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Re-engineering and Optimization of Material Collection and Distribution in Hospitals

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DECLARAÇÃO

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ABSTRACT

The recent economical climate brought the search for efficiency into priority in the different sectors of economic activities. The healthcare sector needs many resources to accomplish proper functioning and its management and organization can become a complicated task. Operations Research tools can be an added value when treating these tasks by giving reliable results and freeing working time for these tasks' performers.

This dissertation was developed as the final project for Mestrado Integrado em Engenharia e Gestão Industrial from Universidade do Minho. The project was developed in the logistics department of Hospital de Braga.

The main goal of this project was the analysis of the current practice for internal material distribution and to propose improvements for efficiency. The project focused on the internal transportation of documents, which revealed to be an area that would benefit from improvements. The project was mainly the creation of a routing system that would make the task of collecting and delivering documents inside the hospital more efficient than the current practice.

In this dissertation, several working methodologies were formulated, adapting well-known routing problems such as the traveling salesman problem and the multiple traveling salesman problem. These adaptations were made properly for reliable formulation of the problem's characteristics that later served to simulate the performance obtained with the implementation of the proposed methodologies. As result, the presented methodologies proved to give significant improvements for the collection and delivery of documents, which led to the installation of one of these methodologies.

KEYWORDS

Traveling Salesman Problem, multiple Traveling Salesman Problem, Hospital Efficiency, Internal Distribution, Routing.

Resumo

Com a atual conjuntura económica, a procura de eficiência tornou-se um lema nos diversos sectores das atividades económicas. O sector da saúde necessita de bastantes recursos para conseguir um funcionamento apropriado e a sua gestão e organização pode ser uma tarefa bastante complicada. As ferramentas de Investigação Operacional podem tornar-se numa mais valia no tratamento destas tarefas ao dar resultados fidedignos e ao libertar tempo de trabalho aos seus responsáveis.

Esta dissertação foi desenvolvida no decurso do projeto final do Mestrado Integrado em Engenharia e Gestão Industrial da Universidade do Minho. O projeto foi desenvolvido no departamento de logística do Hospital de Braga.

O principal objectivo do projeto era analisar a atual prática de distribuição interna de material e propor melhorias no sentido de melhorar a sua eficiência. O projeto incidiu no transporte interno de documentos, por esta se ter revelado uma área que poderia beneficiar com algumas melhorias. O problema residia principalmente no estabelecimento de um sistema de rotas que tornasse a tarefa de recolher e entregar documentos dentro do hospital mais eficiente que a prática implementada.

Nesta dissertação, diversas metodologias de trabalho foram formuladas, adaptando problemas de estabelecimento de rotas bastante conhecidos como é o caso do problema do caixeiro viajante e do problema dos múltiplos caixeiros viajantes. Estas adaptações foram geradas para proporcionar formulações fidedignas das características do problema que serviriam para simular o desempenho obtido na implementação das diferentes metodologias apresentadas. Como resultado, comprovou-se que as metodologias apresentadas obteriam melhorias significativas na tarefa de recolha e entrega de documentos, o que levou à implementação operacional de uma delas

Palavras-Chave

Problema do caixeiro-viajante, Problema de múltiplos caixeiros-viajantes, Eficiência Hospitalar, Distribuição Interna, Criação de Rotas.

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ABBREVIATIONS AND SYMBOLS

ATSP	Asymmetric Traveling Salesman Problem
CPU	Central Processing Unit
CSCMP	Council of Supply Chain Management Professionals
GDP	Gross Domestic Product
IP	Integer Programming
LP	Linear Programming
mTSP	multiple Traveling Salesman Problem
mTSPTW	multiple Traveling Salesman Problem with Time Windows
OPL	Optimization Programming Language
OR	Operations Research
RP	Routing Problems
STSP	Symmetric Traveling Salesman Problem
TSP	Traveling Salesman Problem
VBA	Visual Basic for Applications
VRP	Vehicle Routing Problem
WHO	World Health Organization

1. INTRODUCTION

1.1 Motivation

The concept of logistics is expanding. Growing interest of various industries in logistics applications and techniques is opening up new challenges and research areas. Over the years, health care industry has become a significant part of a developed country's economy. In Portugal, total health care expenses reached more than 10% of GDP in 2010, a value that takes on a greater importance when compared to the European average, which reaches around 9% (WHO, 2012).

Typically, an healthcare supply chain system consumes 20 to 30% of its total expenses (Brennan, 1998). Therefore, it is a great burden on the system and integration of various collection and distribution services can provide for cost reduction while improving the speed and quality of the services.

Hospitals can be considered as one of the main examples of health care centres. They are organizations with complex systems and require the best coordination of all the processes and resources to guarantee patient's and other stakeholder's satisfaction. In this context, logistics is vital as it takes on the responsibility for reception, management and distribution of all kind of materials, both extra- and intra-hospital.

Proper management of logistics typically reduces operational costs, increases resource efficiency, and enables effective material management. Internal collection and distribution of materials is part of any hospital's supply chain and takes care of material management inside the hospital. Therefore, it is very important for this service to be coordinated as well as possible so that the provision of materials and medical procedures can be successfully and efficiently preformed.

While there is increasing pressure to provide health care services in a cost-efficient way, development of mathematical models for real-world health care planning and particularly for its applications is remarkably underdeveloped (Doerner and Hartl, 2008).

When dealing with internal distribution, different hospital departments must be covered. Therefore, relevant materials for distribution must reach the recommended departments on time. With regards to such logistics, if distribution of several hospital services can be coordinated and managed all together, then much time and resources can be saved, reducing overall costs (Carvalho and Ramos, 2009). The use of Operational Research (OR) analytical methods can be expanded to these areas and consequentially the results can allow achievement of significant savings.

Regarding transportation of materials, optimization concerning routing problems can be very useful for dealing with real-world applications. Many problems have been studied in this context. The most popular are the Travelling Salesman Problem (TSP) and the Vehicle Routing Problem (VRP), which are combinatorial optimization problems concerning optimal design of routes. Each of these problems has their own specification and variants for these problems can be formed by adding constraints.

This project will take on a specific case study to explore the properties of these problems and generate new working models, i.e., new ways to perform the job of collecting and delivering materials inside hospital facilities. The case study refers to the collection and delivery of documents such as medical reports, specific exam requests, mail and others inside the facilities of Hospital de Braga. Routes on this service are not defined and currently made up by each courier who provides the service. The problem then is to determine the most efficient working model and design a set of routes for the couriers.

1.2 Objectives

The main objective of this dissertation is to improve efficiency of document collection and delivery in a hospital. Associated to this main objective, other aspects have to be considered, such as:

An analysis of the current status and needs in the hospital, which include an evaluation of current practice;

Formulation and implementation of new optimization models for changing the current processes via use of more effective solution approaches.

1.3 Organization of Dissertation

This dissertation is organized in seven chapters.

In the second chapter, firstly we describe the entity where the problem is found. Later an explanation of the problem can be found with an insight of the current working processes and how they are organized. The third chapter gives a literature review, where some of the main Operations Research (OR) problems related to routing problems are described and solution methods explained.

In chapter 4, an evaluation of the efficiency of the current status is given. Later, different methodologies to solve the problem are proposed. These approaches consist of the restructure of the current working processes, which explore alternatives to the current practice. Also, different methodologies need different mathematical formulations; they are introduced in this chapter after the respective methodology is presented.

Next chapter presents computational analysis, where results are compared and discussed. Also, different solution methods to solve the problem and data input strategies are discussed.

Finally, chapter 6 presents an insight into the implementation of one of the proposed methodologies at the hospital facilities and chapter 7 presents conclusion, where an appreciation of the achieved objectives is discussed and possible future work is introduced.

2. PROBLEM DESCRIPTION

There are many logistics issues in hospitals and one key issue is the transfer of materials and products from one place to another. The availability and needs of various types of products in the hospital can impact the efficiency of logistics and timeliness of different medical procedures. Therefore, material and product transfer within the hospital must be done as well as possible. The problem described in this chapter is based on an actual situation in a hospital.

2.1 Hospital de Braga

The hospital in this study concerns Hospital de Braga. Having a building structure of 140.000 m^2 of area, this hospital opened in May of 2011. It is the successor of Hospital S. Marcos, an institution with over 500 years in Braga. It provides healthcare treatment to over 1.1 million people in the districts of Braga and Viana do Castelo and serves also as a platform for research and university teaching.

This structure was built to be the most effective and efficient possible for providing healthcare services to the people of its coverage area. In this sense, it was built with:

- Internment rooms with a maximum of two beds in each and all with private bathrooms;
- Twelve operating rooms;
- Delivery rooms;
- 60 offices for medical consultancy;
- Psychiatric service with own private access;
- Helipad for quicker transportation of urgent patients.

Aiming for high efficiency, a management partnership was established with Grupo José de Mello Saúde in 2009.

For having large area, material transfers and movements between the different units need to be coordinated and managed properly to prevent waste of time and improve usage of materials and resources. Although the building was designed and constructed to prevent wastes, that does not mean it cannot happen.

2.2 Logistic Issues in the Hospital

Distribution of products and materials inside a hospital is something of great importance. A large number of materials must be moved for different services to be properly preformed. These materials include documents, medical and surgical supplies, pharmaceutical materials, laundry, sterilization and waste products. Each of these categories has its own operational characteristics and a single team is dedicated for each purpose:

Documents - circulation of information between hospital departments;

Medical and Surgical Supplies - delivery of material used for medical procedures;

Pharmaceutical Material - delivery of medicine;

Laundry - delivery of clean laundry and collection of dirty ones;

Sterilization - collection of dirty medical materials and delivery of clean ones;

Waste - collection of wastes.

This thesis is focused on the category of documents, which is discussed in detail bellow.

2.2.1 Document Collection and Delivery Problem

This problem concerns the distribution of the documents inside the facilities of Hospital de Braga. Transportation of documents between the various departments is a critical issue for proper functioning of the hospital since efficiency and effectiveness of most procedures involve patient profiles and records, diagnostic reports, applications for exams, relevant notes and mail, etc.

The tasks of collection and delivery of the documents for each department takes place in an office or balcony. These offices or balconies represent the location for different departments. Some of these departments are joined in the same office or balcony for operational ease. There are over 62 different department locations in the hospital available for the couriers to collect and deliver documents. In 50 of them, both collection and delivery tasks can happen while only delivery of documents happens in the others.

The objectives of the problem include reduction in the number of visits to each department and the assignment of the departments to the couriers for designing the travel routes. The overall result must fulfil the global objective of minimizing the total time required to accomplish the tasks of collection and delivery of the documents.

The following assumptions are made:

- Each courier is assigned a container for carrying the documents. Capacity of each container is large enough and not a limiting factor;
- Information on whether a department has documents for collection is unknown;
- Information on the departments to deliver the documents is also unknown until the documents are collected;
- Each department must be visited at least twice daily for collection of the documents and the documents collected must be delivered on the same day. Due to the protocols with some documents for ensuring deliverance, upon delivery of a document, a new delivery is assigned for the protocol to be returned to the origin of the document, which can be made in the following day.
- Most documents have specific pairs for collection and delivery departments. Few protocols from a particular type of documents require those documents to travel together.
- No time windows are assigned for collection or delivery of the documents.
- Service times are associated with the collection and the delivery of the documents.

2.3 Current Solution Method

At present, six couriers fulfill document distribution within the hospital facilities. The team works five working days per week, on seven-hour shift each day. These couriers typically scout the hospital, collecting documents that need to be collected from certain departments and delivering them to their destination departments. This process is structured as a two-phase cycle presented in the following diagram, which is repeated twice per day. The cycle requires the couriers only to pick up the documents in the first phase and deliver them in the second phase. Also, repetition of this cycle has the purpose of making the documents arrive at their final destinations faster. The sequence in which the departments are visited is not fixed and the routing options are based on the experience of the couriers.

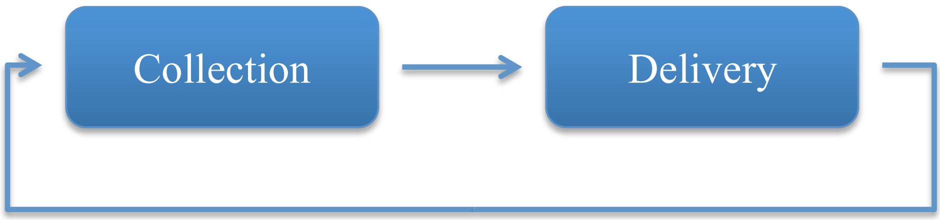

Figure 2.1 - Collection and Delivery Cycle

In the first phase, each courier is assigned to visit a number of closely located departments to pick up the documents. When visiting a department, all its documents are allocated to the visiting courier. The information on where to collect the documents and where to deliver them is not known until the couriers physically visit the departments. The courier then becomes responsible for delivering the documents to their destination departments.

The delivery phase for each courier begins only after all relevant departments for document collection have been visited by the courier. Therefore, this second phase is not synchronized for all couriers. Its beginning is dependent on the different departments assigned to each courier along with the time spent in the collection phase.

In the second phase, each courier visits only departments to deliver the documents he had already picked up. After visiting the relevant departments in the collection phase, the couriers do not come back to the location where they started the route. The starting location for the second phase is the end location of the collection phase. At that point all information related to the departments to visit for delivery of documents is known.

In each phase, two different processes that require time from the couriers can be distinguished. One is the travel between the departments and the other relates to each department's collection, delivery or organization of documents previously collected. Let the times spent for the two processes be defined as travelling time and service time, respectively.

As described earlier, the routing that each courier takes in the second phase is dependent on the destination department to which each document is addressed.

There are different types of documents to deliver but concerning their transportation only the destination and one other specific characteristic are important to complete the delivery: There are some documents with high level of importance in which case a protocol is attached to the document to keep track of its delivery. This protocol must be signed when delivered and returned to the department of origin.

There are different protocol types and most are attached to documents having one destination. Exception is with the protocols for documents with more than one destination. These protocols have more than one document attached, which can have different destinations and the courier must visit all destinations. This can only happen in three different departments, but not for every document leaving them.

Regarding departments to visit, one problem arises when different tasks are associated with different departments: there are some departments where both collection and delivery are needed whereas most departments only need delivery. This distinction is described in the table appendix I Couriers treat this case differently; they only visit these departments in the second phase and only if there are documents to be delivered.

When analyzing the delivery phase, two factors arise that can increase the time each courier would take to complete it. Both travelling and service times depend on:

- The number of departments for delivery;
- The experience of the couriers when choosing the paths between the departments.

Since documents are allocated to the couriers who collect them, the couriers need to visit all departments the documents are addressed to, independent of the number of documents collected. Experience is a critical factor regarding the travelling times of the sequence chosen to visit the departments. The sequence can be tricky because it depends on individual knowledge and perspective couriers have of the hospital facilities, which are going to influence the decisions on routing.

Problem Description

3. LITERATURE REVIEW

3.1 Healthcare and Routing

Distribution and logistics are important aspects of industrial and economic activities and their proper management is essential for every business entity. The Council of Supply Chain Management Professionals states that "Logistics management is that part of supply chain management that plans, implements, and controls the efficient, effective forward and reverses flow and storage of goods, services and related information between the point of origin and the point of consumption in order to meet customers' requirements" (CSCMP, 2013).

Many elements can be associated with the concept of logistics, one of which is material transportation. Within logistics, transportation problems are often hard for decision making because costs and restrictions are involved.

In a healthcare environment, material demand, availability and delivery can be extremely important because timely distribution of the materials must occur for efficient service to be provided. Aptel and Pourjalali (2001) show how healthcare centers can benefit from improvement methodologies. It suggests that the usage of new management methods can bring not only better operational synergy but also cost reduction onto healthcare industry. Optimization is one area that can be helpful in this respect.

Recently, interest in optimization problems within healthcare has been growing and becoming more relevant. Main reason is the higher ageing of population and increase of longevity in most of developed countries, which escalated costs for this social service. Certain optimization problems can address hospital issues; for instance, addressing hospital logistics, "optimized" material flow inside healthcare facilities can bring significant cost reduction. Many other examples can be found in Rais and Viana (2010), where a case study shows a possible 20% cost reduction with optimization of the flow of sterile instruments in the Netherlands. Also in Florez et al. (2008) a 31% reduction on the total travelled distance is achieved by creating a set of routes for a laundry service in a public hospital.

Within Operations Research (OR), optimization problems concerning the efficiency of transportation of goods are widely studied. Combinatorial optimization often has the goal of find the best element over a finite set of feasible solutions for some problem (Korte and Vygen, 2012). One such case is the routing problem dealing with transportation.

Routing Problems (RP) can be defined on graphs consisting of vertices and arcs connecting the vertices. These problems have received a lot of attention over the last half of the century. Enhanced capability and availability of computers over these past years had a significant influence on studying the RPs (Cook, 2012; Eksioglu et al., 2009; Waterloo, 2007). Researchers were able to study more complex and harder models, narrowing the gap between academic research and industry's needs, where several obstacles can arise when dealing with these problems.

Quite recently, the term "Rich Vehicle Routing" appeared to describe problems oriented for concrete real-world applications. Objective is to decrease the differences between practice and literature's basic models for routing vehicles and achieve better practical results with their application (Bertazzi et al., 2008; Drexl, 2012). Schmid et al. (2013) gives a recent overlook over the recent studied problems driven by their particular operational characteristics.

There are several classifications of RP depending on their specific characteristics (Eksioglu et al., 2009). There are two main categories based on the services' occurrence location: arc routing and node routing problems.

In node routing problem, the service activity happens essentially at the nodes where customer sites and demands are located. The arcs serve only as paths to connect the nodes (Assad et al., 1995). From this classification surges a ramification of a number of well-studied problems. Such as this project's problem, they involve the design of distinct tours for all the demand points to be visited on the most efficient way possible. Common problems of this kind are the Traveling Salesman Problem (TSP), the multiple-TSP (mTSP).

3.2 Traveling Salesman Problem

Given a collection of cities and the distances between the pairs, this problem is to find the shortest route to visit all cities exactly once and return to the starting city. Although the problem was defined with the intention of solving the particular problem of a salesman, it has several other applications in different fields beyond route planning (Jünger et al., 1995). Figure 3.1 shows an example of a TSP.

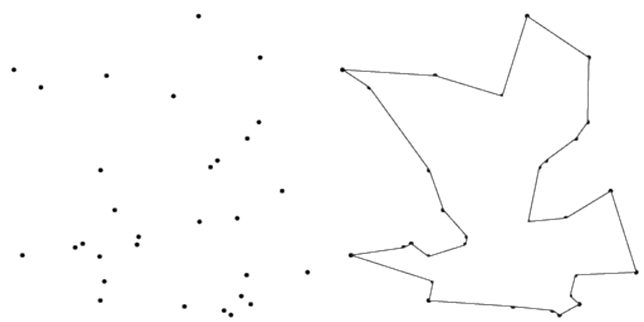

Figure 3.1 - TSP Example: on the left an instance, on the right an optimal solution of it

3.2.1 Integer Programming Model

Let G= (V, A) be a graph where V is the node set (representing cities) and A is the arc set. For each arc $(i, j) \in A$, a non-negative cost (c_{ij}), the cost required to travel from i to j, is associated which results in a matrix C = $\{c_{ij}\}^{vxv}$ called the cost matrix, where v is the number of nodes. It is considered 0 to be the initial node.

Depending on the nature of the cost matrix, TSP is classified into two classes. If $c_{ij} = c_{ji}$, then the TSP is called a symmetric traveling salesman problem (STSP). Otherwise, when $c_{ij} \neq c_{ji}$, it is called the asymmetric traveling salesman problem (ATSP).

The objective of this problem is to find one tour in G, i.e., a cycle which visits each node in the graph exactly once such that the sum of the costs of the arcs in the tour is as small as possible.

TSPs can be formulated as integer programming models. These integer programming formulations are based on binary variables, x_{ij}, which equals to 1 if node j is visited immediately after i and 0 otherwise. Additional subtour elimination constraints ensure that no subtours can be formed while solving the problem (Shmoys et al., 1985). These constraints can be modeled in different ways.

The basic model is as follows:

$$Minimize \sum_{(i,j)\in A} c_{ij}x_{ij} \tag{3.1}$$

Subject to:

$$\sum_{j\in V} x_{ij} = 1, \qquad \forall i \in V \tag{3.2}$$

$$\sum_{j \in V} x_{ji} = 1, \qquad \forall i \in V \tag{3.3}$$

$$+\ subtour\ elimination\ constraints \tag{3.4}$$

$$x_{ij} \in \{0,1\}, \qquad \forall (i,j) \in A, \tag{3.5}$$

The objective function (3.1) corresponds to the minimization of the sum of all costs of the arcs traversed, i.e. the total cost. Constraints (3.2) and (3.3) ensure that each node has only one outgoing and one ingoing arc, respectively. Constraint (3.5) guarantees the variable to be binary.

Constraints (3.4) can be incorporated in the model in different ways, as the two next presented.

Dantzig, Fulkerson and Johnson subtour elimination constraints are given by:

$$\sum_{i,j \in S} x_{ij} \leq |S| - 1, \qquad S \subseteq V \backslash \{0\},\ \ 2 \leq |S| \leq V - 1 \tag{3.6}$$

Constraints (3.6) state that from any subset S of the node set V, at most $|S| - 1$ arcs can be used. Such constraints grow in exponential number with n, which can make it impractical to solve (Bektas, 2006).

Sarin, Sherali and Bhootra´s subtour elimination constraints are given by:

$$y_{ij} \geq x_{ij}, \qquad i,j \in V \backslash \{0\}, \tag{3.7}$$

$$y_{ij} + y_{ji} = 1, \qquad i,j \in V \backslash \{0\}, \tag{3.8}$$

$$y_{ij} + y_{jp} + y_{pi} \leq 2, \qquad i,j,p \in V \backslash \{0\}. \tag{3.9}$$

Where y_{ij} is a binary variable such that it equals to 1 if node i precedes j in the route, i.e. if node j is visited after i even if not immediatly and 0 otherwise.

The variable y_{ij} relates to x_{ij} to determine a precedence relationship between i compared to j, preventing subtours to appear. Constraints (3.7) force node i to precede j if arc $ij \in A$ is traversed. Constraints (3.8) do only allow i to precede j or j to precede i, but not both. Constraints (3.9) do not allow tours without the initial node to be formed. These constraints together with the other constraints provide a valid formulation for the TSP. When compared with other formulations, the formulation with Sarin, Sherali and Bhootra´s subtour elimination constraints requires significantly reduced effort for solving because fewer solution candidates are explored computationally (Sarin et al., 2005).

This formulation with Sarin, Sherali and Bhootra´s subtour elimination constraints was considered for ATSP cases. However, since the STSP is a particular case of the ATSP, where the costs of the arcs $ij \in A$ and $ji \in A$ are same, the formulations presented are valid for both of them (Gutin and Punnen, 2002).

For the sake of brevity only these formulations are presented. More information about other TSP formulations can be found in Gutin and Punnen (2002) and Öncan et al. (2009).

3.3 Variants of the Traveling Salesman Problem

3.3.1 Multiple Traveling Salesman Problem

Given a set of nodes and a set of salesmen, the mTSP states that each node must be visited exactly once by one of the salesmen. Each salesman begins and ends his tour at a predetermined origin node. The objective is to minimize the total cost of visiting all nodes.

Various formulations for the mTSP have been proposed in literature. Among them are assignment-based formulation and a flow-based formulation.

Assignment-based formulations

This is the most commonly known formulation for the mTSP where 0 is the initial node for the routes and x_{ij} is a binary variable that takes the value of 1 if arc $ij \in A$ is on a tour, 0 otherwise. It can be stated as follows:

$$Minimize \sum_{(i,j)\in A} c_{ij}x_{ij} \tag{3.10}$$

Subject to:

$$\sum_{j\in V\setminus\{0\}} x_{0j} = m, \tag{3.11}$$

$$\sum_{j\in V\setminus\{0\}} x_{j0} = m, \tag{3.12}$$

$$\sum_{j\in V} x_{ij} = 1, \qquad \forall i \in V\setminus\{0\} \tag{3.13}$$

$$\sum_{j \in V} x_{ji} = 1, \qquad \forall i \in V \backslash \{0\} \tag{3.14}$$

$$+ \; subtour\ elimination\ constraints \tag{3.15}$$

$$x_{ij} \in \{0,1\}, \qquad \forall (i,j) \in A, \tag{3.16}$$

Constraints (3.13) and (3.14) are the same assignment constraints presented above for the TSP that ensure the node to be visited only once. (3.16) ensure that the variable x_{ij} is binary. Constraints (3.11) and (3.12) guarantee the departure and return of m salesmen to the depot, respectively. Although the already described subtour elimination constraints have been initially proposed for the TSP, they are also valid for the mTSP. This set of constraints (3.15) degenerate tours that are formed between nodes and are not connected to the origin.
mTSP differs from the TSP because instead of routing just one salesman, it considers routing m salesmen. This makes it more fitting to model certain real life situations.

Flow-based formulation

Assuming formal description, let K be the set of salesmen indexed by $k \in K$. We introduce here the three-index variable x_{ij}^k, which equals to 1 if salesman k visits node j immediately after node i and 0 otherwise. The formulation is given as follows:

$$Minimize \sum_{k \in K} \sum_{(i,j) \in A} c_{ij} x_{ij}^k \tag{3.17}$$

subject to:

$$\sum_{k \in K} \sum_{i \in V \backslash \{0\}} x_{ij}^k = 1\,, \qquad \forall j \in V \tag{3.18}$$

$$\sum_{j \in V} x_{ij}^k - \sum_{j \in V} x_{ji}^k = 0, \qquad \forall k \in K, \forall i \in V \tag{3.19}$$

$$\sum_{j \in V} x_{0j}^k = 1, \qquad \forall k \in K \tag{3.20}$$

$$+ \; subtour\ elimination\ constraints \tag{3.21}$$

$$x_{ij}^k \in \{0,1\}, \qquad \forall i, j, k. \tag{3.22}$$

Constraints (3.18) state that each node should be visited exactly once. Constraints (3.19) are the flow conservation constraints, which ensure that once a salesman visits a node then he must also depart from the same node. Constraints (3.20) ensure that each salesman is used exactly once.

An issue can arise using this model. The number of variables that are generated can turn out to be overly big for software to solve it, depending on the size of the mTSP. Thereby, solving directly a problem as such to optimality may be impractical. (Bektas, 2006)

3.3.2 mTSP with Time Windows

Time windows arise naturally in problems at business organizations with flexible time schedules.

The mTSP with Time Windows (mTSPTW) is a special case that incorporates time and its limitations into the problem. Such as previous problems, the mTSPTW involves the determination of the set of routes, which incurs on the minimal traveling cost. These routes start and end at a single depot and cover a set of nodes. However, it is determined that the visit at those nodes must begin within a time window when the service at that node is allowed.

Integer programming model

Assuming descriptions above, let x_{ij}^k be a decision variable, which will equal to 1 as value if salesman k visits node j immediately after node i and 0 otherwise. Let v be the fixed maximum number of salesmen to be used and T_i^k be the instant at which node i is visited. For each arc $ij \in A$ and $k \in K$, let c_{ij} be the cost to travel from i to j and t_{ij} be its traversal time. For each node $i \in A$, let s_i represent the service time at the node i. This service must be completed within the time interval $[a_i^k, b_i^k]$, where $a_i^k < b_i^k$ and $0<s_i<b_i^k - a_i^k$. Then mTSPTW is defined to find the least cost set of tours that satisfy problem's restrictions. This formulation takes the form:

$$Minimize \sum_{k \in K} \sum_{(i,j) \in A} c_{ij} x_{ij}^k \tag{3.23}$$

Subject to:

$$\sum_{k \in K} \sum_{j \in V} x_{ij}^k = 1, \qquad \forall i \in V \backslash \{0\} \tag{3.24}$$

$$\sum_{k\in K}\sum_{j\in V\backslash\{0\}} x_{0j}^{k} \le v, \tag{3.25}$$

$$\sum_{j\in V\backslash\{0\}} x_{0j}^{k} = 1, \qquad \forall k \in K \tag{3.26}$$

$$\sum_{j\in V} x_{ij}^{k} - \sum_{j\in V} x_{ji}^{k} = 0, \qquad \forall k \in K, \forall i \in V\backslash\{0\} \tag{3.27}$$

$$\sum_{j\in V\backslash\{0\}} x_{j0}^{k} = 1, \qquad \forall k \in K \tag{3.28}$$

$$x_{ij}^{k}\left(T_i^k + t_{ij} + s_i - T_j^k\right) \le 0, \qquad \forall k \in K, \forall (i,j) \in A \tag{3.29}$$

$$a_i^k \le T_i^k \le b_i^k, \qquad \forall k \in K, \forall i \in V \tag{3.30}$$

$$x_{ij}^{k} \in \{0,1\}, \qquad \forall i,j,k. \tag{3.31}$$

The objective function (3.23) represents the total cost. Constraints (3.24) impose that each node is visited exactly once. Constraint (3.25) limites a maximum number of salesmen to be used. Constraints (3.26)-(3.28) describe the routes' flow. Constraints (3.26) and (3.28) ensure that the salesman leaves and returns to the initial node, respectively. (3.27) ensure that if a salesman enters a node it has to leave it. Constraints (3.29) and (3.30) ensure feasibility of the time schedule and binary conditions on the flow variables are given in (3.31).
Linearization of constraints (3.29) is useful. Since binary conditions for flow variables are present, it can be written as:

$$T_i^k + t_{ij}^k - T_j^k \le M\left(1 - x_{ij}^k\right), \qquad \forall k \in K, \forall (i,j) \in A. \tag{3.32}$$

where M is a large constant.

3.4 Solution Methods

The combinatorial nature of these problems suggests that the number of combinations (possibly the candidates for the solutions) for only a few nodes can be very high. Over the years, the increase of computational power and the accomplishment of new theoretical results allowed the increase of the size of nontrivial instances solved (Applegate et al., 1998).

Two directions can be taken to solve these problems. On one hand, the optimality of the solution can be guaranteed by disregarding the time until this attainment, which normally is a lot. On the other hand, close-to-optimal solutions can be obtained rather quickly. The first direction refers to exact methods and the second refers to heuristics or approximate methods.

3.4.1 Exact Methods

Exact methods guarantee an optimal solution. To talk about exact methods, linear and integer programming concepts must be understood.

Linear Programming (LP) is an optimization method that aims to determine the best-valued solution for a linear objective function with a finite number of variables. Its value can be the maximum or minimum depending on the objective defined for the problem. The solution is also subject to an additional set of linear functions, equalities or inequalities, which must be respected. Therefore, the set of feasible solutions is formed by the intersection of these finite halfspaces. Integer Programming (IP) states that an additional constraint is introduced, imposing the solution to be integer.

The most common approach, virtually all software packages for integer programming include it, is branch and bound. Branch-and-bound relies on solving relaxations of the integer problem, obtained by dismissing the integrality constraints, using a linear programming algorithm as simplex.

These methods take a great number of iterations for complex problems to achieve the optimal solution. Thereby, the time spent to find the optimal solution can become excessive and impractical.

More information about these problems and their solution methods can be found in any introductory book on Operations Research, such as Korte and Vygen (2012).

3.4.2 Heuristics

Large instances or excessive computational time may be some of the difficulties when exact methods are used. In such cases approximate algorithms can be used to determine the best solution possible.

Heuristics are approximate algorithms that seek to find the best feasible solution possible in a problem’s search space in reasonable amounts of time. Heuristics fall into two groups. One is named *Constructive Heuristics* and it strategically constructs a feasible solution from scratch.

The other is *Improvement Heuristics* that systematically improves a given solution but can present only local minimum solutions. It occurs because the search for *Improvement Heuristics* ends whenever a better solution cannot be reached, giving a limited scope for the solution search. Typically both of these methods are included when searching for a solution. Despite not guaranteeing optimal solutions, heuristics can be easily implemented and take shorter processing times compared to exact methods. They also present more flexibility when dealing with different problems, can be easily changed to accommodate different restrictions. Gutin and Punnen (2002) concluded that similar results arise when comparing the implementation of the same heuristics on both STSP and ATSP.

In multiple routes' scenarios, construction algorithms are subdivided into sequential and parallel depending on the number of eligible routes for the insertion of a node. Sequential methods expand only one route at a time, whereas parallel methods consider more than one route simultaneously. (Cordeau et al., 2007)

As for improvement algorithms, they can operate on single routes or on several routes at a time to improve their global solution. For multiple routes' scenarios, the exchange of route parts, such as single nodes or connected paths, between routes is considered. Regarding this practice, different strategies can be used (Toth and Vigo, 2002). Some are classified as:

- string cross — There is an exchange of parts of two routes by crossing two arcs (Figure 3.2);

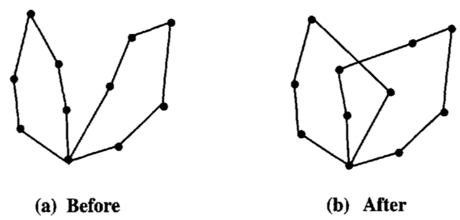

Figure 3.2 - String Cross

- string exchange — There is an exchange of k vertices between two routes (Figure 3.3);

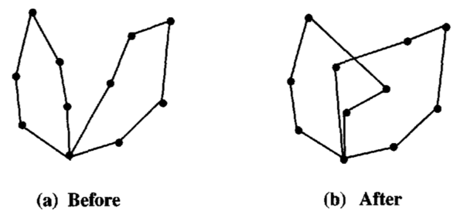

Figure 3.3 - String Exchange

- string relocation There is an exchange of k vertices from one route to another (Figure 3.4).

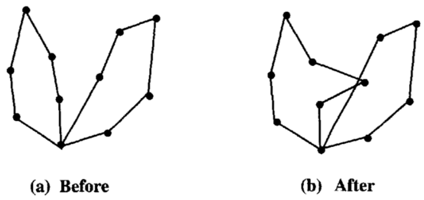

Figure 3.4 - String Relocation

Clark and Wright Heuristics Very well known, this heuristic is based on the concept of savings – the cost reduction that is obtained when two nodes are visited sequentially as it happens in the figure 3.5 on the right-side, instead of having them visited separately in the figure 3.5 on the left-side.

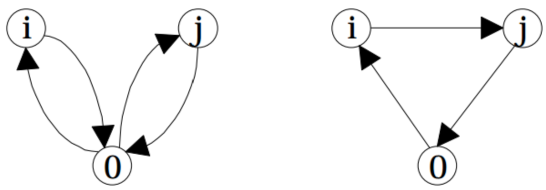

Figure 3.5 - Clarke and Wright Principle

Therefore, two nodes can be served consecutively on the same route if the savings provided is beneficial and does not violate any constraint of the problem (Clark and Wright, 1964). Denote by S_{ij} the savings given by summing the cost of the eliminated trips, between the depot and i (c_{0i}) and another between j and the depot (c_{j0}), and subtract the cost of the added trip between the two clients (c_{ij}). Savings can be provided by the following formula:

$$S_{ij} = c_{i0} + c_{0j} - c_{ij}$$

The algorithm starts with the calculation of the savings for all pairs of nodes i and j, $i \neq j$, which will be inserted in a list in a decreasing order. Let this be the savings list. Both parallel and sequential versions of this constructive algorithm can be processed when savings list is finished.

Parallel approach – the search for the best routes to merge is considered before a route extension. Verification on savings starts from the top of the savings list. It is determined for the arc in analysis whether there are two created routes that can be merged. If possible and considering the problem constraints, the merge is performed with the creation of the arc between i and j, which will connect the two routes. In case the merge is not possible, it is checked if the arc can be inserted on any routes' ends. New routes are created with this arc whenever it cannot be inserted.

Sequential approach - considering the routes already created, check if it is possible for a given arc from the savings list to be inserted on any end of the route in construction. If any insertion is feasible then a new route is created.

Motivation behind this heuristic lies on maximizing the distance saved on each iteration. The biggest disadvantage of this method is its greedy nature. Therefore, the inclusion of the "best" connections at certain moment can prevent better overall connections to be formed and consequently better solutions may not appear. In this particular heuristics, implementation of route merging is known to improve final heuristics solution (Cordeau et al., 2007)

Firstly presented for a multiple routing problem it can also be presented for the context of TSP (Shmoys et al., 1985) and therefore mTSP where the number of vehicles is a decision variable (Toth and Vigo, 2002).

As for what concerns time windows, heuristics for the TSP and the mTSP can fit mTSPTW also. Main difference lies with the restrictions not admitting nodes to be served outside time windows.

Insertion Heuristics Beginning with a starting route, this heuristics consists of choosing the better possible node to be inserted and where it is inserted. There are several criteria to make this choice. Examples can be given by nearest insertion, cheapest insertion, and greatest angle insertion. (Shmoys et al., 1985)

The procedures in these algorithms are similar and independent of the used criteria. Given the criteria, all nodes are checked for an insertion in another route. Afterwards, the node that fits better the criteria is selected and inserted.

These algorithms are also considered as greedy.

2-opt heuristics This local search algorithm detects two arcs, which give a better overall roptesult to the solution if switched. Therefore, it deletes these two arcs, breaking the tour into two paths and reconnects them with different arcs. In this sense, the tour can be systematically improved from one tour to its best neighbour until no further improvement is possible. Figure 3.6 presents the 2-opt heuristics procedure.

The arc exchange procedure is also used for more then two arcs, such is the case of r-opt where r arcs are removed and reconnected in the best possible way. 2-opt is considered a special case of the r-opt heuristics where only the exchange of two arcs occurs.

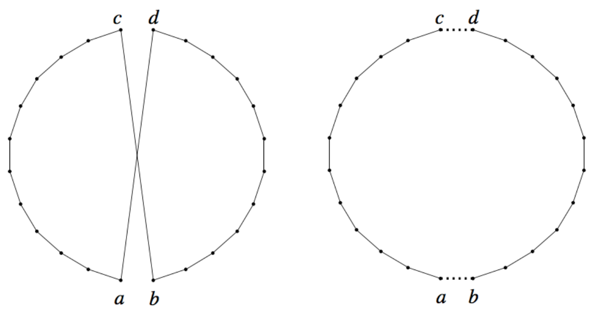

Figure 3.6 - 2-opt Principle

There are also other procedures to generate and improve solutions. Such is the case of metaheuristics. They are iterative generation processes which guide subordinate heuristics by intelligently combining different concepts for exploring and exploiting the search space. Learning strategies are used to structure information in order to find efficiently near-optimal solutions. Compared to the heuristics, this method give better results since they search throughout an amplified neighborhood of solutions but they also take more time to do so.

4. Proposed Methodologies and Methods to Solve the Documents Problem

In this chapter we propose the methodologies to solve the problem. These methodologies restructure the way the couriers work, to achieve better efficiency for collection and delivery of the documents. The described methodologies are based on the search for the optimal set of routes to solve each methodology's problem. Therefore, after each description of the methodology problem, its model is introduced, using adapted formulations from the literature depending on the characteristics of the problem.

4.1 Current Situation Analysis

As there are no guidelines for the couriers to travel between the departments, the current situation is dependent on decisions based on their past experience. To propose changes, an analysis of the current situation was necessary. Since there was no previous data on the current situation´s status, it was necessary to gather information about the collection and delivery processes. The indicators measured included travelling and service times spent by the couriers and information regarding the origin and destination departments of the documents, which determine the visiting patterns for the departments.

During a two-week period, data regarding the indicators were measured. Collected data supported a preliminary analysis. The chart 4.1 shows the difference in the average times spent for the travel and service.

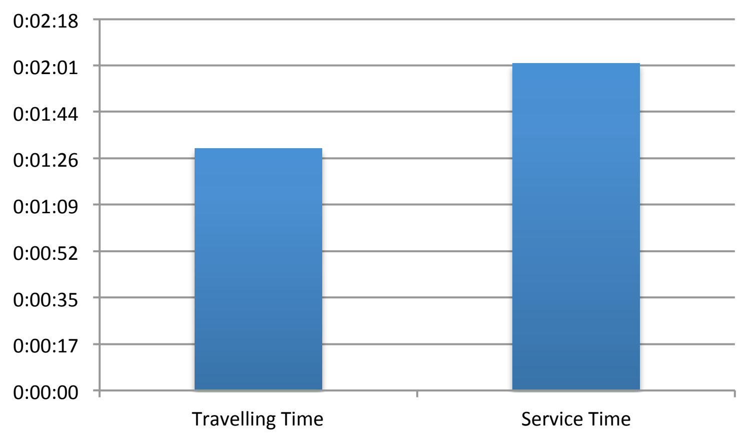

Chart 4.1 - Travelling and service average time (h:m:s)

Table 4.1 - Travelling and service average time (h:m:s)

	Average	Total Measured Time
Travelling Time	0:01:30	11:11:37
Service Time	0:02:02	15:33:08

A close look at the table 4.1 shows that the service time also plays a significant role on the total time spent for collection and delivery of the documents. The time taken to service each department is in average larger than the travel between the departments. Differences are also found between the collection and delivery's service and travelling times (table 4.2).

