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Decision support system for route planning: Application in the air conditioning industry

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Master’s in Business Analytics

Supervisor:
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September, 2024

BUSINESS SCHOOL

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Abstract

The purpose of this research is the development of a route planning optimization tool at ProgressClim Solutions in order to minimize the time spent on manual route management.

The development and testing methodology is based on CRISP-DM, using historical data provided by the company, which allows for a comprehensive comparison of the tool's performance compared to the traditional manual method. The results demonstrate a significant reduction in the time required for daily planning with the tool, leading to enhanced operational efficiency and more optimal resource allocation. Nevertheless, it is essential to acknowledge that in scenarios involving extended planning, the total time required tends to increase.

Despite the significant improvements in efficiency and time window management provided by the tool, certain limitations were identified, such as the lack of adaptation to unexpected situations. Future research lines will focus on improving efficiency over longer time periods and the tool's ability to deal with unexpected situations.

Keywords: Route Planning, VRP Solver, Decision Support System, Operational Efficiency

Resumo

O objetivo desta investigação é o desenvolvimento de uma ferramenta de otimização do planeamento de rotas na ProgressClim Solutions, com o intuito de minimizar o tempo despendido na gestão manual de rotas.

A metodologia adotada baseia-se no CRISP-DM para o desenvolvimento e testagem, utilizando dados históricos fornecidos pela empresa, o que permite comparar o desempenho da ferramenta com o método manual. Os resultados demonstram uma redução significativa do tempo necessário para o planeamento diário com a ferramenta, o que conduz a uma maior eficiência operacional e a uma melhor afetação de recursos. No entanto, é essencial reconhecer que, em cenários que envolvem um planeamento alargado, o tempo total necessário tende a aumentar.

Apesar das melhorias significativas na eficiência e na gestão da janela temporal proporcionadas pela ferramenta, são identificadas algumas limitações, como a ausência de adaptação em situações inesperadas e a necessidade de otimizar o tempo total necessário para planear rotas para grandes volumes de dados. Pretende-se em trabalhos futuros de investigação melhorar a eficiência em períodos de tempo mais longos e na capacidade da ferramenta para lidar com situações inesperadas.

Palavras-chave: Planeamento de Rotas, VRP Solver, Sistema de Apoio à Decisão, Eficiência Operacional

Index

Figure Index

Glossary

VRP - Vehicle Routing Problem

BPP - Bin Packing Problem

TSP - Traveling Salesman Problem

CVRP - Capacitated Vehicle Routing Problem

MDVRP - Multi-Depot Vehicle Routing Problem

VRPTW - Vehicle Routing Problem with Time Windows

VRPPD - Vehicle Routing Problem with Pickup and Delivery

PVRP - Periodic Vehicle Routing Problem

GIS - Geographic Information System

VBA – Visual Basic for Applications

Chapter 1.
Introduction

1.1 Context and Motivation

Over time, numerous companies have encountered difficulties associated with route planning. The objective is to create routes that are both efficient and cost-effective, while also ensuring customer satisfaction (Louro, 2012). One of the most extensively studied problems in this context is the Vehicle Routing Problem (VRP), first introduced by (Dantzig & Ramser, 1959). The VRP is based on the optimization of a fleet of vehicles that depart from and return to a single central depot, with the goal of meeting customer demands (Sousa & Asada, 2012).

In the professional environment, the need to confront challenges when developing an in-house solution to the VRP problem is an inevitable aspect of the process. Despite the availability of numerous commercial software programs for solving the VRP, the primary challenge for companies lies in the necessity of maintaining a relationship with the software developer. In this context, the VRP Spreadsheet Solver tool was presented as a Microsoft Excel add-in. It overcomes some of the difficulties encountered by other software and offers a user-friendly interface (Erdoğan, 2017).

1.2 Problem Definition

Considering the above, the primary problem that this research seeks to address is the absence of an efficient technological solution for route planning that meets the specific operational needs of ProgressClim Solutions. This absence results in manual management, increasing response times and reducing the operational efficiency of the company.

ProgressClim Solutions is a Bosch subcontracted service center operating in the Greater Lisbon area. It has three certified teams, each consisting of two people and a vehicle. The process begins with the reception of requests for assistance by e-mail, which are then scheduled and planned over the course of working days. Due to the lack of an appropriate tool to meet its operational needs, the company faces challenges such as inefficient route planning and increased response times, resulting in a reliance on manual processes for scheduling services and deploying teams.

1.3 Research Question and Objectives

The research is guided by the following research question:

- How can the implementation of an automated route planning tool reduce the time spent by ProgressClim Solutions employees compared to the current manual process?

In light of the research question outlined above, the following objectives are established:

- The development of a tool adapted to the specific needs of ProgressClim Solutions. This tool will optimize employees' time in route planning, as well as improve the management of customers slots, thereby ensuring greater operational efficiency.
- The VRP Spreadsheet Solver will serve as the foundation for the new tool, which will be adapted to offer a simplified route planning interface. It will be developed in an interactive manner, with continuous testing and modifications conducted in collaboration with the company.

1.4 Theoretical and Practical Contributions

This research seeks to contribute, both theoretically and in practice, to the field of route optimization and operational efficiency in the context of business processes. The contributions are outlined as follows.

1.4.1 Theoretical Contributions

The research will contribute to the existing literature on route optimization by integrating automated tools and analyzing their impact on operational efficiency. It will also provide insights into best practices for companies facing similar challenges. Furthermore, it will put forth a conceptual model that elucidates the way automated tools can be efficacious in route planning and the means of evaluating their implementation. A key focus is the identification of critical factors is a fundamental aspect of this research, such as execution time and resources used, thereby providing a more detailed view of logistics management.

1.4.2 Practical Contributions

The primary practical contribution is the development of an automated route planning tool that has been specifically designed to meet the operational needs of ProgressClim Solutions, addressing real-world inefficiencies. The implementation of the proposed tool should result in a notable reduction in the time employees spend on manual route planning, which should, in turn, lead to an improvement in productivity and resource allocation within the company. Finally, the iterative development process will yield valuable insights and practical guidelines for other organizations that may wish to adopt similar solutions, thereby promoting the wider adoption of efficient practices within the industry.

1.5 Structure

The research will be divided into chapters, each representing a different phase of the research. The second chapter will review the literature on the topic. The third chapter will be dedicated to a detailed description of the case study. The fourth chapter will focus on the methodology used to develop the tool and will provide a detailed explanation of how the tool works. In the fifth chapter, an analysis of different scenarios and the results obtained will be presented. Finally, the sixth chapter will discuss the main conclusions drawn from the results obtained, as well as mentioning the limitations encountered during the development of the tool, also suggesting possible directions for future research.

