Air versus Land Vehicle Decisions for Interfacility Air Medical Transport

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A thesis submitted in conformity with the requirements
for the degree of Master of Applied Science

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Abstract

In emergency medical transport, "time to definite care" is very important. In the setting of a trauma patient, this time interval is referred to as "the golden hour" in recognition that transport to a designated trauma centre positively impacts patient outcome. The same is true for other time-sensitive conditions such as acute myocardial infarction, acute ischemic stroke, and sepsis. Emergency medical services and transport medicine agencies have several possible vehicle options for interfacility transfers. Use of a land vehicle, helicopter, or fixed wing aircraft will be dependent on patient condition, distance between sending and receiving hospitals, crew configuration and capabilities, and other factors such as weather and road conditions.

This thesis lays out the complex process of patient transfers and highlights the challenges in decision making under time pressure; it then describes the behaviour of human operators in estimating time to definite care. Analysis of a historical dataset on

interfacility transfers revealed that time to definite care estimates deviate significantly from observed times; in particular, transfers involving an air leg were found to be highly underestimated.

In order to support the operators in choosing a transportation mode, a decision support tool was built, which provides relevant time estimates for interfacility transfers based on historical dispatch and call data. The goal is to enable operators to make evidence-based decisions on vehicle allocation.

The design requirements for the tool were identified through interviews with the end-users and field observations. The process was first split into subcomponents based on how the operations are conducted and time estimates for each interval was then generated based on historical data. Algorithms were then developed to aggregate the estimates of each interval and determine transfer times for all combinations of sending and receiving facilities. Finally, a prototype interface was generated and was evaluated through a usability study.

Acknowledgment

I would like to express my deepest appreciation to my supervisors, Dr. Birsen Donmez and Dr. Russell MacDonald, for providing me with the opportunity to work on this project, and for their invaluable assistance, support and guidance during this work. I especially would like to thank Dr. Donmez for her time and attention in editing this thesis, and Dr. MacDonald for motivating me and helping me to complete this thesis in a timely manner. I would also like to thank Mahvareh Ahghari for her extensive support in providing all the necessary information and requirements regarding this project. It has been a pleasure working with all of you, and I appreciate all the insight you have provided me.

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Many thanks to all the Ornge operations managers, transport medicine physicians, communications officers, the pilots and paramedics of Toronto Island, Timmins and Markham bases for taking the time to speak with me, walk me through the task process, and answer my questions. Special thanks to Mark Repic and Donald Bradley for all the support and assistance during my field observations and interviews at the Ornge communications centre (OCC).

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I would like to dedicate this thesis to my beloved parents and brothers for their understanding, endless patience and encouragement when it was most required.

Arsham Fatahi
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Chapter 1

Introduction

1.1 Transport Medicine

Transport medicine is about delivering specialized care in a mobile environment, which has become a key component of healthcare in many countries throughout the world. In Canada, patient transfers between facilities or between facilities and a specialty care resource have increased as a result of regionalization, specialization, and facility designation. Further, air medical transport services are playing an increasingly important role in transport medicine systems, by moving patients safely and swiftly throughout the country [1].

The comprehensive process involved before, during, and after moving a patient from one location to another is called a patient transfer. Meeting patient needs and maintaining continuity of care are important issues related to patient transfers. Personnel who provide care are highly trained, familiar with the associated demands of land and air transport, legally authorized to perform these skills, and prepared to handle the variety of patient contingencies that may arise during transport [2].

Patients can be picked up from a trauma scene or transferred from one facility to another due to a lack of resources in the former. The trauma scene responses are generally emergent, requiring immediate response, whereas interfacility transfers can be emergent, urgent, or non-urgent. Building and maintaining highly specialized healthcare personnel, equipment, and services (e.g., stroke centres, cardiac centres, trauma centres, and high-risk obstetrics) are more expensive than those provided for a general level of care. Integration and regionalization avoids redundancy and promotes the most efficient use of these resources [2]. The care delivery model, where centres of excellence concentrate expertise in a small number of centres, requires patients with potentially time-sensitive or unstable conditions to be transferred from one facility to another in order to access care. The risks versus benefits of interfacility transfers have been reviewed [3], and there is evidence to support the regionalized care model.

1.2 Mode of Transport

Dispatch plays a significant role for medical transport systems: receiving and analyzing transport requests, and assigning proper medical personnel and equipment to these requests [4]. The goal of dispatch is to match patient needs with adequate provider knowledge and skills, as well as equipment that provide seamless patient flow during transport. Transport medicine agencies may select from multiple vehicle types (i.e., fixed-wing aircraft, helicopter, and land ambulances), and a multi-specialty team (e.g., physicians, planners, operation managers) can select from the various vehicles depending on patient and transport factors. Therefore, there must be a high-level medical and planning oversight in a transport medicine dispatch centre to select appropriate modes of transportation.

There is this perception that provision of air medical transport compared to land transport results in better benefits to the patients and/or regions. The putative explanation for improved outcome is the increment in speed afforded by the air transport vehicle. However, there is continued debate surrounding the use of air transport compared to land transport. The appropriateness of air medical transport can be judged only in light of a given patient's status; temporal, regional, and logistic considerations are also necessary.

For example, a patient with an amputation of a dominant thumb may require helicopter or fixed-wing evacuation from an offshore island or remote wilderness area; conversely, a patient with severe vehicular trauma occurring within or near city limits may be best served by land transport [5].