Table 4.2 - Time analysis for the collection and delivery phases (h:m:s)

Phase	Overall Time Average	Overall Time Standard Deviation	Maximum Overall Time	Total Travelling Time Average	Total Service Time Average
Collection	0:31:18	0:09:00	0:48:00	0:08:39	0:22:56
Delivery	1:06:13	0:33:20	2:35:19	0:32:42	0:33:30

Table 4.2 shows the weight that both travelling and service time have on the overall time for each phase changes significantly. This makes the total time spent to accomplish both collection and delivery phases to be different. This variation is shown in chart 4.2. Its analisys concludes that both travelling and service times are bigger on the delivery phase and the travelling time has a bigger increase compared to the service time. Also the standard deviation for each phase states that the delivery phase has a much bigger value compared to the collection phase. Therefore the collection phase is more "controled" compared to the delivery phase.

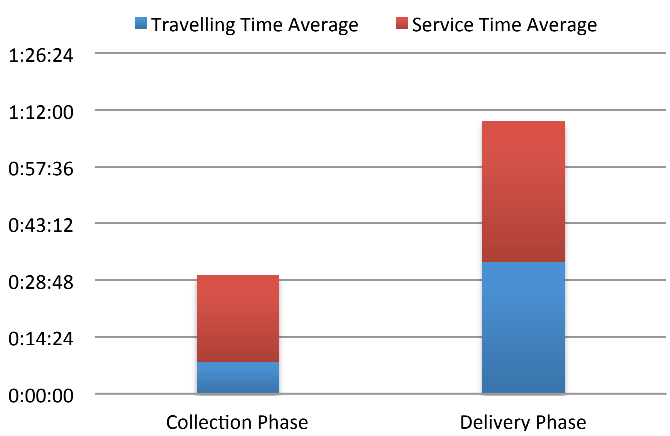

Chart 4.2 - Difference between each phases' time duration (h:m:s)

The difference in the service times between the two phases is based on the nature of the task to be completed and their different bottlenecks (reasons why the services become delayed). The main bottleneck in the collection process is the organization of documents to be delivered and subsequent routing decisions to be taken by the couriers. As for the delivery process, the waiting time for the protocols to be signed is a concern. This waiting time occurs if the person responsible to receive the documents and sign the protocols is not available.

Regarding travelling times, the fact that couriers only travel between the nearby departments in the collection phase makes the overall time spent on this phase to be much smaller compared to the one spent on the delivery phase. In this last phase, couriers cover the entire hospital to deliver documents.

Also, the variation in the number of visits that all couriers make to each department also affects the total travelling and service time. Chart 4.3 shows the variation of visits in each phase between the departments. It is presented as the daily average number of visits each department received during the period the data was collected and distinguishes also the visits from the collection and the delivery phase. Each department is identified below the chart and the bar above its name gives the average number of visits.

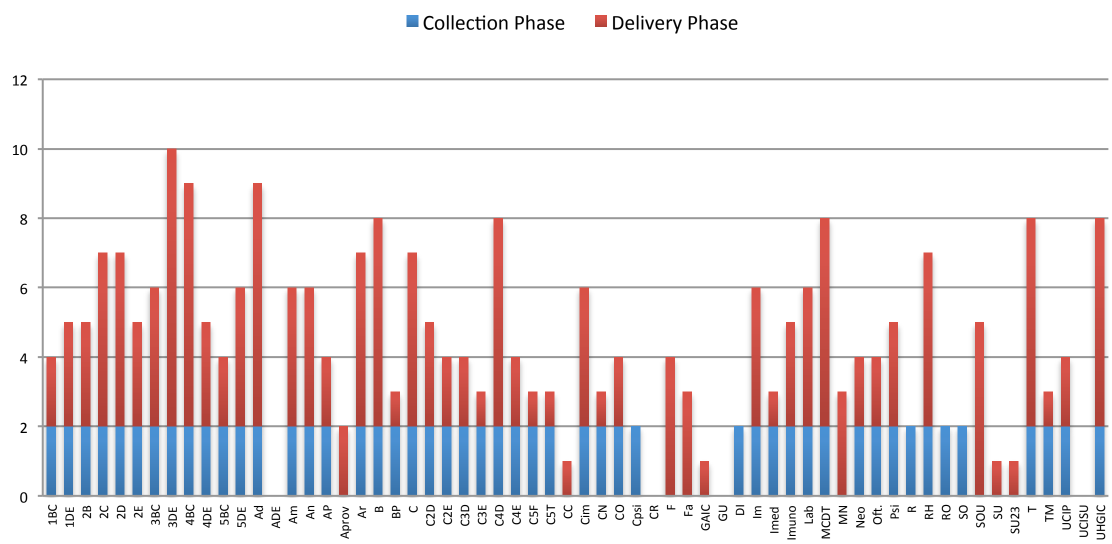

Chart 4.3 - Difference between each department's average daily number of visits

It is stated on chart 4.3 that the daily number of visits to each department with the purpose of collecting documents is only two, while the daily number of visits for each department in the delivery phase varies. This happens because each courier, in the delivery phase, has to visit all destination departments for the documents he is carrying. Consequently, there are departments that will receive more visits if different couriers have collected documents addressed to the same departments. In the collection phase, the number of visits is "controlled" because departments are previously distributed through the couriers and only two visits per day are necessary to collect the documents from each department.

4.2 Current Situation Optimization

In this problem, the optimization aspect is a challenging routing problem where couriers travel from a central depot to various departments in the hospital, incurring minimum total travel time. Therefore, current situation can improve by using optimization techniques for routing both the collection and the delivery phases. Firstly, we will introduce a routing improvement in the current way they collect and deliver documents.

Two integer-programming models can be used sequentially, each one describing each phase of the collection and the delivery process. The sequential usage of the models is necessary because it is only after the documents are collected that the information on the departments to visit in the second phase is known. Therefore, the first phase needs to be complete before the second phase begins.

Collection Phase

For the collection phase, an intelligent selection of the departments each courier must visit is required. Later, the routing passes through the selected departments in the minimum cost manner. This phase would include only the necessary departments, where there are commonly documents to be collected but because of the unpredictability on whether there are documents to be collected makes it necessary for those couriers to visit all the collection departments.

Time limitation in this phase is required. This limitation guarantees the collection phase not to take too long to be accomplished so that there would be sufficient time to visit all departments necessary in the delivery phase. This limitation must be imposed for each courier and consequently each route would be limited. Since the collection of the documents is unpredictable, the documents to be delivered and the time spent on the delivery phase would also share this reality. Therefore, it is important to limit time to a level where the worst-case scenario would be feasible. No capacity restrictions are imposed.

Integer programming model

This model is based on the flow-based formulation of the mTSP presented on literature review. Therefore, same notation is used. Also, for each arc $ij \in A$, denote by t_{ij} the time required to travel from i to j. Let x_{ij}^k be a binary decision variable that equals to 1 if arc $ij \in A$ is used by courier $k \in K$, 0 otherwise. Let s_j define the service time at node j. Let $E(Q)$ be the set of arcs formed by the set of nodes Q.

Let T_{max} be the maximum time allowed for a courier to accomplish the tasks. The objective of the problem is to minimize the total time used by all couriers in the collection phase thus guaranteeing a time-efficient way. The corresponding integer-programming model can be written as follows:

$$Minimize \sum_{ij\in A} \sum_{k\in K} t_{ij} x_{ij}^k \tag{4.1}$$

Subject to

$$\sum_{j\in V} x_{0j}^k \leq 1, \forall k \in K \tag{4.2}$$

$$\sum_{i\neq j\in V} \sum_{k\in K} x_{ij}^k \geq 1, \qquad \forall i \in V\backslash\{0\} \tag{4.3}$$

$$\sum_{i\neq j\in V} x_{ij}^k - \sum_{i\neq j\in V} x_{ji}^k = 0, \qquad \forall k \in K, \forall i \in V\backslash\{0\} \tag{4.4}$$

$$\sum_{ij\in E(Q)} x_{ij}^k \leq |Q| - 1, \qquad \forall k \in K, \forall Q \subset V\backslash\{0\} \tag{4.5}$$

$$\sum_{ij\in A} (t_{ij} + s_i) x_{ij}^k \leq T_{max}, \qquad \forall k \in K \tag{4.6}$$

$$x_{ij}^k \in \{0,1\}, \qquad \forall ij \in A, \forall k \in K \tag{4.7}$$

Constraints (4.2) forces each courier to take at most one arc starting from the depot 0. Constraints (4.3) guarantees that one courier visits each node at least once. Constraints (4.4) conserve the flow of couriers through the network, excluding the depot. Constraints (4.5) disallow subtours in the solution and (4.6) limits the travel time for each courier.

Since the subtour elimination constraints can make the model rather impractical to solve, another model can be formed via replacing the constraints (4.5) by the following:

$$y_{ij}^k \geq x_{ij}^k, \qquad i,j \in V\backslash\{0\}, \forall k \in K, \tag{4.8}$$

$$y_{ij}^k + y_{ji}^k = 1, \qquad i,j \in V\backslash\{0\}, \forall k \in K, \tag{4.9}$$

$$y_{ij}^k + y_{jp}^k + y_{pi}^k \leq 2, \qquad i,j,p \in V\backslash\{0\}, \forall k \in K. \tag{4.10}$$

Constraints (4.8) force node i to precede j if arc $ij \in A$ is traversed by courier k. Constraints (4.9) do only allow i to precede j or j to precede i for every courier k, but not both. Constraints (4.10) do not allow tours without the initial node to be formed.

This set of constraints disallows subtours on each courier's route of the model's solution by not permitting the precedence for three different nodes, except if one of them is the initial node. This way, arcs connecting three nodes would not be formed and consequently also subtours would not be formed.

This set of subtour elimination constraint makes this model practical to solve because when the number of nodes to be visited in the problem grows its number of decision variables does not grow exponentially.

An assignment-based formulation presented in the literarature review cannot handle the fact that each route needs to be time limited because different routes created are not indexed and cannot be singly limited. If the different routes cannot be singly traced and identified in the model then this time limitation cannot be singly attributed for each route. Thus, this time limitation can be introduced in the model by adapting the flow-based variant of the mTSP. The index k on the binary variables gives the information if certain courier takes arc $ij \in A$. Therefore, by keeping track of the different couriers, time can be associated to all arcs each courier takes.

By solving this model, the time needed to collect all documents from the departments can be optimized. In other words, the solution of this model will give the minimum travelling time spent between the departments and not violate any constraints of the problem.

Delivery Phase

In the delivery phase, each courier visits all departments to which the documents collected by himself are addressed to deliver them. This premise makes the routing problem during the delivery phase to be different. Also, each courier has a different routing problem to solve.

Since the couriers only have all the information when they end the first phase, they start the second one immediately from where they ended the previous one. This operational constraint influences formulation and solution of this methodology.

The problem of each courier in this second phase can be modelled as a TSP for each courier. Given this problem's definition, the cities to be visited correspond to the departments to which deliveries must be made.
Since the information needed for this phase is only known after the collection phase is completed, both phases cannot be modelled together. Time to accomplish the delivery phase is dependent on the number of departments to visit and their proximity given the collected documents.

Integer programming model

Notation for this formulation is a bit different. The problem is defined in a subgrpah G* (V*, A*) of the graph representing all the departaments, G. Let x_{ij} be a binary decision variable such that it equals to 1 if arc $ij \in A^*$ is used and 0 otherwise. The corresponding integer programming model can be written as follows:

$$Minimize \sum_{ij \in A^*} t_{ij} x_{ij} \tag{4.11}$$

Subject to:

$$\sum_{i \neq j \in V^*} x_{ij} = 1, \qquad \forall i \in V^* \tag{4.12}$$

$$\sum_{i \neq j \in V^*} x_{ji} = 1, \qquad \forall i \in V^* \tag{4.13}$$

$$+ \ subtour\ elimination\ constraints \tag{4.14}$$

$$x_{ij} \in \{0,1\}, \qquad \forall ij \in A^* \tag{4.15}$$

The objective function (4.11) minimizes the travelling time. Equations (4.12) and (4.13) guarantee the courier visits each node once by exiting and entering a node exactly once, respectively. Constraints (4.14) disallow subtours in the solution.

In the problem, couriers do not comeback to the depot when changing from collection to delivery phase. In this sense, the end node for each route of the mTSP would have be the starting node for the TSP.

To use the described formulations and keep the integrity on their solution, an adjustment must be placed on the models' data when solving. For the mTSP, the return of the courier from the end node to the depot would be allowed. However, this would be a virtual comeback and would have no cost associated. Therefore, when a solution is obtained the comeback is performed but has no influence in it.

As for the TSP, each courier's starting node would have to be the same as the end node of the mTSP's solution. In this case, the arc between the depot and the first node, which have no cost associated also, would be forced. However, since there was no cost associated this would have also no influence in the solution.

This changes would keep the integrity on the solution because information about departments to visit on the delivery phase is only known after the collection phase is finished. Therefore, routing the delivery phase can only be performed when collection phase is over, i.e., in the last department of the collection phase as this changes assume.

4.3 Transhipment with Independent Collection and Delivery

The current methodology is not ideal because several couriers are able to visit each department on the delivery phase. Thus, some departments receive more visits than necessary because each courier's visit is driven by the destination departments from their collected documents and not the overall set of documents collected by all couriers. Therefore, while in the collection phase only one courier visits certain department, in the delivery phase many couriers can visit the same department to accomplish their deliveries (chart 4.3). Meanwhile, instead of having only one visit to accomplish the delivery of all documents for a certain department, many visits occur from several couriers to the same department. This is noticed when comparing the difference between the number of visits for the collection phase and the delivery phase.

One way to tackle this situation is by using transhipment. Transhipment can be defined as the act of off-loading certain goods from one transport to another. In this case, it would allow documents to change couriers while being transported to their destination departments. By changing the couriers, it will allow distribution of all documents to the same department. These documents would be assigned only to one courier to deliver them, thus saving the time of multiple visits to the departments during the delivery process.

The concept of a transportation hub lies with a place where cargo can be exchanged between vehicles or transport modes. The hub would be a common place in the hospital designated to facilitate the exchange of documents between the couriers. The creation of a hub would allow improving the performance of the documents' distribution between the collection and the delivery phases. Routes would be designed depending on the necessary departments to visit. It is expected that this would minimize the total distance travelled by the couriers and decrease the number of visits to each department.

This methodology changes the perspective on what the courier has to accomplish. Instead of accomplishing the delivery of all the documents he has collected, he has to accomplish the delivery of all documents collected by the team for a certain number of departments. This change of perspective of the courier's task is an important factor for eliminating unnecessary visits and decreasing the time spent for travelling. The elimination of visits reaches 20% as shown in table 4.3 where the daily average number of visits for all departments in the current situation and an expected daily average number of visits for all departments in this new methodology are given. The first average is given by the sum of the average number of visits for each department. The second is an expected average given by the sum of the values of the red line level on the chart 4.4. A minimum level of service is to be performed daily, meaning that documents must be collected at least twice a day and be all delivered. It is then expected that at most four visits (two for collection and delivery) are necessary to perform this level for departments where both collection and delivery of documents happen. The other departments would only be visited if necessary in the delivery phase. The chart 4.4 shows an estimation of the reduction in the number of visits for each department brought by this methodology.

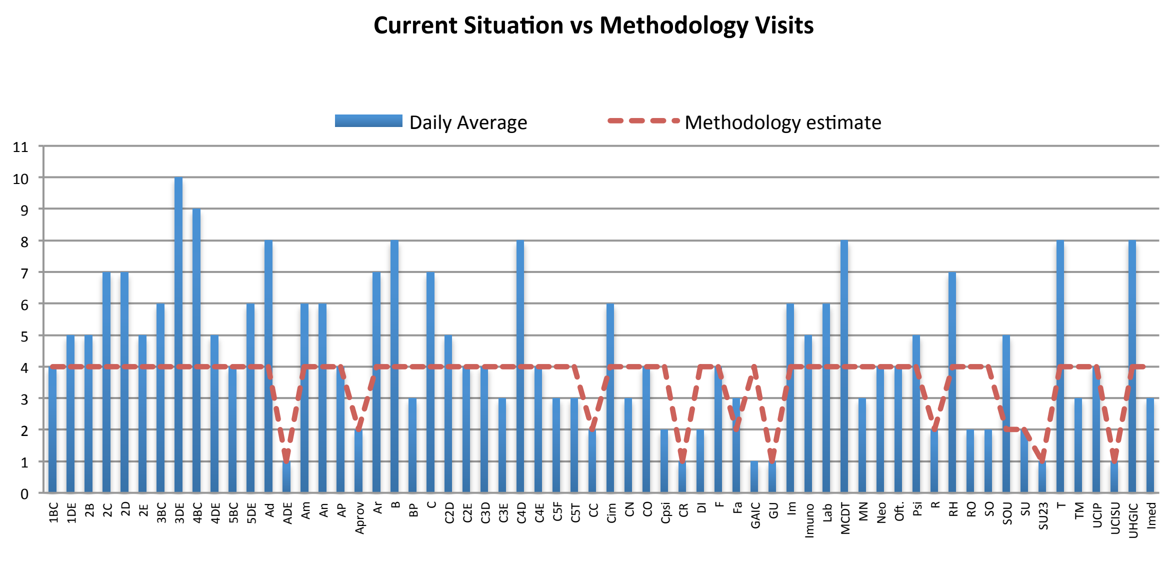

Chart 4.4 - Difference between the number of visits for each department in the current situation and independent collection and delivery methodology

Table 4.3 - Difference between total number of visits in current situation and in the independent collection and delivery methodology

	Current Situation	Independent Methodology Estimation	Expected Improvement
Daily Visits	283	226	20.1%

Also, phases should be time-balanced for the couriers to arrive at the hub at around the same time for transhipment or exchange of documents and to begin the next phase with the higher number of documents possible. Also, since a certain level of service needs to be performed, limiting time is essential to keep the routes from becoming too long such that the necessary number of phases may not be accomplished in a day.

It is important to consider the possibility of the delivery phase taking longer than the collection phase when limiting each phase's time. The problem of creating routes for the delivery phase changes from cycle to cycle because visits to the departments for delivering the documents are uncertain and happen only if the documents are addressed to them. The unpredictability of the departments to deliver the documents is thereby a factor that can make the routes vary depending on the information given by the collected documents about the departments to visit.

Also there is possibility of the delivery phase being longer for the delivery of the documents compared to document collection phase. Therefore, time limitation of the collection phase must be accordingly adjusted to the case of delivery phase taking longer. The worst-case scenario for the delivery phase can determine the maximum collection time limit to be imposed on each courier.

In this methodology, the same integer model is used to address both collection and delivery phases. In the first phase, it guarantees that the departments for the collection of the documents are divided appropriately amongst the couriers to minimize the weighted sum of the total distance travelled and the deviations between the time spent by each courier and their average times.

The delivery phase for this methodology differs from the current situation in practice, which uses the TSP for each courier's problem. The biggest difference is the distribution of the documents to be delivered by the couriers as explained earlier. This document transhipment would make it possible for the departments to be visited only once.

The modelling of this methodology is also based on an adaptation of the flow-based variant of the mTSP, which fits time limitations for each courier. The key difference concerns time balancing for the couriers to finish the tasks at around the same time.

The time-balanced mTSP would not only accomplish the task of dividing the departments for each courier to visit but also determine the routes where the time for each courier would be similar for the purpose of coordination.

Integer programming model

Let w be the weight used to balance the objective function, which is later on explained in this section. Let T^k be a variable that defines the route time of each courier k and $\bar{T}$ the average time for all T^k routes. Let a^k and b^k be the deviation between the route time of a courier and the average time taken by all of them, representing its negative or positive values, respectively. The integer programming model is:

$$Minimize \left(\sum_{ij \in A^*} \sum_{k \in K} t_{ij} x_{ij}^k \right) w + (\sum_{k \in K} a^k + b^k)(1 - w) \qquad (4.16)$$

subject to:

$$\sum_{j \in V^*} x_{0j}^k \leq 1, \qquad \forall k \in K \qquad (4.17)$$

$$\sum_{i \neq j \in V^*} \sum_{k \in K} x_{ji}^k \geq 1, \qquad \forall i \in V^* \backslash \{0\} \qquad (4.18)$$

$$\sum_{i \neq j \in V^*} x_{ij}^k - \sum_{i \neq j \in V^*} x_{ji}^k = 0, \qquad \forall k \in K, \forall i \in V^* \qquad (4.19)$$

$$+ \; subtour \; elimination \; constraints \qquad (4.20)$$

$$T^k = \sum_{ij \in A^*} (t_{ij} + s_i) x_{ij}^k, \qquad \forall k \in K \qquad (4.21)$$

$$T^k \leq T_{max}, \qquad \forall k \in K \qquad (4.22)$$

$$\bar{T} = \frac{\sum_{k \in K} T^k}{|K|}, \qquad (4.23)$$

$$T^k - \bar{T} + a^k - b^k = 0, \qquad \forall k \in K \qquad (4.24)$$

$$x_{ij}^k \in \{0,1\}, \qquad \forall ij \in A^*, \forall k \in K \qquad (4.25)$$

$$a^k, b^k, T^k \geq 0, \qquad \forall k \in K. \qquad (4.26)$$

The objective function (4.16) accommodates now the minimization of a weighted sum of the travelling time for the couriers and the sum of the deviations between the times for the different couriers. Constraints (4.17) force each courier to take at most one arc starting from the depot. Constraints (4.18) guarantee that one courier visits each node at least once. Constraints (4.19) are for the conservation of the flow of couriers through the network. Constraints (4.20) disallow subtours in the solution. Constraints (4.21) measures the travelling time for each courier and (4.22) limits it. Constraints (4.23) gives the mean of the travel times of all the couriers and Constraints (4.24) measures the deviation on the time of each courier in comparison to this mean.

The main objective of the problem is to minimize total travel time. Route balancing is not an objective that must be taken to extreme and is considered less important. Therefore, the problem's objective is the minimization of the sum of two parts with different weights. In one hand, the first part has to do with the travelling time. On the other hand, the balancing part has to do with the deviation of each route's time. This way, the creation of routes would be assured such that the time each courier waits for the others to finish their routes is minimum and the wasted time is minimized.
To keep focus on each objective's importance, a weight w was coupled to the parts of the objective function keeping the minimization of the travelled time as the primary objective of the problem (i.e., would take values much higher than 0.5). Variables concerning the part where time deviations are minimized (a^k and b^k) have values concerning total time spent, which is the sum of service and travelling times while variables used in the part concerning the routing time minimization are only associated with travelling times. Therefore, by being considered a part of higher valued times, variables for time deviation could be more representative when solving the model. Thereby, the model's solution would prioritize the route balance, which goes against the main objective.

4.4 Transhipment with Integrated Collection and Delivery

In this second methodology, both collection and delivery would be performed during the same visit to a department. Collection and delivery tasks are thus joined in the same phase. Let us name the phase with these characteristics as integrated phase. Visits would be dependent on whether a department needs to be served and one of the two reasons can drive the visit: either to collect the documents or there are documents, from the previous phase, to be delivered. Couriers may therefore visit each department fewer times and accomplish the same level of service for transportation of the documents. The variation of the visits compared to the current situation is shown in the table 4.4. In this case it reaches around 38%. An estimation of the expected daily number of visits for all departments was made. The integration is not allowed during the first or the last phase of the day because the hub cannot hold documents from one day to another, except for the signed protocols. Therefore, the first phase of the day is a document collection phase and the last phase of the day is a document delivery phase only. In this case, for departments where collection and delivery happens, it is expected that only three visits are necessary to perform the level of service: one for collection, one for an integrated phase, and one for delivery. The other departments would only be visited if necessary and whenever the delivery task is performed. The chart 4.5 shows an estimation of the reduction on the number of visits for each department brought by this methodology.

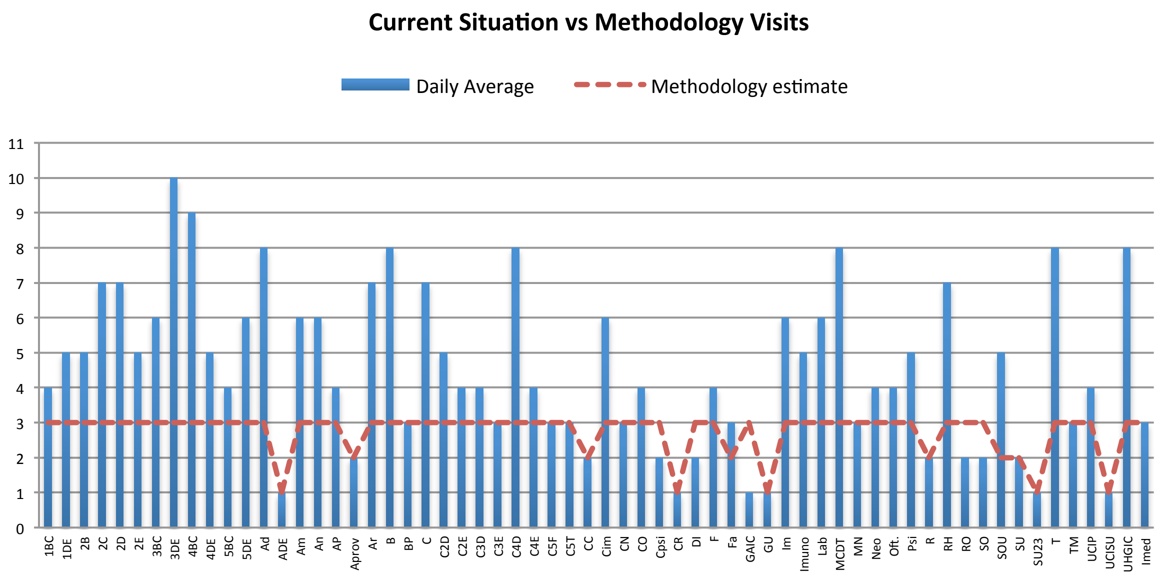

Chart 4.5 - Difference between the predicted number of visits in each department for the current situation and the integrated collection and delivery methodology

Table 4.4 - Difference between total number of visits in current situation and integrated collection and delivery methodology

	Current Situation	Integrated Methodology Estimation	Expected Improvement
Daily Visits	283	175	38.2%

Operational constraints and behaviours for this methodology are not that different from the "Transhipment with Independent Collection and Delivery" previously discussed. The same model introduced earlier for "Transhipment with Independent Collection and Delivery" can be applied for the integrated phases.

The main difference is in considering the departments for both collection and delivery when creating the routes for the same phase. Therefore, when routing the integrated phases, it is important to consider the departments where documents need to be collected and the departments to which the collected documents need to be delivered. This integration can lead to higher workload for these phases since there will be an increase in the number of the documents to be dealt with by each courier.

4.5 Transhipment with Fixed and Flexible Routes

The third methodology brings more flexibility when serving urgent deliveries and an opportunity for routing standardization. Since urgent deliveries need dynamic and fast responses from the moment they appear, previous methodologies may be improper to attend to the needs. The creation of fixed and flexible routes can address them. This methodology would determine the creation of two different working modalities and therefore two different teams, one for each type of route.

Fixed Routes

Fixed routes would service departments in which collection of documents is necessary to be performed. As in the previous methodology, each department's visit would integrate the tasks of collection and delivery of the documents to increase the efficiency.

Also, as in the previous methodology, departments are distributed in order to create routes that minimized travel time. For each courier on the fixed route team, one route would be assigned and respective departments determined on that route would be visited. When each phase finishes distribution of the documents for all couriers is borne on the hub to begin the next phase with the higher number of documents possible.

This fixed routes team would be serving the same departments in every phase of the day because, in every phase, collection for all of these departments is necessary. Therefore, in each phase of this methodology, same routes would be used to service these departments. Therefore, standard routes (routes used systematically over the phases) for collection and delivery of the documents are created.

The fixed routes team accomplishing this task has the same operational behaviour as the "Transhipment with Integrated Collection and Delivery" methodology. The main objective is to distribute the departments to visit among the members of the team and route them for most reduced time possible. The limitation and balance of time is also essential on this team for the same reasons described earlier.

Since exchange of documents is mainly made between the members of the team, coordination is necessary to begin the next phase with the highest number of the documents possible. Main difference is that the routes remain the same on every phase performed. The time-balanced model for the previous methodology describes this team's problem well.

Flexible Routes

The routing problem changes with the task definition for the flexible route team. This flexible routes team would perform routes with the departments that the team with fixed routes do not visit or is not capable to visit because of their standard routes. These routes are called flexible because departments to visit are mainly departments where collection of documents is not necessary and therefore it is unpredictable which departments have to be visited. Consequently, the routes would vary in every phase performed and would be adapted to include the necessary departments to be visited. Phases for this team start with the collection of the documents on the hub and end when these documents are all delivered. Therefore, it is assumed that this team would not be synchronized with the team with fixed routes.

The task for these flexible routes would be satisfying urgent deliveries, deliveries for the departments where only delivery happens and the high time-consuming deliveries that had not been accomplished by the fixed routes.

It is this flexible route team's role to accomplish the delivery of the documents and avoid bottlenecks on the fixed routes. Therefore, each delivery that lasts more time than expected and ends up not being delivered is given to this flexible route team to make the delivery. This happens mainly because documents with protocol cannot be delivered if receiving person is unavailable at the department. For instance, in a case where receiving person is unavailable and it is taking too long for the courier with a fixed route to make the delivery, this courier doesn't make this delivery and continues its route. When he comes back to the hub, he gives this document or documents to a courier with a flexible route for him to perform the delivery since he can spend more time delivering them. This document's delivery is not performed on the next phase of the courier with a fixed route because same situation could happen and this way efficiency could be increased for these couriers by decreasing the wasted time at the departments.

This team also treats the few protocols within which there are different documents for more than one department. The protocol attached to these documents needs to travel with them and only one courier can travel with it at a time. Therefore, if documents on these protocols were given to the fixed routes team only, they could visit the hub more than once to exchange courier. Consequently, more time would be spent until all deliveries on the protocol would be finished. Giving them to a courier with a flexible route helps to fasten the delivery process for these documents.

As described earlier, the flexible route team would have the responsibility to give a fast response to urgent deliveries. If an urgent delivery appears, then the predicted route would be broken and urgent delivery would be made. Predicted route would be restored afterwards. Since this is a flexible route team and there is no synchronization with the other team then performing this task would have less impact on this team than on the team with fixed routes.

Information on which departments to visit can only be known in the hub. The information for the urgent deliveries is also not known in advance, cannot be predicted and need to be taken care of as soon as possible.

The problem is different from the fixed routes since the operational constraints are not the same. Hence, both teams have separate and different formulations.

One courier easily accomplishes this team's workload. Therefore, this problem can be modelled as a TSP for this courier, with the cities corresponding to the departments to which the documents are addressed. A route would be created with the departments to which there are documents to be delivered and also the departments to which there are documents not delivered by the fixed-route team. This problem is similar to the second phase of the current situation, where the courier gets a set of the documents necessary to be delivered and visits the departments to which the documents are addressed. Therefore, the same model as the one described earlier for the delivery phase of the current situation can be used. Also, since all documents need to be delivered, no time limits need to be imposed for this team.

This methodology allows a trade-off between maintaining the number of visits to the departments at the lowest level possible and quickening the documents delivery process. In this case, the variation of the visits cannot be exactly predicted because it is unpredictable which departments the flexible route team will visit. It is only known that the number of visits in the best-case scenario would be equal to the "Transhipment with Integrated Pickup and

Delivery" methodology because the best case scenario determines that all documents are delivered in the first visit of each courier to a department and no unnecessary visits would be made and therefore the number of visits would be kept to a minimum.

4.6 Solving the Models Heuristically

The heuristics solution methods are mostly used when time is a critical factor for the solution of problems as such. By giving a fast processing time, heuristics can compensate the fact that close-to-optimal solutions can be achieved with their use. Following heuristic methods can be used to solve the presented methodologies. Exception is made for the "Insertion for Balancing" for the current situation improvement because methodologies that do not predict the creation of a hub do not need to synchronize routes' times for the distribution purpose.
The constructive heuristic creates an initial solution, which is then improved by the improvement heuristics. Since the improvement would be performed on an initial solution, the initial solution quality has a major weight in influencing the quality of the results. The construction heuristic implemented is based on the Savings concept by Clark and Wright.

Clarke and Wright Heuristic A parallel approach is used on this greedy heuristic to create routes, which allowed the simultaneous construction of different routes.
The various restrictions of the problem have to be addressed when routing. In this regard, the initial solution has to obey time limitations and number of routes imposed. The time balancing factor is brought later. A description of the algorithm is now presented step by step:

1. Compute and sort the savings list in a descending order considering all arcs in A.
2. Initialize route creation by generating a first route considering the highest saving on the list.
3. Run the savings list from the top and proceed as following.
4. If one node of the chosen arc has been already inserted in a route:
    4.1. If this node is either on the first or last place of the route; insert arc in-between the node and the depot assuming it does not exceed time limitations; Restart savings list;
5. If neither one of the nodes from the chosen arc is inserted on a route and if maximum route duration and maximum number of routes is not exceeded than create another route; Restart savings list;
6. If both nodes on the chosen arc have been already inserted in different routes:

    6.1. If both nodes are on the extremities of their routes than invert necessary routes and merge them; Restart savings list;
7. If there is any node that has not been inserted in any route, a list is formed with all of them:
    7.1. Compute the entire list, introducing every node in every possible place of every route; Insert the node on the route where the minimum cost increase happens, guarantying that time limitations are not surpassed
8. If there is any node still to be inserted in the any route than create a route and insert those nodes in the route using previous insertion steps.

2-Opt heuristic The 2-opt heuristic is the first heuristic used with the purpose of improving the initial solution. It intends to improve each route singularly by comparing if a better connection between the departments can be found. If a better result appears then it switches the sequence in which the departments are visited.

It is assumed that the improved route will not violate the constraints because the each route of the initial solution already conforms with them. Therefore, to implement this heuristic, it is not necessary to verify if the problem's constraints are respected. A description of the algorithm is now presented step by step:

1. Compute each route at a time;
2. While there is a set of arcs available; Choose two arcs in A, where one arc needs to be upfront on the chosen route;
3. For each chosen arc, compute possible improvement by swapping a part of the route breaking the chosen edges;
    3.1. If improvement is positive than swap is made;
    3.2. If there is no improvement than no swap is made;

Insertion heuristic The 2-opt had a limited improvement search and didn't cover the exchange of the departments between the different routes. The principle for this heuristic was to take the constructed solution and check if changing any department from their original routes would be beneficial in the overall result. In this case, constraints have to be checked and respected. A description of the algorithm is now presented step by step:

1. While improvement exists; compute each route at a time;

2. For every possible node in every route and for each arc in each route other than the one of i, compute the best possible improvement by changing the place of the chosen node on the current route to other place in between the chosen arc;
   2.1. If there is a positive improvement than change is made;
   2.2. If there is no improvement, no change is made.

4.6.1 Insertion for Balancing

In this improvement algorithm the same principal of department exchange is made through the routes, only different objectives were considered. The objective for this model is to balance the routes at the lowest cost as possible. The model would search for departments to exchange routes that would add less time on the inserting route. Departments would change routes until a balanced result would appear.

It is clear that balancing the routes would either worsen or make the overall result at least equal. In this regard, a limitation was inserted on how much the overall result could worsen compared to the solution given before balancing with the purpose of controlling this worsening process.

After this algorithm, 2-opt was also used to reorganize visits in each route. The purpose is to build the most efficient route possible. However, route balance could be lost with this action. Thereby, the balancing algorithm is ran a limited amount of times before stopping. This limitation is imposed for the model not to be trapped in an infinite loop. A description of the algorithm is now presented step by step:

1. While improvement exists; compute each route at a time;
2. For every possible node in every route and for each arc on each route other than the one of the chosen node, compute the best possible insertion by changing the place of the chosen node on the current route to other place in between the chosen arc:
   2.1 If there is an insertion that does not exceed time limitations, decreases time variation between routes and does not exceed a level of deterioration over the initial solution than the change that gives the better overall time is made;
   2.2 If there is an insertion inside those limitations is not acquired than search ends;

Proposed Methodologies to Solve the Problem

5. COMPUTATIONAL ANALYSIS

This chapter starts by giving an overview of the strategies used on optimization engines to explore the potential of the presented formulations, obtain results and consequently extract the best methodology to solve the problem. It presents also the comparison of each presented methodology with the current situation and the importance of better routing for this problem.

5.1 The Exact Approach

To obtain results for the previous methodologies two different solution approaches were used with OPL Studio and a built VBA toolkit.

In a first stage, OPL Studio was used to solve the different optimization approaches for the methodologies. It used IBM ILOG CPLEX Optimization Studio, a decision support application that enables the solution of Mathematical and Constraint Programming problems (IBM, 2012) . In this optimization engine exact methods are used. However, a great number of iterations are necessary to find the optimal solution. A summary of the optimization approaches is presented in table 5.1.

Table 5.1 - Optimization approaches for the different methodologies

Methodology	Optimization Approaches
Current Situation	mTSP with Time Limitation + TSP
Transhipment with Independent Collection and Delivery	Time Balanced mTSP
Transhipment with Integrated Collection and Delivery	Time Balanced mTSP
Transhipment with Fixed and Flexible Routes	Time Balanced mTSP + TSP

Preliminary tests on the optimization approaches showed that a run time limitation had to be implemented because a great amount of time would be necessary for the optimization engine to find the global optimal solution. The program’s running time for each formulation was limited to 3 CPU processing hours. Exception was made for the TSP, which was limited to 1 hour.

Also, these preliminary tests showed that the program couldn’t find any integer solutions within the stipulated time. Another strategy was necessary to find feasible solutions.

Grouping some of the departments would decrease the size of the problem, hopefully taking less time to find solutions.
This grouping would have to follow some rules to prevent the upcoming solutions to diverge too much from the overall objective. This rules state that:

- only nearby departments are joined. Thereby, departments with travelling time less than 30 seconds between them are considered for joining.
- if the departments are on a no-end corridor or without any access to other parts of the hospital, then it would be reasonable to couple these departments.

The coupled departments enabled a reduction on the number of departments from 62 to 39 and they are presented in the appendix II.
However, the optimization engine was very slow at obtaining the results. Also, treating departments separately while routing would be interesting because better results could potentially arise. This was one of the reasons to build a toolkit that gives very similar results but in a much smaller execution time. This toolkit was built using Excel, on a VBA environment for the purpose of constructing routes. A detailed description of this toolkit can be found in the chapter 6.

5.2 Case Study Data

Before a methodology comparison could be performed, some specific information must be presented. The collected information presented in chapter 2 was filtered and developed to serve as input for the optimization approaches. Below we describe how the collected data was handled to build this input:

Service time - its calculation was based on an average estimation of the time the couriers spent in each department. Each department was treated separately since there are differences in the service time for each department, which can vary significantly depending on the departments' workload.

Travelling time - estimation based on the average walking velocity ($v_{average}$) combined with the distance between the departments (d_{ij}) was used to produce an average of the time taken between each pair of departments. The formula below describes exactly how the final estimation was calculated. Estimations for vertical movements such as the change of floors were also made. They were based on the average time taken to go up or down the stairs (t_{stairs}) or the time taken to use the elevator, including the waiting time ($t_{elevator}$).

$$t_{ij} = v_{average} \times d_{ij} + (t_{stairs} + t_{elevator})$$

For both ergonomic and efficiency reasons, the change of the floors are to be avoided. Ergonomic reasons claim that physical effort increases while climbing a flight of stairs. Efficiency reasons state that physical effort decreases the courier's overtime velocity and also the waiting time for the elevator is most of the times very high.
To prevent vertical movements, a penalty was added to the travelling times from the departments belonging to different floors on the hospital facilities. This penalty would only allow transition between different floors if it is beneficial.

Department Coverage - each department's visit was determined from the information on the collected documents, such as their destination.

5.3 Results and Comparison of Described Methodologies

The scenario comparison is based on the work efficiency and time effectiveness that each scenario presents. For all the methodologies to be properly compared, the same level of service was introduced on each methodology. Therefore, for each methodology, a scenario would be created where the collection has to be performed twice a day and the collected documents have to be delivered.
Also, route limitation for the balanced model was assumed. Preliminary tests on the non-balanced model have given the number of routes for its minimum solution possible. It is supposed that limiting the balanced model with this number of routes would extract the best solution possible for the balanced model because if the best solution for the overall non-balanced model is given by a certain number of routes then the best solution for a the balanced model would be given within that number of routes.
The described methodologies were tested in order to verify the times when performing the scenarios for the same collection and delivery tasks. This enabled a comparison between methodologies and allowed a conclusion on which of them would perform better for this problem's characteristics. Tests were made in a personal computer with 2 x 2GHz Intel Core 2 Duo and 2 GB DDR3 of random access memory. CPLEX ran at 64 bits.