Chapter 2.
Literature Review

Route planning became increasingly important as trade intensified and became more complex. With the development of society, route planning has become a crucial element for various companies, leading to it being one of the central topics studied in the literature, where the aim is to develop route optimization techniques due to its economic importance(Cacchiani et al., 2014).

The Vehicle Routing Problem is a mathematical problem that enables the modeling of various practical everyday scenarios, such as logistics, transportation, delivery planning, among other (Toth et al., 2014). Its purpose is to plan the route of a set vehicles to meet the needs of a set of customers, seeking to optimize them while considering certain constraints (Laporte, 2007). In this sense, the VRP is an extension of two types of problems, Bin Packing Problem (BPP), which consists of the efficient allocation of packages so that the sum of the packages in each set does not exceed a predefined limit value, and the Traveling Salesman Problem (TSP), that seeks to determine the most efficient route to visit all customers, starting from a single depot and returning to the same depot, travelling the shortest distance possible (Ralphs et al., 2003).

In scientific literature, the VRP was introduced by Dantzig and Ramser (1959). The authors designated the problem as a "truck dispatching problem", i.e. a problem of a set of vehicles, centered on the efficient management of the routes of a set of fuel distributions trucks. Afterward, Clarke and Wright (1964) generalized it to an optimization problem consisting of providing services to a set of customers geographically dispersed around a single central depot, therefore this problem became known by its current name of Vehicle Routing Problem.

2.1 Variants of the Vehicle Routing Problem

The nature of transport operations planning and the variety of specificities of different business sectors have led to the advent of variants of the VRP, each with different characteristics.

2.1.1 The Capacitated Vehicle Routing Problem

One of the most extensively studied variants is the Capacitated Vehicle Routing Problem (CVRP), in which the set of vehicles has limited capacity. In this variant, it is assumed that the vehicles depart from and return to a single depot, and there is a set of customers with known demands, where each customer is visited only once. The primary objective is to minimize the total distance traveled (Rizzoli et al., 2007).

2.1.2 The Multi-Depot Vehicle Routing Problem

The Multi-Depot Vehicle Routing Problem (MDVRP), introduced by Wren and Holliday (1972), consists of planning routes from several depots, where the situation may arise that not all depots have to be used (Renaud et al., 1996). This type of variant is crucial for companies with several large distribution centers. In this variant, a set of homogeneous vehicles is considered, and the location of the customers and their respective orders are already known. The main objective of this variant is to minimize the total distance travelled and, consequently, the number of vehicles required, it is solved in two stages: first, customers are assigned to depots and the routes are created to those depots (Ho et al., 2008). However, according to Daneshzand (2011), a more efficient way of solving this variant is to combine the two steps into a single step.

2.1.3 The Vehicle Routing Problem with Time Windows

Another variant is the Vehicle Routing Problem with Time Windows (VRPTW), since there are a large number of practical situations that contain time constraints. Thus, the main objective of this variant is to meet the needs of all customers within defined time intervals in which lower and upper limits are set to delimit a given event (Cordeau et al., 2007).

This variant can be subdivided into the Vehicle Routing Problem with Rigid Time Windows and the Vehicle Routing Problem with Flexible Time Windows. In this problem, customer service must start within a given time interval. Time windows are considered hard if violations are not allowed - vehicles can wait at no cost if they arrive early but are strictly prohibited from service if they arrive late. Conversely, time windows are soft when they can be violated, but at the cost of a penalty (Taş et al., 2014).

2.1.4 The Vehicle Routing Problem with Pickup and Delivery

In the Vehicle Routing Problem with Pickup and Delivery (VRPPD), the products to be transported are not originally grouped in warehouses but are distributed among the nodes of the network. Specifically, it requires collecting products from a specific location and delivering them to their recipients, usually with time windows for delivery and collection (Rizzoli et al., 2007). Min (1989), was the first to introduce this variant into the literature.

2.1.5 The Periodic Vehicle Routing Problem

The Periodic Vehicle Routing Problem (PVRP) was introduced into the literature by Beltrami and Bodin (1974), in which routes are planned for a horizon of several periods, since a set of customers can be visited more than once. In other words, the various customers are assigned to specific days, considering their needs (Daneshzand, 2011). The main objective is to minimize the total distance travelled, while allocating customers to the most appropriate day, which consequently imposes certain restrictions on this planning. In this variant, there are three important types of decision to consider, the first being to figure out when to visit each customer and how often. The second is how to group the customers into routes for each day and, finally, how to plan the route of each vehicle for each group of customers (Cacchiani et al., 2014).

2.2 Solution Methods

Given that the VRP has been widely discussed topics in the literature, an advancement in knowledge and technology have led to the development of two primary methods for solving this problem: exact algorithms and heuristics (Shi & Niu, 2023). However, there is another method known as hybrid methods, which combine exact algorithms and heuristics. In these approaches, an exact algorithm is typically used in an initial phase, followed by the application of heuristics (Koç & Karaoglan, 2016).

2.2.1 Exact Algorithms

Exact algorithms aim to find an optimal solution to the problem and, therefore, are more suited for smaller instances. As the complexity of this type of problem has been increasing, it poses challenges to the efficiency of these algorithms in achieving an optimal solution (Toth & Vigo, 2002). Such algorithms are typically based on integer linear programming, dynamic programming, or Branch-and-Bound (Laporte, 2007).

2.2.2 Heuristics

Heuristics are widely recognized among researchers because they try to find a good solution without guaranteeing that the optimum solution will be obtained. They are often used when the speed of the process to solve a problem is as important as the quality of the solution obtained, i.e. finding a good solution in a reasonable amount of time (Martí et al., 2011).

2.3 Software for Route Planning

After realizing the various variants of the Vehicle Routing Problem, it becomes clear that the complexity of this subject is a crucial factor and, therefore, from the point of view of companies, the internal development of a solution for the VRP is challenging. Even when creating an open-source code, there can be the obstacle of collecting distance and duration data from a Geographic Information System (GIS), which can lead to significant costs for companies (Erdoğan, 2017).

2.3.1 VRP Spreadsheet Solver

Erdoğan (2017) presented the VRP Spreadsheet Solver, which integrates Excel functions, more specifically Visual Basic Applications (VBA), with public geographic information and heuristic techniques, making it free open-source software for solving and visualizing VRP and CVRP results (Gansterer & Klug, 2020). However, according to Erdoğan (2015), like other software packages for VRP, this one also has its drawbacks and limitations. The tool is based on open-source VBA which offers some advantages due to the basic functionality and flexibility of the language and VBA programming. However, this programming cannot compete with C++ code in other software, due to its lower efficiency in basic arithmetic operations. Another limitation is that it has a limit of two hundred clients, which can be increased by modifying the code, but this is not recommended due to the tool's efficiency. Finally, another limitation is that the tool does not evaluate all the costs that could be considered, since the costs considered are only the fixed costs of the vehicle and the cost per unit of distance.