One important criterion in selecting transportation type for time-sensitive patients, is “time to definite care”, defined as the time interval from when the call is received in the dispatch centre to the time the patient arrives at the receiving hospital. In the setting of a trauma patient, this time interval is referred to as “the golden hour” in recognition that transport to a designated trauma centre positively impacts patient outcome. The same is true for other time-sensitive conditions such as acute myocardial infarction [6, 7], acute ischemic stroke [8], and sepsis.

There are also other time related variables that a travel planner or physician may take into consideration when deciding the mode of transportation for interfacility transfers. These variables include “time to patient’s bed at the sending facility” and “patient out-of-hospital time”. Time to patient’s bed at the sending facility (also known as time to sending facility) refers to the amount of time that it takes for paramedics to arrive at the patient’s bed at the sending facility. This variable is important especially for patients who require a higher level of care that is not available at the sending hospital but can be provided by the transport medicine team. Patient out-of-hospital time refers to the amount of time that it takes to transfer the patient from his bed in the sending facility to his bed in the receiving facility. This variable is important especially for patients who are critically ill, and require being in a stable environment with a higher level of care [1].

Time-critical interfacility transfers are often faster when serviced with a helicopter compared to a land ambulance [9], but this is not universally the case. While transport by air may appear to be faster than land transportation, transport by air requires additional steps. These steps include aviation factors such as flight planning, aircraft rollout and start-up, and air traffic control limitations. Air transport also includes the potential for multiple patient transfers between vehicles if there is a land ambulance leg required between an airport and a hospital. Furthermore, due to resource limitations and costs, the aircraft are located in a few dedicated locations so they can provide services to more facilities; however, the land bases are often located in many more different locations. Thus compared to land ambulances, the aircraft in general need to travel greater distances to the sending facilities. Each of these factors may offset the faster travel times provided by aircraft. Thus, there is a clear need for evidence-based estimates of transfer times for different transportation modes, which have to be compared for informed decision making.

Given the multiple factors affecting transfer times, accurate estimation of transfer time can be a challenge for medical transport decisions makers. Despite this challenge, supporting transport mode decisions has not received much attention from the research community. For example, [10] developed simple deterministic decision rules for trauma scene responses based on averages obtained from historical data from a single hospital. However, these decision rules did not capture the variability that is inherent in the process. [9] examined 145 cases in a comparison between air and land transport times in interfacility medical transfers, and found that helicopter transport was always faster than land transport. However, the authors only examined transfers between 20 hospitals and an intensive care unit at the University of Wisconsin and the generalizability of these findings to other cases is still an open research question. Overall, there is still very little research done in this area, especially regarding how medical dispatchers can make use of historical data to refine their transport decisions in time-critical situations, which is a characteristic of the domain. The effect of time pressure on decision making will be described in the following section.

1.3 An Introduction to Decision Making under Time Pressure

Emergencies in general, require actions under risk and time constraints, which are imposed on the responders by the environment and thus are largely out of the decision makers' control. The onset of an emergency usually creates a need for action that is timely as when in a triage situation when patients are needed to be sorted immediately into those who need critical attention and those with less serious injuries. All of these factors contribute to the need for response personnel to manage the situation and make quick decisions with resources that are or can be made available within the limited time that is allotted. Decision making in these situations involves making judgments under uncertain and time-limited conditions [11].

Time-pressure reduces the quality of decision making when humans have to acquire and process information from multiple sources [12]. In terms of information acquisition, research has shown that humans tend to cope with time-pressed situations in different ways [13]. Humans may use acceleration, which is attending to all information sources at a faster rate, which in turn may cause errors due to temporary overload of working memory and/or processing capacity. Another strategy is filtration, i.e., gathering only the subjectively important information. Earlier studies on decision making and judgment under time pressure indicate increased importance given to negative evidence [14]. Overall, time pressure makes individuals switch to simpler decision-making strategies [15].

The need to process large amounts of information in a short period of time has a definite impact on the decision process and the decision quality. Decisions made without sufficient thought may lead to poor results. Decision-making involves a delicate balance between the competing demands of response speed and choice accuracy, a balance that is usually referred to as the speed–accuracy trade-off [16]. In the cognitive sciences, this trade-off is thought to be modulated by a response threshold that determines the amount of diagnostic information that is required to make a decision and initiate an action [16]. Because the accumulation of diagnostic information takes time, high response thresholds lead to accurate, yet slow decisions, and low response thresholds lead to fast, yet error-prone decisions [17].

Other research in bet acceptance tasks [18], in the accuracy of choice responses [19], and in military attack simulations [20] have found that individuals perform significantly worse under time pressure. Furthermore, researchers have found an inverse relationship between the amount of time spent to deliberate on a decision and an individual's confidence in that decision [21].

The role of decision support tools and information systems is to counteract the negative impact of time pressure on decision strategy selection and performance. Decision support tools for dynamic ambulance relocation and automatic ambulance dispatching are examples of the systems that are optimized for speed of decision making [22]. These tools utilize a measure for preparedness, which is a way of evaluating the ability to serve current and future calls anywhere in the area. Tools for simulating ambulance operations are other examples used for evaluating strategic decisions, such as where to locate ambulance stations or how large the ambulance fleet should be. There are also simulation tools for training of ambulance dispatchers to make quick decisions [22].

Given the uncertainties associated with emergency situations and the time-critical nature of patient transfers, accurate estimation of transfer times and the associated transport mode decisions can be a challenge for medical transport decisions makers. However, as stated previously, very little research has been conducted in the area of supporting transport mode decisions. Therefore, this thesis lays out the process of developing a decision support tool aimed to support transport mode decisions, in particular, for Ornge, Ontario's air medical transport provider. This tool provides relevant time estimates for interfacility emergent/urgent transfers generated based on historical dispatch and call data. The goal is to enable operators to make evidence-based decisions for vehicle type selection.

