARP
2. Define similarities and differences in those cases with this one
   2.1. Social, political, and economic landscape differences

    2.2. Different restrictions
    2.3. Different clientele
    2.4. Different objective
3. Assess if the approach used in the other cases applies to this
4. Filter the important information from other cases
5. Study them and apply them in this case

The main principle of the approach formulated is the D3 (Do, Discover, Decide). D3 is a tool that assists the researcher in tackling any knowledge question. The "Do" part of the approach includes activities as the research indicated in the first step and the study and application of important information indicated in the fourth. "Discover" includes activities as the assessment of whether the approach used in other cases applies to this. Lastly, filtering the important information forms the "Decide" part of D3.

Below the first two steps, some indications are made for important points to consider when executing the activities. VRPs is the family of problems that this case belongs to, and in particular, DARP. 1.3 indicates the integration of client choice to the problem. Lastly, 2.1, 2.2, 2.3, and 2.4 are some important factors to take into account when comparing the two systems.

Appendix D: Research design for each research question

Research questions	Research type	Research method	Activity plan
1. What is the current strategy of X?	Exploratory	Qualitative	Discuss with supervisors (who are familiar with the situation). Study Weijzen's thesis.
2. How is client choice known to be modelled in a DAR system?	Descriptive	Qualitative	Perform a systematic literature review
3. How should the client allocation model be constructed?	Exploratory	Qualitative and quantitative	Construct the mathematical model. More than one may be needed for each variable being subject to client choice. Also, with different degrees of freedom. Research about KPIs known to be used in that case from literature.
4. What is the performance of the strategies concerning the selected KPIs?	Evaluative	Quantitative	Test the model by using data and algorithm. Compare the different degrees of freedom. Define optimal solution and compare it

Table 1. Research design for each research question