Tools such as the VRP Spreadsheet Solver play an important role in solving route planning problems, and it is worth highlighting some practical cases that have adopted this tool. Erdoğan (2017) mentions two case studies, in the health and tourism sectors, in which the application of the tool was successful.

The first case involves a non-profit organization based in Turkey, which offers home healthcare services, including medical visits, physiotherapy and logistical services such as patient transport. It has a portfolio of three hundred registered clients, three warehouses and a fleet of ninety vehicles. The company's manager chose to use the tool to optimize a specific service, in which it operates with a fleet of twenty vehicles, serving an average of 150 patients a day, with visits planned in advance and without time windows. Although the company did not disclose specific data on the costs minimized, the feedback received highlighted that the process has become more transparent for the team, thus facilitating route planning.

The second case refers to a tourism company that offers travel packages, the main product being a ferry trip between two cities. The company's highest costs are related to the subcontracted bus service to collect customers from their homes and then deliver them to the same points. With the subcontractor spread across seven depots and vehicles of different characteristics, the company's goal is to minimize the daily fixed costs of the vehicles, reducing the need for them. In addition, the challenge includes the consideration that some depots are geographically distant and the absence of time windows. This specific problem is a variant called the Close-Open Mixed Vehicle Routing Problem, which was first introduced by Liu and Jiang (2012).

2.3.2 Routific

Routific, developed by Marc Kuo, is distinguished by its provision of route planning, whereby users can visualize and manipulate interactive maps containing detailed information, including time windows, durations, vehicle capacity and more. Furthermore, the software offers additional features such as the importation of addresses, the real-time adjustment of routes, tracking and the generation of detailed analytical reports (Miranda, 2018).

2.3.3 DirectRoute

DirectRoute, developed by Declan Cahill, focuses on maximizing distribution efficiency and customer service, significantly reducing planning time and associated costs. Its features include route optimization, flexible daily route construction, real-time monitoring and detailed financial analysis (Miranda, 2018).

2.3.4 My Smart Route

My Smart Route is a route planning application, created by David and Blake Walsh, that is exclusively available for smartphones that use the Android operating system. The optimization objectives of My Smart Route can be broadly categorized into three main areas: minimizing distance, minimizing time and balancing distance and time. Furthermore, the application offers the ability to store and map an unlimited number of locations, save an unlimited number of routes per month, plan up to 150 addresses per route, and provides free support for up to 15 locations. Additionally, it can calculate round-trip routes, avoiding tolls and motorways, among other features (Miranda, 2018).

2.3.5 Google OR-Tools

Google OR-Tools, created by Laurent Perron, is an open-source software developed by Google with the objective of optimizing a range of issues associated with route planning. One of its significant advantages is that it is straightforward to integrate with other software, regardless of the programming language employed. Although OR-Tools is not primarily focused on solving the initial problem of calculating the route between two or more points, it is especially efficient at solving the second problem, namely calculating optimized routes taking into account various constraints, using specific algorithms for this purpose (Fournier, 2022).

2.3.6 Route4Me

The Route4Me, developed in 2009 by Dan Khasis, has been one of the most widely used pieces of software by companies. This is due to the fact that its continuous development of new technologies enables rapid optimization of dynamic routes. This software enables users to optimize, plan and share any route both on the website and in the smartphone application. The software's principal advantages are its user-friendly interface, time savings, lack of training requirements and adaptability to different business sectors (Miranda, 2018).

Chapter 3.

Case Study

ProgressClim Solutions is a small and medium-sized enterprise (SME) founded in 2013 and located in Alverca do Ribatejo, Portugal. The company's core business focuses on the repair and installation of gas systems, air conditioning, central heating, solar panels, as well as the maintenance and repair of various domestic hot water, air conditioning and solar energy equipment. To achieve these goals, the company has established several strategic partnerships, including with Bosch and Rubis Energia.

For this research, the partnership with Bosch is of particular relevance, focusing on technical assistance in the areas of air conditioning and hot water systems. Bosch has multiple partnerships with other companies across Portugal. Therefore, Bosch sends requests for assistance and maintenance via email to the designated company, with ProgressClim Solutions predominantly handling the Lisbon district, while other companies manage other geographical areas.

ProgressClim's operational structure for this partnership consists of three technical assistance teams, organized as follows: Team 1 and Team 2 are responsible for air conditioning equipment, where Team 1 works five days a week, while Team 2 operates only one day a week on a variable basis. Team 3 is dedicated to services related to domestic hot water equipment, operating only one day a week on a variable basis.

Currently, the route planning for these teams is conducted manually, representing a considerable challenge for the company. The process begins with service or maintenance requests generated by Bosch, which contain all the essential information, such as the customer's complete address with zip code, the description and type of service, and other relevant details. Based on this information, employees use Google Maps to plan daily routes, a task that typically takes around 10 minutes. Additionally, it is the responsibility of the teams themselves to determine the specific routes they will follow.

The primary goal for the employee responsible for planning is to determine both the day and the time slot each customer will be assisted, either in the morning or afternoon, to provide advance notice to the customers. Customers are informed ahead of time about the day they will be assisted, within a maximum of three working days from the moment the request is received by the company.

The office structure includes the Director of Technical Assistance, a Technical Assistance Manager, and two employees who share the responsibilities of route planning. Over a 2-week cycle one employee is responsible for preparing and sending service reports to Bosch, while the other oversees route planning. Additionally, these employees have other responsibilities within their roles. The Director and the Manager supervise these two employees but do not oversee the other staff members.

In this sense, the company needs a tool to plan routes for a period of 10 working days, covering the three technical assistance teams. Considering the particularities of the service, such as the time windows for service, which are: morning (8am to 1pm) and afternoon (2pm to 5pm). The decision as to which day teams 2 and 3 will work on the technical assistance is taken a priori from the route planning and is decided by the employees responsible for route planning.

The operational dynamic includes the continuous entry of new requests into the system, in this case via email, throughout the day. At the end of each working day, these same requests are scheduled for the next available days. In addition, there may be urgent requests that require the immediate attention of the employees, which are inserted into the nearest suitable route. All services must be carried out within the standard operating hours, between 8am and 5pm, with a 1-hour lunch break. However, there is no fixed interval for the lunch break, which is decided by the teams responsible for performing the services.