1.4 Thesis Organization and Phases of Research

The process of patient transfers in Ontario's air medical transport system, Ornge, will be laid out in Chapter 2. This information was collected through field observations, and review of Ornge documents. The behaviour of human operators in estimating time to definite care was assessed through the analysis of a historical dataset on interfacility transfers. The results of this analysis will be discussed in Chapter 3. In order to support the operators in choosing the transportation mode, a decision support tool was created, which provides relevant time estimates for interfacility transfers based on large historical dispatch and call data. The method used for managing, and analyzing the historical data (i.e., modular design) will be discussed in Chapter 4. Chapter 5 will describe the design requirements for the tool identified through interviews with end-users, field observations, and statistical analyses. Underlying algorithms used for generating relevant time estimates will be presented in Chapter 6. The results of a usability study conducted to evaluate the preliminary prototype interface will be described in Chapter 7. Chapter 8 will provide a discussion of the findings of this thesis and suggestions for future research.

Chapter 2

Air Medical Transport System in Ontario

2.1 General Information

Ornge is a non-profit organization that provides air and land critical care medical transportation for ill and critically injured patients in Ontario. The province of Ontario has a total area of 1,076,395 km², which is an area the size of France, Spain, and the Netherlands combined. Due to the vast size of Ontario, Ornge plays a significant role in ensuring that medical care is accessible to all residents of the province. Accessibility to health services is one of the five key principles in the Canada Health Act of 1977 [23].

As the sole provider for air and land critical care transport medicine services in Ontario, this service performed approximately 81,000 interfacility patient transfers and 7,000 on-scene responses in the five-year interval between 2007 and 2011. Interfacility patient transfers and on-scene responses were the most common medical transport services provided (Table 2-1). Among them, emergent and urgent interfacility transfers were the most common and are the focus of this thesis.

Table 2-1 Ornge General Information

	On-scene Responses	Inter-facility Transfers
Transfers in Ontario, Canada 2007-2011	7,000 Transfers	81,000 Transfers
Call Types	• Emergent & Urgent	• Emergent & Urgent (63%) • Non-urgent (37%)
Vehicle Types	• Helicopter	• Helicopter • Fixed-wing Aircraft • Land Vehicle

Interfacility transfers typically occur when the patients require a higher level of care that is not available at the sending hospital. Such transfers can be divided into emergent (time-sensitive, immediate threat to life – 42%), urgent (stable but risk for deterioration or threat to life or limb – 21%), or non-urgent (acute but non-urgent, where transfer can safely be deferred – 37%). For this type of transfer, Ornge utilizes one or more of the following vehicle types: helicopters, fixed-wing aircraft, and land vehicles.

Anytime an interfacility emergency response is initiated that meets the criteria for possible air transport, a sending facility notifies Ornge that its service may be needed. Currently, it is the responsibility of the sending facility and Ornge operators to determine if air transport is needed or not.

Ornge also responds to on-scene calls. The goal of on-scene responses is to quickly transport trauma patients from an accident scene to a provincial trauma centre or patients suffering from time-sensitive or potentially life-threatening conditions to a centre of excellence where air transport decreases the time to definite care. All Ornge on-scene responses are carried out via helicopter. Thus, Ornge dispatch does not have to make a transport mode decision for on-scene responses.

Anytime an on-scene emergency response is initiated that meets the criteria for possible air transport, the local dispatch centre notifies Ornge that its service may be needed. It is the responsibility of the land EMS dispatchers and paramedics to determine if air transport is needed or not and relay that information to 911, who in turn contacts Ornge. The EMS land crew decides that patient care should be turned over to the Ornge flight crew if it deems it necessary to transport the patient by air [24].

The focus of this thesis is on emergent and urgent interfacility transfers which are the most common type of transfers at Ornge, and require a transport mode decision.

2.2 Field Observations and Interviews

Ornge transport medicine service consists of two active divisions: a communications centre (or dispatch) and the ambulance bases (air and/or land).

A team of medical and transport experts operate the communications centre where the transport requests are received (by phone, fax, or online), analyzed, and assigned to the proper medical personnel and equipment. The communications centre includes an operations manager (physically present), a transport medicine physician (can work remotely), travel planners (physically present), and medical analysts (physically present). A team of paramedics and pilots operate the ambulance bases. In order to get familiar with these divisions multiple field observations and interviews were conducted. Most of the knowledge on Ornge operations presented in this thesis is gained through these observations and the review of internal Ornge documents.

2.2.1 Interviews and Shadowing of Ornge Communications Centre (OCC) Staff

As mentioned before, the purpose of this research was to design a computer-based decision support tool for improved decision making at Ornge Communications Centre (OCC). The design of an effective user interface required an understanding of the users, their needs, and their tasks. During the first three months, the author spent two day shifts a week at the OCC, and conducted multiple interviews with trip planners, medical analysts, transport medicine physicians, and operation managers at the OCC. These interviews helped the author to better understand the users' tasks, their decision making strategies, and terminologies. These interviews also helped the author to get familiar with the data tracking systems used at the Ornge Communications Centre and select the appropriate datasets for analysis. In general, most of the end-users expected an easy to use and simple to understand tool that would allow them to perform fast comparisons between land and air scenarios without interrupting their routine activities. Most of them had sufficient knowledge of using Excel and interpreting basic statistical graphs. The other findings from OCC interviews will be discussed in the upcoming sections.