A scenario with the current structure of the collection and delivery situation was simulated with the optimization engines to have a comparison basis for the new methodologies. This scenario includes all current structural decisions, such as the number of couriers used and the distribution of the departments on the collection phase. Its solution is compared with the solutions of the new methodologies. It became necessary to do so because it was not possible to get data for all couriers' routes and times over the period that data was collected. Only estimations can be pulled from this data. Notice that this solution would also be slightly improved because achieved routes would not be necessarily as what couriers actiually did.
To support this fact, a comparison was done between the travelling times for real situations, which were possible to be followed, and improved travelling times from the optimization engines. Table 5.2 shows how routing influences the travelling time for these cases.

Table 5.2 - Routing improvement

	Current Situation	OPL Studio	Improvement	VBA	Improvement
Day 1	1:15:55	1:05:27	14%	1:06:00	13%
Day 2	1:28:59	1:04:14	28%	1:08:28	23%
Day 3	1:17:49	1:03:29	18%	1:05:53	15%
Day 4	1:05:50	1:08:25	-4%	1:11:54	-9%
Day 5	1:33:21	1:10:42	24%	1:09:01	26%

Note that in day 4 the results are negative for the improvement. This possibly happened because data for creating routes through an optimization engine is deterministic and it can be lagged compared to what happened that day and with that single courier.

The hub suggested on the methodologies could be situated in any location of the hospital facilities. To achieve the best results possible, three different locations were tested. One of them was the same place where the couriers currently started the routes.
A summary of the methodologies' results is presented in table 5.3. It presents the total travelling time and the total time that each methodology spends for the same collection and delivery job departing from different locations. It also presents the improvement between the methodology and current situation. The detailed routing results obtained can be found in appendix III and IV.

Table 5.3 - Routing time results

		OPL Studio				VBA			
		Total Time	Improvement	Total Travelling Time	Improvement	Total Time	Improvement	Total Travelling Time	Improvement
Arquivo	Current Situation	96,0	-	33,1	-	80,0	-	33,4	-
	Routed Current Situation	70,6	26%	21,9	34%	68,3	15%	27,6	17%
	Independent Collection and Delivery Scenario	56,4	41%	20,7	37%	53,8	33%	23,0	30%
	Integrated Collection and Delivery Scenario	43,6	55%	16,6	50%	40,8	49%	17,6	47%
	Fixed and Flexible Routes Scenario	46,4	52%	17,4	47%	47,1	41%	20,4	38%
Hub on the first floor	Independent Collection and Delivery Scenario	53,6	44%	17,8	46%	51,0	36%	20,0	40%
	Integrated Collection and Delivery Scenario	40,7	58%	13,2	60%	39,3	51%	15,3	54%
	Fixed and Flexible Routes Scenario	44,6	54%	15,6	53%	44,6	44%	17,8	46%
Hub on the third floor	Independent Collection and Delivery Scenario	54,2	44%	17,9	46%	51,6	36%	20,7	37%
	Integrated Collection and Delivery Scenario	41,0	57%	14,2	57%	39,8	50%	15,9	52%
	Fixed and Flexible Routes Scenario	46,1	52%	16,1	51%	45,7	43%	19,0	43%

The time presented refers to the hours spent for a week's work by the couriers

As expected, combining the tasks of collection and delivery in the same phase reduces travelling and total time spent to complete the job. A quick analysis of the results presents the ”Integrated Collection and Delivery Scenario” starting from the first floor as the scenario which brings better improvement and, consequently, the quickest. With this methodology the same work can be accomplished in less than half of the time spent currently. In the better case shown, it decreased 58% time to accomplish the work and the couriers would walk less 60% of the time they used to.
However, the practice of this methodology needs constant generation of routes when a new phase begins. Therefore, more processes are necessary for this methodology to work properly. Identifying the departments to visit, inputting data onto the computer, waiting for the results and actually remembering after the solution given are some examples of these processes. Performing these processes would make this methodology decrease its time performance, making its overall results less beneficial.
The “Fixed and Flexible Routes Scenario” benefits from a standardization of routes, which can bring a better understanding and compromise to the job. The previous processes have less importance in this methodology. Also, the urgency label on some documents makes it necessary for some flexibility. In this sense, the solution for this scenario can give a better trade-off between proper routing and flexibility, maintaining a good quality of servicing different types of documents. This methodology decreases 54% of the total time and 53% of the travelling time spent by the couriers.

Regarding both solution methods, it is shown that even with the department grouping strategy, the exact methods applied on OPL Studio bring better results than the applied heuristics. Although, in some situations, the solution values for these two solution methods can be close.

6. IMPLEMENTATION AT HOSPITAL FACILITIES

This chapter presents the implementation of one of the described methodologies and the results. Firstly, we present a simple description of the toolkit built in a VBA platform also used when programming routes for the couriers. Later, we present how the hub space was planned and built to be as reliable as possible.

6.1 Software for practitioners' use

With the objective of constructing a toolkit that programs couriers' routes a set of constructive and improvement heuristics were gathered to create them in a close to the optimal fashion.

6.1.1 User Interface

Problem constraints depend on operational characteristics. The limitation on the maximum number of routes, given by the number of couriers available and maximum duration of a cycle are these operational characteristics. These constraints have to be entered on the system from a users interface.

Excel has a very ample set of tools that allow the construction of a simple and user-friendly interface. The built interface should allow the toolkit to be flexible on the problems parameter. Purpose was to make the user able to enter information about departments to visit and the rest of the limitations onto the problem's solution.

To run the toolkit, a userform appears for the user to choose how the restrictions will limit the route creation. The maximum number and the routes' duration are those restrictions. Given these constraints, if the insertion of all the departments is impossible then a message will appear to let the user know that routing all chosen departments is impossible and it is necessary to insert larger limitations. The level of route and time balance expected needs also to be inserted depending on how balanced the routes are expected to be.

The following figures give a small tour of what the user should expect to choose, showing the interface.

Figure 6.1 - Toolkit's interface

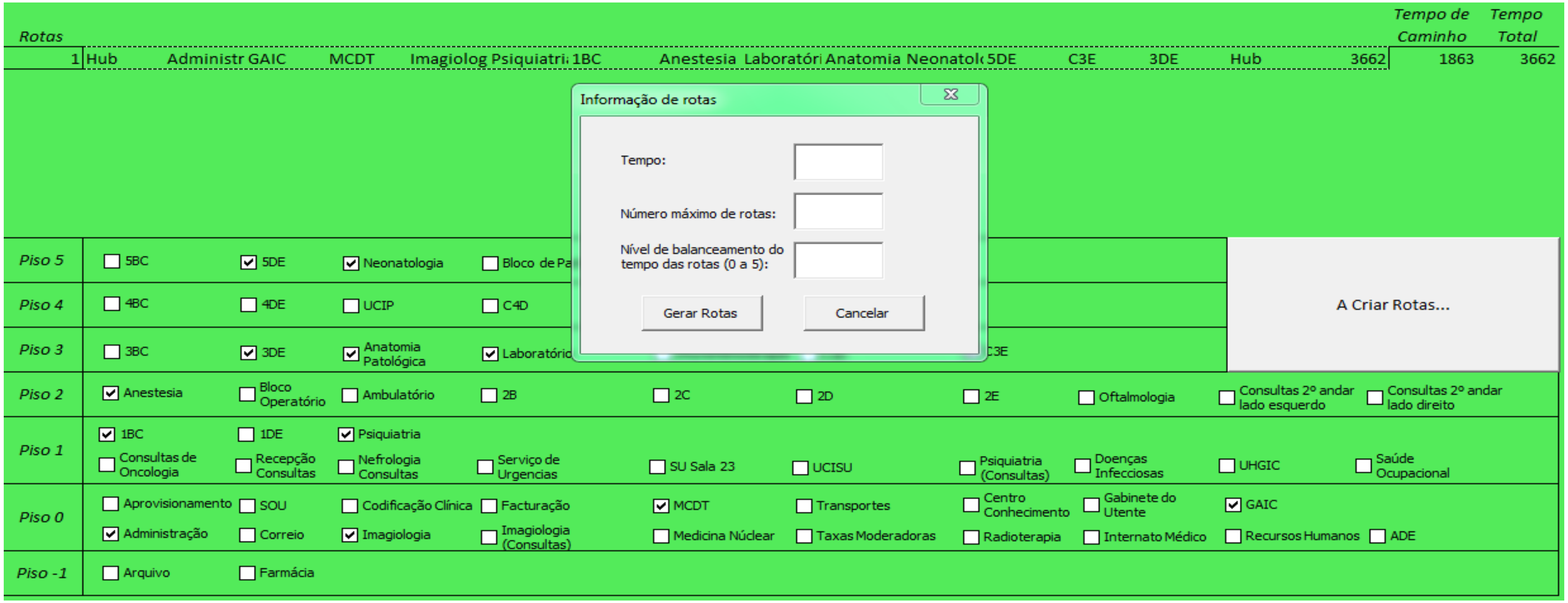

Figure 6.2 – User form on the interface

In a first stage it is expected for the user to choose the departments necessary to visit, in this case the ones it is expected to build the routes with. Next step is to click the button "Criar Rotas" and a user form will appear as presented in the figure 6.2.
This toolkit would be one piece that supported the installation but other tasks also had to be performed.

6.2 Installation

The scenario implementation followed with the construction of structures to support the correct functioning of the chosen scenario. These would guarantee proper functioning and reliability for a new collection and delivery system.
The chosen scenario to be implemented was the "**Transhipment with Fixed and Flexible Routes scenario".** Promising a good trade-off between standardization and flexibility to the methodology's practice, it is welcome operationally because the systematic creation of routes would only affect one courier.
Planning starts with the definition of each route. Working procedures and physical structures are also a concern in the system restructure. Physical structures include not only the construction of the hub space but also departments. They need structures to facilitate visibility and access to their incoming and outgoing documents.
Alterations in departments suggested the placement of different shelves in every department, where collection was necessary. This allows the couriers to differentiate incoming from outgoing documents. Also, the difference between these and other shelves present at the collection departments, make it easier to identify where the documents are.
The hub's space was built from scratch. An organized way was thought to enable a better exchange of the documents from the couriers. It suggested the construction of a divided booth where documents would be divided by the destination departments.

A quick analysis comparing which routes had more documents to exchange was performed. The purpose for this analysis was to build a booth where the couriers would make small movements when distributing the mostly weighted set of documents and make the department's disposition on the booth the least burdensome possible.
Booth positions for the departments from the same routes where kept close with the purpose of making the process of collecting each routes' documents when leaving the hub the quickest possible. Also, each routes' space was kept closer depending on the documents' exchange

routes had with each other. Finally, departments that receive more documents and more often were kept on racks with easier accessibility.

A label with the department's name and visual separation was inserted between department-reserved spaces on the booth for easier document placement. Figure 6.3 shows the result and how the hub space ended up organized.

Figure 6.3 - Booth's organization and labeling

Working procedures for the couriers were not defined previously and couriers were able to choose the procedure they thought best. This might potentiate time loss when collecting and delivering the documents. Thereby, stipulating procedures would organize and determine different steps for the collection and delivery of documents. The figure 6.4 shows how the methodology works.

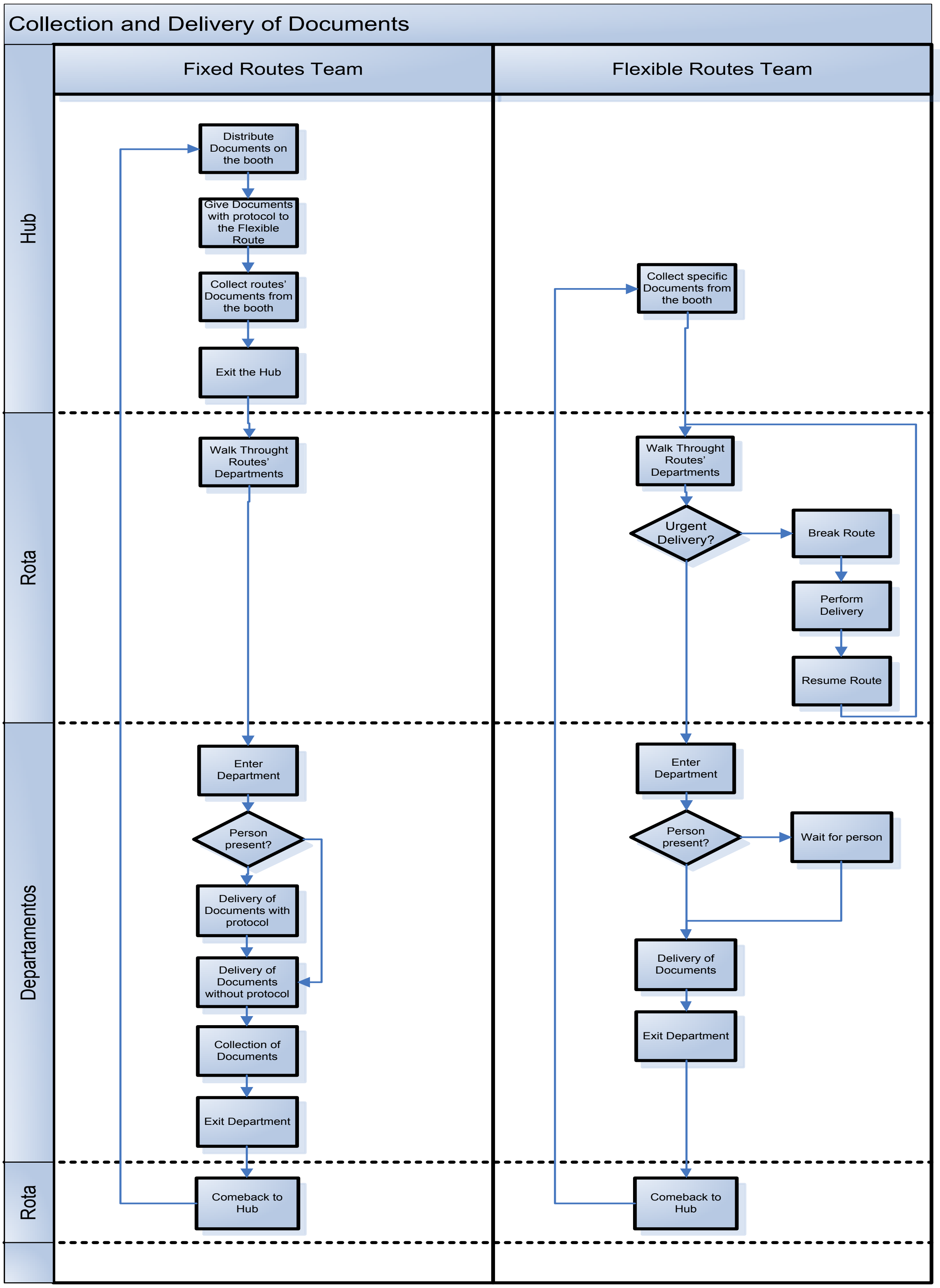

Figure 6.4 - Flowchart of the methodology's functioning

After implementing and putting the methodology to work, an operational overview of the time spent and number of department's visits was performed. The purpose is to verify improvements and the alignment to the expectations.

Chart 6.1 shows a comparison between the best-case scenario expected and the daily average level measured after implementation. Note that the level of service increased in this implementation. One more visit for collection and delivery of documents was introduced.

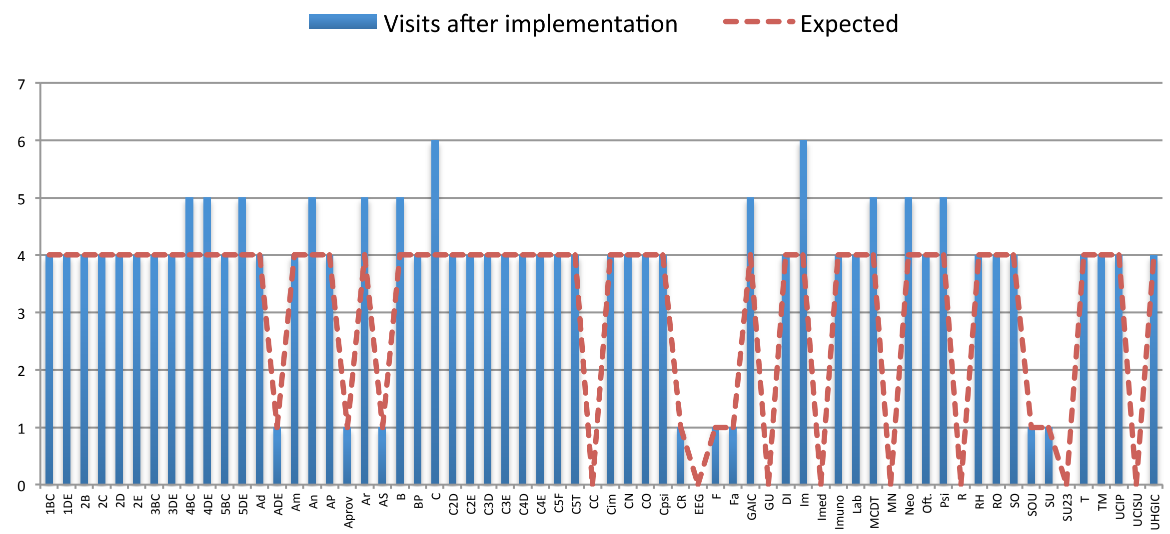

Chart 6.1 - Alignment between daily average number of visits for the methodology implemented and its expected value

As expected, more visits occur where protocols with documents for different departments are collected and also on their destination departments. It shows also a better alignment with the expected situation compared to what happens currently.

In the next table, a comparison is shown between the daily average values of total visits on the pre and post-implementation situations. It shows that even with an increase in the level of service, the total number of visits to the departments decreased.

Table 6.1 - Improvement on the daily average number of visits for the implemented methodology

	Pre-implementation Situation	Best Case Situation	Post-implementation Situation	Improvement
Visits	283	200	214	24.4%

It was possible to increase the level of service for the decrease of the total time spent collecting and delivering documents. The chart 6.2 shows a comparison between the average travelling time from one department to another. It shows a decrease of this time after implementing the methodology. It also shows a slight increase on service time, which was expected because of the increase of tasks to do when visiting a department.

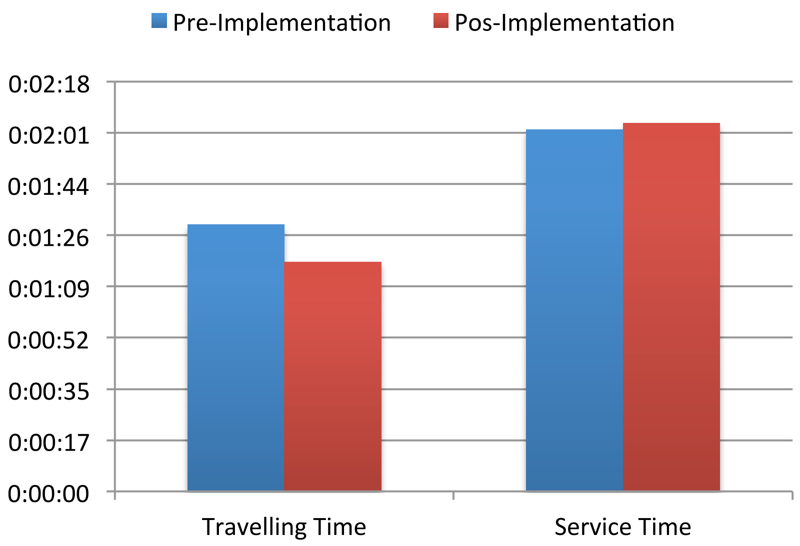

Chart 6.2 - Difference between pre and post travelling and service time (h:m:s)

The time spent distributing documents in the hub is about 6 minutes. Therefore, it is important in the overall time of the implementation. An overview of the post-implementation phase is presented in the table 6.2.

Table 6.2 - Time analysis of the implemented methodology (h:m:s)

Phase	Total Time Average	Total Time Standard Deviation	Maximum Total Time	Travelling Time Average	Service Time Average	Hub Average Service Time
Post-Implement.	0:40:52	0:13:12	1:00:31	0:14:07	0:26:45	0:06:38

An estimation of the time spent by all the couriers performing the Current Situation work structure over a week can be given by the collected data. Given the fact that each courier performs both collection and delivery phases twice a day and works five days per week, the estimation would be made as follows:

Table 6.3 - Estimation for the total week's time spent before implementing new methodology (h:m:s)

	Collection Phase	Delivery Phase	Both Collection and Delivery Phases	Estimation of a Week's Work
Total Average Time	0:31:18	1:06:13	1:37:31	97:31:04
Travelling Average Time	0:08:39	0:32:42	0:41:21	41:21:11

Same estimation is performed for the implemented methodology:

Table 6.4 - Estimation for the total week's time after implementing methodology (h:m:s)

	Post-Implementation Phase	One Day's Work	Estimation of a Week's Work
Total Average Time	0:40:52	2:02:35	51:04:39
Travelling Average Time	0:14:07	0:42:21	17:38:49

The comparison of both estimations allows concluding that the implementation of the new methodology brought an estimated improvement of around 48% over the total time spent collecting and delivering documents. It is estimated also that the travelling time decreased by approximately 57%.

7. CONCLUSIONS

The transportation problem of documents in the hospital envolved its collection and delivery for different departments located in different locations of the hospital. A team of couriers was in charge of performing these tasks but better efficiency could be performed. The analysis of the distribution system revealed its strengths and weaknesses from which methodologies would be created and modelled.

The result was a set of formulations adapted to feature the different characteristics of the problem found in Hospital de Braga and improve the current practice. The set of formulations were capable of performing as expected. For instance, the time-balanced model proposed was able to reduce travelling time without disregarding the time balance but also did not worsen the solution at a point that the time balance would be more important than the time reduction.

Due to difficulties in obtaining optimal solutions, two different solution methods were built to achieve the better solutions possible and compare which of the strategies would obtain better results. Collected information from current functioning enabled the creation of scenarios with the same level of service for the different methodologies and their solution with both methods. It was concluded that changes could bring time-savings up to more then 50%. Therefore, this proposed methodologies proved to be more efficient then the current practice.

Also, one of these solution methods enabled the creation of a toolkit that intends to support day-to-day planning of the couriers.

This results lead to the installation of one of the methodologies for the practice of collecting and delivering documents. To obtain maximum improvements and decrease difficulties for the practice of this new working methodology, necessary changes were planned and implemented. As expected, significant improvements resulted from this changes and improvements around 50% were achieved.

Due to limited time and substantial time spent when solving with any methodology, not all possibilities regarding the extent of the solutions' characteristics and methods could be covered. Therefore, some changes possibly beneficial for the problems' solution can be presented for further analysis:

- A less greedy solution method, which did not disregard processing times, could be considered for the toolkit that helps planning routes. Such method should bring better solution results when implemented. Other alternative is to introduce changes on the improvement heuristics for a bigger search scope to be considered.

- Presented methodologies brought such results that time limitations to perform different phases could be further extended. This extension could be beneficial when considering both time reduction and the resources used to complete the collection and delivery of the documents. Although the results predict a reduction on the number of couriers necessary to complete these tasks, the number could decrease. Other tasks could be assigned for the couriers thereby expanding the service range for the team. Distributing urgent deliveries of other materials is an example to expand and would bring benefits for the teams performing material deliveries.
- Different frequency for the number of visits that each department receives could be introduced. It would depend on the weight each department's documents have on their overall transportation job and on each departments' level of satisfaction.

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APPENDIX I - DEPARTMENT IDENTIFICATION

Table I.1 - Department identification

Department	*Floor*	*Phase Associated*	*ID Name*	*Department*	*Floor*	*Phase Associated*	*ID Name*
Farmácia	-1	Delivery	F	Consultas de Doenças Infecciosas	1	Delivery	DI
Arquivo	-1	Collection/ Delivery	Ar	Consulta de Nefrologia/ Reumatologia	1	Collection/ Delivery	CN
Administração	0	Collection/ Delivery	Ad	Anestesia	2	Collection/ Delivery	An
Taxas Moderadoras	0	Collection/ Delivery	TM	Bloco	2	Collection/ Delivery	B
Aprovisionamento	0	Delivery	Aprov	Ambulatório	2	Delivery	Am
SOU	0	Delivery	SOU	Internamentos de Cirurgia Geral (2B)	2	Delivery	2B
Correio	0	Collection/ Delivery	C	Internamentos de Cirurgia Plástica/ Gastro (2C)	2	Collection/ Delivery	2C
Controlo Codificação Clínico	0	Delivery	CC	Internamentos de Urologia/ Cirurgia vascular (2D)	2	Delivery	2D
Facturação	0	Delivery	Fa	Internamentos de Urologia/ Otorrino (2E)	2	Delivery	2E
MCDT	0	Collection/ Delivery	MCDT	Internamentos de Oftalmologia	2	Collection/ Delivery	Oft
Transportes	0	Collection/ Delivery	T	Consulta de Cirurgia Geral/Urologia/ Gastro	2	Collection/ Delivery	C2D
Consultas de Imagiologia	0	Collection/ Delivery	Cim	Consulta de Oftalmologia/ Otorrino	2	Collection/ Delivery	C2E
Imagiologia	0	Collection/ Delivery	Im	Internamentos de Ortopedia (3BC)	3	Collection/ Delivery	3BC
Medicina Nuclear	0	Delivery	MN	Internamentos de Neurologia/ MFR (3DE)	3	Delivery	3DE
Recursos Humanos	0	Collection/ Delivery	RH	Anatomia Patológica	3	Collection/ Delivery	AP
Radioterapia	0	Delivery	R	Laboratórios	3	Delivery	Lab

Department Identification

ADE	0	Delivery	ADE	Imunohemoterapia	3	Delivery	Imuno
Gabinete do Utente	0	Delivery	GU	Consulta de Exames Electromiografias/ MFR	3	Collection/ Delivery	C3
GAIC	0	Collection/ Delivery	GAIC	Consulta de Exames Eletroencefalografia	3	Collection/ Delivery	C3
Internato Médico	0	Collection/ Delivery	Imed	Internamentos de Cardiologia/ Pneumologia (4BC)	4	Delivery	4BC
Centro de Reconhecimento	0	Delivery	CR	Medicina Interna (4DE)	4	Collection/ Delivery	4DE
Consulta Oncologia	1	Collection/ Delivery	CO	UCIP	4	Collection/ Delivery	UCIP
Recepção das Consultas	1	Collection/ Delivery	RO	Consulta de Pneumologia/ Cardiologia	4	Delivery	C4D
Serviço de Urgências	1	Delivery	SU	Consulta de Medicina Interna/ Cirurgia Vascular	4	Delivery	C4E
Sala 23	1	Delivery	SU23	Neonatologia	5	Collection/ Delivery	Neo
Unidade Cuidados Intensivos Urgentes	1	Delivery	UCISU	Bloco de Partos	5	Collection/ Delivery	BP
UHGIC	1	Collection/ Delivery	UHGIC	Internamentos de Obstetrícia/ Cirurgia Pediátrica (5BC)	5	Collection/ Delivery	5BC
Saúde Ocupacional	1	Collection/ Delivery	SO	Internamentos de Ginecologia/ Pediatria (5DE)	5	Collection/ Delivery	5DE
Internamentos de Doenças Infecciosas/ Neurocirurgia (1BC)	1	Collection/ Delivery	1BC	Consulta de Pedopsiquiatria/ Pediatria	5	Collection/ Delivery	C5
Internamentos de Oncologia (1DE)	1	Collection/ Delivery	1DE	Consultas de Obstetrícia/ Ginecologia	5	Collection/ Delivery	C5
Internamento de Psiquiatria	1	Collection/ Delivery	Psi				
Consultas de Psiquiatria	1	Collection/ Delivery	Cpsi				

APPENDIX II - COUPLED DEPARTMENTS

Table II.1 – Coupled Departments

Coupled Departments				*ID Name*
Aprovisionamento	Facturação	Controlo Codificação Clínico	SOU	AprovSOUCCFa
MCDT	Transportes	Gabinete do Utente		MCDTTGU
Internato Médico	Centro de Reconhecimento	Recursos Humanos	ADE	ImedRHADECR
Consulta Oncologia	Recepção das Consultas	Consulta de Nefrologia/ Reumatologia		COROCN
	UHGIC	Saúde Ocupacional		UHGICSO
	Sala 23	Unidade Cuidados Intensivos Urgentes		SU23UCISU
Internamento de Psiquiatria	Consultas de Psiquiatria	Consultas de Doenças Infecciosas		PsiCpsiDI
	Ambulatório	Anestesia		AmAn
	Internamentos de Cirurgia Geral (2B)	Internamentos de Cirurgia Plástica/ Gastro (2C)		2B2C
	Internamentos de Urologia/ Cirurgia vascular (2D)	Internamentos de Urologia / Otorrino (2E)		2D2E
	Consulta de Cirurgia Geral/Urologia/ Gastro	Consulta de Oftalmologia/ Otorrino		C2EC3D
	Laboratórios	Imunohemoterapia		LabImuno
	Consulta de Ortopedia/ Neurologia	Consulta de Exames Electromiografias/ MFR		C3DC3E
	Consulta de Pneumologia/ Cardiologia	Consulta de Medicina Interna/ Cirurgia Vascular		C4EC4D
	Neonatologia	Bloco de Partos		NeoBP
	Consulta de Pedopsiquiatria/ Pediatria	Consultas de Obstetricia/ Ginecologia		C5FC5T

APPENDIX III - DETAILED ROUTING RESULTS ON OPL STUDIO

Current Situation Structure Results

Table III.1 - Opl resuts for current situation structure morning collection phase

Day	N^er	Morning Collection Phase Route	Total Time	Travel Time
Day 1	1	Ar, Ad, TM, ImedRHADECR, GAIC, MCDTTGU, Cim, Im, PsiCpsiDI, C	2.81	0.98
	2	Ar, 5DE, 5BC, NeoBP, 1BC, 1DE		
	3	Ar, UHGICSO, B, AnAm, 2B2C, Oft, 2D2E		
	4	Ar, 3DE, 3BC, LabImuno, AP		
	5	Ar, 4DE, 4BC, UCIP		
	6	Ar, COROCN, C2EC2D, C3DC3E, C4EC4D, C5FC5T		
Day 2	1	Ar, Ad, TM, ImedRHADECR, GAIC, MCDTTGU, Cim, Im, PsiCpsiDI, C, Ar	2.81	0.98
	2	Ar, 5DE, 5BC, NeoBP, 1BC, 1DE, Ar		
	3	Ar, UHGICSO, B, AnAm, 2B2C, Oft, 2D2E, Ar		
	4	Ar, 3DE, 3BC, LabImuno, AP, Ar		
	5	Ar, 4DE, 4BC, UCIP, Ar		
	6	Ar, COROCN, C2EC2D, C3DC3E, C4EC4D, C5FC5T, Ar		
Day 3	1	Ar, Ad, TM, ImedRHADECR, GAIC, MCDTTGU, Cim, Im, PsiCpsiDI, C, Ar	2.81	0.98
	2	Ar, 5DE, 5BC, NeoBP, 1BC, 1DE, Ar		
	3	Ar, UHGICSO, B, AnAm, 2B2C, Oft, 2D2E, Ar		
	4	Ar, 3DE, 3BC, LabImuno, AP, Ar		
	5	Ar, 4DE, 4BC, UCIP, Ar		
	6	Ar, COROCN, C2EC2D, C3DC3E, C4EC4D, C5FC5T, Ar		
Day 4	1	Ar, Ad, TM, ImedRHADECR, GAIC, MCDTTGU, Cim, Im, PsiCpsiDI, C, Ar	2.81	0.98
	2	Ar, 5DE, 5BC, NeoBP, 1BC, 1DE, Ar		
	3	Ar, UHGICSO, B, AnAm, 2B2C, Oft, 2D2E, Ar		
	4	Ar, 3DE, 3BC, LabImuno, AP, Ar		
	5	Ar, 4DE, 4BC, UCIP, Ar		
	6	Ar, COROCN, C2EC2D, C3DC3E, C4EC4D, C5FC5T, Ar		
Day 5	1	Ar, Ad, TM, ImedRHADECR, GAIC, MCDTTGU, Cim, Im, PsiCpsiDI, C, Ar	2.81	0.98
	2	Ar, 5DE, 5BC, NeoBP, 1BC, 1DE, Ar		
	3	Ar, UHGICSO, B, AnAm, 2B2C, Oft, 2D2E, Ar		
	4	Ar, 3DE, 3BC, LabImuno, AP, Ar		
	5	Ar, 4DE, 4BC, UCIP, Ar		
	6	Ar, COROCN, C2EC2D, C3DC3E, C4EC4D, C5FC5T, Ar		

* N^er distinguishes the different couriers' routes.

Table III.2 - Opl resuts for current situation structure morning delivery phase

Day	N[er]	Morning Delivery Phase Route	Total Time	Travel Time
Day 1	1	C, Ad, ImedRHAdeCR, GAIC, MCDTTGU, UHGICSO, 2B2C, B, LabImuno, UCIP, 4BC, C4EC4D, NeoBP, 5DE, Ar	7.77	2.48
	2	1DE, COROCN, 2D2E, 5DE, 5BC, NeoBP, 4BC, LabImuno, AnAm, B, SU, Im, MN, ImedRHADECR, C, Ar		
	3	2D2E, C2EC2D, 3DE, 3BC, 4BC, 2B2C, AnAm, B, SU, Im, UHGICSO, 1DE, AprovSOUCCFa, C, Ad, F, Ar		
	4	AP, 3BC, 4BC, C4EC4D, 1DE, 2D2E, AnAm, B, Im, Cim, MCDTTGU, ImedRHAdeCR, C, Ar		
	5	UCIP, 4BC, 5BC, 5DE, 2D2E, 3DE, LabImuno, 2BC, 1BC, MCDTTGU, ImedRHAdeCR, Ad, C, AprovSOUCCFa, Ar		
	6	C5FC5T, UCIP, AP, LabImuno, AnAm, 2B2C, C3DC3E, 3DE, 2D2E, C2EC2D, COROCN, UHGICSO, MCDTTGU, Cim, MN, ImedRHAdeCR, Ad, C, AprovSOUCCFa, F, Ar		
Day 2	1	C, AprovSOUCCFa, Ad, TM, ImedRHAdeCR, GAIC, MCDTTGU, PsiCpsiDI, 2B2C, AnAm, LabImuno, 4BC, 4DE, C4EC4D, 3DE, Ar	7.80	2.52
	2	1DE, UHGICSO, 2B2C, B, AnAm, C2EC2D, 3DE, 4BC, NeoBP, 5DE, Ad, ImedRHAdeCR, C, AprovSOUCCFa, Ar		
	3	2D2E, 2B2C, B, 3BC, 4BC, UCIP, 5BC, NeoBP, C4EC4D, COROCN, 1DE, UHGICSO, Im, MCDTTGU, ImedRHAdeCR, Ad, C, AprovSOUCCFa, F, Ar		
	4	AP, LabImuno, AnAm, B, 3BC, 3DE, C3DC3E, COROCN, UHGICSO, Im, MCDTTGU, ImedRHAdeCR, Ad, C, AprovSOUCCFa, F, Ar		
	5	UCIP, LabImuno, 4BC, 4DE, C4EC4D, 3DE, 2D2E, 2B2C, 1BC, PsiCpsiDI, Im, MCDTTGU, C, Ar		
	6	C5FC5T, C4EC4D, 4BC, AP, 3DE, C3DC3E, C2EC2D, COROCN, ImedRHAdeCR, Cim, MN, MCDTTGU, Ad, AprovSOUCCFa, F, Ar		
Day 3	1	C, Ad, MCDTTGU, 1BC, 2B2C, Oft, 3DE, 3BC, 4BC, 5BC, 5DE, Ar	7.05	2.25
	2	1DE, UHGICSO, 2D2E, 5DE, NeoBP, C4EC4D, 3DE, 3BC, LabImuno, B, Cim, ImedRHAdeCR, Ad, C, AprovSOUCCFa, Ar		
	3	2D2E, Oft, 3DE, 3BC, 4BC, UCIP, AnAm, B, 2B2C, UHGICSO, 1DE, COROCN, Ad, C, F, Ar		
	4	AP, LabImuno, 4BC, 4DE, C4EC4D, C5FC5T, TM, ImedRHAdeCR, Cim, B, AnAm, 2B2C, UHGICSO, 1DE, C, AprovSOUCCFa, Ar		
	5	UCIP, C4EC4D, 5DE, 3DE, LabImuno, 2B2C, PsiCpsiDI, MN, Cim, ImedRHAdeCR, C, Ar		
	6	C5FC5T, 5DE, C4EC4D, C3DC3E, 3DE, LabImuno, AP, 3BC, 2D2E, C2EC2D, COROCN, ImedRHAdeCR, MN, Cim, MCDTTGU, AprovSOUCCFa, F, Ar		
Day 4	1	C, Ad, TM, ImedRHAdeCR, GAIC, MCDTTGU, UHGICSO, PsiCpsiDI, 5BC, C5FC5T, 4DE, 4BC, LabImuno, 3DE, 2D2E, Ar	7.77	2.49
	2	1DE, C2EC2D, C4EC4D, 5DE, 5BC, NeoBP, 4BC, LabImuno, AP, B, AnAm, 2B2C, UHGICSO, 1BC, MN, Cim, MCDTTGU, ImedRHAdeCR, C, Ar		
	3	2D2E, C2EC2D, 3DE, 4DE, 4BC, 3BC, 2B2C, AnAm, 1BC, UHGICSO, 1DE, ImedRHAdeCR, C, AprovSOUCCFa, F, Ar		
	4	AP, LabImuno, 3BC, 3DE, 4DE, C4EC4D, 5DE, 5BC, AnAm, B, UHGICSO, 1DE, Im, MCDTTGU, ImedRHAdeCR, C, AprovSOUCCFa, Ar		
	5	UCIP, 4BC, C4EC4D, 3DE, 2D2E, LabImuno, Im, Cim, MCDTTGU, ImedRHAdeCR, C, AprovSOUCCFa, Ar		

	6	C5FC5T, C4EC4D, 4BC, AP, LabImuno, 3DE, C3DC3E, C2EC2D, 2D2E, 2B2C, MN, Cim, MCDTTGU, ImedRHAdeCR, Ad, AprovSOUCCFa, F, Ar		
Day 5	1	C, AprovSOUCCFa, Ad, ImedRHAdeCR, GAIC, MCDTTGU, Cim, PsiCpsiDI, 4BC, LabImuno, Ar	7.27	2.43
	2	1DE, UHGICSO, 2B2C, AnAm, B, LabImuno, 3BC, NeoBP, C5FC5T, ImedRHAdeCR, MCDTTGU, C, AprovSOUCCFa, F, Ar		
	3	2D2E, 3DE, C4EC4D, UCIP, 4BC, 3BC, 2B2C, AnAm, B, SU23UCISU, PsiCpsiDI, UHGICSO, 1DE, ImedRHAdeCR, C, F, Ar		
	4	AP, LabImuno, 3BC, C3DC3E, 3DE, 4DE, 2D2E, Oft, 2B2C, AnAm, B, UHGICSO, Im, MN, MCDTTGU, ImedRHAdeCR, TM, C, AprovSOUCCFa, Ar		
	5	UCIP, 4BC, 3DE, 2D2E, 2B2C, 1DE, PsiCpsiDI, SU, MN, MCDTTGU, ImedRHAdeCR, C, Ar		
	6	C5FC5T, C4EC4D, 4BC, AP, 3BC, 3DE, 2D2E, C2EC2D, 2B2C, Im, Cim, MCDTTGU, ImedRHAdeCR, AprovSOUCCFa, F, Ar		

Table III.3 - Opl resuts for current situation structure afternoon collection phase

Day	N^er	Afternoon Collection Phase		
		Route	Total Time	Travel Time
Day 1	1	Ar, Ad, TM, ImedRHADECR, GAIC, MCDTTGU, Cim, Im, PsiCpsiDI, C	2.81	0.98
	2	Ar, 5DE, 5BC, NeoBP, 1BC, 1DE		
	3	Ar, UHGICSO, B, AnAm, 2B2C, Oft, 2D2E		
	4	Ar, 3DE, 3BC, LabImuno, AP		
	5	Ar, 4DE, 4BC, UCIP		
	6	Ar, COROCN, C2EC2D, C3DC3E, C4EC4D, C5FC5T		
Day 2	1	Ar, Ad, TM, ImedRHADECR, GAIC, MCDTTGU, Cim, Im, PsiCpsiDI, C, Ar	2.81	0.98
	2	Ar, 5DE, 5BC, NeoBP, 1BC, 1DE, Ar		
	3	Ar, UHGICSO, B, AnAm, 2B2C, Oft, 2D2E, Ar		
	4	Ar, 3DE, 3BC, LabImuno, AP, Ar		
	5	Ar, 4DE, 4BC, UCIP, Ar		
	6	Ar, COROCN, C2EC2D, C3DC3E, C4EC4D, C5FC5T, Ar		
Day 3	1	Ar, Ad, TM, ImedRHADECR, GAIC, MCDTTGU, Cim, Im, PsiCpsiDI, C, Ar	2.81	0.98
	2	Ar, 5DE, 5BC, NeoBP, 1BC, 1DE, Ar		
	3	Ar, UHGICSO, B, AnAm, 2B2C, Oft, 2D2E, Ar		
	4	Ar, 3DE, 3BC, LabImuno, AP, Ar		
	5	Ar, 4DE, 4BC, UCIP, Ar		
	6	Ar, COROCN, C2EC2D, C3DC3E, C4EC4D, C5FC5T, Ar		
Day 4	1	Ar, Ad, TM, ImedRHADECR, GAIC, MCDTTGU, Cim, Im, PsiCpsiDI, C, Ar	2.81	0.98
	2	Ar, 5DE, 5BC, NeoBP, 1BC, 1DE, Ar		
	3	Ar, UHGICSO, B, AnAm, 2B2C, Oft, 2D2E, Ar		
	4	Ar, 3DE, 3BC, LabImuno, AP, Ar		
	5	Ar, 4DE, 4BC, UCIP, Ar		
	6	Ar, COROCN, C2EC2D, C3DC3E, C4EC4D, C5FC5T, Ar		
Day 5	1	Ar, Ad, TM, ImedRHADECR, GAIC, MCDTTGU, Cim, Im, PsiCpsiDI, C, Ar	2.81	0.98
	2	Ar, 5DE, 5BC, NeoBP, 1BC, 1DE, Ar		
	3	Ar, UHGICSO, B, AnAm, 2B2C, Oft, 2D2E, Ar		
	4	Ar, 3DE, 3BC, LabImuno, AP, Ar		
	5	Ar, 4DE, 4BC, UCIP, Ar		
	6	Ar, COROCN, C2EC2D, C3DC3E, C4EC4D, C5FC5T, Ar		