Chapter 4.
Methodology

4.1 Research Methodology

The method adopted for processing the data and developing the tool is based on CRISP-DM (Cross Industry Standard Process for Data Mining) (Chapman et al., 1999). Although CRISP-DM is widely applied in the context of data mining and analysis, for this research it was adapted in the specific context of developing the tool. Following the case study, which is equivalent to Business Understanding, the next steps involve Data Understanding, Data Preparation and finally the development of the tool.

After understanding the business and the current process route planning, the historical data given by the company was analyzed, ranging from January 2023 to March 2024. This data includes information about customers, such as the order number, the customer's name and their location. It also includes details about the type of service, the type of equipment, the model, the reference equipment and the description of the service. In addition, the date on which the service was performed.

However, it became evident that some information was lacking, namely data on estimated service times and zip codes. In response to the need for execution times, a sample of historical data was collected, including a case of each of the 49 types of service. From the sample, a meeting was held with the company, specifically with the manager and the technical assistance director, to assign the execution times for each type of service.

As far as the integration of zip code, a sample was collected from January 2024 to March 2024 to cross-reference with their customer data file. This is due to the fact that the introduction of zip code information into the system only started at the beginning of 2024, and the previous data was only in physical format, which would have made integration difficult.

In data preparation, the columns that would be needed to develop and test the tool were analyzed. The result was the elimination of redundant columns and the selection of the essential columns such as: order number, zip code, location, type of service, estimated time of execution and date of service. In addition, the zip code and location columns were combined to improve the accuracy of customers locations when entering them into the VRP Spreadsheet Solver. All the selected columns, apart from the execution date, are important for the development of the tool, since this is the information that is entered into the tool. The execution date, in turn, is relevant for determining the data sets to be inserted to test the tool.

4.2 Solution Method

The VRP Spreadsheet Solver tool, originally developed for single-day route planning, has been significantly modified to meet the company's need for planning over a ten-business day period. This modification was implemented through various technical changes.

A procedure was developed that employs a systematic structure to ensure the correct input of the customer's data into the "1. Locations" sheet. This procedure incorporates an interactive loop that allows multiple clients to be entered without the need to restart the process (Algorithm 1). Additionally, the tool automatically generates the necessary sheets for route planning, considering the existing and the available days for allocating new customers. For each specific day, the tool creates dedicated sheets with the customers scheduled for that day and updates any formula that needs to be updated (Algorithm 2).

To perform route planning, it was developed a procedure to check if all the customers that are in the sheet "1. Locations" are also in sheet "4. Fictitious Solution", determining their assigned day and insert them into the route on the route sheet, verifying their feasibility (Algorithm 3). If the route is not feasible, i.e., it exceeds 5pm, the user must decide whether to remove the customer(s) that exceed the time limit. However, sometimes it is preferable to keep the customers scheduled for that day due to prior agreements and staff considerations. In such cases, the user has the option to retain the customer(s) on that day. If the customer(s) are removed, the process of feasibility is repeated until the route is within the allowable time limits. This procedure introduced several changes compared to the original version. In particular, the inclusion of a lunch break, an aspect previously unaccounted for. The tool now ensures that route planning includes a lunch break, accurately reflecting operational reality. In addition, the current code considers customers with previously blocked schedules. That is, the tool respects the established schedule for customers previously informed of their allocation in specific time slots, such as morning or afternoon, ensuring that these customers remain in their pre-agreed time intervals.

The new tool also considers the availability of Team 2, as indicated on the "VRP Solver Console" sheet. Furthermore, code was implemented to allow the user to delete past routes that are no longer necessary for viewing. This code ensures that the deleted data is stored in memory, preserving the route history for future reference or analysis.

Algorithm 1

Input:

Sheet “1. Locations” containing information on service location

Sheet “VRP Solver Console” containing information for route planning

Data entry form

Step 1: display form to obtain new request data

o - order number

zc – customer’s zip code

d – service duration

s – type of service

Step 2: processing data

Insert the collected data in the new line of the "1. Locations" sheet.

Update the last completed line of the same sheet

Update the number of customers on the "VRP Solver Console" sheet

Step 3: repeat and exit

Ask the users if they want to add another customer:

If yes, repeat step 1 and 2

If no, exit the Loop

Output:

Sheet "1. Locations" updated with new requests

"VRP Solver Console" sheet updated with number of customers

Algorithm 2

Input:

Sheet "1. Locations" containing information on service locations

Sheet "4. Fictitious Solution"

Configuration variables, such as "NumDays" which indicates the working day: NumDays = 1

Step 1: Determining the working day for the new “o”

Loop to find a valid day based on the times on the "4. Fictitious Solution " sheet, incrementing NumDays until a day is found where the end time of the services does not exceed 5PM

Step 2: update the "1. Locations" sheet

Update the day available for the new “o”

Step 3: Configuration

Carry out procedures to configure data and sheets related to the new day

Output:

Sheet of locations, distances, vehicles, vehicle compatibility, fictitious solution and current solution created/updated.

Algorithm 3

Input:

Sheet "1. Locations" containing information on service locations

Sheet "4. Fictitious Solution" containing information about service locations, such as addresses, coordinates, operating hours, etc.

Configuration variables, such as "NumDays" which indicates the working day: NumDays = 1

Step 1: Determine the working day for the new "o"

Loop to find a valid day:

Initialization: Start "NumDays" at 1.

Search for the end time:

Determine the last filled row in the time column on the "4. Fictitious Solution" sheet.

Find the maximum end time of the services planned for the current day.

Validity check:

Compare the maximum end time with 5 PM.

If the end time is less than or equal to 5 PM, the day is considered valid.

Otherwise, increment NumDays and repeat the process until a valid day is found.

Step 2: Update the "1. Locations" sheet

Update the available day:

Identify the last filled row on the "1. Locations" sheet.

Navigate through the rows of the specific column indicating the day available.

For each empty cell, update with the value "Day No." followed by the NumDays value.

Step 3: Configuration

Configuration procedures:

Delete old sheets: Check and delete worksheets related to the old days if necessary.

Set up locations for the new day: Add or modify entries on the locations sheet to reflect the new working day.

Set up distances for the new day: Update or recalculate distances between service locations.

Set up vehicles: Check and configure the availability and operational parameters of vehicles for the new day.

Set up vehicle compatibility: Check and configure the compatibility of vehicle based on the new locations and services.

Set up the day's solution: Prepare the solution table for the new day by inserting the new service allocations.

Solve the routing problem: Execute the VRP Solver algorithm to optimize routes based on the new data.

Adjust lunch breaks: Ensure lunch breaks are properly set up and do not conflict with the new services.

Output:

Updated sheets:

Locations: Updated with the new service days and time windows.