2.2.2 Interviews and Shadowing of Ornge Paramedics

The author also shadowed paramedics in three Ornge bases (2 day shifts in each base): Toronto Rotor-wing Base (Figure 2-1 and Figure 2-2), Greater Toronto Area (GTA) Land Base and Timmins Fixed-wing Base (Figure 2-3) to get familiar with the transport process and the origins of the data from which the tool is built.

Figure 2-1 Toronto Rotor-wing Base (Photo by Author)

In general, most paramedics believed that too many factors were required to be taken into account in order to accurately estimate time to definite care. However, only a few of these factors are tracked and recorded. The paramedics also believed that their data entry during patient transfers is accurate. However, some inconsistencies in their terminologies were observed. For example, one paramedic believed that if a facility has a helipad on the roof then the time for "arrive pick-up site" should be recorded as the same as the time for "arrive patient site"; while according to the definitions and guidelines, "arrive pick-up site" refers to the time the helicopter lands on the pick-up site and "arrive patient site" refers to the time the paramedics get to the patient's bedside.

Figure 2-2 Toronto Rotor-wing Base (Photos by Author)

Figure 2-3 Timmins Fixed-wing Base (Photos by Author)

2.3 Ornge Transport Medicine Team

As per the Ambulance Act, the Ornge Communications Centre (OCC) provides coordination and communication services to air and land ambulance dispatch centres. Unlike Emergency Medical Services (EMS), Ornge is not accessible to the public through a public access emergency number, i.e., 911. At the request of a local ambulance dispatch centre, Ornge ambulances (especially air ambulances) will be deployed to the scene of an accident or a remote area of Ontario [1].

Table 2-2 shows the names, locations and vehicle types of the dedicated Ornge bases as of September 2012. Some bases operate multiple modes of transportation and some operate only one mode. For example, Ottawa base might transfer patients either by land or rotor-wing aircraft, but the only mode of transportation for Timmins base is fixed-wing aircraft. Currently, dedicated land bases are located in southern Ontario, fixed-wing aircraft are located in northern Ontario, and rotor-wing aircraft are in southern and northern Ontario. Figure 2-4 shows the locations of dedicated Ornge bases.

Table 2-2 Ornge Base Providers

Base	Vehicle Type	Location
GTA (Greater Toronto Area)	Land	South West
Kenora	Rotor	North West
London	Rotor	South West
Moosonee	Rotor	North East
Ottawa	Rotor	South East
Ottawa Land	Land	South East
Paediatric Unit	Land	South West
Peterborough	Land	South West
Sioux Lookout	Fixed	North West
Sudbury	Rotor	North East
Thunder Bay	Rotor	North West
Thunder Bay Primary	Fixed	North West
Thunder Bay Secondary	Fixed	North West
Timmins	Fixed	North East
Toronto Primary	Rotor	South West
Toronto Secondary	Rotor	South West

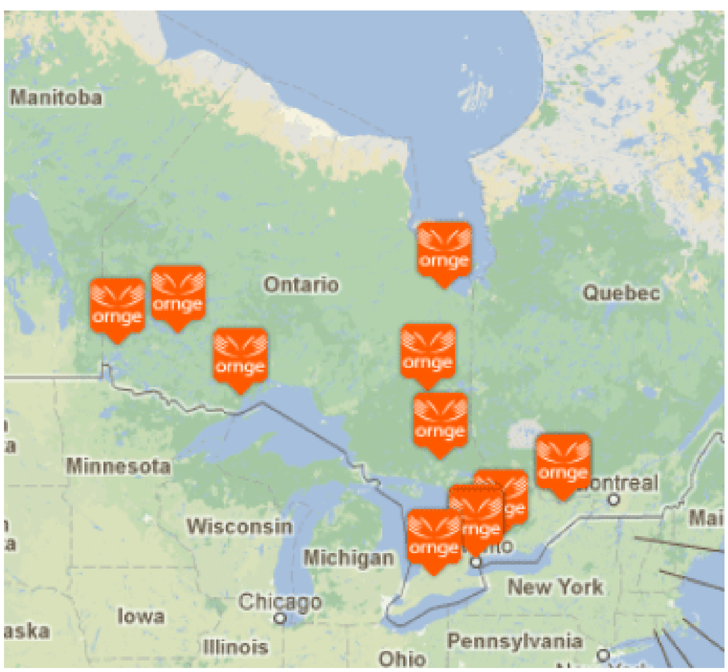


Figure 2-4 Map of Ornge Base Providers

Usually two paramedics are assigned for each call. For air ambulances, these paramedics are accompanied by two pilots. Some paramedics have expertise in a wider variety of medical care (primary care < advanced care < critical care). Primary care flight paramedic or PCP(f) can care for the uncomplicated stable patient. Advanced care flight paramedic or ACP(f) can also care for the more seriously ill or injured patient. Critical care flight paramedic or CCP(f) is the only type of paramedic that can care for the critically ill or injured patient. The paramedics are only semi-exchangeable. For example, a primary-care-level paramedic cannot go on a call requiring critical care, whereas the opposite is permitted.