Table III.4 - Opl afternoon delivery phase resuts for current situation structure

Day	N^er	Afternoon Delivery Phase – Route	Total Time	Travel Time
Day 1	1	C, PsiCpsiDI, LabImuno, C4EC4D, NeoBP, 5DE, Ar	6.06	2.21
	2	1DE, COROCN, UHGICSO, 1BC, B, AnAm, 4BC, C4EC4D, C2EC2D, 2D2E, Ar		
	3	2D2E, C2EC2D, 3DE, 4DE, C4EC4D, UCIP, B, AnAm, 2B2C, 1DE, UHGICSO, PsiCpsiDI, SU23UCISU, Im, MN, MCDTTGU, C, AprovSOUCCFa, Ar		
	4	AP, C4EC4D, 4DE, 2D2E, 2B2C, B, AnAm, Im, MCDTTGU, Ar		
	5	UCIP, 4BC, 5DE, C4EC4D, 3DE, LabImuno, 2B2C, C2DC2E, 1DE, PsiCpsiDI, MCDTTGU, Ad, C, AprovSOUCCFa, Ar		
	6	C5FC5T, 4DE, C4EC4D, C2EC2D, Cim, MCDTTGU, Ad, AprovSOUCCFa, F, Ar		
Day 2	1	C, Ad, MCDTTGU, PsiCpsiDI, 1DE, COROCN, Oft, 3DE, AP, 4BC, 5DE, Ar	6.19	2.26
	2	1DE, 5DE, 5BC, 4BC, C4EC4D, 3DE, Oft, B, AnAm, Im, MCDTTGU, Ad, AprovSOUCCFa, Ar		
	3	2D2E, 3DE, 4DE, C4EC4D, UCIP, AnAm, B, 2B2C, 1DE, UHGICSO, Im, MCDTTGU, Ar		
	4	AP, LabImuno, 4BC, C4EC4D, 3DE, B, AnAm, UHGICSO, COROCN, MCDTTGU, Ad, AprovSOUCCFa, Ar		
	5	UCIP, 4BC, C4EC4D, C2EC2D, 2D2E, 3DE, LabImuno, AnAm, 1BC, PsiCpsiDI, Im, MCDTTGU, Ar		
	6	C5FC5T, C4EC4D, C3DC3E, LabImuno, MN, Cim, MCDTTGU, UHGICSO, COROCN, Ad, AprovSOUCCFa, Ar		
Day 3	1	C, Ad, MCDTTGU, PsiCpsiDI, 1BC, Oft, 2D2E, 3DE, AP, 4BC, UCIP, 5BC, C5FC5T, 5DE, Ar	6.22	2.26
	2	1DE, SU23UCISU, B, AnAm, 2B2C, 2D2E, 5DE, 4DE, Ad, Ar		
	3	2D2E, Oft, 2B2C, AnAm, B, 3BC, 3DE, C4EC4D, 4BC, NeoBP, 5DE, 1DE, UHGICSO, SU23UCISU, Cim, MCDTTGU, ImedRHAdeCR, Ad, AprovSOUCCFa, Ar		
	4	AP, LabImuno, 4BC, 3BC, 3DE, 2D2E, AnAm, B, SU, UHGICSO, MCDTTGU, Cim, AprovSOUCCFa, Ar		
	5	UCIP, C4EC4D, 3DE, LabImuno, B, 2B2C, MCDTTGU, Ad, AprovSOUCCFa, Ar		
	6	C5FC5T, 4BC, LabImuno, B, C2EC2D, UHGICSO, MCDTTGU, Cim, Ad, AprovSOUCCFa, F, Ar		
Day 4	1	C, AprovSOUCCFa, Ad, TM, ImedRHAdeCR, GAIC, MCDTTGU, AP, LabImuno, 3DE, 4DE, Ar	6.09	2.29
	2	1DE, 2D2E, 3DE, 5DE, 5BC, UCIP, B, Im, Cim, AprovSOUCCFa, Ar		
	3	2D2E, Oft, 2B2C, AnAm, B, 3BC, 3DE, C3DC3E, C4EC4D, 4DE, 4BC, NeoBP, 5DE, 1DE, UHGICSO, 1BC, Cim, Ad, AprovSOUCCFa, F		
	4	AP, LabImuno, 3BC, 4DE, C4EC4D, C2EC2D, AnAm, UHGICSO, Im, Ad, AprovSOUCCFa, F, Ar		
	5	UCIP, 4BC, C4EC4D, C2EC2D, C3DC3E, 3DE, 3BC, LabImuno, SU, MCDTTGU, Ad, AprovSOUCCFa, Ar		
	6	C5FC5T, LabImuno, UHGICSO, PsiCpsiDI, MN, Cim, MCDTTGU, AprovSOUCCFa, Ar		
Day 5	1	C, Ad, GAIC, MCDTTGU, Im, PsiCpsiDI, 1BC, AnAm, LabImuno, AP, NeoBP, 5DE, 3DE, Ar	5.71	2.12
	2	1DE, 2D2E, 4DE, 4BC, UCIP, B, PsiCpsiDI, Im, Cim, Ar		
	3	2D2E, 1DE, MCDTTGU, UHGICSO, SU23UCISU, B, AnAm, 2B2C, 3BC, 4DE, 5BC, 5DE, F, Ar		
	4	AP, 4BC, 4DE, C4EC4D, 3DE, C3DC3E, C2EC2D, 2D2E, 2B2C, AnAm, B, Im, MCDTTGU, F, Ar		
	5	UCIP, 4BC, LabImuno, 2B2C, 2D2E, 1DE, Im, MN, MCDTTGU, Ad, Ar		
	6	C5FC5T, C3DC3E, C2EC2D, COROCN, Cim, MCDTTGU, AprovSOUCCFa, Ar		

Improved Current Situation Methodology Results

Table III.5 - Opl morning collection phase resuts for improved current situation

Day	N^{er}	Morning Collection Phase Route	Total Time	Travel Time
Day 1	1	Ar, 5DE, C5TC5F, C4EC4D, 4DE, 4BC, UCIP, 5BC, NeoBP	2.59	0.71
	2	Ar, C, Ad, TM, ImedRHAdeCC, COROCN, 1DE, UHGICSO, 1BC, PsiCpsiDI		
	3	Ar, 3DE, C3DC3E, C2EC2E, 2D2E, Oft, 2B2C, AnAm, B, 3BC, LabImuno, AP		
	4	Ar, GAIC, MCDTTGU, Cim, Im		
Day 2	1	Ar, 5DE, C5TC5F, C4EC4D, 4DE, 4BC, UCIP, 5BC, NeoBP	2.59	0.71
	2	Ar, C, Ad, TM, ImedRHAdeCC, COROCN, 1DE, UHGICSO, 1BC, PsiCpsiDI		
	3	Ar, 3DE, C3DC3E, C2EC2E, 2D2E, Oft, 2B2C, AnAm, B, 3BC, LabImuno, AP		
	4	Ar, GAIC, MCDTTGU, Cim, Im		
Day 3	1	Ar, 5DE, C5TC5F, C4EC4D, 4DE, 4BC, UCIP, 5BC, NeoBP	2.59	0.71
	2	Ar, C, Ad, TM, ImedRHAdeCC, COROCN, 1DE, UHGICSO, 1BC, PsiCpsiDI		
	3	Ar, 3DE, C3DC3E, C2EC2E, 2D2E, Oft, 2B2C, AnAm, B, 3BC, LabImuno, AP		
	4	Ar, GAIC, MCDTTGU, Cim, Im		
Day 4	1	Ar, 5DE, C5TC5F, C4EC4D, 4DE, 4BC, UCIP, 5BC, NeoBP	2.59	0.71
	2	Ar, C, Ad, TM, ImedRHAdeCC, COROCN, 1DE, UHGICSO, 1BC, PsiCpsiDI		
	3	Ar, 3DE, C3DC3E, C2EC2E, 2D2E, Oft, 2B2C, AnAm, B, 3BC, LabImuno, AP		
	4	Ar, GAIC, MCDTTGU, Cim, Im		
Day 5	1	Ar, 5DE, C5TC5F, C4EC4D, 4DE, 4BC, UCIP, 5BC, NeoBP	2.59	0.71
	2	Ar, C, Ad, TM, ImedRHAdeCC, COROCN, 1DE, UHGICSO, 1BC, PsiCpsiDI		
	3	Ar, 3DE, C3DC3E, C2EC2E, 2D2E, Oft, 2B2C, AnAm, B, 3BC, LabImuno, AP		
	4	Ar, GAIC, MCDTTGU, Cim, Im		

Table III.6 - Opl morning delivery phase resuts for improved current situation

		Morning Delivery Phase		
Day	N[er]	Route	Total Time	Travel Time
Day 1	1	NeoBP, 5DE, C5FC5T, C2EC2D, 2D2E, 3BC, LabImuno, B, 2B2C, 1BC, SU, MN, Cim, MCDTTGU, ImedRHAdeCR, Ad, C, AprovSOUCCFa, Ar	5.72	1.76
	2	PsiCpsiDI, SU23UCISU, Im, MN, MCDTTGU, 4BC, LabImuno, B, AnAm, 2B2C, Oft, 3DE, C3DC3E, C2EC2D, COROCN, GAIC, C, AprovSOUCCFa, Ar		
	3	AP, B, AnAm, 4BC, C4EC4D, 3DE, 2D2E, C2EC2D, 1DE, UHGICSO, Im, Cim, MCDTTGU, ImedRHAdeCR, Ad, C, AprovSOUCCFa, F, Ar		
	4	Im, MN, MCDTTGU, 3BC, LabImuno, UCIP, NeoBP, 5DE, C5FC5T, C4EC4D, C2EC2D, 1DE, COROCN, GAIC, Ad, Ar		
Day 2	1	NeoBP, 5DE, 4BC, LabImuno, 3DE, 2D2E, C2EC2D, 2B2C, AnAm, B, 1BC, PsiCpsiDI, Im, MN, Cim, MCDTTGU, ImedRHAdeCR, Ad, C, AprovSOUCCFa, Ar	4.45	1.29
	2	PsiCpsiDI, UHGICSO, 2B2C, B, AnAm, C2EC2D, C3DC3E, C4EC4D, C5FC5T, 4BC, MCDTTGU, Cim, GAIC, C, AprovSOUCCFa, F, Ar		
	3	AP, UCIP, 4BC, C4EC4D, 3DE, 2D2E, 2B2C, B, Im, Cim, MCDTTGU, UHGICSO, 1DE, COROCN, ImedRHAdeCR, Ad, C, AprovSOUCCFa, F, Ar		
	4	Im, 2B2C, LabImuno, 3BC, 4BC, 4DE, C4EC4D, 3DE, Ad, AprovSOUCCFa, Ar		
Day 3	1	NeoBP, 5DE, 3DE, LabImuno, B, 2B2C, C2EC2D, 1DE, PsiCpsiDI, MN, Cim, MCDTTGU, ImedRHAdeCR, Ad, C, AprovSOUCCFa, Ar	5.01	1.58
	2	PsiCpsiDI, 1BC, MN, MCDTTGU, C, AprovSOUCCFa, ImedRHAdeCR, COROCN, 2D2E, Oft, 2B2C, B, LabImuno, 3BC, 4BC, 5BC, 5DE, C5FC5T, C4EC4D, C3DC3E, 3DE, F, Ar		
	3	AP, B, AnAm, 2B2C, 2D2E, 3DE, 4DE, 4BC, UCIP, C4EC4D, C5FC5T, COROCN, UHGICSO, MCDTTGU, Cim, ImedRHAdeCR, TM, Ad, C, AprovSOUCCFa, F, Ar		
	4	Im, Ad, Ar		
Day 4	1	NeoBP, 5DE, 4BC, AP, LabImuno, 3DE, 2D2E, C2EC2D, AnAm, B, UHGICSO, Im, MN, Cim, MCDTTGU, ImedRHAdeCR, C, AprovSOUCCFa, Ar	5.50	1.70
	2	PsiCpsiDI, 1BC, B, AnAm, 2B2C, Oft, C2EC2D, C3DC3E, 3DE, 3BC, LabImuno, AP, UCIP, 4BC, C4EC4D, C5FC5T, 5DE, 5BC, Im, MN, Cim, MCDTTGU, GAIC, ImedRHAdeCR, C, AprovSOUCCFa, Ar		
	3	AP, B, AnAm, 2B2C, 5BC, 5DE, C4EC4D, 4DE, 3DE, 2D2E, 1DE, UHGICSO, 1BC, Im, Cim, MCDTTGU, ImedRHAdeCR, Ad, C, AprovSOUCCFa, F, Ar		
	4	Im, LabImuno, 4BC, 4DE, 3DE, Ad, Ar		
Day 5	1	NeoBP, C5FC5T, 3DE, LabImuno, AnAm, 2B2C, 2D2E, 1DE, UHGICSO, PsiCpsiDI, SU, Cim, MCDTTGU, ImedRHAdeCR, C, AprovSOUCCFa, F, Ar	5.39	1.72
	2	PsiCpsiDI, MN, Cim, MCDTTGU, C, AprovSOUCCFa, ImedRHAdeCR, GAIC, COROCN, C2EC2D, 2D2E, 2B2C, AnAm, B, 3BC, 4BC, C5FC5T, C4EC4D, 3DE, F		
	3	AP, UCIP, 4BC, 4DE, C4EC4D, C3DC3E, 3DE, 2D2E, 2B2C, AnAm, B, SU23UCISU, UHGICSO, PsiCpsiDI, Im, Cim, MCDTTGU, ImedRHAdeCR, TM, C		
	4	Im, MN, LabImuno, 2B2C, Ad, AprovSOUCCFa, Ar		

Table III.7 - Opl afternoon collection phase resuts for improved current situation

Day	N^er	Afternoon Collection Phase		
		Route	Total Time	Travel Time
Day 1	1	Ar, 5DE, C5TC5F, C4EC4D, 4DE, 4BC, UCIP, 5BC, NeoBP		
	2	Ar, C, Ad, TM, ImedRHAdeCC, COROCN, 1DE, UHGICSO, 1BC, PsiCpsiDI		
	3	Ar, 3DE, C3DC3E, C2EC2E, 2D2E, Oft, 2B2C, AnAm, B, 3BC, LabImuno, AP		
	4	Ar, GAIC, MCDTTGU, Cim, Im	2.59	0.71
Day 2	1	Ar, 5DE, C5TC5F, C4EC4D, 4DE, 4BC, UCIP, 5BC, NeoBP		
	2	Ar, C, Ad, TM, ImedRHAdeCC, COROCN, 1DE, UHGICSO, 1BC, PsiCpsiDI		
	3	Ar, 3DE, C3DC3E, C2EC2E, 2D2E, Oft, 2B2C, AnAm, B, 3BC, LabImuno, AP		
	4	Ar, GAIC, MCDTTGU, Cim, Im	2.59	0.71
Day 3	1	Ar, 5DE, C5TC5F, C4EC4D, 4DE, 4BC, UCIP, 5BC, NeoBP		
	2	Ar, C, Ad, TM, ImedRHAdeCC, COROCN, 1DE, UHGICSO, 1BC, PsiCpsiDI		
	3	Ar, 3DE, C3DC3E, C2EC2E, 2D2E, Oft, 2B2C, AnAm, B, 3BC, LabImuno, AP		
	4	Ar, GAIC, MCDTTGU, Cim, Im	2.59	0.71
Day 4	1	Ar, 5DE, C5TC5F, C4EC4D, 4DE, 4BC, UCIP, 5BC, NeoBP		
	2	Ar, C, Ad, TM, ImedRHAdeCC, COROCN, 1DE, UHGICSO, 1BC, PsiCpsiDI		
	3	Ar, 3DE, C3DC3E, C2EC2E, 2D2E, Oft, 2B2C, AnAm, B, 3BC, LabImuno, AP		
	4	Ar, GAIC, MCDTTGU, Cim, Im	2.59	0.71
Day 5	1	Ar, 5DE, C5TC5F, C4EC4D, 4DE, 4BC, UCIP, 5BC, NeoBP		
	2	Ar, C, Ad, TM, ImedRHAdeCC, COROCN, 1DE, UHGICSO, 1BC, PsiCpsiDI		
	3	Ar, 3DE, C3DC3E, C2EC2E, 2D2E, Oft, 2B2C, AnAm, B, 3BC, LabImuno, AP		
	4	Ar, GAIC, MCDTTGU, Cim, Im	2.59	0.71

Table III.8 - Opl afternoon delivery phase resuts for improved current situation

Day	N^er	Afternoon Delivery Phase: Route	Total Time	Travel Time
Day 1	1	NeoBP, 5DE, 3DE, LabImuno, AnAm, 2B2C, C2EC2D, 1DE, PsiCpsiDI, Cim, MCDTTGU, Ad, AprovSOUCCFa, Ar	4.38	1.58
	2	PsiCpsiDI, SU23UCISU, 1BC, UHGICSO, COROCN, C2EC2D, 2D2E, 2B2C, AnAm, B, 4BC, C4EC4D, 5DE, F, AprovSOUCCFa, Ar		
	3	AP, UCIP, C4EC4D, 4DE, 3DE, C2EC2D, AnAm, 2B2C, 1DE, UHGICSO, PsiCpsiDI, Im, Cim, MCDTTGU, Ad, AprovSOUCCFa, F, Ar		
	4	Im, MN, NeoBP, LabImuno, Ar		
Day 2	1	NeoBP, 5DE, 2D2E, C2EC2D, C3DC3E, 3DE, LabImuno, AnAm, 1BC, PsiCpsiDI, Im, MN, Cim, MCDTTGU, COROCN, Ad, AprovSOUCCFa, Ar	3.92	1.39
	2	PsiCpsiDI, 1DE, Oft, 3DE, 5DE, 4BC, AP, B, Im, MCDTTGU, Ad, Ar		
	3	AP, LabImuno, UCIP, 4BC, 4DE, C4EC4D, 3DE, 2D2E, 2B2C, AnAm, B, Im, MCDTTGU, UHGICSO, COROCN, Ad, AprovSOUCCFa, Ar		
	4	Im, Ar		
Day 3	1	NeoBP, 4BC, LabImuno, 3DE, C2EC2D, 2B2C, B, AnAm, Cim, MCDTTGU, Ad, AprovSOUCCFa, Ar	4.18	1.49
	2	PsiCpsiDI, SU23UCISU, 2B2C, AnAm, AP, 4BC, UCIP, 5BC, 5DE, C5FC5T, 4DE, 3DE, Oft, 2D2E, 1DE, MCDTTGU, Ad, Ar		
	3	AP, 4BC, NeoBP, 5DE, C4EC4D, 3DE, 2D2E, Oft, 2B2C, AnAm, B, SU23UCISU, Cim, MCDTTGU, UHGICSO, COROCN, Ad, F, Ar		
	4	Im, PsiCpsiDI, Oft, 1DE, Ad, Ar		
Day 4	1	NeoBP, LabImuno, 3BC, 3DE, C3DC3E, C2EC2D, SU, PsiCpsiDI, MN, Cim, MCDTTGU, Ad, AprovSOUCCFa, Ar	3.44	1.34
	2	PsiCpsiDI, B, Oft, 2D2E, 5DE, 3DE, 4DE, UCIP, AP, LabImuno, Cim, MCDTTGU, GAIC, AprovSOUCCFa, Ar		
	3	AP, AnAm, C3DC3E, C4EC4D, 4DE, UHGICSO, 1BC, Im, Cim, Ad, AprovSOUCCFa, F, Ar		
	4	Im, Ad, Ar		
Day 5	1	NeoBP, LabImuno, 2B2C, C3DC3E, C2EC2D, Cim, MCDTTGU, AprovSOUCCFa, Ar	2.77	0.99
	2	PsiCpsiDI, 5BC, 3BC, AprovSOUCCFa, Ar		
	3	AP, 4BC, 4DE, C4EC4D, 5DE, C2EC2D, COROCN, 1DE, UHGICSO, 2B2C, AnAm, B, SU23UCISU, Im, Cim, MCDTTGU, AprovSOUCCFa, F, Ar		
	4	Im, Ar		

Independent Collection and Delivery Methodology Results with Arquivo as Hub

Table III.9 - Opl morning collection phase resuts for arquivo's independent methodology

Day	Ner	Morning Collection Phase		
		Route	Total Time	Travel Time
Day 1	1	Ar, C, Ad, 1DE, Oft, 2D2E, C2EC2D, C3DC3E, 3DE, Ar	2.90	1.05
	2	Ar, TM, ImedRHAdeCR, COROCN, UHGICSO, 1BC, PsiCpsiDI, Im, Cim, Ar		
	3	Ar, 4BC, UCIP, NeoBP, 5BC, 5DE, C5TC5F, C4DC4E, 4DE, Ar		
	4	Ar, GAIC, MCDTTGU, 2B2C, AnAm, B, AP, LabImuno, 3BC, Ar		
Day 2	1	Ar, C, Ad, 1DE, Oft, 2D2E, C2EC2D, C3DC3E, 3DE, Ar	2.90	1.05
	2	Ar, TM, ImedRHAdeCR, COROCN, UHGICSO, 1BC, PsiCpsiDI, Im, Cim, Ar		
	3	Ar, 4BC, UCIP, NeoBP, 5BC, 5DE, C5TC5F, C4DC4E, 4DE, Ar		
	4	Ar, GAIC, MCDTTGU, 2B2C, AnAm, B, AP, LabImuno, 3BC, Ar		
Day 3	1	Ar, C, Ad, 1DE, Oft, 2D2E, C2EC2D, C3DC3E, 3DE, Ar	2.90	1.05
	2	Ar, TM, ImedRHAdeCR, COROCN, UHGICSO, 1BC, PsiCpsiDI, Im, Cim, Ar		
	3	Ar, 4BC, UCIP, NeoBP, 5BC, 5DE, C5TC5F, C4DC4E, 4DE, Ar		
	4	Ar, GAIC, MCDTTGU, 2B2C, AnAm, B, AP, LabImuno, 3BC, Ar		
Day 4	1	Ar, C, Ad, 1DE, Oft, 2D2E, C2EC2D, C3DC3E, 3DE, Ar	2.90	1.05
	2	Ar, TM, ImedRHAdeCR, COROCN, UHGICSO, 1BC, PsiCpsiDI, Im, Cim, Ar		
	3	Ar, 4BC, UCIP, NeoBP, 5BC, 5DE, C5TC5F, C4DC4E, 4DE, Ar		
	4	Ar, GAIC, MCDTTGU, 2B2C, AnAm, B, AP, LabImuno, 3BC, Ar		
Day 5	1	Ar, C, Ad, 1DE, Oft, 2D2E, C2EC2D, C3DC3E, 3DE, Ar	2.90	1.05
	2	Ar, TM, ImedRHAdeCR, COROCN, UHGICSO, 1BC, PsiCpsiDI, Im, Cim, Ar		
	3	Ar, 4BC, UCIP, NeoBP, 5BC, 5DE, C5TC5F, C4DC4E, 4DE, Ar		
	4	Ar, GAIC, MCDTTGU, 2B2C, AnAm, B, AP, LabImuno, 3BC, Ar		

Table III.10 - Opl morning delivery phase resuts for arquivo's independent methodology

Day	N^{er}	Morning Delivery Phase Route	Total Time	Travel Time
Day 1	1	Ar, C4DC4E, 4DE, 4BC, UCIP, NeoBP, 5BC, C5FC5T, 5DE, Ar	2.80	1.02
	2	Ar, F, 1DE, UHGICSO, 1BC, SU, Im, MN, MCDTTGU, ImedRHAdeCR, Ar		
	3	Ar, 2D2E, 2B2C, AnAm, B, AP, LabImuno, 3BC, 3DE, Ar		
	4	Ar, AprovSOUCCFa, C, Ad, COROCN, C2EC2D, C3EC3D, Ar		
Day 2	1	Ar, AprovSOUCCFa, C, Ad, TM, C5Fc5T, NeoBP, 5BC, 5DE, Ar	2.99	1.05
	2	Ar, F, 3DE, C3DC3E, 3BC, LabImuno, UCIP, 4BC, C4EC4D, 4DE, Ar		
	3	Ar, 1DE, COROCN, C2EC2D, AnAm, B, 2B2C, 2D2E, Ar		
	4	Ar, ImedRHAdeCR, Gaic, MCDTTGU, Cim, MN, Im, PsiCpsiDI, 1BC, UHGICSO, Ar		
Day 3	1	Ar, AprovSOUCCFa, Ad, 2D2E, C2EC2D, C4eC4D, 4DE, Ar	2.61	0.98
	2	Ar, F, 5DE, C5FC5T, 5BC, NeoBP, UCIP, 4BC, Ar		
	3	Ar, MCDTTGU, Cim, SU, SU23UCISU, PsiCpsiDI, UHGICSO, 1DE, Ar		
	4	Ar, 2D2E, Oft, 2B2C, AnAm, B, LabImuno, 3BC, 3DE, Ar		
Day 4	1	Ar, Ad, ImedRHADECR, GAIC, TM, C3EC3D, C2EC2D, 2D2E, Ar	2.87	1.06
	2	Ar, 3DE, 3BC, 5BC, NeoBP, C4EC4D, C5FC5T, 5DE, Ar		
	3	Ar, AprovSOUCCFa, C, MCDTTGU, Cim, MN, Im, PsiCpsiDI, 1BC, UHGICSO, 1DE, Ar		
	4	Ar, F, 2B2C, AnAm, B, LabImuno, AP, UCIP, 4BC, 4DE, Ar		
Day 5	1	Ar, AprovSOUCCFa, C, Ad, GAIC, TM, ImedRHADECR, COROCN, C2EC2D, Ar	2.95	1.06
	2	Ar, MCDTTGU, Cim, MN, Im, SU, SU23UCISU, PsiCpsiDI, UHGICSO, 1DE, Ar		
	3	Ar, F, 3DE, 4BC, UCIP, NeoBP, C5FC5T, C4EC4D, 4DE, Ar		
	4	Ar, 2D2E, Oft, 2B2C, AnAm, B, Labmuno, 3BC, C3DC3E, Ar		

Table III.11 - Opl afternoon collection phase resuts for arquivo's independent methodology

Day	N^{er}	Afternoon Collection Phase		
		Route	Total Time	Travel Time
Day 1	1	Ar, C, Ad, 1DE, Oft, 2D2E, C2EC2D, C3DC3E, 3DE, Ar	2.90	1.05
	2	Ar, TM, ImedRHAdeCR, COROCN, UHGICSO, 1BC, PsiCpsiDI, Im, Cim, Ar		
	3	Ar, 4BC, UCIP, NeoBP, 5BC, 5DE, C5TC5F, C4DC4E, 4DE, Ar		
	4	Ar, GAIC, MCDTTGU, 2B2C, AnAm, B, AP, LabImuno, 3BC, Ar		
Day 2	1	Ar, C, Ad, 1DE, Oft, 2D2E, C2EC2D, C3DC3E, 3DE, Ar	2.90	1.05
	2	Ar, TM, ImedRHAdeCR, COROCN, UHGICSO, 1BC, PsiCpsiDI, Im, Cim, Ar		
	3	Ar, 4BC, UCIP, NeoBP, 5BC, 5DE, C5TC5F, C4DC4E, 4DE, Ar		
	4	Ar, GAIC, MCDTTGU, 2B2C, AnAm, B, AP, LabImuno, 3BC, Ar		
Day 3	1	Ar, C, Ad, 1DE, Oft, 2D2E, C2EC2D, C3DC3E, 3DE, Ar	2.90	1.05
	2	Ar, TM, ImedRHAdeCR, COROCN, UHGICSO, 1BC, PsiCpsiDI, Im, Cim, Ar		
	3	Ar, 4BC, UCIP, NeoBP, 5BC, 5DE, C5TC5F, C4DC4E, 4DE, Ar		
	4	Ar, GAIC, MCDTTGU, 2B2C, AnAm, B, AP, LabImuno, 3BC, Ar		
Day 4	1	Ar, C, Ad, 1DE, Oft, 2D2E, C2EC2D, C3DC3E, 3DE, Ar	2.90	1.05
	2	Ar, TM, ImedRHAdeCR, COROCN, UHGICSO, 1BC, PsiCpsiDI, Im, Cim, Ar		
	3	Ar, 4BC, UCIP, NeoBP, 5BC, 5DE, C5TC5F, C4DC4E, 4DE, Ar		
	4	Ar, GAIC, MCDTTGU, 2B2C, AnAm, B, AP, LabImuno, 3BC, Ar		
Day 5	1	Ar, C, Ad, 1DE, Oft, 2D2E, C2EC2D, C3DC3E, 3DE, Ar	2.90	1.05
	2	Ar, TM, ImedRHAdeCR, COROCN, UHGICSO, 1BC, PsiCpsiDI, Im, Cim, Ar		
	3	Ar, 4BC, UCIP, NeoBP, 5BC, 5DE, C5TC5F, C4DC4E, 4DE, Ar		
	4	Ar, GAIC, MCDTTGU, 2B2C, AnAm, B, AP, LabImuno, 3BC, Ar		

Table III.12 - Opl afternoon delivery phase resuts for arquivo's independent methodology

Day	N^er	Afternoon Delivery Phase		
		Route	Total Time	Travel Time
Day 1	1	Ar, 4DE, C4DC4E, 4BC, UCIP, NeoBP, 5BC, Ar	2.45	0.97
	2	Ar, AprovSouCCFa, Ad, COROCN, C2EC2D, 2D2E, F, Ar		
	3	Ar, 1DE, UHGICSO, 2B2C, AnAm, B, LabImuno, 3DE, Ar		
	4	Ar, MCDTTGU, Cim, MN, Im, Su23Ucisu, 1BC, PsiCpsiDI, Ar		
Day 2	1	Ar, Ad, COROCN, 1DE, UHGICSO, 1BC, PsiCpsiDI, AprovSOUCCFa, Ar	2.42	0.95
	2	Ar, MCDTTGU, Cim, MN, Im, AnAm, B, 2B2C, Oft, Ar		
	3	Ar, 2D2E, C2DC2E, C3DC3E, C4DC4E, 4DE, Ar		
	4	Ar, 3DE, LabImuno, 4BC, UCIP, 5BC, 5DE, Ar		
Day 3	1	Ar, AprvSOUCCFa, C, 1DE, UHGICSO, 1BC, PsiCpsiDI, MN, Cim, MCDTTGU, Ar	2.87	0.99
	2	Ar, F, 2D2E, Oft, 2B2C, AnAm, B, LabImuno, 3BC, 3DE, Ar		
	3	Ar, 4DE, C4DC4E, 4BC, UCIP, NeoBP, 5BC, C5FC5T, 5DE, Ar		
	4	Ar, Ad, TM, ImedRHADECR, COROCN, C2EC2D, C3DC3E, 3DE, Ar		
Day 4	1	Ar, AprvSOUCCFa, C, UHGICSO, 1BC, B, AnAm, 2B2C, Oft, 2D2E, Ar	2.84	1.02
	2	Ar, ImedRHADECR, GAIC, TM, C2EC2D, C3DC3E, C4EC$D, 4DE, Ar		
	3	Ar, Ad, MCDTTGU, Cim, MN, Im, SU, PsiCpsiDI, F, Ar		
	4	Ar, 5DE, 5BC, NeoBC, 4BC, UCIP, LabImuno, 3BC, 3DE, Ar		
Day 5	1	Ar, Ad, GAIC, MCDTTGU, Cim, MN, Im, 1BC, UHGICSO, 1DE, 2D2E, Ar	2.69	1.07
	2	Ar, F, 3DE, C3DC3E, C4EC4D, NeoBP, 5BC, 5DE, Ar		
	3	Ar, C2EC2D, 3BC, LabImuno, AP, UCIP, 4BC, 4DE, Ar		
	4	Ar, AprovSOUCCFa, PsiCpsiDI, SU23UCISU, B, AnAm, 2B2C, Ar		

Independent Collection and Delivery Methodology Results with Hub on the first floor

Table III.13 - Opl morning collection phase resuts for first floor's independent methodology

Day	N^{er}	Morning Collection Phase Route	Total Time	Travel Time
Day 1	1	Hub1, AnAm, B, AP, LabImuno, 3BC, 3DE, C3DC3E, C2DC2E, Hub1	2.75	0.89
	2	Hub1, 4BC, UCIP, NeoBP, 5BC, 5DE, C5FC5T, C4DC4E, 4DE, Hub1		
	3	Hub1, C, Ar, Ad, TM, ImedRHADECR, GAIC, MCDTTGU, Cim, Im, Hub1		
	4	Hub1, 1BC, PsiCpsiDI, UHGICSO, COROCN, 1DE, 2D2E, Oft, 2B2C, Hub1		
Day 2	1	Hub1, AnAm, B, AP, LabImuno, 3BC, 3DE, C3DC3E, C2DC2E, Hub1	2.75	0.89
	2	Hub1, 4BC, UCIP, NeoBP, 5BC, 5DE, C5FC5T, C4DC4E, 4DE, Hub1		
	3	Hub1, C, Ar, Ad, TM, ImedRHADECR, GAIC, MCDTTGU, Cim, Im, Hub1		
	4	Hub1, 1BC, PsiCpsiDI, UHGICSO, COROCN, 1DE, 2D2E, Oft, 2B2C, Hub1		
Day 3	1	Hub1, AnAm, B, AP, LabImuno, 3BC, 3DE, C3DC3E, C2DC2E, Hub1	2.75	0.89
	2	Hub1, 4BC, UCIP, NeoBP, 5BC, 5DE, C5FC5T, C4DC4E, 4DE, Hub1		
	3	Hub1, C, Ar, Ad, TM, ImedRHADECR, GAIC, MCDTTGU, Cim, Im, Hub1		
	4	Hub1, 1BC, PsiCpsiDI, UHGICSO, COROCN, 1DE, 2D2E, Oft, 2B2C, Hub1		
Day 4	1	Hub1, AnAm, B, AP, LabImuno, 3BC, 3DE, C3DC3E, C2DC2E, Hub1	2.75	0.89
	2	Hub1, 4BC, UCIP, NeoBP, 5BC, 5DE, C5FC5T, C4DC4E, 4DE, Hub1		
	3	Hub1, C, Ar, Ad, TM, ImedRHADECR, GAIC, MCDTTGU, Cim, Im, Hub1		
	4	Hub1, 1BC, PsiCpsiDI, UHGICSO, COROCN, 1DE, 2D2E, Oft, 2B2C, Hub1		
Day 5	1	Hub1, AnAm, B, AP, LabImuno, 3BC, 3DE, C3DC3E, C2DC2E, Hub1	2.75	0.89
	2	Hub1, 4BC, UCIP, NeoBP, 5BC, 5DE, C5FC5T, C4DC4E, 4DE, Hub1		
	3	Hub1, C, Ar, Ad, TM, ImedRHADECR, GAIC, MCDTTGU, Cim, Im, Hub1		
	4	Hub1, 1BC, PsiCpsiDI, UHGICSO, COROCN, 1DE, 2D2E, Oft, 2B2C, Hub1		

Table III.14 -Opl morning collection phase resuts for first floor's independent methodology

Day	N[er]	Morning Delivery Phase		
		Route	Total Time	Travel Time
Day 1	1	Hub1, Ad, ImedRHAdeCR, GAIC, MCDTTGU, Cim, MN, Im, SU, 1BC, UHGICSO, Hub1	2.70	0.89
	2	Hub1, AnAm, B, AP, LabImuno, 3BC, 4BC, UCIP, NeoBP, 5BC, Hub1		
	3	Hub1, 2B2C, C3DC3E, 3DE, C4EC4D, C5FC5T, 5DE, Hub1		
	4	Hub1, C, AprovSOUCCFa, Ar, F, 1DE, COROCN, C2EC2D, 2D2E, Hub1		
Day 2	1	Hub1, C2EC2D, 2D2E, 3DE, 4DE, C4EC4D, C5FC5T, 5DE, Hub1	2.78	0.92
	2	Hub1, 2B2C, C3DC3E, 3BC, LabImuno, UCIP, 4BC, NeoBP, 5BC, Hub1		
	3	Hub1, F, Ar, AprovSOUCCFa, C, Ad, PsiCpsiDI, 1BC, B, AnAm, Hub1		
	4	Hub1, Im, MN, Cim, MCDTTGU, GAIC, TM, ImedRHAdeCR, COROCN, 1DE, UHGICSO, Hub1		
Day 3	1	Hub1, Oft, 2D2E, C2EC2D, C3DC3E, 3DE, 3BC, LabImuno, Hub1	2.69	0.88
	2	Hub1, MCDTTGU, Cim, MN, PsiCpsiDI, 1BC, B, AnAm, 2B2C, Hub1		
	3	Hub1, 4DE, C4EC4D, C5FC5T, 5DE, 5BC, NeoBP, UCIP, 4BC, Hub1		
	4	Hub1, F, Ar, AprovSOUCCFa, C, Ad, TM, ImedRHAdeCR, COROCN, 1DE, UHGICSO, Hub1		
Day 4	1	Hub1, 2B2C, AnAm, B, AP, LabImuno, UCIP, NeoBP, 5BC, Hub1	2.84	0.95
	2	Hub1, UHGICSO, 1DE, 2D2E, C2EC2D, C3DC3E, 3DE, 3BC, 2B2C, Hub1		
	3	Hub1, MCDTTGU, Cim, MN, Im, 4BC, 4DE, C4EC4D, C5FC5T, 5DE, Hub1		
	4	Hub1, F, Ar, AprovSOUCCFa, C, Ad, TM, ImedRHAdeCR, GAIC, PsiCpsiDI, 1BC, Hub1		
Day 5	1	Hub1, MCDTTGU, GAIC, Cim, MN, Im, SU, SU23UCISU, PsiCpsiDI, UHGICSO, Hub1	2.83	0.93
	2	Hub1, Oft, 2D2E, 4DE, C4EC4D, C5FC5T, NeoBP, UCIP, 4BC, Hub1		
	3	Hub1, F, Ar, AprovSOUCCFa, C, Ad, TM, ImedRHAdeCR, COROCN, 1DE, UHGICSO, Hub1		
	4	Hub1, 2B2C, AnAm, B, LabImuno, 3BC, 3DE, C3DC3E, C2EC2D, Hub1		

Table III.15 -Opl afternoon collection phase resuts for first floor's independent methodology