Distances: Updated with recalculated or adjusted distances.

Vehicles: Updated with vehicle availability and configuration.

Vehicle compatibility: Updated with new compatibility information.

Fictitious solution: Updated with the new service allocations.

Current solution: Created or updated to reflect the new route optimization and service allocations.

4.3 User Manual for the New Tool

This section presents the structure of the workbook employed in the present research and offers an analysis of the requisite modifications to adapt the tool developed by Erdoğan (2017) to the company's requirements. The Erdogan's tool was modified in line with company's operational context and thus enhanced its effectiveness. The objective was to prioritize the management of time windows over the detailed visualization of routes.

Regarding the structure of the workbook, initially only the "VRP Solver Console" sheet is presented, while the remaining sheets are created as needed. In the original tool, the sheets created are: "1. Locations", "2. Distances", "3 Vehicles", "3.1. Vehicle Compatibility", "4. Solution", "5. Visualization" (Figure 1). However, for this case study, it was necessary to change the structure of the tool: sheets "1. Locations", "2. Distances", and "3.1. Vehicles Compatibility" must be created for each day. The sheets for the days that are not currently being worked on are deleted to prevent Excel from becoming slow. This is because it is more efficient to recreate these sheets when necessary than to continually update them. Additionally, the new tool has two solution sheets: "4. Fictitious Solution", where the routes are evaluated, and "4.1. Current Solution", where the final and feasible routes are found. Since the company's main concern is not the visualization of routes, but rather the perception of the customer's slots, the creation of the visualization sheet has been deactivated.

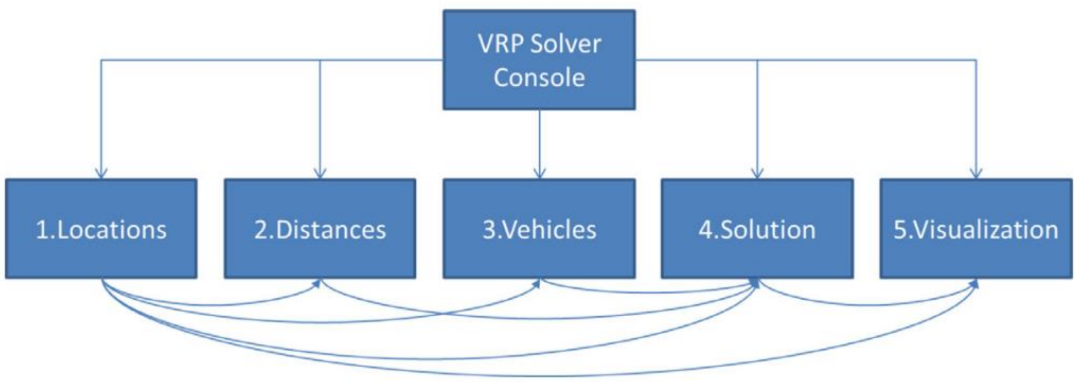

Figure 1 - Spreadsheet structure of VRP Spreadsheet Solver.

In terms of guiding the user to the cells to work with, the color scheme of Erdoğan (2017) is used: “Cells with a black background are defined by the sheets and should not be modified. Cells with a green background are parameters or decisions to be defined by the user. The cells with a yellow background are calculated by the sheets but can be edited by the user to analyze scenarios. Orange background cells signal a warning. Cells with a red background indicate an error.”

The VRP Solver Console sheet, as defined by Erdoğan (2017), stores and provides information for the remaining sheets. It contains detailed data on the size of the instance, including the number of depots and customers, as well as the types of vehicles available. It also allows the user to configure options relating to the retrieval of GIS data and to set the maximum running time for the solver to provide a solution. An extra feature implemented in this sheet is the possibility for the user to define the specific working day for the team that only performs this activity once a week. Another change implemented was to initially set to zero the number of customers and, whenever a new customer is added, this value is automatically increased.

The Locations sheet contains information on the names, addresses, coordinates, time windows and service requirements. As mentioned in the previous chapter, a procedure has been implemented for entering the necessary customer information. The “Name” column contains the service number, the “Address” column contains the addresses, the coordinates columns are filled in via the GIS web service based on the addresses entered, and the Time windows columns are initially set to 8am to 5pm, while the remaining columns, that are not required, are hidden so that they are not visible to the user. In addition, a new column has been added to the indicate the day on which each client is inserted. When the procedure described in Algorithm 2 is carried out, it analyzes which day is available and assigns it to the customer who has this column empty. This column is used to create the location sheet for the different days that the user is working on, the sheet being called “1. Locations Day NºX”. In this sense, the sheet “1. Locations” is important because it allows the user to check all the customers already entered. As this sheet contains information about the day of the customers and their time window, the user can block this time window when creating a feasible route.

The distances sheet contains the distances and travel times between the customers of the corresponding day on the location sheet. The other features of the sheets remain the same as in the VRP Solver.

The vehicle compatibility sheet is generated in a similar manner to the other sheets, but a distinct sheet is created for each day. The generation of this sheet is initiated by the reading of the cell in the "VRP Solver Console" sheet that defines the day on which the requirement for more than one vehicle is necessary. Consequently, if the current day corresponds to the day on which the requirement for more than one vehicle is necessary, the sheet is generated with this information. In addition, the sheet contains the tool's original information, such as cost parameters, e.g. costs per distance unit and per trip, operational parameters such as capacity, driving time limit, etc.

Finally, two solution sheets have been created. Regard the "4. Fictitious Solution" sheet is concerned, its structure remains the same as the original VRP Solver. However, in Figure 2, "4. Fictitious Solution" sheet of the original tool only has one table since it only works for planning a unique route. Thus, the development of the "4. Fictitious Solution" sheet is different, since a table is created that corresponds to the planning of routes for each day, which are created using Algorithm 3 described in the previous chapter. The tables use the information from sheet "1. Locations" of the corresponding day on service times and collection/delivery quantities, as well as the distances and durations in sheet "2. Distances" of the corresponding day to calculate departure/arrival times and travel costs between customers. Another sheet is created from this one, which serves as the current solution, called "4.1. Current Solution". This sheet is an auxiliary sheet, created and updated whenever the feasibility of a route is checked. It helps the procedure created for reading customers who are already on defined routes and new customers.

Lucro líquido total: 0,00

Veículo:	**V1**	**Pára:**	0	**Lucro líquido:**	0,00			
Parar a contagem	**Nome do local**	**Distância viajada**	**Tempo de condução**	**Tempo de chegada**	**Hora de partida**	**Expediente**	**Lucro coletado**	**Carga**
0	Armazém	0,00	0:00		08:00	0:00	0	0
1								
2								
3								
4								
5								
6								

Razões de inviabilidade detectadas

Figure 2 - 4. Solution spreadsheet of the original tool

Chapter 5.
Results and Comparisons

This chapter presents the results obtained, with a comparison of the performance of the new tool with the manual method currently used by the employees. To this end, the new tool was tested in several realistic scenarios using historical data provided by the company.