2.4 Ornge Dispatch Process for Emergent/Urgent Interfacility Transfers

The dispatch process (Figure 2-5) begins when the communications centre receives a request from a sending facility. Any medical facility transferring a patient to another facility for a higher level of care or procedures not available at their facility, and meeting the guidelines for air transport, must make arrangements with the Ornge Communications Centre, as well as the receiving facility and physician [24]. A medical analyst receives the request, acquires the relevant patient information, and forwards a request to a planner. The planner reviews the call details, and contacts the appropriate air or land critical care transfer vehicle to determine if it can service the call. If the vehicle chosen is a land vehicle, it departs on the response within minutes. If the vehicle is an aircraft, the pilot must check the weather and determine if the aircraft can do the flight safely. The pilots will inform the planner within 10 minutes with regards to flight acceptance. If there are several vehicle options, the planner manually estimates the total time to definite care for different transportation modes and forwards these estimates to the transport medicine physician. The transport medicine physician considers these estimates, patient acuity, and resource availability in deciding which vehicle to allocate to the request. It is the responsibility of the medical flight crew and the physician at the Ornge Communications Centre to make decisions regarding the patient's treatment en route.

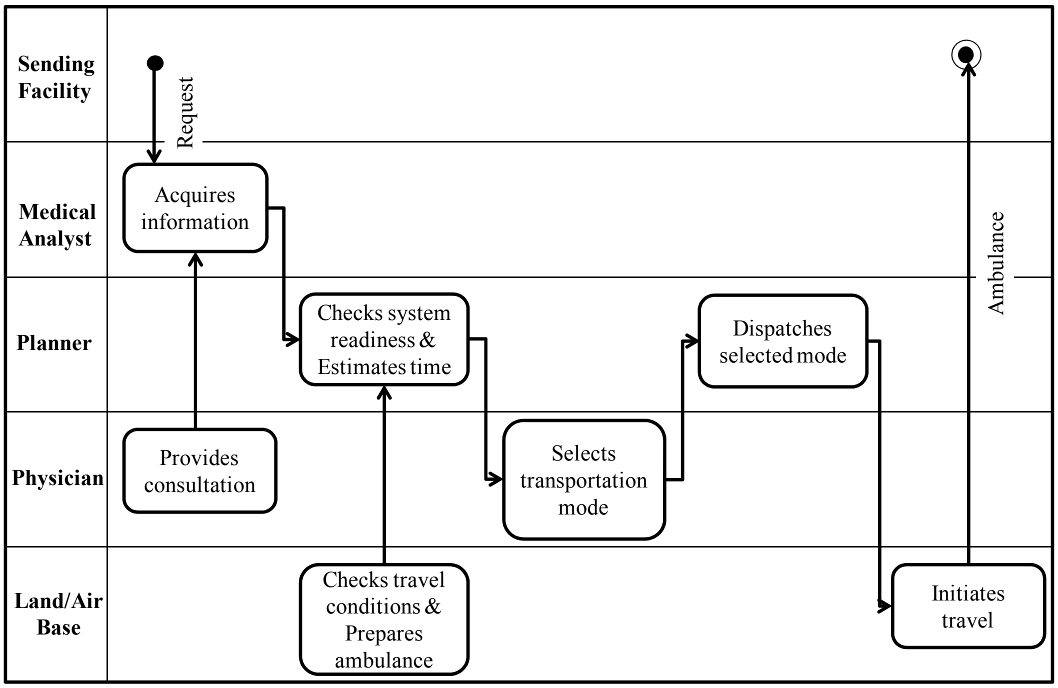


Figure 2-5 Ornge Dispatch Process for Emergent/Urgent Interfacility Transfers

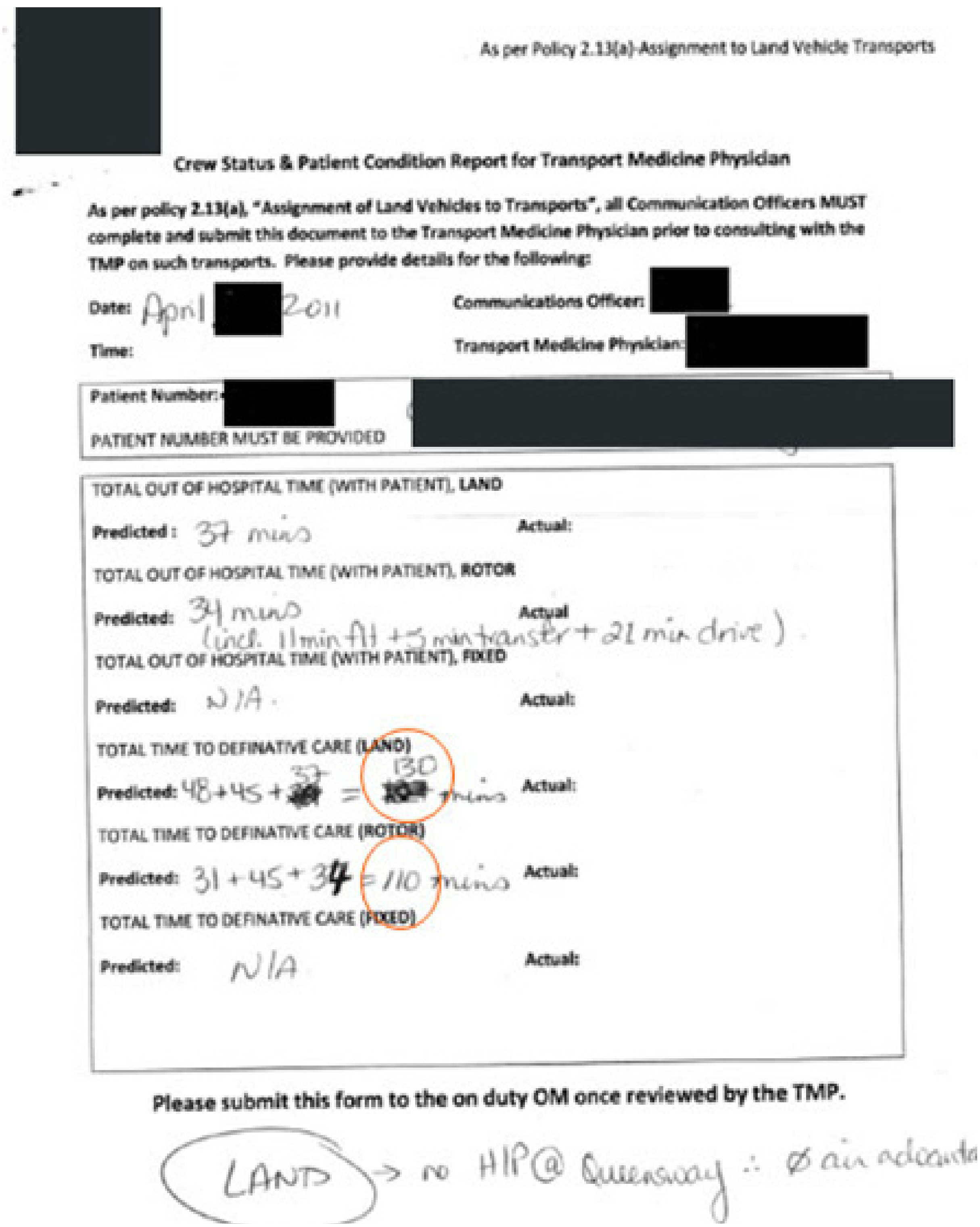
2.5 Ornge Field Operations during Emergent/Urgent Interfacility Transfers