Day	N^er	Afternoon Collection Phase		
		Route	Total Time	Travel Time
Day 1	1	Hub1, AnAm, B, AP, LabImuno, 3BC, 3DE, C3DC3E, C2DC2E, Hub1	2.75	0.89
	2	Hub1, 4BC, UCIP, NeoBP, 5BC, 5DE, C5FC5T, C4DC4E, 4DE, Hub1		
	3	Hub1, C, Ar, Ad, TM, ImedRHADECR, GAIC, MCDTTGU, Cim, Im, Hub1		
	4	Hub1, 1BC, PsiCpsiDI, UHGICSO, COROCN, 1DE, 2D2E, Oft, 2B2C, Hub1		
Day 2	1	Hub1, AnAm, B, AP, LabImuno, 3BC, 3DE, C3DC3E, C2DC2E, Hub1	2.75	0.89
	2	Hub1, 4BC, UCIP, NeoBP, 5BC, 5DE, C5FC5T, C4DC4E, 4DE, Hub1		
	3	Hub1, C, Ar, Ad, TM, ImedRHADECR, GAIC, MCDTTGU, Cim, Im, Hub1		
	4	Hub1, 1BC, PsiCpsiDI, UHGICSO, COROCN, 1DE, 2D2E, Oft, 2B2C, Hub1		
Day 3	1	Hub1, AnAm, B, AP, LabImuno, 3BC, 3DE, C3DC3E, C2DC2E, Hub1	2.75	0.89
	2	Hub1, 4BC, UCIP, NeoBP, 5BC, 5DE, C5FC5T, C4DC4E, 4DE, Hub1		
	3	Hub1, C, Ar, Ad, TM, ImedRHADECR, GAIC, MCDTTGU, Cim, Im, Hub1		
	4	Hub1, 1BC, PsiCpsiDI, UHGICSO, COROCN, 1DE, 2D2E, Oft, 2B2C, Hub1		
Day 4	1	Hub1, AnAm, B, AP, LabImuno, 3BC, 3DE, C3DC3E, C2DC2E, Hub1	2.75	0.89
	2	Hub1, 4BC, UCIP, NeoBP, 5BC, 5DE, C5FC5T, C4DC4E, 4DE, Hub1		
	3	Hub1, C, Ar, Ad, TM, ImedRHADECR, GAIC, MCDTTGU, Cim, Im, Hub1		
	4	Hub1, 1BC, PsiCpsiDI, UHGICSO, COROCN, 1DE, 2D2E, Oft, 2B2C, Hub1		
Day 5	1	Hub1, AnAm, B, AP, LabImuno, 3BC, 3DE, C3DC3E, C2DC2E, Hub1	2.75	0.89
	2	Hub1, 4BC, UCIP, NeoBP, 5BC, 5DE, C5FC5T, C4DC4E, 4DE, Hub1		
	3	Hub1, C, Ar, Ad, TM, ImedRHADECR, GAIC, MCDTTGU, Cim, Im, Hub1		
	4	Hub1, 1BC, PsiCpsiDI, UHGICSO, COROCN, 1DE, 2D2E, Oft, 2B2C, Hub1		

Table III.16 -Opl afternoon delivery phase resuts for first floor's independent methodology

Day	N^{er}	Afternoon Delivery Phase Route	Total Time	Travel Time
Day 1	1	Hub1, 2B2C, AnAm, B, LabImuno, UCIP, 4BC, 4DE, Hub1	2.27	0.82
	2	Hub1, MCDTTGU, Cim, MN, Im, SU23UCISU, PsiCpsiDI, 1BC, UHGICSO, Hub1		
	3	Hub1, 2D2E, 3DE, C4EC4D, NeoBP, 5DE, Hub1		
	4	Hub1, Ad, AprovSOUCCFa, Ar, F, 1DE, COROCN, C2EC2D, Hub1		
Day 2	1	Hub1, 1DE, 4DE, C4EC4D, 5DE, 5BC, UCIP, 4BC, Hub1	2.26	0.79
	2	Hub1, 2B2C, C3DC3E, 3DE, LabImuno, B, AnAm, Hub1		
	3	Hub1, Ar, MCDTTGU, Cim, MN, Im, PsiCpsiDI, 1BC, UHGICSO, Hub1		
	4	Hub1, AprovSOUCCFa, Ad, COROCN, C2EC2D, 2D2E, Oft, Hub1		
Day 3	1	Hub1, MCDTTGU, Cim, Ad, AprovSOUCCFa, Ar, F, 2D2E, C2EC2D, Hub1	2.36	0.85
	2	Hub1, Oft, 3DE, 3BC, LabImuno, UCIP, NeoBP, 5BC, Hub1		
	3	Hub1, PsiCpsiDI, SU23UCISU, SU, B, AnAm, 2B2C, Hub1		
	4	Hub1, UHGICSO, 1DE, 5DE, C5FC5T, C4EC4D, 4DE, 4BC, Hub1		
Day 4	1	Hub1, B, LabImuno, 3BC, 4BC, UCIP, NeoBP, 5BC, 5DE, Hub1	2.77	0.95
	2	Hub1, F, Ar, AprovSOUCCFa, C, Ad, ImedRHAdeCR, TM, C2EC2D, UHGICSO, Hub1		
	3	Hub1, MCDTTGU, GAIC, Cim, MN, Im, SU, PsiCpsiDI, 1BC, UHGICSO, Hub1		
	4	Hub1, AnAm, 2B2C, Oft, 2D2E, 3DE, C3DC3E, C4EC4D, 4DE, Hub1		
Day 5	1	Hub1, MCDTTGU, Cim, MN, Im, SU, SU23UCISU, PsiCpsiDI, 1BC, UHGICSO, Hub1	2.66	0.95
	2	Hub1, MCDTTGU, GAIC, Ad, AprovSOUCCFa, Ar, F, 2D2E, C2EC2D, Hub1		
	3	Hub1, 1DE, 4DE, C4EC4D, 4BC, UCIP, NeoBP, 5BC, 5DE, Hub1		
	4	Hub1, AnAm, B, AP, LabImuno, 3BC, 3DE, C3DC3E, 2B2C, Hub1		

Independent Collection and Delivery Methodology Results with Hub on third floor

Table III.17 - Opl morning collection phase resuts for third floor's independent methodology

Day	Ner	Morning Collection Phase		
		Route	Total Time	Travel Time
Day 1	1	Hub3, 4DE, C4EC4D, C5FC5T, 5DE, 5BC, NeoBP, UCIP, 4BC, Hub3	2.81	0.90
	2	Hub3, 1BC, PsiCpsiDI, R, MCDTTGU, Cim, Im, B, AnAm, 2B2C, Hub3		
	3	Hub3, Ar, C, Ad, ImedRHADECR, TM, GAIC, COROCN, UHGICSO, 1DE, Hub3		
	4	Hub3, 2D2E, C2EC2D, C3DC3E, 3DE, 3BC, LabImuno, AP, Hub3		
Day 2	1	Hub3, 4DE, C4EC4D, C5FC5T, 5DE, 5BC, NeoBP, UCIP, 4BC, Hub3	2.81	0.90
	2	Hub3, 1BC, PsiCpsiDI, R, MCDTTGU, Cim, Im, B, AnAm, 2B2C, Hub3		
	3	Hub3, Ar, C, Ad, ImedRHADECR, TM, GAIC, COROCN, UHGICSO, 1DE, Hub3		
	4	Hub3, 2D2E, C2EC2D, C3DC3E, 3DE, 3BC, LabImuno, AP, Hub3		
Day 3	1	Hub3, 4DE, C4EC4D, C5FC5T, 5DE, 5BC, NeoBP, UCIP, 4BC, Hub3	2.81	0.90
	2	Hub3, 1BC, PsiCpsiDI, R, MCDTTGU, Cim, Im, B, AnAm, 2B2C, Hub3		
	3	Hub3, Ar, C, Ad, ImedRHADECR, TM, GAIC, COROCN, UHGICSO, 1DE, Hub3		
	4	Hub3, 2D2E, C2EC2D, C3DC3E, 3DE, 3BC, LabImuno, AP, Hub3		
Day 4	1	Hub3, 4DE, C4EC4D, C5FC5T, 5DE, 5BC, NeoBP, UCIP, 4BC, Hub3.	2.81	0.90
	2	Hub3, 1BC, PsiCpsiDI, R, MCDTTGU, Cim, Im, B, AnAm, 2B2C, Hub3		
	3	Hub3, Ar, C, Ad, ImedRHADECR, TM, GAIC, COROCN, UHGICSO, 1DE, Hub3		
	4	Hub3, 2D2E, C2EC2D, C3DC3E, 3DE, 3BC, LabImuno, AP, Hub3		
Day 5	1	Hub3, 4DE, C4EC4D, C5FC5T, 5DE, 5BC, NeoBP, UCIP, 4BC, Hub3.	2.81	0.90
	2	Hub3, 1BC, PsiCpsiDI, R, MCDTTGU, Cim, Im, B, AnAm, 2B2C, Hub3		
	3	Hub3, Ar, C, Ad, ImedRHADECR, TM, GAIC, COROCN, UHGICSO, 1DE, Hub3		
	4	Hub3, 2D2E, C2EC2D, C3DC3E, 3DE, 3BC, LabImuno, AP, Hub3		

Table III.18 - Opl morning delivery phase resuts for third floor's independent methodology

Day	N^{er}	Morning Delivery Phase: Route	Total Time	Travel Time
Day 1	1	Hub3, 4BC, UCIP, NeoBP, 5BC, 5DE, C5FC5T, C4EC4D, Hub3	2.66	0.85
	2	Hub3, C3DC3E, 2B2C, AnAm, B, AP, LabImuno, 3BC, 3DE, Hub3		
	3	Hub3, F, Ar, AprovSOUCCFa, C, ImedRHAdeCR, COROCN, C2EC2D, 2D2E, Hub3		
	4	Hub3, Ad, GAIC, MCDTTGU, Cim, MN, Im, SU, 1BC, UHGICSO, 1DE, Hub3		
Day 2	1	Hub3, C2EC2D, 2B2C, AnAm, B, LabImuno, 3BC, C3DC3E, Hub3	2.78	0.92
	2	Hub3, 3DE, 4DE, 4BC, UCIP, NeoBP, 5BC, 5DE, C5FC5T, C4EC4D, Hub3		
	3	Hub3, F, Ar, AprovSOUCCFa, C, Ad, TM, ImedRHAdeCR, GAIC, COROCN, Hub3		
	4	Hub3, MCDTTGU, Cim, MN, Im, PsiCpsiDI, 1BC, UHGICSO, 1DE, 2D2E, Hub3		
Day 3	1	Hub3, Ad, C, AprovSOUCCFa, TM, ImedRHAdeCR, COROCN, C2EC2D, Hub3	2.66	0.85
	2	Hub3, 4DE, C4EC4D, C5FC5T, 5DE, 5BC, NeoBP, UCIP, 4BC, Hub3		
	3	Hub3, F, Ar, MCDTTGU, Cim, MN, PsiCpsiDI, 1BC, UHGICSO, 1DE, Hub3		
	4	Hub3, 2D2E, Oft, 2B2C, AnAm, B, LabImuno, 3BC, C3DC3E, 3DE, Hub3		
Day 4	1	Hub3, 4DE, C4EC4D, C5FC5T, 5DE, 5BC, NeoBP, UCIP, 4BC, Hub3	2.68	0.88
	2	Hub3, C3DC3E, 2B2C, AnAm, B, AP, LabImuno, 3BC, 3DE, Hub3		
	3	Hub3, Ad, C, AprovSOUCCFa, GAIC, ImedRHAdeCR, TM, C2EC2D, 2D2E, Hub3		
	4	Hub3, F, Ar, MCDTTGU, Cim, MN, Im, PsiCpsiDI, 1BC, UHGICSO, 1DE, Hub3		
Day 5	1	Hub3, 3BC, LabImuno, 4BC, UCIP, NeoBP, C5FC5T, C4EC4D, 4DE, Hub3	2.80	0.94
	2	Hub3, 1DE, UHGICSO, PsiCpsiDI, SU23UCISU, SU, B, AnAm, 2B2C, Oft, Hub3		
	3	Hub3, Im, MN, Cim, MCDTTGU, GAIC, ImedRHAdeCR, TM, C3DC3E, 3DE, Hub3		
	4	Hub3, F, Ar, AprovSOUCCFa, C, Ad, COROCN, C2EC2D, 2D2E, Hub3		

Table III.19 - Opl afternoon collection phase resuts for third floor's independent methodology

Day	N^{er}	Afternoon Collection Phase		
		Route	Total Time	Travel Time
Day 1	1	Hub3, 4DE, C4EC4D, C5FC5T, 5DE, 5BC, NeoBP, UCIP, 4BC, Hub3.	2.81	0.90
	2	Hub3, 1BC, PsiCpsiDI, R, MCDTTGU, Cim, Im, B, AnAm, 2B2C, Hub3		
	3	Hub3, Ar, C, Ad, ImedRHADECR, TM, GAIC, COROCN, UHGICSO, 1DE, Hub3		
	4	Hub3, 2D2E, C2EC2D, C3DC3E, 3DE, 3BC, LabImuno, AP, Hub3		
Day 2	1	Hub3, 4DE, C4EC4D, C5FC5T, 5DE, 5BC, NeoBP, UCIP, 4BC, Hub3.	2.81	0.90
	2	Hub3, 1BC, PsiCpsiDI, R, MCDTTGU, Cim, Im, B, AnAm, 2B2C, Hub3		
	3	Hub3, Ar, C, Ad, ImedRHADECR, TM, GAIC, COROCN, UHGICSO, 1DE, Hub3		
	4	Hub3, 2D2E, C2EC2D, C3DC3E, 3DE, 3BC, LabImuno, AP, Hub3		
Day 3	1	Hub3, 4DE, C4EC4D, C5FC5T, 5DE, 5BC, NeoBP, UCIP, 4BC, Hub3.	2.81	0.90
	2	Hub3, 1BC, PsiCpsiDI, R, MCDTTGU, Cim, Im, B, AnAm, 2B2C, Hub3		
	3	Hub3, Ar, C, Ad, ImedRHADECR, TM, GAIC, COROCN, UHGICSO, 1DE, Hub3		
	4	Hub3, 2D2E, C2EC2D, C3DC3E, 3DE, 3BC, LabImuno, AP, Hub3		
Day 4	1	Hub3, 4DE, C4EC4D, C5FC5T, 5DE, 5BC, NeoBP, UCIP, 4BC, Hub3.	2.81	0.90
	2	Hub3, 1BC, PsiCpsiDI, R, MCDTTGU, Cim, Im, B, AnAm, 2B2C, Hub3		
	3	Hub3, Ar, C, Ad, ImedRHADECR, TM, GAIC, COROCN, UHGICSO, 1DE, Hub3		
	4	Hub3, 2D2E, C2EC2D, C3DC3E, 3DE, 3BC, LabImuno, AP, Hub3		
Day 5	1	Hub3, 4DE, C4EC4D, C5FC5T, 5DE, 5BC, NeoBP, UCIP, 4BC, Hub3.	2.81	0.90
	2	Hub3, 1BC, PsiCpsiDI, R, MCDTTGU, Cim, Im, B, AnAm, 2B2C, Hub3		
	3	Hub3, Ar, C, Ad, ImedRHADECR, TM, GAIC, COROCN, UHGICSO, 1DE, Hub3		
	4	Hub3, 2D2E, C2EC2D, C3DC3E, 3DE, 3BC, LabImuno, AP, Hub3		

Table III.20 - Opl afternoon delivery phase resuts for third floor's independent methodology

Day	N^{er}	Afternoon Delivery Phase		
		Route	Total Time	Travel Time
Day 1	1	Hub3, F, Ar, AprovSOUCCFa, Im, MN, Cim, MCDTTGU, Ad, 3DE, Hub3	2.37	0.92
	2	Hub3, C4EC4D, 4DE, 4BC, UCIP, NeoBP, 5DE, Hub3		
	3	Hub3, PsiCpsiDI, SU23UCISU, 1BC, UHGICSO, COROCN, 1DE, Hub3		
	4	Hub3, 2D2E, C2EC2D, 2B2C, AnAm, B, LabImuno, Hub3		
Day 2	1	Hub3, Ar, AprovSOUCCFa, Ad, MCDTTGU, Cim, MN, Im, LabImuno, Hub3	2.41	0.84
	2	Hub3, C3DC3E, C4EC4D, 4DE, 4BC, UCIP, 5BC, 5DE, Hub3		
	3	Hub3, 3DE, 2D2E, C2EC2D, AnAm, B, 2B2C, Oft, Hub3		
	4	Hub3, 2B2C, 1BC, PsiCpsiDI, UHGICSO, COROCN, 1DE, Hub3		
Day 3	1	Hub3, 2B2C, SU, SU23UCISU, PsiCpsiDI, UHGICSO, 1DE, Hub3	2.44	0.84
	2	Hub3, 4BC, UCIP, NeoBP, 5BC, 5DE, C5FC5T, C4EC4D, 4DE, Hub3		
	3	Hub3, F, Ar, AprovSOUCCFa, Ad, MCDTTGU, Cim, C2EC2D, Hub3		
	4	Hub3, 2D2E, Oft, 2B2C, AnAm, B, LabImuno, 3BC, 3DE, Hub3		
Day 4	1	Hub3, Oft, 2D2E, C2EC2D, C3DC3E, C4EC4D, 4DE, Hub3	2.71	0.92
	2	Hub3, 3DE, 3BC, LabImuno, 4BC, UCIP, NeoBP, 5BC, 5DE, Hub3		
	3	Hub3, UHGICSO, 1BC, PsiCpsiDI, SU, B, AnAm, 2B2C, Hub3		
	4	Hub3, Ad, C, AprovSOUCCFa, GAIC, Im, MN, Cim, MCDTTGU, ImedRHAdeCR, TM, Ar, F, Hub3		
Day 5	1	Hub3, 3DE, C3DC3E, 2B2C, B, AnAm, C2EC2D, 2D2E, Hub3	2.63	0.97
	2	Hub3, C4EC4D, 4DE, 4BC, UCIP, NeoBP, 5BC, 5DE, Hub3		
	3	Hub3, F, Ar, AprovSOUCCFa, PsiCpsiDI, SU, SU23UCISU, 1BC, UHGICSO, 1DE, Hub3		
	4	Hub3, Ad, GAIC, MCDTTGU, Cim, MN, Im, AP, LabImuno, 3BC, Hub3		

Integrated Collection and Delivery Methodology Results with Arquivo as Hub

Table III.21 - Opl collection phase resuts for arquivo's integrated methodology

Day	N[er]	Collection Phase		
		Route	Total Time	Travel Time
Day 1	1	Ar, C, Ad, 1DE, Oft, 2D2E, C2EC2D, C3DC3E, 3DE, Ar	2.90	1.05
	2	Ar, TM, ImedRHAdeCR, COROCN, UHGICSO, 1BC, PsiCpsiDI, Im, Cim, Ar		
	3	Ar, 4BC, UCIP, NeoBP, 5BC, 5DE, C5TC5F, C4DC4E, 4DE, Ar		
	4	Ar, GAIC, MCDTTGU, 2B2C, AnAm, B, AP, LabImuno, 3BC, Ar		
Day 2	1	Ar, C, Ad, 1DE, Oft, 2D2E, C2EC2D, C3DC3E, 3DE, Ar	2.90	1.05
	2	Ar, TM, ImedRHAdeCR, COROCN, UHGICSO, 1BC, PsiCpsiDI, Im, Cim, Ar		
	3	Ar, 4BC, UCIP, NeoBP, 5BC, 5DE, C5TC5F, C4DC4E, 4DE, Ar		
	4	Ar, GAIC, MCDTTGU, 2B2C, AnAm, B, AP, LabImuno, 3BC, Ar		
Day 3	1	Ar, C, Ad, 1DE, Oft, 2D2E, C2EC2D, C3DC3E, 3DE, Ar	2.90	1.05
	2	Ar, TM, ImedRHAdeCR, COROCN, UHGICSO, 1BC, PsiCpsiDI, Im, Cim, Ar		
	3	Ar, 4BC, UCIP, NeoBP, 5BC, 5DE, C5TC5F, C4DC4E, 4DE, Ar		
	4	Ar, GAIC, MCDTTGU, 2B2C, AnAm, B, AP, LabImuno, 3BC, Ar		
Day 4	1	Ar, C, Ad, 1DE, Oft, 2D2E, C2EC2D, C3DC3E, 3DE, Ar	2.90	1.05
	2	Ar, TM, ImedRHAdeCR, COROCN, UHGICSO, 1BC, PsiCpsiDI, Im, Cim, Ar		
	3	Ar, 4BC, UCIP, NeoBP, 5BC, 5DE, C5TC5F, C4DC4E, 4DE, Ar		
	4	Ar, GAIC, MCDTTGU, 2B2C, AnAm, B, AP, LabImuno, 3BC, Ar		
Day 5	1	Ar, C, Ad, 1DE, Oft, 2D2E, C2EC2D, C3DC3E, 3DE, Ar	2.90	1.05
	2	Ar, TM, ImedRHAdeCR, COROCN, UHGICSO, 1BC, PsiCpsiDI, Im, Cim, Ar		
	3	Ar, 4BC, UCIP, NeoBP, 5BC, 5DE, C5TC5F, C4DC4E, 4DE, Ar		
	4	Ar, GAIC, MCDTTGU, 2B2C, AnAm, B, AP, LabImuno, 3BC, Ar		

Table III.22 - Opl integrated phase resuts for arquivo's integrated methodology

Day	N^{er}	Integrated Phase Route	Total Time	Travel Time
Day 1	1	Ar, ImedRHAdeCR, TM, GAIC, 2B2C, AnAm, B, AP, LabImuno, 3BC, Ar	3.21	1.22
	2	Ar, AprovSOUCCFa, C, R, MCDTTGU, Cim, MN, Im, SU, PsiCpsiDI, 1BC, UHGICSO, Ar		
	3	Ar, F, 4DE, C4EC4D, 4BC, UCIP, NeoBP, 5BC, 5DE, C5FC5T, Ar		
	4	Ar, Ad, COROCN, 1DE, Oft, 2D2E, C2EC2D, C3DC3E, Ar		
Day 2	1	Ar, F, 2D2E, C2EC2D, C3EC3D, 3DE, 3BC, LabImuno, AP, Ar	3.12	1.15
	2	Ar, 4DE, C4EC4D, 4BC, UCIP, NeoBP, 5BC, C5FC5T, 5DE, Ar		
	3	Ar, AprovSOUCCFa, R, MCDTTGU, Cim, MN, Im, B, AnAm, 2B2C, Oft, Ar		
	4	Ar, Ad, ImedRHADECR, TM, GAIC, COROCN, 1DE, UHGICSO, 1BC, PsiCpsiDI, Ar		
Day 3	1	Ar, F, 2D2E, C2EC2D, C3EC3D, 3DE, 3BC, LabImuno, AP, Ar	3.12	1.15
	2	Ar, 4DE, C4EC4D, 4BC, UCIP, NeoBP, 5BC, C5FC5T, 5DE, Ar		
	3	Ar, AprovSOUCCFa, R, MCDTTGU, Cim, MN, Im, B, AnAm, 2B2C, Oft, Ar		
	4	Ar, Ad, ImedRHADECR, TM, GAIC, COROCN, 1DE, UHGICSO, 1BC, PsiCpsiDI, Ar		
Day 4	1	Ar, F, 2D2E, C2EC2D, C3EC3D, 3DE, 3BC, LabImuno, AP, Ar	3.12	1.15
	2	Ar, 4DE, C4EC4D, 4BC, UCIP, NeoBP, 5BC, C5FC5T, 5DE, Ar		
	3	Ar, AprovSOUCCFa, R, MCDTTGU, Cim, MN, Im, B, AnAm, 2B2C, Oft, Ar		
	4	Ar, Ad, ImedRHADECR, TM, GAIC, COROCN, 1DE, UHGICSO, 1BC, PsiCpsiDI, Ar		
Day 5	1	Ar, ImedRHAdeCR, TM, GAIC, 2B2C, AnAm, B, AP, LabImuno, 3BC, Ar	3.29	1.23
	2	Ar, AprovSOUCCFa, C, R, MCDTTGU, Cim, MN, Im, SU, SU23UCISU, PsiCpsiDI, 1BC, UHGICSO, Ar		
	3	Ar, F, 4DE, C4EC4D, 4BC, UCIP, NeoBP, 5BC, 5DE, C5FC5T, Ar		
	4	Ar, Ad, COROCN, 1DE, Oft, 2D2E, C2EC2D, C3DC3E, Ar		

Table III.23 - Opl delivery phase resuts for arquivo's integrated methodology

Day	N^{er}	Delivery Phase: Route	Total Time	Travel Time
Day 1	1	Ar, 4DE, C4DC4E, 4BC, UCIP, NeoBP, 5BC, Ar	2.45	1.05
	2	Ar, AprovSouCCFa, Ad, COROCN, C2EC2D, 2D2E, F, Ar		
	3	Ar, 1DE, UHGICSO, 2B2C, AnAm, B, LabImuno, 3DE, Ar		
	4	Ar, MCDTTGU, Cim, MN, Im, Su23Ucisu, 1BC, PsiCpsiDI, Ar		
Day 2	1	Ar, Ad, COROCN, 1DE, UHGICSO, 1BC, PsiCpsiDI, AprovSOUCCFa, Ar	2.42	1.01
	2	Ar, MCDTTGU, Cim, MN, Im, AnAm, B, 2B2C, Oft, Ar		
	3	Ar, 2D2E, C2DC2E, C3DC3E, C4DC4E, 4DE, Ar		
	4	Ar, 3DE, LabImuno, UCIP, 4BC, 5BC, 5DE, Ar		
Day 3	1	Ar, AprovSOUCCFa, C, 1DE, UHGICSO, 1BC, PsiCpsiDI, MN, Cim, MCDTTGU, Ar	2.87	1.09
	2	Ar, F, 2D2E, Oft, 2B2C, AnAm, B, LabImuno, 3BC, 3DE, Ar		
	3	Ar, 4DE, C4DC4E, 4BC, UCIP, NeoBP, 5BC, C5FC5T, 5DE, Ar		
	4	Ar, Ad, TM, ImedRHADECR, COROCN, C2EC2D, C3DC3E, 3DE, Ar		
Day 4	1	Ar, AprovSOUCCFa, C, UHGICSO, 1BC, B, AnAm, 2B2C, Oft, 2D2E, Ar	2.84	1.13
	2	Ar, ImedRHADECR, GAIC, TM, C2EC2D, C3DC3E, C4EC$D, 4DE, Ar		
	3	Ar, Ad, MCDTTGU, Cim, MN, Im, SU, PsiCpsiDI, F, Ar		
	4	Ar, 5DE, 5BC, NeoBC, 4BC, UCIP, LabImuno, 3BC, 3DE, Ar		
Day 5	1	Ar, Ad, GAIC, MCDTTGU, Cim, MN, Im, 1BC, UHGICSO, 1DE, 2D2E, Ar	2.69	1.18
	2	Ar, F, 3DE, C3DC3E, C4EC4D, NeoBP, 5BC, 5DE, Ar		
	3	Ar, C2EC2D, 3BC, LabImuno, AP, UCIP, 4BC, 4DE, Ar		
	4	Ar, AprovSOUCCFa, PsiCpsiDI, SU23UCISU, B, AnAm, 2B2C, Ar		

Integrated Collection and Delivery Methodology Results with Hub on the first floor

Table III.24 - Opl collection phase resuts for first floors's integrated methodology

Day	N^{er}	Collection Phase		
		Route	Total Time	Travel Time
Day 1	1	Hub1, AnAm, B, AP, LabImuno, 3BC, 3DE, C3DC3E, C2DC2E, Hub1	2.75	0.89
	2	Hub1, 4BC, UCIP, NeoBP, 5BC, 5DE, C5FC5T, C4DC4E, 4DE, Hub1		
	3	Hub1, C, Ar, Ad, TM, ImedRHADECR, GAIC, MCDTTGU, Cim, Im, Hub1		
	4	Hub1, 1BC, PsiCpsiDI, UHGICSO, COROCN, 1DE, 2D2E, Oft, 2B2C, Hub1		
Day 2	1	Hub1, AnAm, B, AP, LabImuno, 3BC, 3DE, C3DC3E, C2DC2E, Hub1	2.75	0.89
	2	Hub1, 4BC, UCIP, NeoBP, 5BC, 5DE, C5FC5T, C4DC4E, 4DE, Hub1		
	3	Hub1, C, Ar, Ad, TM, ImedRHADECR, GAIC, MCDTTGU, Cim, Im, Hub1		
	4	Hub1, 1BC, PsiCpsiDI, UHGICSO, COROCN, 1DE, 2D2E, Oft, 2B2C, Hub1		
Day 3	1	Hub1, AnAm, B, AP, LabImuno, 3BC, 3DE, C3DC3E, C2DC2E, Hub1	2.75	0.89
	2	Hub1, 4BC, UCIP, NeoBP, 5BC, 5DE, C5FC5T, C4DC4E, 4DE, Hub1		
	3	Hub1, C, Ar, Ad, TM, ImedRHADECR, GAIC, MCDTTGU, Cim, Im, Hub1		
	4	Hub1, 1BC, PsiCpsiDI, UHGICSO, COROCN, 1DE, 2D2E, Oft, 2B2C, Hub1		
Day 4	1	Hub1, AnAm, B, AP, LabImuno, 3BC, 3DE, C3DC3E, C2DC2E, Hub1	2.75	0.89
	2	Hub1, 4BC, UCIP, NeoBP, 5BC, 5DE, C5FC5T, C4DC4E, 4DE, Hub1		
	3	Hub1, C, Ar, Ad, TM, ImedRHADECR, GAIC, MCDTTGU, Cim, Im, Hub1		
	4	Hub1, 1BC, PsiCpsiDI, UHGICSO, COROCN, 1DE, 2D2E, Oft, 2B2C, Hub1		
Day 5	1	Hub1, AnAm, B, AP, LabImuno, 3BC, 3DE, C3DC3E, C2DC2E, Hub1	2.75	0.89
	2	Hub1, 4BC, UCIP, NeoBP, 5BC, 5DE, C5FC5T, C4DC4E, 4DE, Hub1		
	3	Hub1, C, Ar, Ad, TM, ImedRHADECR, GAIC, MCDTTGU, Cim, Im, Hub1		
	4	Hub1, 1BC, PsiCpsiDI, UHGICSO, COROCN, 1DE, 2D2E, Oft, 2B2C, Hub1		

Table III.25 - Opl integrated phase resuts for first floor's integrated methodology

Day	Ner	Integrated Phase		
		Route	Total Time	Travel Time
Day 1	1	Hub1, Oft, 2D2E, C2EC2D, C3DC3E, 3DE, 3BC, LabImuno, AP, B, Hub1	3.02	1.03
	2	Hub1, COROCN, 1DE, UHGICSO, 1BC, PsiCpsiDI, SU, AnAm, 2B2C, Hub1		
	3	Hub1, F, Ar, AprovSOUCCFa, C, Ad, TM, ImedRHAdeCR, GAIC, MCDTTGU, Cim, MN, Im, Hub1		
	4	Hub1, 5BC, NeoBP, UCIP, 4BC, 4DE, C4EC4D, C5FC5T, 5DE, Hub1		
Day 2	1	Hub1, UHGICSO, 2B2C, AnAm, B, AP, LabImuno, 3BC, 3DE, C3DC3E, Hub1	2.91	0.98
	2	Hub1, TM, ImedRHAdeCR, Ad, C, AprovSOUCCFa, Ar, F, 1DE, PsiCpsiDI, 1BC, Hub1		
	3	Hub1, 4BC, UCIP, NeoBP, 5BC, 5DE, C5FC5T, C4EC4D, 4DE, Hub1		
	4	Hub1, Im, MN, Cim, MCDTTGU, GAIC, COROCN, C2EC2D, 2D2E, Oft, Hub1		
Day 3	1	Hub1, UHGICSO, 2B2C, AnAm, B, AP, LabImuno, 3BC, C3DC3E, 3DE, Hub1	2.91	0.98
	2	Hub1, TM, ImedRHAdeCR, Ad, C, AprovSOUCCFa, Ar, F, 1DE, PsiCpsiDI, 1BC, Hub1		
	3	Hub1, 4BC, UCIP, NeoBP, 5BC, 5DE, C5FC5T, C4EC4D, 4DE, Hub1		
	4	Hub1, Im, MN, Cim, MCDTTGU, GAIC, COROCN, C2EC2D, 2D2E, Oft, Hub1		
Day 4	1	Hub1, UHGICSO, 2B2C, AnAm, B, AP, LabImuno, 3BC, C3DC3E, 3DE, Hub1	2.91	0.98
	2	Hub1, TM, ImedRHAdeCR, Ad, C, AprovSOUCCFa, Ar, F, 1DE, PsiCpsiDI, 1BC, Hub1		
	3	Hub1, 4BC, UCIP, NeoBP, 5BC, 5DE, C5FC5T, C4EC4D, 4DE, Hub1		
	4	Hub1, Im, MN, Cim, MCDTTGU, GAIC, COROCN, C2EC2D, 2D2E, Oft, Hub1		
Day 5	1	Hub1, MCDTTGU, GAIC, TM, ImedRHAdeCR, COROCN, C2EC2D, 2D2E, Oft, 1DE, Hub1	2.86	1.05
	2	Hub1, SU23UCISU, SU, B, LabImuno, 3BC, 3DE, C3DC3E, C4EC4D, 4DE, Hub1		
	3	Hub1, F, Ar, AprovSOUCCFa, C, Ad, Cim, MN, Im, PsiCpsiDI, 1BC, UHGICSO, Hub1		
	4	Hub1, 2B2C, AnAm, AP, UCIP, 4BC, NeoBP, 5BC, C5FC5T, 5DE, Hub1		

Table III.26 - Opl delivery phase resuts for first floor's integrated methodology

Day	N^{er}	Delivery Phase Route	Total Time	Travel Time
Day 1	1	Hub1, 2B2C, AnAm, B, LabImuno, UCIP, 4BC, 4DE, Hub1	2.27	0.70
	2	Hub1, MCDTTGU, Cim, MN, Im, SU23UCISU, PsiCpsiDI, 1BC, UHGICSO, Hub1		
	3	Hub1, 2D2E, 3DE, C4EC4D, NeoBP, 5DE, Hub1		
	4	Hub1, Ad, AprovSOUCCFa, Ar, F, 1DE, COROCN, C2EC2D, Hub1		
Day 2	1	Hub1, 1DE, 4DE, C4EC4D, 5DE, 5BC, UCIP, 4BC, Hub1	2.26	0.66
	2	Hub1, 2B2C, C3DC3E, 3DE, LabImuno, B, AnAm, Hub1		
	3	Hub1, Ar, MCDTTGU, Cim, MN, Im, PsiCpsiDI, 1BC, UHGICSO, Hub1		
	4	Hub1, AprovSOUCCFa, Ad, COROCN, C2EC2D, 2D2E, Oft, Hub1		
Day 3	1	Hub1, MCDTTGU, Cim, Ad, AprovSOUCCFa, Ar, F, 2D2E, C2EC2D, Hub1	2.36	0.74
	2	Hub1, Oft, 3DE, 3BC, LabImuno, UCIP, NeoBP, 5BC, Hub1		
	3	Hub1, PsiCpsiDI, SU23UCISU, SU, B, AnAm, 2B2C, Hub1		
	4	Hub1, UHGICSO, 1DE, 5DE, C5FC5T, C4EC4D, 4DE, 4BC, Hub1		
Day 4	1	Hub1, B, LabImuno, 3BC, 4BC, UCIP, NeoBP, 5BC, 5DE, Hub1	2.77	0.82
	2	Hub1, F, Ar, AprovSOUCCFa, C, Ad, ImedRHAdeCR, TM, C2EC2D, UHGICSO, Hub1		
	3	Hub1, MCDTTGU, GAIC, Cim, MN, Im, SU, PsiCpsiDI, 1BC, UHGICSO, Hub1		
	4	Hub1, AnAm, 2B2C, Oft, 2D2E, 3DE, C3DC3E, C4EC4D, 4DE, Hub1		
Day 5	1	Hub1, MCDTTGU, Cim, MN, Im, SU, SU23UCISU, PsiCpsiDI, 1BC, UHGICSO, Hub1	2.66	0.85
	2	Hub1, MCDTTGU, GAIC, Ad, AprovSOUCCFa, Ar, F, 2D2E, C2EC2D, Hub1		
	3	Hub1, 1DE, 4DE, C4EC4D, 4BC, UCIP, NeoBP, 5BC, 5DE, Hub1		
	4	Hub1, AnAm, B, AP, LabImuno, 3BC, 3DE, C3DC3E, 2B2C, Hub1		

Integrated Collection and Delivery Methodology Results with Hub on third floor

Table III.27 - Opl collection phase resuts for third floor's integrated methodology

Day	N^er	Collection Phase		
		Route	Total Time	Travel Time
Day 1	1	Hub3, 4DE, C4EC4D, C5FC5T, 5DE, 5BC, NeoBP, UCIP, 4BC, Hub3	2.81	0.90
	2	Hub3, 1BC, PsiCpsiDI, R, MCDTTGU, Cim, Im, B, AnAm, 2B2C, Hub3		
	3	Hub3, Ar, C, Ad, ImedRHADECR, TM, GAIC, COROCN, UHGICSO, 1DE, Hub3		
	4	Hub3, 2D2E, C2EC2D, C3DC3E, 3DE, 3BC, LabImuno, AP, Hub3		
Day 2	1	Hub3, 4DE, C4EC4D, C5FC5T, 5DE, 5BC, NeoBP, UCIP, 4BC, Hub3	2.81	0.90
	2	Hub3, 1BC, PsiCpsiDI, R, MCDTTGU, Cim, Im, B, AnAm, 2B2C, Hub3		
	3	Hub3, Ar, C, Ad, ImedRHADECR, TM, GAIC, COROCN, UHGICSO, 1DE, Hub3		
	4	Hub3, 2D2E, C2EC2D, C3DC3E, 3DE, 3BC, LabImuno, AP, Hub3		
Day 3	1	Hub3, 4DE, C4EC4D, C5FC5T, 5DE, 5BC, NeoBP, UCIP, 4BC, Hub3	2.81	0.90
	2	Hub3, 1BC, PsiCpsiDI, R, MCDTTGU, Cim, Im, B, AnAm, 2B2C, Hub3		
	3	Hub3, Ar, C, Ad, ImedRHADECR, TM, GAIC, COROCN, UHGICSO, 1DE, Hub3		
	4	Hub3, 2D2E, C2EC2D, C3DC3E, 3DE, 3BC, LabImuno, AP, Hub3		
Day 4	1	Hub3, 4DE, C4EC4D, C5FC5T, 5DE, 5BC, NeoBP, UCIP, 4BC, Hub3	2.81	0.90
	2	Hub3, 1BC, PsiCpsiDI, R, MCDTTGU, Cim, Im, B, AnAm, 2B2C, Hub3		
	3	Hub3, Ar, C, Ad, ImedRHADECR, TM, GAIC, COROCN, UHGICSO, 1DE, Hub3		
	4	Hub3, 2D2E, C2EC2D, C3DC3E, 3DE, 3BC, LabImuno, AP, Hub3		
Day 5	1	Hub3, 4DE, C4EC4D, C5FC5T, 5DE, 5BC, NeoBP, UCIP, 4BC, Hub3	2.81	0.90
	2	Hub3, 1BC, PsiCpsiDI, R, MCDTTGU, Cim, Im, B, AnAm, 2B2C, Hub3		
	3	Hub3, Ar, C, Ad, ImedRHADECR, TM, GAIC, COROCN, UHGICSO, 1DE, Hub3		
	4	Hub3, 2D2E, C2EC2D, C3DC3E, 3DE, 3BC, LabImuno, AP, Hub3		

Table III.28 - Opl integrated phase resuts for third floor's integrated methodology

Day	N^{er}	Integrated Phase – Route	Integrated Phase – Total Time	Integrated Phase – Travel Time
Day 1	1	Hub3, 3DE, 4DE, C4EC4D, C5FC5T, 5DE, 5BC, NeoBP, UCIP, 4BC, Hub3	3.00	1.01
	2	Hub3, F, Ar, AprovSOUCCFa, C, Ad, TM, ImedRHAdeCR, GAIC, MCDTTGU, Cim, MN, Im, Hub3		
	3	Hub3, 3BC, AP, LabImuno, 2B2C, Oft, 2D2E, C2EC2D, C3DC3E, Hub3		
	4	Hub3, 1DE, COROCN, UHGICSO, 1BC, PsiCpsiDI, SU, AnAm, B, Hub3		
Day 2	1	Hub3, 1DE, UHGICSO, PsiCpsiDI, 1BC, B, AnAm, 2B2C, Oft, 2D2E, Hub3	2.85	0.92
	2	Hub3, 3DE, 4DE, C4EC4D, C5FC5T, 5DE, 5BC, NeoBP, UCIP, 4BC, Hub3		
	3	Hub3, F, Ar, AprovSOUCCFa, C, Ad, COROCN, C2EC2D, C3DC3E, Hub3		
	4	Hub3, TM, ImedRHAdeCR, GAIC, MCDTTGU, Cim, MN, Im, AP, LabImuno, 3BC, Hub3		
Day 3	1	Hub3, 1DE, UHGICSO, PsiCpsiDI, 1BC, B, AnAm, 2B2C, Oft, 2D2E, Hub3	2.85	0.92
	2	Hub3, 3DE, 4DE, C4EC4D, C5FC5T, 5DE, 5BC, NeoBP, UCIP, 4BC, Hub3		
	3	Hub3, F, Ar, AprovSOUCCFa, C, Ad, COROCN, C2EC2D, C3DC3E, Hub3		
	4	Hub3, TM, ImedRHAdeCR, GAIC, MCDTTGU, Cim, MN, Im, AP, LabImuno, 3BC, Hub3		
Day 4	1	Hub3, 1DE, UHGICSO, PsiCpsiDI, 1BC, B, AnAm, 2B2C, Oft, 2D2E, Hub3	2.85	0.92
	2	Hub3, 3DE, 4DE, C4EC4D, C5FC5T, 5DE, 5BC, NeoBP, UCIP, 4BC, Hub3		
	3	Hub3, F, Ar, AprovSOUCCFa, C, Ad, COROCN, C2EC2D, C3DC3E, Hub3		
	4	Hub3, TM, ImedRHAdeCR, GAIC, MCDTTGU, Cim, MN, Im, AP, LabImuno, 3BC, Hub3		
Day 5	1	Hub3, F, Ar, AprovSOUCCFa, C, Ad, TM, ImedRHAdeCR, COROCN, C4EC4D, 4DE, Hub3	2.88	1.04
	2	Hub3, B, AnAm, 2B2C, Oft, 2D2E, C2EC2D, C3DC3E, 3DE, Hub3		
	3	Hub3, 3DE, 3BC, LabImuno, AP, 4BC, UCIP, NeoBP, 5BC, C5FC5T, 5DE, Hub3		
	4	Hub3, GAIC, MCDTTGU, Cim, MN, Im, SU, SU23UCISU, PsiCpsiDI, 1BC, UHGICSO, 1DE, Hub3		