As the historical data lacks comprehensive records of the specific routes planned, a direct comparison with the routes planned by the new tool was not possible. However, as the company's main objective is the effective management of slots for customers, and not the specificity of the routes, the analysis focuses on comparing the time required for different scenarios. Three scenarios were tested to assess the time needed for route planning: the first scenario involves planning the route for a single day; the second scenario extends the planning to a two-days period and the third scenario involves planning the route for ten-day period in order to evaluate the proposed maximum limit.

In a first scenario (Figure 3), a set of data was gathered by Team 1 on a designated day, the tool was tested to determine the time required to complete the route planning process for a single day. The data was entered into the sheet designated "1. Locations" in a period of 14 seconds. Subsequently, the remaining sheets were created, namely "2. Distances Day Nº1", "3. Vehicles" and "3.1. Compatibility vehicles Day Nº1", "4. Fictitious Solution" and "4.1. Current Solution", the last two of which are created only once and then only updated, took 26 seconds. The execution of the VRP Solver, the feasibility check and the locking of customer schedules took 2 minutes and 15 seconds. In total, the one day's route planning was completed in 3 minutes and 35 seconds.

Lucro líquido total:	**-112,00**				**Dia Nº1**	
Veículo:	**V1**	**Pára:**	**5**	**Lucro líquido:**	**-112,00**	
Parar a contagem	**Nome do local**	**Distância viajada**	**Tempo de condução**	**Tempo de chegada**	**Hora de partida**	**Expediente**
0	Armazém	0,00	0:00		08:00	0:00
1	1-26802-2023	29,95	0:29	08:29	10:59	2:59
2	1-01320-2024	57,00	0:59	11:29	12:29	4:29
3	1-01778-2024	88,38	1:32	14:02	15:02	7:02
4	3-00278-2024	88,38	1:32	15:02	16:02	8:02
5	Armazém	112,00	1:57	16:27		8:27

Figure 3 - One-day route planning results

The second scenario (Figure 4) was conducted with a different scenario of a two-day period. The process of entering the required a total of 19 seconds. The remaining sheets were created in the same manner as the previous set, with the creation of sheets “4. Fictitious Solution” and “4.1. Current Solution” also included. The processing time for this part was 49 seconds, which reflects the additional computational burden associated with considering the entering of the data set. The VRP Solver was executed in a total of 7 minutes and 14 seconds. The increase in time compared to the previous scenario can be attributed to the fact that the tool performs an admissibility check on all requests on the first day. In that event the tool identifies requests exceeding the 5pm deadline, it removes them and assigns them to the subsequent day, recalculating the routes until it obtains an acceptable solution for each day. In total, it required 8 minutes and 22 seconds to complete the route planning for two days.

Lucro líquido total:	**0,00**				**Dia Nº1**	
Veículo:	**V1**	**Pára:**	**7**	**Lucro líquido:**	**0,00**	
Parar a contagem	**Nome do local**	**Distância viajada**	**Tempo de condução**	**Tempo de chegada**	**Hora de partida**	**Expediente**
0	Armazém	0,00	0:00		08:00	0:00
1	3-03449-2023	9,82	0:17	08:17	08:47	0:47
2	3-03450-2023	9,82	0:17	08:47	09:47	1:47
3	1-03062-2024	42,32	0:45	10:15	11:15	3:15
4	1-02995-2024	47,23	0:59	11:29	12:29	4:29
5	3-01184-2023	51,07	1:11	13:41	14:41	6:41
6	2-00001-2024	55,61	1:21	14:51	15:51	7:51
7	Armazém	84,82	1:50	16:20		8:20

Lucro líquido total:	**0,00**				**Dia Nº2**	
Veículo:	V1	Pára:	6	Lucro líquido:	0,00	
Parar a contagem	Nome do local	Distância viajada	Tempo de condução	Tempo de chegada	Hora de partida	Expediente
0	Armazém	0,00	0:00		08:00	0:00
1	3-00234-2024	20,61	0:19	08:19	09:49	1:49
2	1-03030-2024	57,88	0:49	10:19	11:19	3:19
3	1-03060-2024	64,74	0:59	11:29	12:29	4:29
4	1-03601-2024	64,74	0:59	13:29	14:29	6:29
5	3-02790-2023	95,99	1:23	14:53	15:53	7:53
6	Armazém	118,16	1:41	16:11		8:11

Figure 4 - Two-days route planning results

In the third scenario (Figure 5), route planning was conducted over a 10-day period, once more using the historical data set. The process of entering the data set required a total of 1 minute and 17 seconds, while the creation of the remaining sheets occupied 4 minutes and 1 second. The subsequent execution of VRP Solver required 46 minutes and 41 seconds. As previously stated, the initial step is to evaluate a route with all the requisite data and eliminate those the exceed 5pm. These are passed on to the next day, and this process continues until the result of all the feasible routes has been reached. The total time required to complete the route planning was 52 minutes and 59 seconds.

Lucro líquido total: 0,00 — Dia Nº1

Veículo: V1 Pára: 6 Lucro líquido: 0,00

Parar a contagem	Nome do local	Distância viajada	Tempo de condução	Tempo de chegada	Hora de partida	Expediente
0	Armazém	0,00	0:00		08:00	0:00
1	3-00341-2024	8,50	0:15	08:15	10:00	2:00
2	3-00369-2024	20,61	0:30	10:15	11:45	3:45
3	1-02050-2024	20,61	0:30	11:45	12:45	4:45
4	1-01113-2024	20,61	0:30	13:45	14:45	6:45
5	3-02790-2023	62,90	1:03	15:18	16:18	8:18
6	Armazém	85,07	1:21	16:36		8:36

Lucro líquido total: 0,00 — Dia Nº2

Veículo: V1 Pára: 7 Lucro líquido: 0,00

Parar a contagem	Nome do local	Distância viajada	Tempo de condução	Tempo de chegada	Hora de partida	Expediente
0	Armazém	0,00	0:00		08:00	0:00
1	3-03449-2023	9,82	0:18	08:18	08:48	0:48
2	3-03450-2023	9,82	0:18	08:48	09:48	1:48
3	1-04506-2024	19,06	0:30	10:00	11:00	3:00
4	1-00719-2024	39,05	0:52	11:22	12:52	4:52
5	1-05906-2024	39,05	0:52	13:52	14:52	6:52
6	1-03209-2024	39,05	0:52	14:52	16:22	8:22
7	Armazém	45,25	1:04	16:34		8:34