Once the planner in the communications centre selects the mode of transport, the major steps performed in the field are as follows: 1) vehicle departs base, 2) vehicle arrives at pick-up site (for land vehicles: sending hospital; for aircraft: can be an airport, a helipad at the sending hospital, or a helipad at a nearby location), 3) paramedics arrive at the patient site, 4) paramedics depart with the patient, 5) vehicle departs pick-up site, 6) vehicle arrives at the destination site (for land vehicles: receiving hospital; for air vehicles: can be an airport, a helipad at the receiving hospital, or a helipad at a nearby location), 7) transfer of care (or delivery of the patient). These steps will be explained further in the upcoming sections. For air vehicles, if the receiving and/or sending hospitals do not have a helipad (for helicopter) or the landing site is an airport (for helicopter or fixed wing), there are additional local land ambulance transfers to deliver paramedics to the patient site and/or to deliver the patient to the vehicle or to the receiving hospital.

Chapter 3
The Decision Making Challenge

3.1 Time to Definite Care Estimations

The planners estimate time to definite care through experience, subjective judgments, and consultations with pilots and physicians. Figure 3-1 shows a sample form that is used by planners to report their time estimations. The planners appear to adopt varying strategies to estimate time to definite care. For example, some planners use a web mapping service to estimate land vehicle travel times, whereas others may depend on their own knowledge of the region. In general, planners break down the transfer process into components and estimate a time for each component. For example, in most cases, time spent in the sending facility is assigned 45 minutes regardless of transportation mode. Vehicle preparation on the other hand is longer for an air vehicle compared to a land vehicle and standard estimates are again used for this component. However, in bad weather conditions, when a helicopter has to fly under instrument flight rules (IFR) an additional 20-30 minutes is required to obtain IFR approvals from air traffic control.



[redacted]

As per Policy 2.13(a)-Assignment to Land Vehicle Transports

Crew Status & Patient Condition Report for Transport Medicine Physician

As per policy 2.13(a), "Assignment of Land Vehicles to Transports", all Communication Officers MUST complete and submit this document to the Transport Medicine Physician prior to consulting with the TMP on such transports. Please provide details for the following:

Date: April [redacted] 2011 Communications Officer: [redacted]

Time: Transport Medicine Physician: [redacted]

Patient Number: [redacted]

PATIENT NUMBER MUST BE PROVIDED

TOTAL OUT OF HOSPITAL TIME (WITH PATIENT), LAND

Predicted: 37 mins Actual:

TOTAL OUT OF HOSPITAL TIME (WITH PATIENT), ROTOR

Predicted: 34 mins (incl. 11 min flt + 5 min transfer + 21 min drive) Actual

TOTAL OUT OF HOSPITAL TIME (WITH PATIENT), FIXED

Predicted: N/A. Actual:

TOTAL TIME TO DEFINATIVE CARE (LAND)

Predicted: 48 + 45 + 37 = 130 mins Actual:

TOTAL TIME TO DEFINATIVE CARE (ROTOR)

Predicted: 31 + 45 + 34 = 110 mins Actual:

TOTAL TIME TO DEFINATIVE CARE (FIXED)

Predicted: N/A Actual:

Please submit this form to the on duty OM once reviewed by the TMP.

LAND -> no HIP @ Queensway ∴ ∅ air advanta

Figure 3-1 Sample Form Used by Planners to Report Estimated Times

3.2 Historical Time to Definite Care Estimates

A stratified random sample of 182 interfacility transfers performed by Ornge in 2010-11 was examined. Eighty seven (47.8%) cases utilized a helicopter (with potentially a land leg), and 95 (52.2%) utilized only a land transfer vehicle.