Table III.29 - Opl delivery phase resuts for third floor's integrated methodology

Day	N[er]	Delivery Phase Route	Total Time	Travel Time
Day 1	1	Hub3, F, Ar, AprovSOUCCFa, Im, MN, Cim, MCDTTGU, Ad, 3DE, Hub3	2.37	0.98
	2	Hub3, C4EC4D, 4DE, 4BC, UCIP, NeoBP, 5DE, Hub3		
	3	Hub3, PsiCpsiDI, SU23UCISU, 1BC, UHGICSO, COROCN, 1DE, Hub3		
	4	Hub3, 2D2E, C2EC2D, 2B2C, AnAm, B, LabImuno, Hub3		
Day 2	1	Hub3, Ar, AprovSOUCCFa, Ad, MCDTTGU, Cim, MN, Im, LabImuno, Hub3	2.41	0.91
	2	Hub3, C3DC3E, C4EC4D, 4DE, 4BC, UCIP, 5BC, 5DE, Hub3		
	3	Hub3, 3DE, 2D2E, C2EC2D, AnAm, B, 2B2C, Oft, Hub3		
	4	Hub3, 2B2C, 1BC, PsiCpsiDI, UHGICSO, COROCN, 1DE, Hub3		
Day 3	1	Hub3, 2B2C, SU, SU23UCISU, PsiCpsiDI, UHGICSO, 1DE, Hub3	2.44	0.92
	2	Hub3, 4BC, UCIP, NeoBP, 5BC, 5DE, C5FC5T, C4EC4D, 4DE, Hub3		
	3	Hub3, F, Ar, AprovSOUCCFa, Ad, MCDTTGU, Cim, C2EC2D, Hub3		
	4	Hub3, 2D2E, Oft, 2B2C, AnAm, B, LabImuno, 3BC, 3DE, Hub3		
Day 4	1	Hub3, Oft, 2D2E, C2EC2D, C3DC3E, C4EC4D, 4DE, Hub3	2.71	1.01
	2	Hub3, 3DE, 3BC, LabImuno, 4BC, UCIP, NeoBP, 5BC, 5DE, Hub3		
	3	Hub3, UHGICSO, 1BC, PsiCpsiDI, SU, B, AnAm, 2B2C, Hub3		
	4	Hub3, Ad, C, AprovSOUCCFa, GAIC, Im, MN, Cim, MCDTTGU, ImedRHAdeCR, TM, Ar, F, Hub3		
Day 5	1	Hub3, 3DE, C3DC3E, 2B2C, B, AnAm, C2EC2D, 2D2E, Hub3	2.63	1.04
	2	Hub3, C4EC4D, 4DE, 4BC, UCIP, NeoBP, 5BC, 5DE, Hub3		
	3	Hub3, F, Ar, AprovSOUCCFa, PsiCpsiDI, SU, SU23UCISU, 1BC, UHGICSO, 1DE, Hub3		
	4	Hub3, Ad, GAIC, MCDTTGU, Cim, MN, Im, AP, LabImuno, 3BC, Hub3		

Fixed and Flexible Routes Methodology Results with Arquivo as Hub

Table III.30 - Opl resuts for arquivo's fixed and flexible routes methodology

Day	Route Type	N^er	Route	Total Time	Travel Time
Day 1	Fixed Route	1	Ar, C, Ad, 1DE, Oft, 2D2E, C2EC2D, C3DC3E, 3DE, Ar	3.56	1.44
		2	Ar, TM, ImedRHAdeCR, COROCN, UHGICSO, 1BC, PsiCpsiDI, Im, Cim, Ar		
		3	Ar, 4BC, UCIP, NeoBP, 5BC, 5DE, C5TC5F, C4DC4E, 4DE, Ar		
		4	Ar, GAIC, MCDTTGU, 2B2C, AnAm, B, AP, LabImuno, 3BC, Ar		
	Flexible Route	Morning	Ar, SU, SU23UCISU, MN, AprovSOUCCFa, F, Ar		
		Afternoon	Ar, SU23UCISU, MN, AprovSOUCCFa, F, Ar		
Day 2	Fixed Route	1	Ar, C, Ad, 1DE, Oft, 2D2E, C2EC2D, C3DC3E, 3DE, Ar	3.36	1.29
		2	Ar, TM, ImedRHAdeCR, COROCN, UHGICSO, 1BC, PsiCpsiDI, Im, Cim, Ar		
		3	Ar, 4BC, UCIP, NeoBP, 5BC, 5DE, C5TC5F, C4DC4E, 4DE, Ar		
		4	Ar, GAIC, MCDTTGU, 2B2C, AnAm, B, AP, LabImuno, 3BC, Ar		
	Flexible Route	Morning	Ar, MN, ImedRGAdeCR, AprovSOUCCFa, F, Ar		
		Afternoon	Ar, MN, AprovSOUCCFa, Ar		
Day 3	Fixed Route	1	Ar, C, Ad, 1DE, Oft, 2D2E, C2EC2D, C3DC3E, 3DE, Ar	3.42	1.34
		2	Ar, TM, ImedRHAdeCR, COROCN, UHGICSO, 1BC, PsiCpsiDI, Im, Cim, Ar		
		3	Ar, 4BC, UCIP, NeoBP, 5BC, 5DE, C5TC5F, C4DC4E, 4DE, Ar		
		4	Ar, GAIC, MCDTTGU, 2B2C, AnAm, B, AP, LabImuno, 3BC, Ar		
	Flexible Route	Morning	Ar, MN, AprovSOUCCFa, F, Ar		
		Afternoon	Ar, SU, SU23UCISU, AprovSOUCCFa, F, Ar		
Day 4	Fixed Route	1	Ar, C, Ad, 1DE, Oft, 2D2E, C2EC2D, C3DC3E, 3DE, Ar	3.21	1.20
		2	Ar, TM, ImedRHAdeCR, COROCN, UHGICSO, 1BC, PsiCpsiDI, Im, Cim, Ar		
		3	Ar, 4BC, UCIP, NeoBP, 5BC, 5DE, C5TC5F, C4DC4E, 4DE, Ar		
		4	Ar, GAIC, MCDTTGU, 2B2C, AnAm, B, AP, LabImuno, 3BC, Ar		
	Flexible Route	Morning	Ar, MN, ImedRGAdeCR, AprovSOUCCFa, F, Ar		
		Afternoon	Ar, SU, MN, AprovSOUCCFa, F, Ar		
Day 5	Fixed Route	1	Ar, C, Ad, 1DE, Oft, 2D2E, C2EC2D, C3DC3E, 3DE, Ar	3.50	1.39
		2	Ar, TM, ImedRHAdeCR, COROCN, UHGICSO, 1BC, PsiCpsiDI, Im, Cim, Ar		
		3	Ar, 4BC, UCIP, NeoBP, 5BC, 5DE, C5TC5F, C4DC4E, 4DE, Ar		
		4	Ar, GAIC, MCDTTGU, 2B2C, AnAm, B, AP, LabImuno, 3BC, Ar		
	Flexible Route	Morning	Ar, SU, SU23UCISU, MN, AprovSOUCCFa, F, Ar		
		Afternoon	Ar, SU23UCISU, AprovSOUCCFa, F, Ar		

Fixed and Flexible Routes Methodology Results with Hub on the first floor

Table III.31 - Opl resuts for first floor's fixed and flexible routes methodology

Day	Route Type	N^er	Route	Total Time	Travel Time
Day 1	Fixed Route	1	Hub1, AnAm, B, AP, LabImuno, 3BC, 3DE, C3DC3E, C2DC2E, Hub1	3.51	1.38
		2	Hub1, 4BC, UCIP, NeoBP, 5BC, 5DE, C5FC5T, C4DC4E, 4DE, Hub1		
		3	Hub1, C, Ar, Ad, TM, ImedRHADECR, GAIC, MCDTTGU, Cim, Im, Hub1		
		4	Hub1, 1BC, PsiCpsiDI, UHGICSO, COROCN, 1DE, 2D2E, Oft, 2B2C, Hub1		
	Flexible Route	Morning	Hub1, AprovSOUCCFa, F, MN, SU, SU23UCISU, Hub1		
		Afternoon	Hub1, AprovSOUCCFa, F, MN, SU23UCISU, Hub1		
Day 2	Fixed Route	1	Hub1, AnAm, B, AP, LabImuno, 3BC, 3DE, C3DC3E, C2DC2E, Hub1	3.32	1.24
		2	Hub1, 4BC, UCIP, NeoBP, 5BC, 5DE, C5FC5T, C4DC4E, 4DE, Hub1		
		3	Hub1, C, Ar, Ad, TM, ImedRHADECR, GAIC, MCDTTGU, Cim, Im, Hub1		
		4	Hub1, 1BC, PsiCpsiDI, UHGICSO, COROCN, 1DE, 2D2E, Oft, 2B2C, Hub1		
	Flexible Route	Morning	Hub1, MN, ImedRGAdeCR, F, AprovSOUCCFa, Hub1		
		Afternoon	Hub1, MN, AprovSOUCCFa, Hub1		
Day 3	Fixed Route	1	Hub1, AnAm, B, AP, LabImuno, 3BC, 3DE, C3DC3E, C2DC2E, Hub1	3.32	1.38
		2	Hub1, 4BC, UCIP, NeoBP, 5BC, 5DE, C5FC5T, C4DC4E, 4DE, Hub1		
		3	Hub1, C, Ar, Ad, TM, ImedRHADECR, GAIC, MCDTTGU, Cim, Im, Hub1		
		4	Hub1, 1BC, PsiCpsiDI, UHGICSO, COROCN, 1DE, 2D2E, Oft, 2B2C, Hub1		
	Flexible Route	Morning	Hub1, AprovSOUCCFa, F, MN, Hub1		
		Afternoon	Hub1, F, AprovSOUCCFa, SU, SU23UCISU, Hub1		
Day 4	Fixed Route	1	Hub1, AnAm, B, AP, LabImuno, 3BC, 3DE, C3DC3E, C2DC2E, Hub1	3.11	1.10
		2	Hub1, 4BC, UCIP, NeoBP, 5BC, 5DE, C5FC5T, C4DC4E, 4DE, Hub1		
		3	Hub1, C, Ar, Ad, TM, ImedRHADECR, GAIC, MCDTTGU, Cim, Im, Hub1		
		4	Hub1, 1BC, PsiCpsiDI, UHGICSO, COROCN, 1DE, 2D2E, Oft, 2B2C, Hub1		
	Flexible Route	Morning	Hub1, MN, ImedRGAdeCR, F, AprovSOUCCFa, Hub1		
		Afternoon	Hub1, SU, MN, F, AprovSOUCCFa, Hub1		
Day 5	Fixed Route	1	Hub1, AnAm, B, AP, LabImuno, 3BC, 3DE, C3DC3E, C2DC2E, Hub1	3.47	1.35
		2	Hub1, 4BC, UCIP, NeoBP, 5BC, 5DE, C5FC5T, C4DC4E, 4DE, Hub1		
		3	Hub1, C, Ar, Ad, TM, ImedRHADECR, GAIC, MCDTTGU, Cim, Im, Hub1		
		4	Hub1, 1BC, PsiCpsiDI, UHGICSO, COROCN, 1DE, 2D2E, Oft, 2B2C, Hub1		
	Flexible Route	Morning	Hub1, AprovSOUCCFa, F, MN, SU, SU23UCISU, Hub1		
		Afternoon	Hub1, AprovSOUCCFa, F, SU23UCISU, Hub1		

Fixed and Flexible Routes Methodology Results with Hub on third floor

Table III.32 - Opl results for third floor's fixed and flexible routes methodology

Day	Route Type	N^{er}	Route	Total Time	Travel Time
Day 1	Fixed Route	1	Hub3, 4DE, C4EC4D, C5FC5T, 5DE, 5BC, NeoBP, UCIP, 4BC, Hub3.	3.68	1.49
		2	Hub3, 1BC, PsiCpsiDI, R, MCDTTGU, Cim, Im, B, AnAm, 2B2C, Hub3		
		3	Hub3, Ar, C, Ad, ImedRHADECR, TM, GAIC, COROCN, UHGICSO, 1DE, Hub3		
		4	Hub3, 2D2E, C2EC2D, C3DC3E, 3DE, 3BC, LabImuno, AP, Hub3		
	Flexible Route	Morning	Hub3, SU, SU23UCISU, MN, AprovSOUCCFa, F, Hub3		
		Afternoom	Hub3, F, AprovSOUCCFa, MN, SU23UCISU, Hub3		
Day 2	Fixed Route	1	Hub3, 4DE, C4EC4D, C5FC5T, 5DE, 5BC, NeoBP, UCIP, 4BC, Hub3.	3.50	1.37
		2	Hub3, 1BC, PsiCpsiDI, R, MCDTTGU, Cim, Im, B, AnAm, 2B2C, Hub3		
		3	Hub3, Ar, C, Ad, ImedRHADECR, TM, GAIC, COROCN, UHGICSO, 1DE, Hub3		
		4	Hub3, 2D2E, C2EC2D, C3DC3E, 3DE, 3BC, LabImuno, AP, Hub3		
	Flexible Route	Morning	Hub3, F, AprovSOUCCFa, ImedRHADECR, MN, Hub3		
		Afternoom	Hub3, MN, AprovSOUCCFa, Hub3		
Day 3	Fixed Route	1	Hub3, 4DE, C4EC4D, C5FC5T, 5DE, 5BC, NeoBP, UCIP, 4BC, Hub3.	3.54	1.40
		2	Hub3, 1BC, PsiCpsiDI, R, MCDTTGU, Cim, Im, B, AnAm, 2B2C, Hub3		
		3	Hub3, Ar, C, Ad, ImedRHADECR, TM, GAIC, COROCN, UHGICSO, 1DE, Hub3		
		4	Hub3, 2D2E, C2EC2D, C3DC3E, 3DE, 3BC, LabImuno, AP, Hub3		
	Flexible Route	Morning	Hub3, MN, AprovSOUCCFa, F, Hub3		
		Afternoom	Hub3, F, AprovSOUCCFa, SU23UCISU, SU, Hub3		
Day 4	Fixed Route	1	Hub3, 4DE, C4EC4D, C5FC5T, 5DE, 5BC, NeoBP, UCIP, 4BC, Hub3.	3.22	1.15
		2	Hub3, 1BC, PsiCpsiDI, R, MCDTTGU, Cim, Im, B, AnAm, 2B2C, Hub3		
		3	Hub3, Ar, C, Ad, ImedRHADECR, TM, GAIC, COROCN, UHGICSO, 1DE, Hub3		
		4	Hub3, 2D2E, C2EC2D, C3DC3E, 3DE, 3BC, LabImuno, AP, Hub3		
	Flexible Route	Morning	Hub3, F, AprovSOUCCFa, ImedRHADECR, MN, Hub3		
		Afternoom	Hub3, F, AprovSOUCCFa, MN, SU, Hub3		
Day 5	Fixed Route	1	Hub3, 4DE, C4EC4D, C5FC5T, 5DE, 5BC, NeoBP, UCIP, 4BC, Hub3.	3.62	1.45
		2	Hub3, 1BC, PsiCpsiDI, R, MCDTTGU, Cim, Im, B, AnAm, 2B2C, Hub3		
		3	Hub3, Ar, C, Ad, ImedRHADECR, TM, GAIC, COROCN, UHGICSO, 1DE, Hub3		
		4	Hub3, 2D2E, C2EC2D, C3DC3E, 3DE, 3BC, LabImuno, AP, Hub3		
	Flexible Route	Morning	Hub3, SU, SU23UCISU, MN, AprovSOUCCFa, F, Hub3		
		Afternoom	Hub3, F, AprovSOUCCFa, SU23UCISU, Hub3		

Detailed Routing Results on OPL Studio

APPENDIX IV - DETAILED ROUTING RESULTS ON VBA TOOLKIT

Current Situation Structure Results

Table IV.1 - VBA morning collection phase results for current situation structure

Day	N^er	Morning Collection Phase		
		Route	Total Time	Travel Time
Day 1	1	Ar, C, Ad, TM, RH, Imed, GAIC, MCDT, T, Cim, Im, DI, CPsi, Psi	2.69	1.00
	2	Hub, 1DE, 1BC, Neo, BP, 5BC, 5DE		
	3	Ar, SO, UHGIC, 2E, 2D, Oft, 2C, 2B, An, Am, B		
	4	Ar, 3DE, 3BC, Imuno, Lab, AP		
	5	Ar, 4DE, 4BC, UCIP		
	6	Ar, CO, RO, CN, C2D, C2E, C3D, C3E, C4D, C4E, C5F, C5T		
Day 2	1	Ar, C, Ad, TM, RH, Imed, GAIC, MCDT, T, Cim, Im, DI, CPsi, Psi	2.69	1.00
	2	Ar, 1DE, 1BC, Neo, BP, 5BC, 5DE		
	3	Ar, SO, UHGIC, 2E, 2D, Oft, 2C, 2B, An, Am, B		
	4	Ar, 3DE, 3BC, Imuno, Lab, AP		
	5	Ar, 4DE, 4BC, UCIP		
	6	Ar, CO, RO, CN, C2D, C2E, C3D, C3E, C4D, C4E, C5F, C5T		
Day 3	1	Ar, C, Ad, TM, RH, Imed, GAIC, MCDT, T, Cim, Im, DI, CPsi, Psi	2.69	1.00
	2	Ar, 1DE, 1BC, Neo, BP, 5BC, 5DE		
	3	Ar, SO, UHGIC, 2E, 2D, Oft, 2C, 2B, An, Am, B		
	4	Ar, 3DE, 3BC, Imuno, Lab, AP		
	5	Ar, 4DE, 4BC, UCIP		
	6	Ar, CO, RO, CN, C2D, C2E, C3D, C3E, C4D, C4E, C5F, C5T		
Day 4	1	Ar, C, Ad, TM, RH, Imed, GAIC, MCDT, T, Cim, Im, DI, CPsi, Psi	2.69	1.00
	2	Ar, 1DE, 1BC, Neo, BP, 5BC, 5DE		
	3	Ar, SO, UHGIC, 2E, 2D, Oft, 2C, 2B, An, Am, B		
	4	Ar, 3DE, 3BC, Imuno, Lab, AP		
	5	Ar, 4DE, 4BC, UCIP		
	6	Ar, CO, RO, CN, C2D, C2E, C3D, C3E, C4D, C4E, C5F, C5T		
Day 5	1	Ar, C, Ad, TM, RH, Imed, GAIC, MCDT, T, Cim, Im, DI, CPsi, Psi	2.69	1.00
	2	Ar, 1DE, 1BC, Neo, BP, 5BC, 5DE		
	3	Ar, SO, UHGIC, 2E, 2D, Oft, 2C, 2B, An, Am, B		
	4	Ar, 3DE, 3BC, Imuno, Lab, AP		
	5	Ar, 4DE, 4BC, UCIP		
	6	Ar, CO, RO, CN, C2D, C2E, C3D, C3E, C4D, C4E, C5F, C5T		

Table IV.2 - VBA morning delivery phase results for current situation structure

		Morning Delivery Phase		
Day	N^{er}	Route	Total Time	Travel Time
Day 1	1	Psi, UHGIC, 2B, B, Lab, UCIP, 4BC, C4E, Neo, 5DE, Ad, RH, GAIC, MCDT, C, Ar	6.29	2.59
	2	5DE, C5T, 5BC, Neo, BP, 4BC, Imuno, An, B, SU, Im, MN, T, C, RH, CO, 2E, Ar		
	3	B, An, 2B, 4BC, 3BC, 3DE, 2D, 2E, C2D, C2E, 1DE, SU, Im, Ad, C, SOU, F, Ar		
	4	AP, B, An, 3BC, 4BC, C4D, C2D, 2D, 1DE, MCDT, T, Im, Cim, RH, C, SOU, Ar		
	5	UCIP, Imuno, 4BC, 5BC, 5DE, 3DE, 2D, 2C, 1BC, T, RH, Ad, C, Fa, Ar		
	6	C5T, C3E, 3DE, Lab, AP, Am, 2C, 2B, C3D, C2D, C2E, 2D, 2E, UHGICC2E, CO, RH, MN, Cim, T, MCDT, Ad, Fa, C, SOU, F, Ar		
Day 2	1	Psi, Am, 2C, Lab, 4BC, C4E, 4DE, 3DE, Ad, TM, ADE, RH, Imed, GAIC, MCDT, CC, C, Fa, Ar	6.08	2.54
	2	5DE, Neo, 4BC, 3DE, C2D, Am, B, 2C, UHGIC, RH, Ad, Fa, C, SOU, Ar		
	3	B, 2B, 2C, 2E, 3BC, C4D, 4BC, UCIP, Neo, 5BC, Im, MCDT, UHGIC, 1DE, CO, RH, Ad, C, SOU, F, Ar		
	4	AP, Lab, 3BC, 3DE, C3E, Imuno, An, B, UHGIC, CO, MCDT, Im, RH, Ad, C, SOU, Aprov, F, Ar		
	5	UCIP, 4BC, 4DE, C4D, 3DE, 2E, 2C, 2B, Lab, Imuno, 1BC, CPsi, Im, T, MCDT, C, Aprov, Ar		
	6	C5T, C5F, C4D, 4BC, AP, 3DE, C3E, C3D, C2D, C2E, CN, RH, MCDT, T, MN, Cim, Ad, SOU, F, Ar		
Day 3	1	Psi, 1BC, 2B, 2C, Oft, 3DE, 3BC, 4BC, 5BC, 5DE, Ad, MCDT, Ar	5.53	2.32
	2	5DE, C4D, BP, Neo, B, Lab, 3BC, 3DE, 2E, UHGIC, Cim, RH, Ad, C, SOU, Ar		
	3	B, Am, 2B, 2C, 3BC, UCIP, 4BC, 3DE, Oft, 2D, 2E, SO, UHGIC, CO, Ad, C, F, Ar		
	4	AP, Lab, B, An, 2C, 2B, 1DE, UHGIC, 4BC, 4DE, C4D, C5F, TM, RH, Cim, C, Aprov, Ar		
	5	UCIP, C4D, 5DE, 3DE, Imuno, 2C, Psi, MN, Cim, RH, Imed, C, Ar		
	6	C5T, 5DE, C5F, C4D, C4E, C3E, C3D, C2D, CN, 2D, 3DE, 3BC, Imuno, AP, MN, Cim, T, MCDT, RH, SOU, F, Ar		
Day 4	1	Psi, 5BC, C5T, 4DE, 4BC, UCIP, Lab, 3DE, 2D, Ad, TM, ADE, CR, RH, Imed, GAIC, MCDT, C, Ar	6.18	2.54
	2	5DE, 5BC, Neo, 4BC, AP, Imuno, B, Am, An, 2C, 1BC, UHGIC, C2E, C4D, RH, Cim, MN, T, GU, C, Ar		
	3	B, Am, C2D, 2E, 2D, 3DE, 4DE, 4BC, 3BC, 2C, 2B, 1BC, UHGIC, SOU, C, RH, F, Ar		
	4	AP, Imuno, 3BC, 3DE, 4DE, C4D, 5DE, 5BC, An, B, UHGIC, 1DE, Im, T, MCDT, RH, C, Aprov, Ar		
	5	UCIP, 4BC, C4D, 3DE, 2D, Imuno, Im, Cim, T, RH, Fa, C, SOU, Ar		
	6	C5T, C5F, C4D, C4E, 4BC, Lab, AP, 2C, 2D, C2E, C2D, C3D, C3E, 3DEC2D, Ad, RH, MN, Cim, T, MCDT, SOU, F, Ar		
Day 5	1	Psi, 4BC, Lab, Cim, MCDT, GAIC, RH, Imed, Ad, Fa, C, SOU, Ar	5.69	2.37
	2	5DE, C5T, Neo, BP, 3BC, Lab, B, Am, An, 2B, UHGIC, T, Imed, C, SOU, F, Ar		
	3	B, Am, 3BC, 4BC, UCIP, C4E, 3DE, 2D, 2C, 2B, UCISU, CPsi, UHGIC, RH, C, F, Ar		
	4	AP, Lab, Imuno, 3BC, 3DE, C3D, 4DE, 2D, Oft, 2C, An, B, UHGIC, Im, MN, MCDT, RH, TM, C, Aprov, Ar		
	5	UCIP, 4BC, 3DE, 2D, 2C, SU, Psi, 1DE, T, MN, RH, C, Ar		
	6	C5T, C5F, C4D, 4BC, AP, 3BC, 3DE, 2C, 2D, C2E, C2D, CN, RH, Im, Cim, T, MCDT, CC, SOU, F, Ar		

Table IV.3 - VBA afternoon collection phase results for current situation structure

Day	N^{er}	Afternoon Collection Phase		
		Route	Total Time	Travel Time
Day 1	1	Ar, C, Ad, TM, RH, Imed, GAIC, MCDT, T, Cim, Im, DI, CPsi, Psi	2.69	1.00
	2	Ar, 1DE, 1BC, Neo, BP, 5BC, 5DE		
	3	Ar, SO, UHGIC, 2E, 2D, Oft, 2C, 2B, An, Am, B		
	4	Ar, 3DE, 3BC, Imuno, Lab, AP		
	5	Ar, 4DE, 4BC, UCIP		
	6	Ar, CO, RO, CN, C2D, C2E, C3D, C3E, C4D, C4E, C5F, C5T		
Day 2	1	Ar, C, Ad, TM, RH, Imed, GAIC, MCDT, T, Cim, Im, DI, CPsi, Psi	2.69	1.00
	2	Ar, 1DE, 1BC, Neo, BP, 5BC, 5DE		
	3	Ar, SO, UHGIC, 2E, 2D, Oft, 2C, 2B, An, Am, B		
	4	Ar, 3DE, 3BC, Imuno, Lab, AP		
	5	Ar, 4DE, 4BC, UCIP		
	6	Ar, CO, RO, CN, C2D, C2E, C3D, C3E, C4D, C4E, C5F, C5T		
Day 3	1	Ar, C, Ad, TM, RH, Imed, GAIC, MCDT, T, Cim, Im, DI, CPsi, Psi	2.69	1.00
	2	Ar, 1DE, 1BC, Neo, BP, 5BC, 5DE		
	3	Ar, SO, UHGIC, 2E, 2D, Oft, 2C, 2B, An, Am, B		
	4	Ar, 3DE, 3BC, Imuno, Lab, AP		
	5	Ar, 4DE, 4BC, UCIP		
	6	Ar, CO, RO, CN, C2D, C2E, C3D, C3E, C4D, C4E, C5F, C5T		
Day 4	1	Ar, C, Ad, TM, RH, Imed, GAIC, MCDT, T, Cim, Im, DI, CPsi, Psi	2.69	1.00
	2	Ar, 1DE, 1BC, Neo, BP, 5BC, 5DE		
	3	Ar, SO, UHGIC, 2E, 2D, Oft, 2C, 2B, An, Am, B		
	4	Ar, 3DE, 3BC, Imuno, Lab, AP		
	5	Ar, 4DE, 4BC, UCIP		
	6	Ar, CO, RO, CN, C2D, C2E, C3D, C3E, C4D, C4E, C5F, C5T		
Day 5	1	Ar, C, Ad, TM, RH, Imed, GAIC, MCDT, T, Cim, Im, DI, CPsi, Psi	2.69	1.00
	2	Ar, 1DE, 1BC, Neo, BP, 5BC, 5DE		
	3	Ar, SO, UHGIC, 2E, 2D, Oft, 2C, 2B, An, Am, B		
	4	Ar, 3DE, 3BC, Imuno, Lab, AP		
	5	Ar, 4DE, 4BC, UCIP		
	6	Ar, CO, RO, CN, C2D, C2E, C3D, C3E, C4D, C4E, C5F, C5T		

Table IV.4 - VBA afternoon delivery phase results for current situation structure

Day	N^er	Afternoon Delivery Phase		
		Route	Total Time	Travel Time
Day 1	1	Psi, Lab, C4E, Neo, 5DE, Ar	4.58	2.15
	2	5DE, 4BC, C4D, CN, CO, UHGIC, 1BC, An, B, Am, C2D, 2E, 2D, Ar		
	3	B, Am, An, 2C, C2E, C2D, 2E, 2D, 3DE, 4DE, C4D, UCIP, MCDT, T, MN, Im, SU23, UHGIC, 1DE, Fa, Ar		
	4	AP, C4D, 4DE, 2E, 2C, An, Am, B, Im, T, Ar		
	5	UCIP, 4BC, Imuno, 2B, 2C, C2E, C2D, 3DE, C4D, 5DE, 1DE, Psi, T, Ad, Fa, Aprov, Ar		
	6	C5T, 4DE, C4D, C2D, Cim, T, Ad, Fa, SOU, F, Ar		
Day 2	1	Psi, 1BC, AP, 4BC, 5DE, 3DE, Oft, CO, MCDT, Ad, Ar	4.47	2.15
	2	5DE, 5BC, 4BC, C4D, 3DE, Oft, An, B, Im, T, Ad, Fa, Ar		
	3	B, Am, An, 2B, UHGIC, 1DE, 2D, 3DE, 4DE, C4D, C4E, UCIP, Im, T, Ar		
	4	AP, Lab, 4BC, C4D, 3DE, B, Am, An, UHGIC, CO, MCDT, T, Ad, Aprov, Ar		
	5	UCIP, 4BC, C4D, 3DE, 2D, C2E, Imuno, An, 1BC, Psi, Im, T, Aprov, Ar		
	6	C5T, C4D, C3E, Lab, MN, Cim, T, MCDT, UHGIC, CO, Ad, SOU, Ar		
Day 3	1	Psi, 1DE, Oft, 2E, 3DE, 5DE, C5T, 5BC, UCIP, 4BC, AP, MCDT, Ad, Ar	4.80	2.19
	2	5DE, 4DE, 2E, 2C, Am, B, SU23, Ad, Ar		
	3	B, Am, An, Neo, 5DE, C4D, C4E, 4BC, 3BC, 3DE, 2D, Oft, 2C, UHGIC, SU23, Cim, T, Ad, Fa, Ar		
	4	AP, Lab, 4BC, 3BC, 3DE, 2D, An, Am, B, SU, UHGIC, MCDT, T, Cim, Aprov, Ar		
	5	UCIP, C4D, 3DE, Lab, B, 2B, 2C, T, Ad, SOU, Ar		
	6	C5T, 4BC, Lab, B, C2D, UHGIC, MCDT, T, Cim, Ad, SOU, F, Ar		
Day 4	1	Psi, SOU, CC, C, Fa, Ad, TM, RH, Imed, GAIC, MCDT, AP, Lab, 3DE, 4DE, Ar	4.73	2.27
	2	5DE, 5BC, UCIP, 3DE, 2D, B, Im, Cim, CC, Ar		
	3	B, Am, 2B, 2C, Oft, 2D, 3DE, C3D, 3BC, 4BC, 4DE, C4D, 5DE, Neo, Cim, 1BC, UHGIC, Ad, SOU, F, Ar		
	4	AP, An, Am, Imuno, 3BC, 4DE, C4E, C2D, 2E, UHGIC, Im, Ad, SOU, F, Ar		
	5	UCIP, 4BC, Imuno, 3BC, 3DE, C4D, C3D, C2E, SU, MCDT, T, Ad, Aprov, Ar		
	6	C5T, UHGIC, CPsi, MN, Cim, T, MCDT, SOU, Ar		
Day 5	1	Psi, 1BC, Im, MCDT, GAIC, Ad, 5DE, Neo, An, Lab, AP, 3DE, Ar	4.75	2.21
	2	5DE, 4DE, 4BC, UCIP, B, 2E, 1DE, Psi, Im, Cim, Ar		
	3	B, Am, 2B, 2D, 1DE, UHGIC, SU23, 5BC, 5DE, 4DE, 3BC, MCDT, F, Ar		
	4	AP, An, B, Am, C2D, C3D, C4D, 4DE, 4BC, 3DE, 2D, 2C, Im, T2D, MCDT, F, Ar		
	5	UCIP, 4BC, Imuno, Lab, 2B, 2C, 2D, 1DE, Im, MN, MCDT, Ad, Ar		
	6	C5T, Lab, C3E, C3D, C2D, CO, MCDT, T, Cim, Fa, CC, SOU, Ar		

Improved Current Situation Methodology Results

Table IV.5 - VBA morning collection phase results for improved current situation

		Morning Collection Phase		
Day	N^{er}	Route	Total Time	Travel Time
Day 1	1	Ar, C, Ad, TM, RH, Imed, GAIC, MCDT, T, Cim, Im	2.61	0.93
	2	Ar, 3DE, 3BC, AP, Lab, Imuno, C3E, C3D, CN, RO, CO, 1DE, UHGIC, SO, 1BC, DI, CPsi, Psi		
	3	Ar, 2E, C2D, C2E, 2D, Oft, 2C, 2B, An, Am, B		
	4	Ar, 5DE, C5T, C5F, Neo, BP, 5BC, UCIP, 4BC, 4DE, C4E, C4D		
Day 2	1	Ar, C, Ad, TM, RH, Imed, GAIC, MCDT, T, Cim, Im	2.61	0.93
	2	Ar, 3DE, 3BC, AP, Lab, Imuno, C3E, C3D, CN, RO, CO, 1DE, UHGIC, SO, 1BC, DI, CPsi, Psi		
	3	Ar, 2E, C2D, C2E, 2D, Oft, 2C, 2B, An, Am, B		
	4	Ar, 5DE, C5T, C5F, Neo, BP, 5BC, UCIP, 4BC, 4DE, C4E, C4D		
Day 3	1	Ar, C, Ad, TM, RH, Imed, GAIC, MCDT, T, Cim, Im	2.61	0.93
	2	Ar, 3DE, 3BC, AP, Lab, Imuno, C3E, C3D, CN, RO, CO, 1DE, UHGIC, SO, 1BC, DI, CPsi, Psi		
	3	Ar, 2E, C2D, C2E, 2D, Oft, 2C, 2B, An, Am, B		
	4	Ar, 5DE, C5T, C5F, Neo, BP, 5BC, UCIP, 4BC, 4DE, C4E, C4D		
Day 4	1	Ar, C, Ad, TM, RH, Imed, GAIC, MCDT, T, Cim, Im	2.61	0.93
	2	Ar, 3DE, 3BC, AP, Lab, Imuno, C3E, C3D, CN, RO, CO, 1DE, UHGIC, SO, 1BC, DI, CPsi, Psi		
	3	Ar, 2E, C2D, C2E, 2D, Oft, 2C, 2B, An, Am, B		
	4	Ar, 5DE, C5T, C5F, Neo, BP, 5BC, UCIP, 4BC, 4DE, C4E, C4D		
Day 5	1	Ar, C, Ad, TM, RH, Imed, GAIC, MCDT, T, Cim, Im	2.61	0.93
	2	Ar, 3DE, 3BC, AP, Lab, Imuno, C3E, C3D, CN, RO, CO, 1DE, UHGIC, SO		
	3	Ar, 2E, C2D, C2E, 2D, Oft, 2C, 2B, An, Am, B		
	4	Ar, 5DE, C5T, C5F, Neo, BP, 5BC, UCIP, 4BC, 4DE, C4E, C4D		

Table IV.6 - VBA morning delivery phase results for improved current situation

Day	N^er	Morning Delivery Phase Route	Total Time	Travel Time
Day 1	1	Im, MN, 2B, B, Lab, 3BC, 4BC, UCIP, Neo, 5DE, C5T, C4E, C2D, CO, UHGIC, MCDT, GAIC, Ad, SOU, Ar	4.85	1.99
	2	Psi, SU23, B, An, 2B, 4BC, C4D, 3DE, C3D, C2D, C2E, 2D, CO, RH, MN, Im, Cim, T, MCDT, Fa, C, SOU, Ar		
	3	B, Am, An, AP, 3BC, 4BC, SU, UHGIC, C2D, 2E, 2D, 1DE, SOU, C, Fa, Ad, RH, MCDT, Cim, F, Ar		
	4	C4D, C5T, 5DE, Neo, Lab, Imuno, C3E, 3DE, 2D, B, 1BC, SU, Im, MN, Cim, T, RH, Ad, C, Fa, Ar		
Day 2	1	Im, Psi, Am, 2C, Lab, 3BC, 4BC, C4E, 4DE, 3DE, Ad, C, SOU, CC, Fa, ADE, Ar	5.31	2.14
	2	Psi, UHGIC, Aprov, SOU, C, Ad, MCDT, T, Im, Cim, RH, CO, C2D, C2E, 2C, 2B, An, AP, Lab, Imuno, 4BC, 5BC, C5F, C5T, C4D, C3D		
	3	B, 2B, 2C, 2E, 3BC, 4BC, UCIP, C4D, Neo, Im, Cim, MCDT, UHGIC, 1DE, CO, RH, Ad, C, SOU, F, Ar		
	4	C4D, 3DE, 2E, C2D, Am, B, 2B, 2C, AP, Lab, Imuno, 4BC, 5DE, Neo, 1BC, CPsi, Im, MN, Cim, T, MCDT, RH, Ad, Fa, C, SOU		
Day 3	1	Im, MCDT, 1BC, Oft, 2C, 2B, Lab, 3BC, 3DE, 4BC, 5BC, 5DE, Ad, SOU, Ar	4.81	2.01
	2	Psi, UHGIC, 2E, 2C, 2B, An, B, Lab, Imuno, 3BC, 3DE, C3E, C3D, C4D, C4E, 4DE, 4BC, C5F, TM, RH, MN, Cim, T, C, F, Ar		
	3	B, Am, 2B, AP, 3BC, 4BC, UCIP, C4D, 3DE, 2E, CO, UHGIC, SO, MCDT, T, Cim, RH, Ad, C, SOU, F, Ar		
	4	C4D, 5DE, BP, Imuno, Lab, B, 2C, UHGIC, Psi, MN, Cim, T, MCDT, RH, Imed, Ad, C, SOU, 1DE, C2D, 3DE, Ar		
Day 4	1	Im, Lab, 3BC, 5BC, 5DE, C5T, Neo, UCIP, 4BC, 4DE, 3DE, Oft, 1BC, Psi, CC, C, Ad, ADE, Ar	4.61	1.86
	2	Psi, Im, Cim, T, MCDT, RH, C, UHGIC, 2C, An, B, AP, 5BC, 5DE, C4D, 4DE, 3DE, C2D, C2E, F, Ar		
	3	B, Am, 2C, AP, 4BC, 3BC, 3DE, 2D, 2E, UHGIC, 1BC, Cim, MCDT, RH, Ad, C, SOU, F, Ar		
	4	C4D, C3E, 3DE, Imuno, Lab, AP, B, Am, C2D, 2D, UHGIC, Im, MN, Cim, T, MCDT, GU, RH, Fa, C, SOU, Ar		
Day 5	1	Im, MN, Psi, 2C, 3BC, Lab, 4BC, Ad, Fa, C, SOU, Ar	4.83	2.12
	2	Psi, UHGIC, B, An, 2B, 2C, Oft, 2D, 3DE, 3BC, UCIP, 4BC, 4DE, C5F, C4D, C3D, C2D, C2E, CN, TM, RH, MN, Im, Cim, T, MCDT		
	3	B, AP, UCIP, 4BC, C4E, 3BC, 2D, 2C, 2B, UHGIC, CPsi, UCISU, Im, RH, C, SOU, F, Ar		
	4	C4D, C5T, Neo, BP, AP, Lab, 3DE, 2D, 2C, Am, SU, Psi, UHGIC, 1DE, SOU, CC, C, Imed, RH, MCDT, T, Cim, F, Ar		

Table IV.7 - VBA afternoon collection phase results for improved current situation