Lucro líquido total: 0,00 — Dia Nº3

Veículo: V1 () Pára: 6 Lucro líquido: 0,00

Parar a contagem	Nome do local	Distância viajada	Tempo de condução	Tempo de chegada	Hora de partida	Expediente
0	Armazém	0,00	0:00		08:00	0:00
1	1-03601-2024	9,63	0:17	08:17	08:47	0:47
2	1-31201-2023	43,25	0:45	09:15	11:15	3:15
3	1-30728-2023	67,82	1:13	11:43	12:43	4:43
4	1-01263-2024	69,44	1:17	14:17	15:17	7:17
5	1-01805-2024	70,66	1:20	15:20	16:50	8:50
6	Armazém	117,19	1:54	17:24		9:24

Veículo: V2 () Pára: 6 Lucro líquido: 0,00

Parar a contagem	Nome do local	Distância viajada	Tempo de condução	Tempo de chegada	Hora de partida	Expediente
0	Armazém	0,00	0:00		08:00	0:00
1	1-02342-2024	21,83	0:22	08:22	10:22	2:22
2	1-03062-2024	24,15	0:27	10:27	11:27	3:27
3	1-02995-2024	29,06	0:41	11:41	12:41	4:41
4	3-01184-2023	32,90	0:53	13:53	14:53	6:53
5	1-21010-2024	42,54	1:08	15:08	16:38	8:38
6	Armazém	72,05	1:35	17:05		9:05

Lucro líquido total: 0,00 — Dia Nº4

Veículo: V1 Pára: 5 Lucro líquido: 0,00

Parar a contagem	Nome do local	Distância viajada	Tempo de condução	Tempo de chegada	Hora de partida	Expediente
0	Armazém	0,00	0:00		08:00	0:00
1	1-26651-2024	52,05	0:42	08:42	09:42	1:42
2	2-00001-2024	83,90	1:17	10:17	11:17	3:17
3	3-86601-2023	91,91	1:32	11:32	13:17	5:17
4	1-95251-2023	91,91	1:32	14:17	16:17	7:17
5	Armazém	115,53	1:57	16:42		7:42

Lucro líquido total: 0,00 — Dia Nº5

Veículo: V1 Pára: 4 Lucro líquido: 0,00

Parar a contagem	Nome do local	Distância viajada	Tempo de condução	Tempo de chegada	Hora de partida	Expediente
0	Armazém	0,00	0:00		08:00	0:00
1	1-02341-2024	21,83	0:22	08:22	10:22	2:22
2	1-00390-2024	74,18	1:05	11:05	13:05	4:05
3	3-00598-2024	93,56	1:27	14:27	16:27	7:27
4	Armazém	117,36	1:52	16:52		7:52

Lucro líquido total: 0,00 — Dia Nº6

Veículo: V1 () Pára: 6 Lucro líquido: 0,00

Parar a contagem	Nome do local	Distância viajada	Tempo de condução	Tempo de chegada	Hora de partida	Expediente
0	Armazém	0,00	0:00		08:00	0:00
1	1-03462-2024	28,29	0:25	08:25	10:55	2:55
2	1-00476-2024	31,28	0:32	11:02	12:02	4:02
3	3-01202-2024	34,49	0:41	13:11	14:11	6:11
4	1-02638-2024	34,49	0:41	14:11	15:11	7:11
5	1-01820-2024	52,80	0:59	15:29	16:29	8:29
6	Armazém	68,96	1:14	16:44		8:44

Veículo: V2 () Pára: 5 Lucro líquido: 0,00

Parar a contagem	Nome do local	Distância viajada	Tempo de condução	Tempo de chegada	Hora de partida	Expediente
0	Armazém	0,00	0:00		08:00	0:00
1	1-02813-2024	26,50	0:32	08:32	09:32	1:32
2	1-03030-2024	55,07	0:59	09:59	10:59	2:59
3	1-03060-2024	57,85	1:05	11:05	12:05	4:05
4	1-03787-2024	79,17	1:25	13:25	14:25	6:25
5	Armazém	108,16	1:52	14:52		6:52

Lucro líquido total: 0,00 — Dia Nº7

Veículo: V1 Pára: 8 Lucro líquido: 0,00

Parar a contagem	Nome do local	Distância viajada	Tempo de condução	Tempo de chegada	Hora de partida	Expediente
0	Armazém	0,00	0:00		08:00	0:00
1	1-04354-2024	5,78	0:12	08:12	09:42	1:42
2	1-31152-2023	11,30	0:25	09:55	10:55	2:55
3	1-31148-2023	11,30	0:25	10:55	11:55	3:55
4	1-31145-2023	11,30	0:25	11:55	12:55	4:55
5	1-31132-2023	11,30	0:25	13:55	14:55	6:55
6	3-03550-2023	11,30	0:25	14:55	15:55	7:55
7	3-03881-2023	11,30	0:25	15:55	16:55	8:55
8	Armazém	11,30	0:25	16:55		8:55

Lucro líquido total: 0,00 — Dia Nº8

Veículo: V1 Pára: 5 Lucro líquido: 0,00

Parar a contagem	Nome do local	Distância viajada	Tempo de condução	Tempo de chegada	Hora de partida	Expediente
0	Armazém	0,00	0:00		08:00	0:00
1	1-04136-2024	6,20	0:12	08:12	10:42	2:42
2	3-01611-2023	12,31	0:23	10:53	11:53	3:53
3	3-01610-2023	12,31	0:23	11:53	13:23	5:23
4	1-04750-2024	18,29	0:35	14:35	16:35	8:35
5	Armazém	24,50	0:48	16:48		8:48

Lucro líquido total: 0,00 — Dia Nº9

Veículo: V1 Pára: 8 Lucro líquido: 0,00

Parar a contagem	Nome do local	Distância viajada	Tempo de condução	Tempo de chegada	Hora de partida	Expediente
0	Armazém	0,00	0:00		08:00	0:00
1	1-04717-2024	26,38	0:25	08:25	09:25	1:25
2	1-31143-2023	52,92	0:51	09:51	10:51	2:51
3	1-31142-2023	52,92	0:51	10:51	11:21	3:21
4	1-31140-2023	52,92	0:51	11:21	12:21	4:21
5	1-31137-2023	52,92	0:51	13:21	14:21	6:21
6	1-31136-2023	52,92	0:51	14:21	15:21	7:21
7	1-31134-2023	52,92	0:51	15:21	16:21	8:21
8	Armazém	52,92	0:51	16:21		8:21