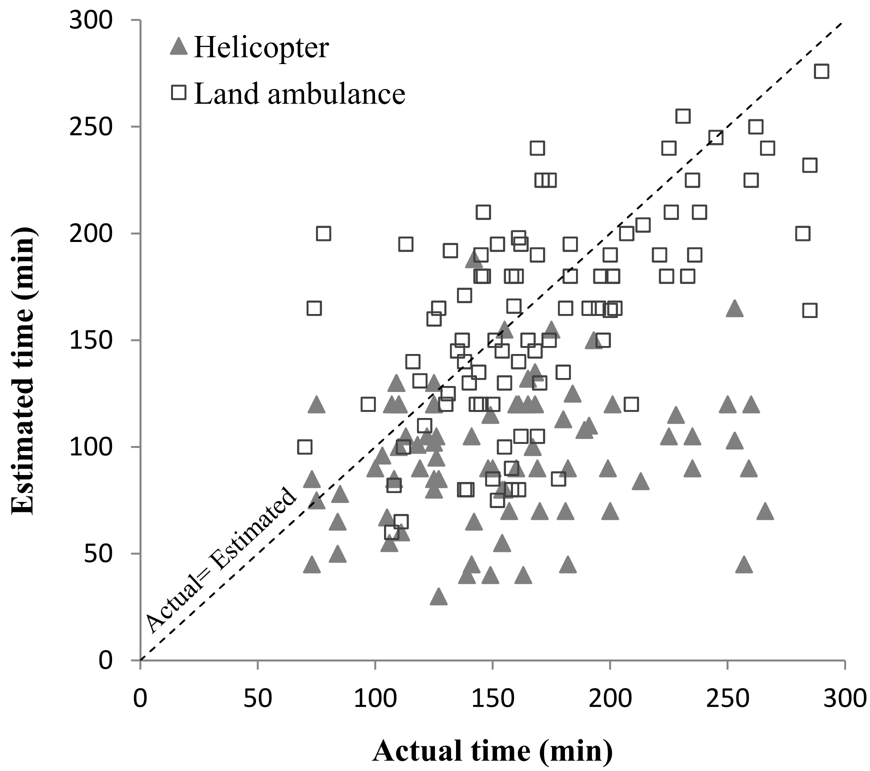


Figure 3-2 Actual Time to Definite Care versus the Times Estimated by Planners

Figure 3-2 shows the actual time to definite care versus the times estimated by the planners. The 45-degree line represents the ideal situation where the estimated time equals to the actual time. Points below this line are underestimates and points above the line are overestimates. Overall, 77% of cases were underestimated, and 23% were overestimated.

Figure 3-3 presents the histograms for the difference between the actual time to definite care and the planner estimate. Figure 3-2 and Figure 3-3 illustrate that transfer times involving a helicopter resulted in a larger number of underestimations (88%), whereas land transfers had a fairly more symmetric distribution of over- and under-estimation (67%) ($\chi2(1)=10.4$, $p=0.001$). In fact, 44% of air transfers were underestimated by more than 60 minutes.