Day	N^{er}	Afternoon Collection Phase Route	Total Time	Travel Time
Day 1	1	Ar, C, Ad, TM, RH, Imed, GAIC, MCDT, T, Cim, Im	2.61	0.93
	2	Ar, 3DE, 3BC, AP, Lab, Imuno, C3E, C3D, CN, RO, CO, 1DE, UHGIC, SO, 1BC, DI, CPsi, Psi		
	3	Ar, 2E, C2D, C2E, 2D, Oft, 2C, 2B, An, Am, B		
	4	Ar, 5DE, C5T, C5F, Neo, BP, 5BC, UCIP, 4BC, 4DE, C4E, C4D		
Day 2	1	Ar, C, Ad, TM, RH, Imed, GAIC, MCDT, T, Cim, Im	2.61	0.93
	2	Ar, 3DE, 3BC, AP, Lab, Imuno, C3E, C3D, CN, RO, CO, 1DE, UHGIC, SO, 1BC, DI, CPsi, Psi		
	3	Ar, 2E, C2D, C2E, 2D, Oft, 2C, 2B, An, Am, B		
	4	Ar, 5DE, C5T, C5F, Neo, BP, 5BC, UCIP, 4BC, 4DE, C4E, C4D		
Day 3	1	Ar, C, Ad, TM, RH, Imed, GAIC, MCDT, T, Cim, Im	2.61	0.93
	2	Ar, 3DE, 3BC, AP, Lab, Imuno, C3E, C3D, CN, RO, CO, 1DE, UHGIC, SO, 1BC, DI, CPsi, Psi		
	3	Ar, 2E, C2D, C2E, 2D, Oft, 2C, 2B, An, Am, B		
	4	Ar, 5DE, C5T, C5F, Neo, BP, 5BC, UCIP, 4BC, 4DE, C4E, C4D		
Day 4	1	Ar, C, Ad, TM, RH, Imed, GAIC, MCDT, T, Cim, Im	2.61	0.93
	2	Ar, 3DE, 3BC, AP, Lab, Imuno, C3E, C3D, CN, RO, CO, 1DE, UHGIC, SO, 1BC, DI, CPsi, Psi		
	3	Ar, 2E, C2D, C2E, 2D, Oft, 2C, 2B, An, Am, B		
	4	Ar, 5DE, C5T, C5F, Neo, BP, 5BC, UCIP, 4BC, 4DE, C4E, C4D		
Day 5	1	Ar, C, Ad, TM, RH, Imed, GAIC, MCDT, T, Cim, Im	2.61	0.93
	2	Ar, 3DE, 3BC, AP, Lab, Imuno, C3E, C3D, CN, RO, CO, 1DE, UHGIC, SO, 1BC, DI, CPsi, Psi		
	3	Ar, 2E, C2D, C2E, 2D, Oft, 2C, 2B, An, Am, B		
	4	Ar, 5DE, C5T, C5F, Neo, BP, 5BC, UCIP, 4BC, 4DE, C4E, C4D		

Table IV.8 - VBA afternoon delivery phase results for improved current situation

Day	N^{er}	Afternoon Delivery Phase		
		Route	Total Time	Travel Time
Day 1	1	Im, MN, Psi, Lab, C4E, Neo, 5DE, Ar	3.96	1.87
	2	Psi, 1BC, Im, T, UHGIC, CO, CN, C4D, 4DE, 4BC, 2C, An, B, Am, C2D, 2E, 2D, F, Ar		
	3	B, 2C, C2E, C2D, 3DE, 4DE, C4D, UCIP, MCDT, T, Cim, Im, Psi, UHGIC, 1DE, SOU, Fa, Ad, F, Ar		
	4	C4D, 5DE, 4BC, Imuno, An, Am, 2C, 2B, 1BC, Psi, Cim, T, C2D, C2E, 3DE, Ad, Fa, Aprov, Ar		
Day 2	1	Im, Psi, 1DE, CO, Oft, 3DE, AP, 4BC, 5DE, Ad, Ar	3.52	1.68
	2	Psi, UHGIC, An, Am, Lab, 4BC, C4D, 3DE, 1DE, CO, MCDT, T, Im, Ad, Aprov, Ar		
	3	B, 2B, 2D, 3DE, 4DE, C4D, C4E, UCIP, Im, Cim, T, UHGIC, SOU, Ar		
	4	C4D, 5DE, 2D, C2E, C3E, 3DE, Imuno, Lab, An, 1BC, Psi, Im, MN, Cim, T, MCDT, CO, Ad, Fa		
Day 3	1	Im, Psi, 2C, Oft, 2E, 3DE, AP, 4BC, UCIP, 5BC, C5T, 5DE, 1DE, Ad, Ar	4.29	1.86
	2	Psi, SU23, SU, Cim, T, MCDT, 4BC, Lab, An, 2C, B, Am, C2D, 2E, 2D, 3DE, 4DE, Ad, Ar		
	3	B, 2C, 2D, 3BC, 4BC, C4E, C4D, 5DE, Neo, SU, UHGIC, T, Cim, Ad, Fa, SOU, F, Ar		
	4	C4D, 5DE, 4BC, Lab, 2C, 2B, B, Am, C2D, 3DE, Ad, Cim, T, MCDT, SOU, F, Ar		
Day 4	1	Im, AP, Lab, 3DE, 4DE, Ad, Fa, CC, SOU, Ar	3.50	1.63
	2	Psi, Im, Cim, Am, B, An, Oft, 2D, 2E, C2D, 3DE, 4DE, C4E, UCIP, 5DE, Ad, RH, C, SOU		
	3	B, 3BC, 3DE, C3D, C4D, 4DE, 4BC, Neo, Cim, 1BC, UHGIC, Ad, SOU, F, Ar		
	4	C4D, C3D, C2E, C3E, 3DE, 3BC, Imuno, SU, CPsi, Im, MN, Cim, T, MCDT, Ad, CC, SOU, Aprov, Ar		
Day 5	1	Im, Ar	2.57	1.22
	2	Psi, 3BC, 3DE, 2D, 2C, An, B, Am, C2D, C4D, 4DE, 4BC, 5BC, Im, T, MCDT, CC, F, Ar		
	3	B, SU23, UHGIC, CO, 1DE, 5DE, 4DE, 3BC, MCDT, T, Cim, Fa, SOU, F, Ar		
	4	C4D, C3D, C3E, C2D, 2C, Lab, Cim, T, MCDT, SOU, Ar		

Independent Collection and Delivery Methodology Results with Arquivo as Hub

Table IV.9 - VBA morning collection phase results for arquivo's independent methodology

Day	N^{er}	Morning Collection Phase		
		Route	Total Time	Travel Time
Day 1	1	Hub, 1DE, RO, CO, UHGIC, SO, 1BC, DI, Psi, CPsi, Im, Cim, T, MCDT, Hub	2.89	1.20
	2	Hub, 4DE, C4D, C4E, 4BC, UCIP, BP, Neo, 5BC, C5T, C5F, 5DE, Hub		
	3	Hub, Oft, 2C, 2B, An, Am, B, AP, Lab, Imuno, 3BC, 3DE, C3E, C3D, Hub		
	4	Hub, 2D, 2E, C2D, C2E, CN, TM, RH, Imed, GAIC, Ad, C, Hub		
Day 2	1	Hub, 1DE, RO, CO, UHGIC, SO, 1BC, DI, Psi, CPsi, Im, Cim, T, MCDT, Hub	2.89	1.20
	2	Hub, 4DE, C4D, C4E, 4BC, UCIP, BP, Neo, 5BC, C5T, C5F, 5DE, Hub		
	3	Hub, Oft, 2C, 2B, An, Am, B, AP, Lab, Imuno, 3BC, 3DE, C3E, C3D, Hub		
	4	Hub, 2D, 2E, C2D, C2E, CN, TM, RH, Imed, GAIC, Ad, C, Hub		
Day 3	1	Hub, 1DE, RO, CO, UHGIC, SO, 1BC, DI, Psi, CPsi, Im, Cim, T, MCDT, Hub	2.89	1.20
	2	Hub, 4DE, C4D, C4E, 4BC, UCIP, BP, Neo, 5BC, C5T, C5F, 5DE, Hub		
	3	Hub, Oft, 2C, 2B, An, Am, B, AP, Lab, Imuno, 3BC, 3DE, C3E, C3D, Hub		
	4	Hub, 2D, 2E, C2D, C2E, CN, TM, RH, Imed, GAIC, Ad, C, Hub		
Day 4	1	Hub, 1DE, RO, CO, UHGIC, SO, 1BC, DI, Psi, CPsi, Im, Cim, T, MCDT, Hub	2.89	1.20
	2	Hub, 4DE, C4D, C4E, 4BC, UCIP, BP, Neo, 5BC, C5T, C5F, 5DE, Hub		
	3	Hub, Oft, 2C, 2B, An, Am, B, AP, Lab, Imuno, 3BC, 3DE, C3E, C3D, Hub		
	4	Hub, 2D, 2E, C2D, C2E, CN, TM, RH, Imed, GAIC, Ad, C, Hub		
Day 5	1	Hub, 1DE, RO, CO, UHGIC, SO, 1BC, DI, Psi, CPsi, Im, Cim, T, MCDT	2.89	1.20
	2	Hub, 4DE, C4D, C4E, 4BC, UCIP, BP, Neo, 5BC, C5T, C5F, 5DE, Hub		
	3	Hub, Oft, 2C, 2B, An, Am, B, AP, Lab, Imuno, 3BC, 3DE, C3E, C3D		
	4	Hub, 2D, 2E, C2D, C2E, CN, TM, RH, Imed, GAIC, Ad, C, Hub		

Table IV.10 -VBA morning delivery phase resuts for arquivo's independent methodology

Day	N^er	Morning Delivery Phase		
		Route	Total Time	Travel Time
Day 1	1	Hub, 5DE, C5T, 5BC, Neo, BP, UCIP, 4BC, C4E, C4D, Hub	2.72	1.19
	2	Hub, 2D, C2E, C2D, Am, B, AP, Lab, 3BC, 3DE, C3E, C3D, Hub		
	3	Hub, Cim, MN, Im, SU, 1BC, An, Imuno, 2B, 2C, 2E, Hub		
	4	Hub, F, 1DE, CO, UHGIC, MCDT, T, GAIC, RH, Ad, Fa, C, SOU, Hub		
Day 2	1	Hub, Cim, MN, Im, SU23, Psi, CPsi, 1BC, C2E, C2D, 2E, Hub	2.81	1.21
	2	Hub, 5DE, C5F, C5T, 5BC, Neo, UCIP, 4BC, C4E, C4D, 4DE, 3DE, Hub4DE		
	3	Hub, C3D, C3E, 3BC, Imuno, Lab, B, Am, An, 2B, 2C, UHGIC, CN, CO, 1DE, Hub		
	4	Hub, Ar, F, ADE, TM, RH, GAIC, T, MCDT, Ad, Fa, C, CC, SOU, Aprov, Hub		
Day 3	1	Hub, 5DE, C5F, Neo, BP, 5BC, UCIP, 4BC, C4E, C4D, Hub	2.62	1.15
	2	Hub, 2E, 2D, Oft, 2C, 2B, An, Am, B, Lab, Imuno, 3BC, 4DE, Hub		
	3	Hub, Aprov, CN, CO, 1DE, UHGIC, SO, 1BC, Psi, MN, Cim, T, MCDT, Hub		
	4	Hub, Ar, F, 3DE, C3E, C3D, C2D, TM, RH, Imed, Ad, C, SOU, Hub		
Day 4	1	Hub, 3DE, 4DE, C4D, C4E, 4BC, UCIP, Neo, 5BC, C5T, C5F, 5DE, Hub	2.83	1.23
	2	Hub, 2C, An, Am, B, AP, Lab, Imuno, 3BC, C3E, C3D, C2D, Hub		
	3	Hub, 2E, 2D, C2E, 2B, 1DE, UHGIC, 1BC, Psi, Im, MN, Cim, Hub		
	4	Hub, Ar, F, SOU, C, Fa, Ad, GU, MCDT, T, GAIC, RH, TM, CR, ADE, Hub		
Day 5	1	Hub, MCDT, T, Cim, MN, Psi, CPsi, UCISU, SU, 2D, Hub	2.72	1.22
	2	Hub, Oft, 4BC, UCIP, C4E, BP, Neo, C5F, C5T, C4D, 4DE, Hub		
	3	Hub, 3DE, 3BC, Imuno, Lab, B, Am, An, 2B, 2C, C2E, C2D, Hub		
	4	Hub, Ar, F, 1DE, CN, TM, RH, Imed, GAIC, Ad, Fa, C, CC, SOU, Aprov, Hub		

Table IV.11 - VBA morning collection phase resuts for arquivo's independent methodology

Day	N^{er}	Afternoon Collection Phase: Route	Total Time	Travel Time
Day 1	1	Hub, 1DE, RO, CO, UHGIC, SO, 1BC, DI, Psi, CPsi, Im, Cim, T, MCDT, Hub	2.89	1.20
	2	Hub, 4DE, C4D, C4E, 4BC, UCIP, BP, Neo, 5BC, C5T, C5F, 5DE, Hub		
	3	Hub, Oft, 2C, 2B, An, Am, B, AP, Lab, Imuno, 3BC, 3DE, C3E, C3D, Hub		
	4	Hub, 2D, 2E, C2D, C2E, CN, TM, RH, Imed, GAIC, Ad, C, Hub		
Day 2	1	Hub, 1DE, RO, CO, UHGIC, SO, 1BC, DI, Psi, CPsi, Im, Cim, T, MCDT, Hub	2.89	1.20
	2	Hub, 4DE, C4D, C4E, 4BC, UCIP, BP, Neo, 5BC, C5T, C5F, 5DE, Hub		
	3	Hub, Oft, 2C, 2B, An, Am, B, AP, Lab, Imuno, 3BC, 3DE, C3E, C3D, Hub		
	4	Hub, 2D, 2E, C2D, C2E, CN, TM, RH, Imed, GAIC, Ad, C, Hub		
Day 3	1	Hub, 1DE, RO, CO, UHGIC, SO, 1BC, DI, Psi, CPsi, Im, Cim, T, MCDT, Hub	2.89	1.20
	2	Hub, 4DE, C4D, C4E, 4BC, UCIP, BP, Neo, 5BC, C5T, C5F, 5DE, Hub		
	3	Hub, Oft, 2C, 2B, An, Am, B, AP, Lab, Imuno, 3BC, 3DE, C3E, C3D, Hub		
	4	Hub, 2D, 2E, C2D, C2E, CN, TM, RH, Imed, GAIC, Ad, C, Hub		
Day 4	1	Hub, 1DE, RO, CO, UHGIC, SO, 1BC, DI, Psi, CPsi, Im, Cim, T, MCDT, Hub	2.89	1.20
	2	Hub, 4DE, C4D, C4E, 4BC, UCIP, BP, Neo, 5BC, C5T, C5F, 5DE, Hub		
	3	Hub, Oft, 2C, 2B, An, Am, B, AP, Lab, Imuno, 3BC, 3DE, C3E, C3D, Hub		
	4	Hub, 2D, 2E, C2D, C2E, CN, TM, RH, Imed, GAIC, Ad, C, Hub		
Day 5	1	Hub, 1DE, RO, CO, UHGIC, SO, 1BC, DI, Psi, CPsi, Im, Cim, T, MCDT, Hub	2.89	1.20
	2	Hub, 4DE, C4D, C4E, 4BC, UCIP, BP, Neo, 5BC, C5T, C5F, 5DE, Hub		
	3	Hub, Oft, 2C, 2B, An, Am, B, AP, Lab, Imuno, 3BC, 3DE, C3E, C3D, Hub		
	4	Hub, 2D, 2E, C2D, C2E, CN, TM, RH, Imed, GAIC, Ad, C, Hub		

Table IV.12 - VBA afternoon delivery phase results for arquivo's independent methodology

Day	N^er	Afternoon Delivery Phase Route	Total Time	Travel Time
Day 1	1	Hub, 2C, 2B, An, Am, B, Lab, Imuno, UCIP, Neo, C4E, C4D, 4DE, Hub	2.14	0.98
	2	Hub, Aprov, SOU, Fa, MCDT, T, MN, Im, SU23, Psi, 1BC, UHGIC, CN, CO, 1DE, Hub		
	3	Hub, Ar, F, 2E, C2D, C2E, 2D, 3DE, 4BC, 5DE, Ad, Hub		
	4			
Day 2	1	Hub, Ar, Am, B, An, Lab, Imuno, 4BC, UCIP, 5BC, 5DE, Hub	1.93	0.87
	2	Hub, MCDT, T, Cim, MN, Im, Psi, 1BC, UHGIC, CO, C2E, Hub		
	3	Hub, Aprov, Fa, Ad, 1DE, 2B, Oft, 2D, 3DE, C3E, C4D, C4E, 4DE, Hub		
	4			
Day 3	1	Hub, 2C, 2B, An, Am, B, Lab, 3BC, 4BC, UCIP, Neo, 5BC, Hub	2.09	0.92
	2	Hub, Ar, F, 1DE, UHGIC, Psi, SU23, Cim, T, MCDT, Ad, Fa, SOU, Aprov, Hub		
	3	Hub, 5DE, C5T, C4D, C4E, 4DE, 3DE, C2D, 2E, Oft, 2D, Hub		
	4			
Day 4	1	Hub, 2C, An, Am, B, Lab, Imuno, 3BC, 4BC, UCIP, Neo, 5BC, Hub	2.71	1.14
	2	Hub, 2D, Oft, 2B, UHGIC, 1BC, CPsi, SU, Im, MN, Cim, Hub		
	3	Hub, Ar, 2E, C2D, C2E, C3D, 3DE, 4DE, C4E, C4D, 5DE, Hub		
	4	Hub, F, ADE, TM, RH, GAIC, T, MCDT, Ad, C, CC, SOU, Aprov, Fa, Hub		
Day 5	1	Hub, 2C, 2B, An, Am, B, AP, Lab, Imuno, 3BC, 4BC, UCIP, Neo, 5BC, Hub	2.33	1.10
	2	Hub, 1DE, SU23, Psi, 1BC, UHGIC, CO, 2D, C2D, C3D, C3E, C4D, 4DE, Hub		
	3	Hub, Ar, F, 5DE, Im, MN, Cim, T, MCDT, GAIC, Ad, Fa, CC, SOU, Hub		
	4			

Independent Collection and Delivery Methodology Results with Hub on first floor

Table IV.13 - VBA morning collection phase results for first floor's independent methodology

Day	N^er	Morning Collection Phase Route	Total Time	Travel Time
Day 1	1	Hub, CO, CN, RO, 1DE, 5DE, C5F, C5T, C4D, C4E, BP, Neo, 5BC, Hub	2.73	1.03
	2	Hub, 4DE, 4BC, UCIP, AP, Lab, 3BC, 3DE, C3E, C3D, C2D, C2E, Hub		
	3	Hub, SO, Psi, CPsi, DI, 1BC, B, Am, Imuno, An, 2B, 2C, Oft, 2D, 2E, Hub		
	4	Hub, UHGIC, Im, Cim, T, MCDT, GAIC, Imed, RH, TM, Ad, Ar, C, Hub		
Day 2	1	Hub, CO, CN, RO, 1DE, 5DE, C5F, C5T, C4D, C4E, BP, Neo, 5BC, Hub	2.73	1.03
	2	Hub, 4DE, 4BC, UCIP, AP, Lab, 3BC, 3DE, C3E, C3D, C2D, C2E, Hub		
	3	Hub, SO, Psi, CPsi, DI, 1BC, B, Am, Imuno, An, 2B, 2C, Oft, 2D, 2E, Hub		
	4	Hub, UHGIC, Im, Cim, T, MCDT, GAIC, Imed, RH, TM, Ad, Ar, C, Hub		
Day 3	1	Hub, CO, CN, RO, 1DE, 5DE, C5F, C5T, C4D, C4E, BP, Neo, 5BC, Hub	2.73	1.03
	2	Hub, 4DE, 4BC, UCIP, AP, Lab, 3BC, 3DE, C3E, C3D, C2D, C2E, Hub		
	3	Hub, SO, Psi, CPsi, DI, 1BC, B, Am, Imuno, An, 2B, 2C, Oft, 2D, 2E, Hub		
	4	Hub, UHGIC, Im, Cim, T, MCDT, GAIC, Imed, RH, TM, Ad, Ar, C, Hub		
Day 4	1	Hub, CO, CN, RO, 1DE, 5DE, C5F, C5T, C4D, C4E, BP, Neo, 5BC, Hub	2.73	1.03
	2	Hub, 4DE, 4BC, UCIP, AP, Lab, 3BC, 3DE, C3E, C3D, C2D, C2E, Hub		
	3	Hub, SO, Psi, CPsi, DI, 1BC, B, Am, Imuno, An, 2B, 2C, Oft, 2D, 2E, Hub		
	4	Hub, UHGIC, Im, Cim, T, MCDT, GAIC, Imed, RH, TM, Ad, Ar, C, Hub		
Day 5	1	Hub, CO, CN, RO, 1DE, 5DE, C5F, C5T, C4D, C4E, BP, Neo, 5BC, Hub	2.73	1.03
	2	Hub, 4DE, 4BC, UCIP, AP, Lab, 3BC, 3DE, C3E, C3D, C2D, C2E, Hub		
	3	Hub, SO, Psi, CPsi, DI, 1BC, B, Am, Imuno, An, 2B, 2C, Oft, 2D, 2E, Hub		
	4	Hub, UHGIC, Im, Cim, T, MCDT, GAIC, Imed, RH, TM, Ad, Ar, C, Hub		

Table IV.14 – VBA afternoon delivery phase results for first floor's independent methodology

Day	N^er	Morning Delivery Phase		
		Route	Total Time	Travel Time
Day 1	1	Hub, 5DE, C5T, C4D, C4E, BP, Neo, 5BC, UCIP, 4BC, Hub	2.50	0.97
	2	Hub, AP, Lab, Imuno, 3BC, 3DE, C3E, C3D, C2D, C2E, 2D, 2E, Hub		
	3	Hub, 1BC, Im, MN, Cim, T, MCDT, GAIC, RH, Ad, Fa, C, SOU, Hub		
	4	Hub, UHGIC, CO, 1DE, F, 2C, 2B, An, Am, B, SU, Hub		
Day 2	1	Hub, UHGIC, 4DE, C4E, C4D, C5T, C5F, 5DE, 5BC, Neo, UCIP, 4BC, Hub	2.64	1.04
	2	Hub, 2E, C2E, C3D, C3E, 3DE, 3BC, Imuno, Lab, B, Am, An, 2B, 2C, 1BC, Hub		
	3	Hub, CPsi, Psi, SU23, Im, MN, Cim, T, MCDT, GAIC, RH, ADE, Hub		
	4	Hub, F, Ar, Aprov, SOU, CC, C, Fa, Ad, TM, C2D, CN, CO, 1DE, Hub		
Day 3	1	Hub, Aprov, 5DE, C5F, C4D, 4DE, C4E, BP, Neo, 5BC, UCIP, Hub	2.53	1.06
	2	Hub, 4BC, Lab, Imuno, 3BC, 3DE, C3E, C3D, C2D, 2E, 2D, Oft, Hub		
	3	Hub, MCDT, T, MN, Cim, Imed, RH, TM, Ad, C, SOU, Ar, F, Hub		
	4	Hub, 2C, 2B, An, Am, B, 1BC, Psi, SO, UHGIC, CN, CO, 1DE, Hub		
Day 4	1	Hub, 4DE, C4E, C4D, C5T, 5DE, 5BC, Neo, UCIP, 4BC, 2C, Hub	2.68	1.08
	2	Hub, C2E, C2D, C3D, C3E, 3DE, 3BC, Imuno, Lab, AP, B, Am, An, 2B, Hub		
	3	Hub, ADE, CR, RH, GAIC, Ad, Fa, C, SOU, Ar, F, 2D, 2E, Hub		
	4	Hub, 1DE, C5F, TM, GU, MCDT, T, Cim, MN, Im, Psi, 1BC, UHGIC, Hub		
Day 5	1	Hub, 4BC, UCIP, C4E, BP, Neo, C5F, C5T, 4DE, C4D, C3D, C2E, Hub	2.65	1.11
	2	Hub, UHGIC, 1DE, CN, C2D, 2D, Oft, 3DE, 3BC, Imuno, Lab, An, 2B, 2C, Hub		
	3	Hub, B, Am, SU, UCISU, CPsi, Psi, Imed, Ad, Aprov, Hub		
	4	Hub, Fa, C, CC, SOU, F, Ar, TM, RH, GAIC, MN, Cim, T, MCDT, Hub		

Table IV.15 - VBA afternoon collection phase results for first floor's independent methodology

Day	N^{er}	Afternoon Collection Phase Route	Total Time	Travel Time
Day 1	1	Hub, CO, CN, RO, 1DE, 5DE, C5F, C5T, C4D, C4E, BP, Neo, 5BC, Hub	2.73	1.03
	2	Hub, 4DE, 4BC, UCIP, AP, Lab, 3BC, 3DE, C3E, C3D, C2D, C2E, Hub		
	3	Hub, SO, Psi, CPsi, DI, 1BC, B, Am, Imuno, An, 2B, 2C, Oft, 2D, 2E, Hub		
	4	Hub, UHGIC, Im, Cim, T, MCDT, GAIC, Imed, RH, TM, Ad, Ar, C, Hub		
Day 2	1	Hub, CO, CN, RO, 1DE, 5DE, C5F, C5T, C4D, C4E, BP, Neo, 5BC, Hub	2.73	1.03
	2	Hub, 4DE, 4BC, UCIP, AP, Lab, 3BC, 3DE, C3E, C3D, C2D, C2E, Hub		
	3	Hub, SO, Psi, CPsi, DI, 1BC, B, Am, Imuno, An, 2B, 2C, Oft, 2D, 2E, Hub		
	4	Hub, UHGIC, Im, Cim, T, MCDT, GAIC, Imed, RH, TM, Ad, Ar, C, Hub		
Day 3	1	Hub, CO, CN, RO, 1DE, 5DE, C5F, C5T, C4D, C4E, BP, Neo, 5BC, Hub	2.73	1.03
	2	Hub, 4DE, 4BC, UCIP, AP, Lab, 3BC, 3DE, C3E, C3D, C2D, C2E, Hub		
	3	Hub, SO, Psi, CPsi, DI, 1BC, B, Am, Imuno, An, 2B, 2C, Oft, 2D, 2E, Hub		
	4	Hub, UHGIC, Im, Cim, T, MCDT, GAIC, Imed, RH, TM, Ad, Ar, C, Hub		
Day 4	1	Hub, CO, CN, RO, 1DE, 5DE, C5F, C5T, C4D, C4E, BP, Neo, 5BC, Hub	2.73	1.03
	2	Hub, 4DE, 4BC, UCIP, AP, Lab, 3BC, 3DE, C3E, C3D, C2D, C2E, Hub		
	3	Hub, SO, Psi, CPsi, DI, 1BC, B, Am, Imuno, An, 2B, 2C, Oft, 2D, 2E, Hub		
	4	Hub, UHGIC, Im, Cim, T, MCDT, GAIC, Imed, RH, TM, Ad, Ar, C, Hub		
Day 5	1	Hub, CO, CN, RO, 1DE, 5DE, C5F, C5T, C4D, C4E, BP, Neo, 5BC, Hub	2.73	1.03
	2	Hub, 4DE, 4BC, UCIP, AP, Lab, 3BC, 3DE, C3E, C3D, C2D, C2E, Hub		
	3	Hub, SO, Psi, CPsi, DI, 1BC, B, Am, Imuno, An, 2B, 2C, Oft, 2D, 2E, Hub		
	4	Hub, UHGIC, Im, Cim, T, MCDT, GAIC, Imed, RH, TM, Ad, Ar, C, Hub		

Table IV.16 - VBA afternoon delivery phase results for first floor's independent methodology

Day	N^{er}	Afternoon Delivery Phase: Route	Total Time	Travel Time
Day 1	1	Hub, 5DE, Neo, UCIP, 4BC, C4E, C4D, 4DE, 3DE, Imuno, Lab, Hub	2.07	0.88
	2	Hub, UHGIC, 1DE, F, Ar, Aprov, SOU, Fa, Ad, CO, CN, C2D, C2E, 2D, 2E, Hub		
	3	Hub, MCDT, T, Cim, MN, Im, Psi, 1BC, SU23, B, Am, An, 2B, 2C, Hub		
	4			
Day 2	1	Hub, C2E, 2D, 3DE, C3E, Imuno, Lab, UCIP, 4BC, C4E, C4D, 4DE, Hub	1.93	0.85
	2	Hub, 1DE, Oft, 2B, An, B, Am, 5BC, 5DE, Ar, Aprov, SOU, Hub		
	3	Hub, UHGIC, 1BC, Psi, Im, MN, Cim, T, MCDT, Fa, Ad, CO, Hub		
	4			
Day 3	1	Hub, 4BC, UCIP, Neo, 5BC, 5DE, C5T, C4D, C4E, 4DE, 3DE, Hub	1.98	0.81
	2	Hub, Ad, Fa, SOU, Aprov, Ar, F, 1DE, Psi, SU23, Cim, T, MCDT, Hub		
	3	Hub, UHGIC, 2C, 2B, An, Am, B, Lab, 3BC, Oft, 2D, 2E, C2D, Hub		
	4			
Day 4	1	Hub, C2E, C2D, C3D, 3DE, 3BC, Lab, Imuno, C4E, C4D, 4DE, Hub	2.55	0.98
	2	Hub, 4BC, UCIP, Neo, 5BC, 5DE, F, Ar, Fa, CC, SOU, Aprov, Hub		
	3	Hub, Im, MN, Cim, T, MCDT, GAIC, RH, ADE, TM, Ad, C, Hub		
	4	Hub, UHGIC, 1BC, CPsi, SU, B, Am, An, 2B, 2C, Oft, 2D, 2E, Hub		
Day 5	1	Hub, 5DE, 5BC, Neo, UCIP, 4BC, 4DE, C4D, C3D, C3E, 3DE, 2D, C2D, Hub	2.18	0.91
	2	Hub, UHGIC, 1BC, Psi, SU23, An, Am, B, AP, Lab, Imuno, 3BC, 2B, 2C, Hub		
	3	Hub, Im, MN, Cim, T, MCDT, GAIC, Ad, Fa, CC, SOU, Ar, F, 1DE, CO, Hub		
	4			

Independent Collection and Delivery Methodology Results with Hub on third floor

Table IV.17 - VBA morning collection phase results for third floor's independent methodology

Day	Ner	Morning Collection Phase Route	Total Time	Travel Time
Day 1	1	Hub, 1BC, DI, Psi, CPsi, Im, Cim, T, MCDT, GAIC, Imed, RH, TM, Hub	2.77	1.08
	2	Hub, 4DE, C4D, C4E, 4BC, UCIP, 5BC, BP, Neo, C5F, C5T, 5DE, Hub		
	3	Hub, 2D, C2E, C2D, CN, RO, CO, 1DE, UHGIC, SO, Ad, C, Ar, Hub		
	4	Hub, 2E, Oft, 2C, 2B, An, Am, B, AP, Lab, Imuno, 3BC, C3E, C3D, 3DE, Hub		
Day 2	1	Hub, 1BC, DI, Psi, CPsi, Im, Cim, T, MCDT, GAIC, Imed, RH, TM, Hub	2.77	1.08
	2	Hub, 4DE, C4D, C4E, 4BC, UCIP, 5BC, BP, Neo, C5F, C5T, 5DE, Hub		
	3	Hub, 2D, C2E, C2D, CN, RO, CO, 1DE, UHGIC, SO, Ad, C, Ar, Hub		
	4	Hub, 2E, Oft, 2C, 2B, An, Am, B, AP, Lab, Imuno, 3BC, C3E, C3D, 3DE, Hub		
Day 3	1	Hub, 1BC, DI, Psi, CPsi, Im, Cim, T, MCDT, GAIC, Imed, RH, TM, Hub	2.77	1.08
	2	Hub, 4DE, C4D, C4E, 4BC, UCIP, 5BC, BP, Neo, C5F, C5T, 5DE, Hub		
	3	Hub, 2D, C2E, C2D, CN, RO, CO, 1DE, UHGIC, SO, Ad, C, Ar, Hub		
	4	Hub, 2E, Oft, 2C, 2B, An, Am, B, AP, Lab, Imuno, 3BC, C3E, C3D, 3DE, Hub		
Day 4	1	Hub, 1BC, DI, Psi, CPsi, Im, Cim, T, MCDT, GAIC, Imed, RH, TM, Hub	2.77	1.08
	2	Hub, 4DE, C4D, C4E, 4BC, UCIP, 5BC, BP, Neo, C5F, C5T, 5DE, Hub		
	3	Hub, 2D, C2E, C2D, CN, RO, CO, 1DE, UHGIC, SO, Ad, C, Ar, Hub		
	4	Hub, 2E, Oft, 2C, 2B, An, Am, B, AP, Lab, Imuno, 3BC, C3E, C3D, 3DE, Hub		
Day 5	1	Hub, 1BC, DI, Psi, CPsi, Im, Cim, T, MCDT, GAIC, Imed, RH, TM, Hub	2.77	1.08
	2	Hub, 4DE, C4D, C4E, 4BC, UCIP, 5BC, BP, Neo, C5F, C5T, 5DE, Hub		
	3	Hub, 2D, C2E, C2D, CN, RO, CO, 1DE, UHGIC, SO, Ad, C, Ar, Hub		
	4	Hub, 2E, Oft, 2C, 2B, An, Am, B, AP, Lab, Imuno, 3BC, C3E, C3D, 3DE, Hub		

Table IV.18 - VBA morning delivery phase results for third floor's independent methodology

Day	N^{er}	Morning Delivery Phase Route	Total Time	Travel Time
Day 1	1	Hub, C3E, CO, MCDT, T, Cim, MN, Im, SU, 1BC, UHGIC, 2E, Hub	2.52	0.99
	2	Hub, 3BC, 4BC, UCIP, BP, Neo, 5BC, 5DE, C5T, C4D, C4E, Hub		
	3	Hub, 3DE, C3D, F, SOU, C, Fa, Ad, RH, GAIC, 1DE, Hub		
	4	Hub, C2D, C2E, 2D, 2C, 2B, An, Am, B, AP, Lab, Imuno, Hub		
Day 2	1	Hub, TM, ADE, RH, GAIC, MCDT, T, Cim, MN, Im, Psi, CPsi, Hub	2.65	1.05
	2	Hub, F, Ar, Aprov, SOU, CC, C, Fa, Ad, CO, CN, C2E, C2D, 2E, Hub		
	3	Hub, C3E, C3D, C4D, C4E, 4DE, 4BC, UCIP, 5BC, Neo, C5F, C5T, 5DE, Hub		
	4	Hub, 1DE, UHGIC, 1BC, SU23, 2C, 2B, An, Am, B, Lab, Imuno, 3BC, 3DE, Hub		
Day 3	1	Hub, TM, RH, Imed, MCDT, T, Cim, MN, Psi, 1BC, SO, Hub	2.51	1.04
	2	Hub, 4DE, C4D, C4E, 4BC, UCIP, 5BC, BP, Neo, C5F, 5DE, Hub		
	3	Hub, 2D, C2D, CN, CO, 1DE, UHGIC, Aprov, SOU, C, Ad, Ar, F, Hub		
	4	Hub, 2E, Oft, 2C, 2B, An, Am, B, Lab, Imuno, 3BC, C3D, C3E, 3DE, Hub		
Day 4	1	Hub, Psi, Im, MN, Cim, T, MCDT, GU, GAIC, ADE, CR, Hub	2.66	1.06
	2	Hub, 5DE, C5T, C5F, Neo, 5BC, UCIP, 4BC, 4DE, C4E, C4D, C3D, C3E, Hub		
	3	Hub, 2D, 2E, C2D, C2E, TM, RH, Ad, Fa, C, SOU, Ar, F, Hub		
	4	Hub, 3DE, 3BC, Imuno, Lab, AP, B, Am, An, 2C, 2B, 1BC, UHGIC, 1DE, Hub		
Day 5	1	Hub, CPsi, Psi, UCISU, SU, MN, Cim, MCDT, Ar, F, Hub	2.64	1.15
	2	Hub, 3DE, 3BC, Imuno, UCIP, 4BC, C4E, BP, Neo, C5F, C5T, C4D, 4DE, Hub		
	3	Hub, 2D, C2D, TM, RH, Imed, GAIC, Aprov, SOU, CC, C, Fa, Ad, Hub		
	4	Hub, 1DE, T, CN, C2E, Oft, 2C, 2B, An, Am, B, Lab, Hub		

Table IV.19 - VBA afternoon collection phase results for third floor's independent methodology

Day	N^{er}	Afternoon Collection Phase Route	Total Time	Travel Time
Day 1	1	Hub, 1BC, DI, Psi, CPsi, Im, Cim, T, MCDT, GAIC, Imed, RH, TM, Hub	2.77	1.08
	2	Hub, 4DE, C4D, C4E, 4BC, UCIP, 5BC, BP, Neo, C5F, C5T, 5DE, Hub		
	3	Hub, 2D, C2E, C2D, CN, RO, CO, 1DE, UHGIC, SO, Ad, C, Ar, Hub		
	4	Hub, 2E, Oft, 2C, 2B, An, Am, B, AP, Lab, Imuno, 3BC, C3E, C3D, 3DE, Hub		
Day 2	1	Hub, 1BC, DI, Psi, CPsi, Im, Cim, T, MCDT, GAIC, Imed, RH, TM, Hub	2.77	1.08
	2	Hub, 4DE, C4D, C4E, 4BC, UCIP, 5BC, BP, Neo, C5F, C5T, 5DE, Hub		
	3	Hub, 2D, C2E, C2D, CN, RO, CO, 1DE, UHGIC, SO, Ad, C, Ar, Hub		
	4	Hub, 2E, Oft, 2C, 2B, An, Am, B, AP, Lab, Imuno, 3BC, C3E, C3D, 3DE, Hub		
Day 3	1	Hub, 1BC, DI, Psi, CPsi, Im, Cim, T, MCDT, GAIC, Imed, RH, TM, Hub	2.77	1.08
	2	Hub, 4DE, C4D, C4E, 4BC, UCIP, 5BC, BP, Neo, C5F, C5T, 5DE, Hub		
	3	Hub, 2D, C2E, C2D, CN, RO, CO, 1DE, UHGIC, SO, Ad, C, Ar, Hub		
	4	Hub, 2E, Oft, 2C, 2B, An, Am, B, AP, Lab, Imuno, 3BC, C3E, C3D, 3DE, Hub		
Day 4	1	Hub, 1BC, DI, Psi, CPsi, Im, Cim, T, MCDT, GAIC, Imed, RH, TM, Hub	2.77	1.08
	2	Hub, 4DE, C4D, C4E, 4BC, UCIP, 5BC, BP, Neo, C5F, C5T, 5DE, Hub		
	3	Hub, 2D, C2E, C2D, CN, RO, CO, 1DE, UHGIC, SO, Ad, C, Ar, Hub		
	4	Hub, 2E, Oft, 2C, 2B, An, Am, B, AP, Lab, Imuno, 3BC, C3E, C3D, 3DE, Hub		
Day 5	1	Hub, 1BC, DI, Psi, CPsi, Im, Cim, T, MCDT, GAIC, Imed, RH, TM, Hub	2.77	1.08
	2	Hub, 4DE, C4D, C4E, 4BC, UCIP, 5BC, BP, Neo, C5F, C5T, 5DE, Hub		
	3	Hub, 2D, C2E, C2D, CN, RO, CO, 1DE, UHGIC, SO, Ad, C, Ar, Hub		
	4	Hub, 2E, Oft, 2C, 2B, An, Am, B, AP, Lab, Imuno, 3BC, C3E, C3D, 3DE, Hub		

Table IV.20 - VBA afternoon delivery phase results for third floor's independent methodology

Day	N^er	Afternoon Delivery Phase Route	Total Time	Travel Time
Day 1	1	Hub, UHGIC, 1BC, Psi, SU23, Im, MN, T, MCDT, Aprov, SOU, Fa, Ad, Hub	2.06	0.90
	2	Hub, 5DE, Neo, UCIP, 4BC, Imuno, Lab, B, Am, An, 2B, 2C, Hub		
	3	Hub, 3DE, C4E, C4D, 4DE, F, Ar, 1DE, CO, CN, C2E, C2D, 2E, 2D, Hub		
	4			
Day 2	1	Hub, Ad, Fa, MCDT, T, Cim, MN, Im, Psi, 1BC, UHGIC, Hub	1.88	0.83
	2	Hub, 2D, C2E, C3E, 2B, An, Am, B, Lab, Imuno, 5BC, 5DE, Hub		
	3	Hub, 3DE, 4BC, UCIP, C4E, C4D, 4DE, Ar, Aprov, CO, 1DE, Oft, Hub		
	4			
Day 3	1	Hub, F, Ar, Aprov, SOU, Fa, Ad, MCDT, T, Cim, SU23, Psi, Hub	2.03	0.86
	2	Hub, 3DE, 2D, 5DE, C5T, 5BC, Neo, UCIP, 4BC, C4E, C4D, 4DE, Hub		
	3	Hub, 1DE, UHGIC, C2D, 2E, Oft, 2C, 2B, An, Am, B, Lab, 3BC, Hub		
	4			
Day 4	1	Hub, GAIC, MCDT, T, Cim, MN, Im, SU, CPsi, UHGIC, Hub	0.67	2.59
	2	Hub, F, Ar, Aprov, SOU, CC, C, Fa, Ad, RH, ADE, TM, C2D, Hub		
	3	Hub, 4DE, C4E, C4D, 5DE, 5BC, Neo, UCIP, 4BC, Imuno, C3D, 3DE, Hub		
	4	Hub, 2D, 2E, C2E, Oft, 2C, 2B, 1BC, An, Am, B, Lab, 3BC, Hub		
Day 5	1	Hub, GAIC, MCDT, T, Cim, MN, Im, SU23, Psi, Hub	2.29	1.06
	2	Hub, C3D, Imuno, 4BC, UCIP, Neo, 5BC, 5DE, C4D, 4DE, Hub		
	3	Hub, C3E, 3BC, Lab, AP, B, Am, An, 2C, 2B, 1DE, 2D, Hub		
	4	Hub, C2D, CO, UHGIC, 1BC, SOU, CC, Fa, Ad, Ar, F, Hub		