Lucro líquido total: 0,00 — Dia Nº10

Veículo: V1 Pára: 5 Lucro líquido: 0,00

Parar a contagem	Nome do local	Distância viajada	Tempo de condução	Tempo de chegada	Hora de partida	Expediente
0	Armazém	0,00	0:00		08:00	0:00
1	1-04151-2024	24,38	0:26	08:26	09:56	1:56
2	1-04812-2024	43,92	0:47	10:17	12:17	4:17
3	1-01082-2024	72,42	1:16	13:46	14:46	6:46
4	1-00460-2024	117,88	1:51	15:21	16:51	8:51
5	Armazém	117,88	1:51	16:51		8:51

Figure 5 - Ten-day route planning results

A comparison between the average time of 10 minutes taken by the manual process with the results obtained using the new tool revealed a significant reduction in the requisite time. For a single day's route planning, the tool required a total of 3 minutes and 35 seconds, representing a significant reduction in time of 6 minutes and 25 seconds. When considering a two-day period, the tool required only seven minutes and 12 seconds, significantly shorter time than the average manual time of 20 minutes. This further demonstrates the efficiency of the tool. Over a course of 10 working days, the total time of 52 minutes and 59 seconds remains less than the average time per day multiplied by the days that we are working with.

It is important to note that the time required for entering customer data may be longer than indicated, as the data was already organized and compiled. In practice, employes will have to organize the data in a way that allows them to enter it, which may add to the time needed. It is also noteworthy that the route planning for a ten-day period was conducted to assess the tool's capacity limits. It is likely thar such a large volume of customers will only be entered on an occasional basis in practical situations. The company will use the tool on a daily basis and is unlikely to need to plan routes for such extended periods. Nevertheless, it would be prudent to consider this possibility because of its potential need, for instance after the company's holidays periods.

Chapter 6.
Conclusions

This chapter presents the principal insights derived from the research project. The research also identifies the limitations inherent to the tool under examination. Furthermore, the chapter will also present suggestions for future research.

The objective of this research was to develop a tool to assist ProgressClim Solutions in planning routes for their teams, with the primary goal of reducing the time spent by employees in the manual process of route planning and managing customer slots.

The results showed that while the tool is effective in reducing the time currently spent by employees in certain situations, the total time required for planning increases as both customer volume and the number of days to be planned increase. As shown in the previous section, the route planning scenario for a single day was completed in 3 minutes and 35 seconds, in strong contrast to the 10 minutes typically required for the manual process. Nevertheless, when the planning period was extended to ten days, the tool required 52 minutes and 59 seconds, a significant increase in time.

The tool developed offers significant benefits to the company, most notably in terms of time savings, particularly in the context of daily route planning. At present, employees are required to plan routes on a daily basis for the following days, and the tool has the potential to significantly reduce this administrative burden. Furthermore, the company has a limited workforce of only two individuals, and fluctuations in staffing levels, such as turnover or extended vacations, can make this task challenging. The tool helps to mitigate this problem by reducing the reliance on employee knowledge and presence. The tool enables more efficient management of customer time windows, ensuring service fulfillment. Although the company works with two different time windows to avoid overlapping schedules, it is important to note that the tool allows the visualization of travel and service times for each customer.

However, it lacks human knowledge and common sense, which is a significant limitation. In other words, a route may be identified by employees with specific experience and knowledge as sub-optimal due to the characteristics of the service or specific conditions. Such conditions may include the weather, which can impact the viability of certain services on rainy days or in extreme heat. Additionally, in situations where flexibility and rapid adaptation are required, human employees can demonstrate greater agility in adjusting routes in response to unforeseen changes. This is a capability that the tool can perform, although not with the same degree of effectiveness.

The tool's adaptability to alternative business contexts is encouraging, given its flexible structure and functionality based on the company ProgressClim Solutions, but it still has features that facilitate its adaptation to other business contexts, in a manner analogous to that of the original VRP Spreadsheet Solver.

The tool's modularity represents a significant advantage, the flexibility of the spreadsheet format allows for the incorporation of different data types and specific requirements of other companies. For example, companies that provide a variety of services, have specific delivery and collection requirements, and have different opening hours may find this tool beneficial. The customizability of this tool enables its incorporation into existing operational processes in various business contexts. Furthermore, as the tool is constructed from VBA code, the necessary modifications to adapt the algorithm to the specific requirements of other companies can be achieved with relative ease.

Moreover, the tool enhances efficiency and time management in sectors that rely on route planning, including delivery and collection services, technical maintenance, and logistics.

In summary, the recently developed tool for route planning is demonstrating efficacy in reducing the time required by employees, particularly in the context of daily planning. Notwithstanding the augmented time expenditure associated with route planning over several days, the tool has demonstrably reduced the time required compared to the manual process. However, the tool is not without limitations. For instance, it lacks the capacity to integrate human technical knowledge and is less able to adapt to unforeseen circumstances than a human operator. In conclusion, the tool represents a significant advancement in route planning, offering a practical and adaptable solution for a range of business contexts, and contributing to enhanced operational efficiency.

6.1 Limitations

Notwithstanding the advantages of the new tool, there are still considerable constraints that have an adverse effect on its efficacy.

One of the principal constraints is the processing time, which remains inadequate. The need to continually create and delete spreadsheets as one progresses through the various days results in a time-consuming process. Excel's increased total time when dealing with a substantial number of clients and multiple days to be planned is a consequence of this.

A further limitation is the way the days are represented in the tool. Instead of the conventional date format (dd/mm/yyyy), the days are represented as numerals, such as 1, 2, 3, and so forth. Although this approach is functional, it can lead to confusion when tracking specific days, necessitating manual entry to avoid confusion. Furthermore, the software does not permit the consolidation of the three work teams into a single file. At present, the management of Teams 1 and 2 is conducted within a single file, whereas the management of Team 3 is conducted within a separate file.

In conclusion, these limitations indicate areas for further investigation and potential enhancements to the tool.

6.2 Future Research

Regarding future work, it is imperative to surmount the constraints that were identified during the tool's development to enhance its efficacy.

One of the principal objectives for future work will be to optimize processing time. The necessity to create and delete spreadsheets has a considerable impact on the system's processing speed. Consequently, a significant enhancement will be the storage of variables directly in the code, which can reduce the necessity for repetitive operations and accelerate processing time. It would be beneficial to explore the possibility of replacing the sequential day format with actual dates. This alteration will facilitate the administration of particular days, thereby offering a more precise representation of the planning process.

Furthermore, unifying the three work teams into a single file will facilitate enhanced coordination of general operations, thereby promoting operational efficiency. Consequently, planning time will be less encumbered by the necessity of working on two files simultaneously.

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