Integrated Collection and Delivery Methodology Results with Arquivo as Hub

Table IV.21 - VBA collection phase results for arquivo's integrated methodology

Day	N^er	Collection Phase		
		Route	Total Time	Travel Time
Day 1	1	Hub, 1DE, RO, CO, UHGIC, SO, 1BC, DI, Psi, CPsi, Im, Cim, T, MCDT, Hub	2.89	1.20
	2	Hub, 4DE, C4D, C4E, 4BC, UCIP, BP, Neo, 5BC, C5T, C5F, 5DE, Hub		
	3	Hub, Oft, 2C, 2B, An, Am, B, AP, Lab, Imuno, 3BC, 3DE, C3E, C3D, Hub		
	4	Hub, 2D, 2E, C2D, C2E, CN, TM, RH, Imed, GAIC, Ad, C, Hub		
Day 2	1	Hub, 1DE, RO, CO, UHGIC, SO, 1BC, DI, Psi, CPsi, Im, Cim, T, MCDT, Hub	2.89	1.20
	2	Hub, 4DE, C4D, C4E, 4BC, UCIP, BP, Neo, 5BC, C5T, C5F, 5DE, Hub		
	3	Hub, Oft, 2C, 2B, An, Am, B, AP, Lab, Imuno, 3BC, 3DE, C3E, C3D, Hub		
	4	Hub, 2D, 2E, C2D, C2E, CN, TM, RH, Imed, GAIC, Ad, C, Hub		
Day 3	1	Hub, 1DE, RO, CO, UHGIC, SO, 1BC, DI, Psi, CPsi, Im, Cim, T, MCDT, Hub	2.89	1.20
	2	Hub, 4DE, C4D, C4E, 4BC, UCIP, BP, Neo, 5BC, C5T, C5F, 5DE, Hub		
	3	Hub, Oft, 2C, 2B, An, Am, B, AP, Lab, Imuno, 3BC, 3DE, C3E, C3D, Hub		
	4	Hub, 2D, 2E, C2D, C2E, CN, TM, RH, Imed, GAIC, Ad, C, Hub		
Day 4	1	Hub, 1DE, RO, CO, UHGIC, SO, 1BC, DI, Psi, CPsi, Im, Cim, T, MCDT, Hub	2.89	1.20
	2	Hub, 4DE, C4D, C4E, 4BC, UCIP, BP, Neo, 5BC, C5T, C5F, 5DE, Hub		
	3	Hub, Oft, 2C, 2B, An, Am, B, AP, Lab, Imuno, 3BC, 3DE, C3E, C3D, Hub		
	4	Hub, 2D, 2E, C2D, C2E, CN, TM, RH, Imed, GAIC, Ad, C, Hub		
Day 5	1	Hub, 1DE, RO, CO, UHGIC, SO, 1BC, DI, Psi, CPsi, Im, Cim, T, MCDT, Hub	2.89	1.20
	2	Hub, 4DE, C4D, C4E, 4BC, UCIP, BP, Neo, 5BC, C5T, C5F, 5DE, Hub		
	3	Hub, Oft, 2C, 2B, An, Am, B, AP, Lab, Imuno, 3BC, 3DE, C3E, C3D, Hub		
	4	Hub, 2D, 2E, C2D, C2E, CN, TM, RH, Imed, GAIC, Ad, C, Hub		

Table IV.22 - VBA integrated phase results for arquivo's integrated methodology

Day	N^{er}	Integrated Phase: Route	Total Time	Travel Time
Day 1	1	Hub, Ad, UHGIC, SO, 1BC, CPsi, Psi, DI, SU, Im, MN, Cim, T, MCDT, Hub	3.11	1.27
	2	Hub, 5DE, C5F, C5T, 5BC, Neo, BP, UCIP, 4BC, C4E, C4D, 4DE, F, Hub		
	3	Hub, Ar, C3D, C3E, 3DE, 3BC, Imuno, Lab, AP, B, Am, An, 2B, 2C, Oft, 1DE, Hub		
	4	Hub, 2D, 2E, C2D, C2E, CO, RO, CN, TM, RH, Imed, GAIC, Fa, C, SOU, Hub		
Day 2	1	Hub, MCDT, T, Cim, MN, Im, SU23, CPsi, Psi, DI, 1BC, SO, UHGIC, CO, CN, RO, 1DE, Hub	3.18	1.29
	2	Hub, 3DE, 4DE, C4D, C4E, 4BC, UCIP, BP, Neo, 5BC, C5T, C5F, 5DE, Hub		
	3	Hub, 2E, 2D, Oft, 2C, 2B, An, Am, B, AP, Lab, Imuno, 3BC, C3E, C3D, C2E, Hub		
	4	Hub, Aprov, SOU, CC, C, Fa, Ad, GAIC, Imed, RH, ADE, TM, C2D, F, Ar, Hub		
Day 3	1	Hub, MCDT, T, Cim, MN, Im, CPsi, Psi, DI, 1BC, SO, UHGIC, CO, CN, RO, 1DE, Hub	3.01	1.26
	2	Hub, 5DE, C5F, C5T, 5BC, Neo, BP, UCIP, 4BC, C4E, C4D, 4DE, Hub		
	3	Hub, F, C3D, C3E, 3DE, 3BC, Imuno, Lab, AP, B, Am, An, 2B, 2C, 2D, Hub		
	4	Hub, Ar, Oft, 2E, C2D, C2E, TM, RH, Imed, GAIC, Ad, C, SOU, Aprov, Hub		
Day 4	1	Hub, 1DE, RO, CO, UHGIC, SO, 1BC, DI, Psi, CPsi, Im, MN, Cim, T, MCDT, GU, Hub	3.09	1.25
	2	Hub, Ar, 5DE, C5F, C5T, 5BC, Neo, BP, UCIP, 4BC, C4E, C4D, 4DE, Hub		
	3	Hub, C3D, C3E, 3DE, 3BC, Imuno, Lab, AP, B, Am, An, 2B, 2C, Oft, 2D, 2E, Hub		
	4	Hub, SOU, C, Fa, Ad, GAIC, RH, ADE, CR, TM, CN, C2D, C2E, F, Hub		
Day 5	1	Hub, Ar, DI, Psi, CPsi, SU, UCISU, 1BC, SO, UHGIC, RO, 1DE, Hub	2.76	1.48
	2	Hub, 5DE, C5F, C5T, 5BC, Neo, BP, UCIP, 4BC, C4E, C4D, 4DE, Hub		
	3	Hub, C3D, C3E, 3DE, 3BC, Imuno, Lab, AP, B, Am, An, 2B, 2C, Hub		
	4	Hub, 2D, Oft, 2E, C2D, C2E, CN, CO, MN, Im, Cim, T, Hub		

Table IV.23 - VBA delivery phase results for arquivo's integrated methodology

Day	N^er	Delivery Phase Route	Total Time	Travel Time
Day 1	1	Hub, 2C, 2B, An, Am, B, Lab, Imuno, UCIP, Neo, C4E, C4D, 4DE, Hub	2.14	0.98
	2	Hub, Aprov, SOU, Fa, MCDT, T, MN, Im, SU23, Psi, 1BC, UHGIC, CN, CO, 1DE, Hub		
	3	Hub, Ar, F, 2E, C2D, C2E, 2D, 3DE, 4BC, 5DE, Ad, Hub		
	4			
Day 2	1	Hub, Ar, Am, B, An, Lab, Imuno, 4BC, UCIP, 5BC, 5DE, Hub	1.93	0.87
	2	Hub, MCDT, T, Cim, MN, Im, Psi, 1BC, UHGIC, CO, C2E, Hub		
	3	Hub, Aprov, Fa, Ad, 1DE, 2B, Oft, 2D, 3DE, C3E, C4D, C4E, 4DE, Hub		
	4			
Day 3	1	Hub, 2C, 2B, An, Am, B, Lab, 3BC, 4BC, UCIP, Neo, 5BC, Hub	2.09	0.92
	2	Hub, Ar, F, 1DE, UHGIC, Psi, SU23, Cim, T, MCDT, Ad, Fa, SOU, Aprov, Hub		
	3	Hub, 5DE, C5T, C4D, C4E, 4DE, 3DE, C2D, 2E, Oft, 2D, Hub		
	4			
Day 4	1	Hub, 2C, An, Am, B, Lab, Imuno, 3BC, 4BC, UCIP, Neo, 5BC, Hub	2.71	1.14
	2	Hub, 2D, Oft, 2B, UHGIC, 1BC, CPsi, SU, Im, MN, Cim, Hub		
	3	Hub, Ar, 2E, C2D, C2E, C3D, 3DE, 4DE, C4E, C4D, 5DE, Hub		
	4	Hub, F, ADE, TM, RH, GAIC, T, MCDT, Ad, C, CC, SOU, Aprov, Fa		
Day 5	1	Hub, 2C, 2B, An, Am, B, AP, Lab, Imuno, 3BC, 4BC, UCIP, Neo, 5BC	2.33	1.10
	2	Hub, 1DE, SU23, Psi, 1BC, UHGIC, CO, 2D, C2D, C3D, C3E, C4D, 4DE, Hub		
	3	Hub, Ar, F, 5DE, Im, MN, Cim, T, MCDT, GAIC, Ad, Fa, CC, SOU		
	4			

Integrated Collection and Delivery Methodology Results with Hub on first floor

Table IV.24 - VBA collection phase results for first floor's integrated methodology

Day	N^er	Collection Phase Route	Total Time	Travel Time
Day 1	1	Hub, CO, CN, RO, 1DE, 5DE, C5F, C5T, C4D, C4E, BP, Neo, 5BC, Hub	2.73	1.03
	2	Hub, 4DE, 4BC, UCIP, AP, Lab, 3BC, 3DE, C3E, C3D, C2D, C2E, Hub		
	3	Hub, SO, Psi, CPsi, DI, 1BC, B, Am, Imuno, An, 2B, 2C, Oft, 2D, 2E, Hub		
	4	Hub, UHGIC, Im, Cim, T, MCDT, GAIC, Imed, RH, TM, Ad, Ar, C, Hub		
Day 2	1	Hub, CO, CN, RO, 1DE, 5DE, C5F, C5T, C4D, C4E, BP, Neo, 5BC, Hub	2.73	1.03
	2	Hub, 4DE, 4BC, UCIP, AP, Lab, 3BC, 3DE, C3E, C3D, C2D, C2E, Hub		
	3	Hub, SO, Psi, CPsi, DI, 1BC, B, Am, Imuno, An, 2B, 2C, Oft, 2D, 2E, Hub		
	4	Hub, UHGIC, Im, Cim, T, MCDT, GAIC, Imed, RH, TM, Ad, Ar, C, Hub		
Day 3	1	Hub, CO, CN, RO, 1DE, 5DE, C5F, C5T, C4D, C4E, BP, Neo, 5BC, Hub	2.73	1.03
	2	Hub, 4DE, 4BC, UCIP, AP, Lab, 3BC, 3DE, C3E, C3D, C2D, C2E, Hub		
	3	Hub, SO, Psi, CPsi, DI, 1BC, B, Am, Imuno, An, 2B, 2C, Oft, 2D, 2E, Hub		
	4	Hub, UHGIC, Im, Cim, T, MCDT, GAIC, Imed, RH, TM, Ad, Ar, C, Hub		
Day 4	1	Hub, CO, CN, RO, 1DE, 5DE, C5F, C5T, C4D, C4E, BP, Neo, 5BC, Hub	2.73	1.03
	2	Hub, 4DE, 4BC, UCIP, AP, Lab, 3BC, 3DE, C3E, C3D, C2D, C2E, Hub		
	3	Hub, SO, Psi, CPsi, DI, 1BC, B, Am, Imuno, An, 2B, 2C, Oft, 2D, 2E, Hub		
	4	Hub, UHGIC, Im, Cim, T, MCDT, GAIC, Imed, RH, TM, Ad, Ar, C, Hub		
Day 5	1	Hub, CO, CN, RO, 1DE, 5DE, C5F, C5T, C4D, C4E, BP, Neo, 5BC, Hub	2.73	1.03
	2	Hub, 4DE, 4BC, UCIP, AP, Lab, 3BC, 3DE, C3E, C3D, C2D, C2E, Hub		
	3	Hub, SO, Psi, CPsi, DI, 1BC, B, Am, Imuno, An, 2B, 2C, Oft, 2D, 2E, Hub		
	4	Hub, UHGIC, Im, Cim, T, MCDT, GAIC, Imed, RH, TM, Ad, Ar, C, Hub		

Table IV.25 - VBA integrated phase results for first floor's integrated methodology

Day	N^er	Integrated Phase Route	Total Time	Travel Time
Day 1	1	Hub, 5BC, Neo, BP, C4E, 4DE, C4D, C5T, C5F, 5DE, RO, CN, CO, UHGIC, Hub	2.96	1.13
	2	Hub, 4BC, UCIP, AP, Lab, Imuno, 3BC, 3DE, C3E, C3D, C2D, C2E, 2D, 1DE, Hub		
	3	Hub, SO, 1BC, CPsi, Psi, DI, SU, B, Am, An, 2B, 2C, Oft, 2E, Hub		
	4	Hub, Im, MN, Cim, T, MCDT, GAIC, Imed, RH, TM, Ad, C, Fa, Ar, F, Hub		
Day 2	1	Hub, 2C, 2B, Am, B, An, 5BC, Neo, BP, C4E, C4D, C5T, C5F, 5DE, Hub	3.03	1.14
	2	Hub, 4DE, 4BC, UCIP, AP, Lab, Imuno, 3BC, 3DE, C3E, C3D, C2D, C2E, Oft, Hub		
	3	Hub, Ad, Fa, C, CC, SOU, Aprov, Ar, F, 2E, 2D, 1BC, DI, Psi, CPsi, SU23, Hub		
	4	Hub, MCDT, T, Cim, Im, MN, GAIC, TM, ADE, RH, Imed, RO, CN, CO, 1DE, UHGIC, SO, Hub		
Day 3	1	Hub, 2B, An, Am, B, Imuno, 5BC, Neo, BP, C4E, C4D, C5T, C5F, 5DE, Hub	2.88	1.13
	2	Hub, 1DE, 4DE, 4BC, UCIP, AP, Lab, 3BC, 3DE, C3E, C3D, C2D, C2E, Hub		
	3	Hub, CO, CN, RO, Cim, Psi, CPsi, DI, 1BC, SO, UHGIC, 2C, Oft, 2D, 2E, Hub		
	4	Hub, Im, MN, T, MCDT, GAIC, Imed, RH, TM, Ad, C, SOU, Aprov, Ar, F, Hub		
Day 4	1	Hub, 2C, 2B, Am, B, An, 5BC, Neo, BP, C4E, C4D, C5T, C5F, 5DE, Hub	2.99	1.12
	2	Hub, 4DE, 4BC, UCIP, AP, Lab, Imuno, 3BC, 3DE, C3E, C3D, C2D, C2E, Oft, Hub		
	3	Hub, 2E, 2D, F, Ar, Fa, C, Ad, CN, 1DE, Psi, CPsi, DI, 1BC, Hub		
	4	Hub, Im, MN, Cim, T, MCDT, GU, GAIC, Imed, RH, TM, ADE, CR, RO, CO, UHGIC, SO, Hub		
Day 5	1	Hub, 2B, 5BC, Neo, BP, C4E, 4DE, C4D, C5T, C5F, 5DE, Hub	3.12	1.21
	2	Hub, 4BC, UCIP, AP, Lab, Imuno, 3BC, 3DE, C3E, C3D, C2D, C2E, Hub		
	3	Hub, CPsi, Psi, DI, UCISU, SU, B, Am, An, 2C, Oft, Hub		
	4	Hub, 1DE, CO, CN, RO, Imed, Ad, C, Fa, Ar, F, 2D, 2E, Hub		

Table IV.26 - VBA delivery phase results for first floor's integrated methodology

Day	N^er	Delivery Phase: Route	Total Time	Travel Time
Day 1	1	Hub, 5DE, Neo, UCIP, 4BC, C4E, C4D, 4DE, 3DE, Imuno, Lab, Hub	2.07	0.88
	2	Hub, UHGIC, 1DE, F, Ar, Aprov, SOU, Fa, Ad, CO, CN, C2D, C2E, 2D, 2E, Hub		
	3	Hub, MCDT, T, Cim, MN, Im, Psi, 1BC, SU23, B, Am, An, 2B, 2C, Hub		
	4			
Day 2	1	Hub, C2E, 2D, 3DE, C3E, Imuno, Lab, UCIP, 4BC, C4E, C4D, 4DE, Hub	1.93	0.85
	2	Hub, 1DE, Oft, 2B, An, B, Am, 5BC, 5DE, Ar, Aprov, SOU, Hub		
	3	Hub, UHGIC, 1BC, Psi, Im, MN, Cim, T, MCDT, Fa, Ad, CO, Hub		
	4			
Day 3	1	Hub, 4BC, UCIP, Neo, 5BC, 5DE, C5T, C4D, C4E, 4DE, 3DE, Hub	1.98	0.81
	2	Hub, Ad, Fa, SOU, Aprov, Ar, F, 1DE, Psi, SU23, Cim, T, MCDT, Hub		
	3	Hub, UHGIC, 2C, 2B, An, Am, B, Lab, 3BC, Oft, 2D, 2E, C2D, Hub		
	4			
Day 4	1	Hub, C2E, C2D, C3D, 3DE, 3BC, Lab, Imuno, C4E, C4D, 4DE, Hub	2.55	0.98
	2	Hub, 4BC, UCIP, Neo, 5BC, 5DE, F, Ar, Fa, CC, SOU, Aprov, Hub		
	3	Hub, Im, MN, Cim, T, MCDT, GAIC, RH, ADE, TM, Ad, C, Hub		
	4	Hub, UHGIC, 1BC, CPsi, SU, B, Am, An, 2B, 2C, Oft, 2D, 2E, Hub		
Day 5	1	Hub, 5DE, 5BC, Neo, UCIP, 4BC, 4DE, C4D, C3D, C3E, 3DE, 2D, C2D, Hub	2.18	0.91
	2	Hub, UHGIC, 1BC, Psi, SU23, An, Am, B, AP, Lab, Imuno, 3BC, 2B, 2C, Hub		
	3	Hub, Im, MN, Cim, T, MCDT, GAIC, Ad, Fa, CC, SOU, Ar, F, 1DE, CO, Hub		
	4			

Integrated Collection and Delivery Methodology Results with Hub on third floor

Table IV.27 - VBA collection phase results for third floor's integrated methodology

Day	Ner	Collection Phase Route	Total Time	Travel Time
Day 1	1	Hub, 1BC, DI, Psi, CPsi, Im, Cim, T, MCDT, GAIC, Imed, RH, TM, Hub	2.77	1.08
	2	Hub, 4DE, C4D, C4E, 4BC, UCIP, 5BC, BP, Neo, C5F, C5T, 5DE, Hub		
	3	Hub, 2D, C2E, C2D, CN, RO, CO, 1DE, UHGIC, SO, Ad, C, Ar, Hub		
	4	Hub, 2E, Oft, 2C, 2B, An, Am, B, AP, Lab, Imuno, 3BC, C3E, C3D, 3DE, Hub		
Day 2	1	Hub, 1BC, DI, Psi, CPsi, Im, Cim, T, MCDT, GAIC, Imed, RH, TM, Hub	2.77	1.08
	2	Hub, 4DE, C4D, C4E, 4BC, UCIP, 5BC, BP, Neo, C5F, C5T, 5DE, Hub		
	3	Hub, 2D, C2E, C2D, CN, RO, CO, 1DE, UHGIC, SO, Ad, C, Ar, Hub		
	4	Hub, 2E, Oft, 2C, 2B, An, Am, B, AP, Lab, Imuno, 3BC, C3E, C3D, 3DE, Hub		
Day 3	1	Hub, 1BC, DI, Psi, CPsi, Im, Cim, T, MCDT, GAIC, Imed, RH, TM, Hub	2.77	1.08
	2	Hub, 4DE, C4D, C4E, 4BC, UCIP, 5BC, BP, Neo, C5F, C5T, 5DE, Hub		
	3	Hub, 2D, C2E, C2D, CN, RO, CO, 1DE, UHGIC, SO, Ad, C, Ar, Hub		
	4	Hub, 2E, Oft, 2C, 2B, An, Am, B, AP, Lab, Imuno, 3BC, C3E, C3D, 3DE, Hub		
Day 4	1	Hub, 1BC, DI, Psi, CPsi, Im, Cim, T, MCDT, GAIC, Imed, RH, TM, Hub	2.77	1.08
	2	Hub, 4DE, C4D, C4E, 4BC, UCIP, 5BC, BP, Neo, C5F, C5T, 5DE, Hub		
	3	Hub, 2D, C2E, C2D, CN, RO, CO, 1DE, UHGIC, SO, Ad, C, Ar, Hub		
	4	Hub, 2E, Oft, 2C, 2B, An, Am, B, AP, Lab, Imuno, 3BC, C3E, C3D, 3DE, Hub		
Day 5	1	Hub, 1BC, DI, Psi, CPsi, Im, Cim, T, MCDT, GAIC, Imed, RH, TM, Hub	2.77	1.08
	2	Hub, 4DE, C4D, C4E, 4BC, UCIP, 5BC, BP, Neo, C5F, C5T, 5DE, Hub		
	3	Hub, 2D, C2E, C2D, CN, RO, CO, 1DE, UHGIC, SO, Ad, C, Ar, Hub		
	4	Hub, 2E, Oft, 2C, 2B, An, Am, B, AP, Lab, Imuno, 3BC, C3E, C3D, 3DE, Hub		

Table IV.28 - VBA integrated phase results for third floor's integrated methodology

Day	Ner	Integrated Phase		
		Route	Total Time	Travel Time
Day 1	1	Hub, SO, 1BC, DI, Psi, CPsi, SU, Im, MN, Cim, T, MCDT, GAIC, Hub	3.06	1.22
	2	Hub, C3E, 3DE, 5DE, C5T, C5F, Neo, BP, 5BC, UCIP, 4BC, C4E, C4D, 4DE, Hub		
	3	Hub, Oft, 1DE, UHGIC, CO, RO, CN, TM, RH, Imed, Ad, Fa, C, SOU, Ar, F, Hub		
	4	Hub, 2D, 2E, C2D, C2E, 2C, 2B, An, Am, B, Lab, AP, Imuno, 3BC, C3D, Hub		
Day 2	1	Hub, 1DE, UHGIC, SO, 1BC, CPsi, Psi, DI, SU23, Im, MN, Cim, T, MCDT, GAIC, Hub	3.00	1.12
	2	Hub, 3DE, C3D, C4D, 4DE, C5T, C5F, 5DE, 5BC, Neo, BP, C4E, UCIP, 4BC, Hub		
	3	Hub, F, Ar, Aprov, SOU, CC, C, Fa, Ad, TM, ADE, RH, Imed, RO, CN, CO, 2D, Hub		
	4	Hub, 2E, C2D, C2E, Oft, 2C, 2B, An, Am, B, Lab, AP, Imuno, 3BC, C3E, Hub		
Day 3	1	Hub, 1BC, DI, Psi, CPsi, Im, MN, Cim, T, MCDT, GAIC, Imed, RH, TM, Hub	2.90	1.15
	2	Hub, C4D, C4E, 4BC, UCIP, 5BC, BP, Neo, C5F, C5T, 5DE, 2E, 2D, Hub		
	3	Hub, 3DE, C2D, CN, RO, CO, 1DE, UHGIC, SO, Ad, C, SOU, Aprov, Ar, F, Hub		
	4	Hub, 3BC, Imuno, AP, Lab, B, Am, An, 2B, 2C, Oft, C2E, C3E, C3D, 4DE, Hub		
Day 4	1	Hub, F, Ar, GU, MCDT, T, Cim, MN, Im, CPsi, Psi, DI, 1BC, SO, UHGIC, Hub	2.99	1.15
	2	Hub, C3E, 3DE, 5DE, C5T, C5F, Neo, BP, 5BC, UCIP, 4BC, C4E, C4D, 4DE, Hub		
	3	Hub, Oft, 1DE, CO, RO, CN, TM, ADE, CR, RH, GAIC, SOU, C, Fa, Ad, Hub		
	4	Hub, C3D, 3BC, Imuno, AP, Lab, B, Am, An, 2B, 2C, C2E, C2D, 2E, 2D, Hub		
Day 5	1	Hub, 1BC, DI, Psi, CPsi, UCISU, SU, Im, MN, Cim, T, MCDT, GAIC, Hub	3.12	1.21
	2	Hub, 3DE, C3D, C4D, C4E, 4DE, 4BC, UCIP, 5BC, BP, Neo, C5F, C5T, 5DE, Hub		
	3	Hub, F, Ar, Aprov, SOU, CC, C, Fa, Ad, TM, RH, Imed, RO, CN, CO, SO, UHGIC, 1DE, Hub		
	4	Hub, 2D, 2E, C2D, C2E, Oft, 2C, 2B, An, Am, B, Lab, AP, Imuno, 3BC, C3E, Hub		

Table IV.29 - VBA delivery phase results for third floor's integrated methodology

Day	N[er]	Delivery Phase: Route	Total Time	Travel Time
Day 1	1	Hub, UHGIC, 1BC, Psi, SU23, Im, MN, T, MCDT, Aprov, SOU, Fa, Ad, Hub	2.06	0.90
	2	Hub, 5DE, Neo, UCIP, 4BC, Imuno, Lab, B, Am, An, 2B, 2C, Hub		
	3	Hub, 3DE, C4E, C4D, 4DE, F, Ar, 1DE, CO, CN, C2E, C2D, 2E, 2D, Hub		
	4			
Day 2	1	Hub, Ad, Fa, MCDT, T, Cim, MN, Im, Psi, 1BC, UHGIC, Hub	1.88	0.83
	2	Hub, 2D, C2E, C3E, 2B, An, Am, B, Lab, Imuno, 5BC, 5DE, Hub		
	3	Hub, 3DE, 4BC, UCIP, C4E, C4D, 4DE, Ar, Aprov, CO, 1DE, Oft, Hub		
	4			
Day 3	1	Hub, F, Ar, Aprov, SOU, Fa, Ad, MCDT, T, Cim, SU23, Psi, Hub	2.03	0.86
	2	Hub, 3DE, 2D, 5DE, C5T, 5BC, Neo, UCIP, 4BC, C4E, C4D, 4DE, Hub		
	3	Hub, 1DE, UHGIC, C2D, 2E, Oft, 2C, 2B, An, Am, B, Lab, 3BC, Hub		
	4			
Day 4	1	Hub, GAIC, MCDT, T, Cim, MN, Im, SU, CPsi, UHGIC, Hub	2.59	1.02
	2	Hub, F, Ar, Aprov, SOU, CC, C, Fa, Ad, RH, ADE, TM, C2D, Hub		
	3	Hub, 4DE, C4E, C4D, 5DE, 5BC, Neo, UCIP, 4BC, Imuno, C3D, 3DE, Hub		
	4	Hub, 2D, 2E, C2E, Oft, 2C, 2B, 1BC, An, Am, B, Lab, 3BC, Hub		
Day 5	1	Hub, GAIC, MCDT, T, Cim, MN, Im, SU23, Psi, Hub	2.29	1.06
	2	Hub, C3D, Imuno, 4BC, UCIP, Neo, 5BC, 5DE, C4D, 4DE, Hub		
	3	Hub, C3E, 3BC, Lab, AP, B, Am, An, 2C, 2B, 1DE, 2D, Hub		
	4	Hub, C2D, CO, UHGIC, 1BC, SOU, CC, Fa, Ad, Ar, F, Hub		

Fixed and Flexible Routes Methodology Results with Arquivo as Hub

Table IV.30 - VBA resuts for arquivo's fixed and flexible routes methodology

Day	Route Type	N^er	Route	Total Time	Travel Time
Day 1	Fixed Route	1	Hub, 1DE, RO, CO, UHGIC, SO, 1BC, DI, Psi, CPsi, Im, Cim, T, MCDT, Hub	3.70	1.75
		2	Hub, 4DE, C4D, C4E, 4BC, UCIP, BP, Neo, 5BC, C5T, C5F, 5DE, Hub		
		3	Hub, Oft, 2C, 2B, An, Am, B, AP, Lab, Imuno, 3BC, 3DE, C3E, C3D, Hub		
		4	Hub, 2D, 2E, C2D, C2E, CN, TM, RH, Imed, GAIC, Ad, C, Hub		
	Flexible Route	Morning	Hub, F, SU, SU23, MN, Fa, SOU, Hub		
		Afternoon	Hub, F, Aprov, SOU, Fa, SU23, MN, Hub		
Day 2	Fixed Route	1	Hub, 1DE, RO, CO, UHGIC, SO, 1BC, DI, Psi, CPsi, Im, Cim, T, MCDT, Hub	3.53	1.59
		2	Hub, 4DE, C4D, C4E, 4BC, UCIP, BP, Neo, 5BC, C5T, C5F, 5DE, Hub		
		3	Hub, Oft, 2C, 2B, An, Am, B, AP, Lab, Imuno, 3BC, 3DE, C3E, C3D, Hub		
		4	Hub, 2D, 2E, C2D, C2E, CN, TM, RH, Imed, GAIC, Ad, C, Hub		
	Flexible Route	Morning	Hub, F, ADE, MN, Fa, CC, SOU, Hub		
		Afternoon	Hub, MN, Fa, SOU, Hub		
Day 3	Fixed Route	1	Hub, 1DE, RO, CO, UHGIC, SO, 1BC, DI, Psi, CPsi, Im, Cim, T, MCDT, Hub	3.53	1.66
		2	Hub, 4DE, C4D, C4E, 4BC, UCIP, BP, Neo, 5BC, C5T, C5F, 5DE, Hub		
		3	Hub, Oft, 2C, 2B, An, Am, B, AP, Lab, Imuno, 3BC, 3DE, C3E, C3D, Hub		
		4	Hub, 2D, 2E, C2D, C2E, CN, TM, RH, Imed, GAIC, Ad, C, Hub		
	Flexible Route	Morning	Hub, F, MN, SOU, Hub		
		Afternoon	Hub, F, SU, SU23, SOU, Fa, Hub		
Day 4	Fixed Route	1	Hub, 1DE, RO, CO, UHGIC, SO, 1BC, DI, Psi, CPsi, Im, Cim, T, MCDT, Hub	3.28	1.43
		2	Hub, 4DE, C4D, C4E, 4BC, UCIP, BP, Neo, 5BC, C5T, C5F, 5DE, Hub		
		3	Hub, Oft, 2C, 2B, An, Am, B, AP, Lab, Imuno, 3BC, 3DE, C3E, C3D, Hub		
		4	Hub, 2D, 2E, C2D, C2E, CN, TM, RH, Imed, GAIC, Ad, C, Hub		
	Flexible Route	Morning	Hub, SOU, Fa, MN, CR, ADE, F, Hub		
		Afternoon	Hub, F, Fa, CC, SOU, SU, MN, Hub		
Day 5	Fixed Route	1	Hub, 1DE, RO, CO, UHGIC, SO, 1BC, DI, Psi, CPsi, Im, Cim, T, MCDT, Hub	3.72	1.72
		2	Hub, 4DE, C4D, C4E, 4BC, UCIP, BP, Neo, 5BC, C5T, C5F, 5DE, Hub		
		3	Hub, Oft, 2C, 2B, An, Am, B, AP, Lab, Imuno, 3BC, 3DE, C3E, C3D, Hub		
		4	Hub, 2D, 2E, C2D, C2E, CN, TM, RH, Imed, GAIC, Ad, C, Hub		
	Flexible Route	Morning	Hub, F, SU, UCISU, MN, Fa, CC, SOU, Hub		
		Afternoon	Hub, Fa, CC, SOU, SU23, F, Hub		

Fixed and Flexible Routes Methodology Results with Hub on first floor

Table IV.31 - VBA resuts for first floor's fixed and flexible routes methodology

Day	Route Type	N^er	Route	Total Time	Travel Time
Day 1	Fixed Route	1	Hub, CO, CN, RO, 1DE, 5DE, C5F, C5T, C4D, C4E, BP, Neo, 5BC, Hub	3.51	1.56
		2	Hub, 4DE, 4BC, UCIP, AP, Lab, 3BC, 3DE, C3E, C3D, C2D, C2E, Hub		
		3	Hub, SO, Psi, CPsi, DI, 1BC, B, Am, Imuno, An, 2B, 2C, Oft, 2D, 2E, Hub		
		4	Hub, UHGIC, Im, Cim, T, MCDT, GAIC, Imed, RH, TM, Ad, Ar, C, Hub		
	Flexible Route	Morning	Hub, SU23, SU, MN, Fa, SOU, F, Hub		
		Afternoon	Hub, F, Aprov, SOU, Fa, MN, SU23, Hub		
Day 2	Fixed Route	1	Hub, CO, CN, RO, 1DE, 5DE, C5F, C5T, C4D, C4E, BP, Neo, 5BC, Hub	3.34	1.39
		2	Hub, 4DE, 4BC, UCIP, AP, Lab, 3BC, 3DE, C3E, C3D, C2D, C2E, Hub		
		3	Hub, SO, Psi, CPsi, DI, 1BC, B, Am, Imuno, An, 2B, 2C, Oft, 2D, 2E, Hub		
		4	Hub, UHGIC, Im, Cim, T, MCDT, GAIC, Imed, RH, TM, Ad, Ar, C, Hub		
	Flexible Route	Morning	Hub, MN, ADE, F, Fa, CC, SOU, Hub		
		Afternoon	Hub, MN, Fa, SOU, Hub		
Day 3	Fixed Route	1	Hub, CO, CN, RO, 1DE, 5DE, C5F, C5T, C4D, C4E, BP, Neo, 5BC, Hub	3.35	1.47
		2	Hub, 4DE, 4BC, UCIP, AP, Lab, 3BC, 3DE, C3E, C3D, C2D, C2E, Hub		
		3	Hub, SO, Psi, CPsi, DI, 1BC, B, Am, Imuno, An, 2B, 2C, Oft, 2D, 2E, Hub		
		4	Hub, UHGIC, Im, Cim, T, MCDT, GAIC, Imed, RH, TM, Ad, Ar, C, Hub		
	Flexible Route	Morning	Hub, MN, SOU, F, Hub		
		Afternoon	Hub, SU23, SU, Fa, SOU, F, Hub		
Day 4	Fixed Route	1	Hub, CO, CN, RO, 1DE, 5DE, C5F, C5T, C4D, C4E, BP, Neo, 5BC, Hub	3.13	1.27
		2	Hub, 4DE, 4BC, UCIP, AP, Lab, 3BC, 3DE, C3E, C3D, C2D, C2E, Hub		
		3	Hub, SO, Psi, CPsi, DI, 1BC, B, Am, Imuno, An, 2B, 2C, Oft, 2D, 2E, Hub		
		4	Hub, UHGIC, Im, Cim, T, MCDT, GAIC, Imed, RH, TM, Ad, Ar, C, Hub		
	Flexible Route	Morning	Hub, F, SOU, Fa, CR, ADE, MN, Hub		
		Afternoon	Hub, F, SOU, CC, Fa, MN, SU, Hub		
Day 5	Fixed Route	1	Hub, CO, CN, RO, 1DE, 5DE, C5F, C5T, C4D, C4E, BP, Neo, 5BC, Hub	3.53	1.52
		2	Hub, 4DE, 4BC, UCIP, AP, Lab, 3BC, 3DE, C3E, C3D, C2D, C2E, Hub		
		3	Hub, SO, Psi, CPsi, DI, 1BC, B, Am, Imuno, An, 2B, 2C, Oft, 2D, 2E, Hub		
		4	Hub, UHGIC, Im, Cim, T, MCDT, GAIC, Imed, RH, TM, Ad, Ar, C, Hub		
	Flexible Route	Morning	Hub, UCISU, SU, MN, Fa, CC, SOU, F, Hub		
		Afternoon	Hub, SU23, F, Fa, CC, SOU, Hub		

Fixed and Flexible Routes Methodology Results with Hub on third floor

Table IV.32 - VBA resuts for third floor's fixed and flexible routes methodology

Day	Route Type	N^{er}	Route	Total Time	Travel Time
Day 1	Fixed Route	1	Hub, 1BC, DI, Psi, CPsi, Im, Cim, T, MCDT, GAIC, Imed, RH, TM, Hub	3.64	1.69
		2	Hub, 4DE, C4D, C4E, 4BC, UCIP, 5BC, BP, Neo, C5F, C5T, 5DE, Hub		
		3	Hub, 2D, C2E, C2D, CN, RO, CO, 1DE, UHGIC, SO, Ad, C, Ar, Hub		
		4	Hub, 2E, Oft, 2C, 2B, An, Am, B, AP, Lab, Imuno, 3BC, C3E, C3D, 3DE, Hub		
	Flexible Route	Morning	Hub, F, SOU, Fa, MN, SU23, SU, Hub		
		Afternoon	Hub, F, Aprov, SOU, Fa, MN, SU23, Hub		
Day 2	Fixed Route	1	Hub, 1BC, DI, Psi, CPsi, Im, Cim, T, MCDT, GAIC, Imed, RH, TM, Hub	3.52	1.57
		2	Hub, 4DE, C4D, C4E, 4BC, UCIP, 5BC, BP, Neo, C5F, C5T, 5DE, Hub		
		3	Hub, 2D, C2E, C2D, CN, RO, CO, 1DE, UHGIC, SO, Ad, C, Ar, Hub		
		4	Hub, 2E, Oft, 2C, 2B, An, Am, B, AP, Lab, Imuno, 3BC, C3E, C3D, 3DE, Hub		
	Flexible Route	Morning	Hub, MN, ADE, Fa, CC, SOU, F, Hub		
		Afternoom	Hub, Fa, SOU, MN, Hub		
Day 3	Fixed Route	1	Hub, 1BC, DI, Psi, CPsi, Im, Cim, T, MCDT, GAIC, Imed, RH, TM, Hub	3.48	1.60
		2	Hub, 4DE, C4D, C4E, 4BC, UCIP, 5BC, BP, Neo, C5F, C5T, 5DE, Hub		
		3	Hub, 2D, C2E, C2D, CN, RO, CO, 1DE, UHGIC, SO, Ad, C, Ar, Hub		
		4	Hub, 2E, Oft, 2C, 2B, An, Am, B, AP, Lab, Imuno, 3BC, C3E, C3D, 3DE, Hub		
	Flexible Route	Morning	Hub, MN, SOU, F, Hub		
		Afternoom	Hub, SU23, SU, SOU, Fa, F, Hub		
Day 4	Fixed Route	1	Hub, 1BC, DI, Psi, CPsi, Im, Cim, T, MCDT, GAIC, Imed, RH, TM, Hub	3.21	1.35
		2	Hub, 4DE, C4D, C4E, 4BC, UCIP, 5BC, BP, Neo, C5F, C5T, 5DE, Hub		
		3	Hub, 2D, C2E, C2D, CN, RO, CO, 1DE, UHGIC, SO, Ad, C, Ar, Hub		
		4	Hub, 2E, Oft, 2C, 2B, An, Am, B, AP, Lab, Imuno, 3BC, C3E, C3D, 3DE, Hub		
	Flexible Route	Morning	Hub, F, SOU, Fa, CR, ADE, MN, Hub		
		Afternoom	Hub, SU, MN, Fa, CC, SOU, F, Hub		
Day 5	Fixed Route	1	Hub, 1BC, DI, Psi, CPsi, Im, Cim, T, MCDT, GAIC, Imed, RH, TM, Hub	3.66	1.65
		2	Hub, 4DE, C4D, C4E, 4BC, UCIP, 5BC, BP, Neo, C5F, C5T, 5DE, Hub		
		3	Hub, 2D, C2E, C2D, CN, RO, CO, 1DE, UHGIC, SO, Ad, C, Ar, Hub		
		4	Hub, 2E, Oft, 2C, 2B, An, Am, B, AP, Lab, Imuno, 3BC, C3E, C3D, 3DE, Hub		
	Flexible Route	Morning	Hub, F, SOU, CC, Fa, MN, UCISU, SU, Hub		
		Afternoom	Hub, SU23, SOU, CC, Fa, F, Hub		