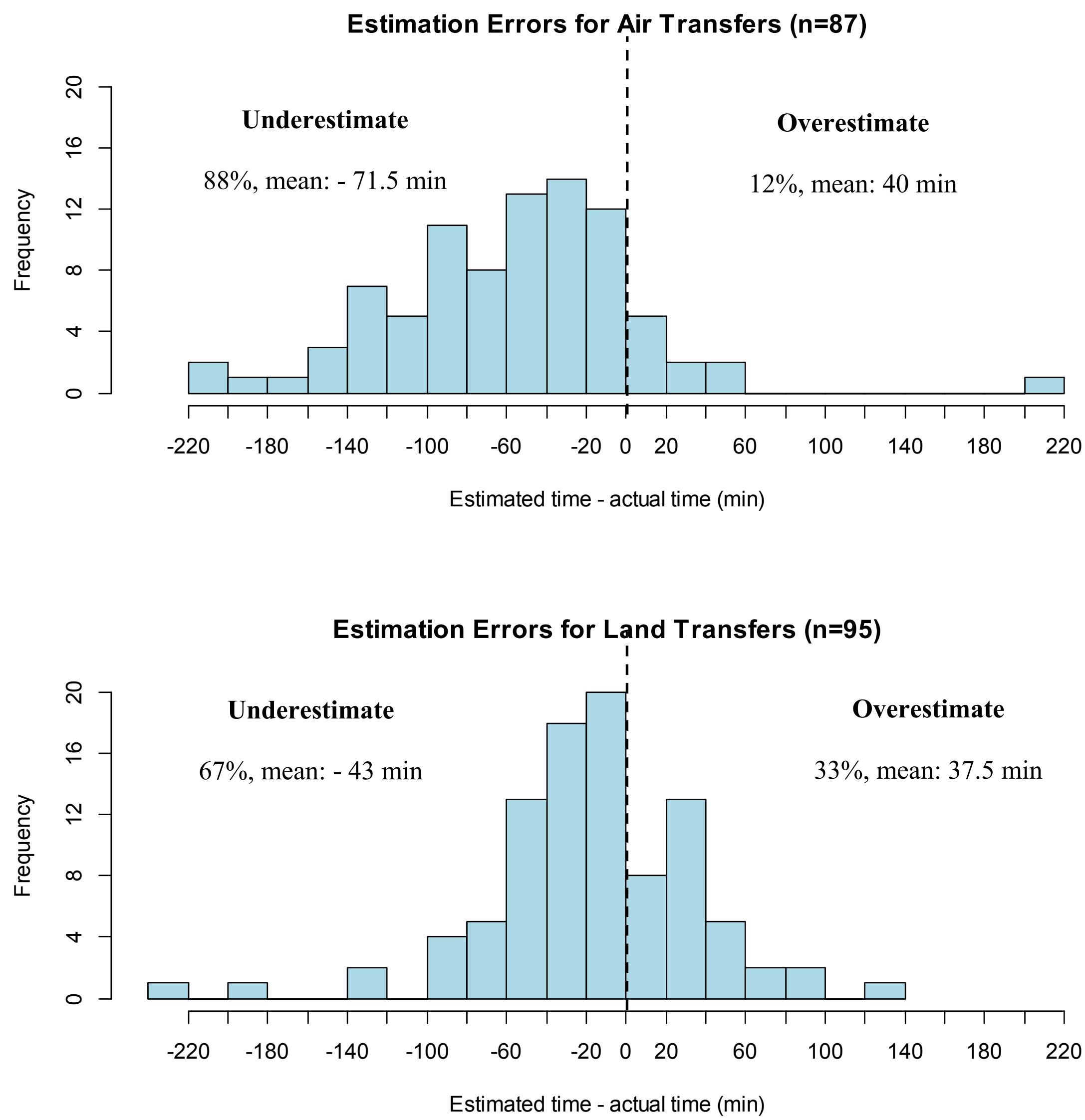


Figure 3-3 Histograms of Estimation Errors for Air and Land Transfers

Further, the sample standard deviation of actual transfer times was larger than the sample standard deviation of planner estimates for both air and land transfers (Table 3-1).

However, the variance of actual times was significantly greater than the variance of estimated times for air transfers ($F(1, 172)=7.67$, $p=.006$), whereas no significant differences were found for land transfers ($F(1, 188)=0.41$, $p=.52$). This suggests that planners' estimates may not be accurately capturing the variability in the air transfer process.

Table 3-1 Standard Deviations of Actual and Estimated Time to Definite Care Values

	Standard deviation	
	Helicopter	Land ambulance
Actual time to definite care	51 min	61.5 min
Estimated time to definite care	39 min	50 min

In order to improve the time estimations and support the operators in choosing a transportation mode, a decision support tool was built, which provides relevant time estimates for interfacility transfers based on historical dispatch and call data (from 2007 to 2010). The characteristics of the historical dispatch data and the strategies used for data analysis will be discussed in the following chapter.

Chapter 4
Data Analysis Strategy

In order to create a decision support tool for the Ornge Communications Centre (OCC), a large historical database was analyzed. This chapter introduces the available data fields and data characteristics. The strategy used for data analysis and producing time estimates will also be discussed.

4.1 Ornge Historical Data

4.1.1 ACRV Database

ACRV is an Ornge dataset that is filled out by paramedics during patient transfers. Beginning in March 2010, the ACRV data entry transitioned from paper-based to digital, with fully digital records at all Ornge bases by 2012; Ornge paramedics used to fill out paper forms before, and currently they use Toughbooks for this purpose. The ACRV dataset is known as the most reliable and detailed database to investigate the transfer process at Ornge, as it is filled out by the paramedics who have direct contact with the patient. There is another important dataset called OPTIMAS, which is filled out by the communications officers who dispatch the calls. Compared to ACRV, OPTIMAS provides less and more general information about the transfer.

ACRV dataset (from 2007 to 2011) was selected as the main dataset for the analysis, and OPTIMAS was used as a back-up for verifying or filling out missing ACRV data.

4.1.2 Relevant Data Fields

The following relevant ACRV data fields were provided to the researcher:

- **Patient Number:** A unique number assigned to each patient once the call is received in the communications centre.
- **Flight Number (Trip ID):** A unique number assigned to each ambulance trip. A trip is considered from the time the vehicle departs the base to the time the vehicle returns to the base. An ambulance might transfer multiple patients during one trip.
- **Vehicle Code:** The code assigned to each ambulance.
- **Dispatch Priority ID:** The priority code assigned to each patient at the communications centre (e.g., scheduled, emergent, urgent, etc.).
- **Call Type:** As discussed before, a call to the communications centre can mainly be an interfacility or scene transfer request.
- **Sending/Receiving Facility Codes:** A unique number assigned to each facility.
- **Sending/Receiving Landing Sites:** A unique number assigned to each landing site.
- **Service Provider Base Name:** The name of the base provider who accepted the call.
- **Call Accepted:** The time the call was accepted by the base provider.
- **Depart Base:** The time the ambulance departed the base to pick-up the patient.
- **Arrive Pick-up Site:** The time the ambulance arrived at the sending facility's landing site.
- **Arrive Patient Site:** The time the paramedics arrived at the patient's side.
- **Depart Patient Site:** The time the paramedics departed the patient's side.

- **Depart Landing Site:** The time the ambulance departed the sending facility's landing site.
- **Arrive Destination Landing Site:** The time the ambulance arrived at the receiving facility's landing site.
- **Delivery Patient Site:** The time the patient was delivered to the receiving facility.

Additional variables such as **month**, **time of day**, and **distance** were derived from these fields and included in the data for analysis.

4.1.3 Data Characteristics and Limitations

- **Lack or Scarcity of Observations:** Lack or scarcity of data for particular facility combinations is one of the main characteristics of this dataset, which has major implications for decision support tool design. Some sending-receiving combinations are known as common routes (e.g., a local facility that always sends its patients to a nearby specialized health centre). While there might be hundreds of observations for particular combinations, the rest might have only a few or no observations. The implications on the tool design will be addressed in chapter 6.
- **Inaccurate GPS Coordinates (Inaccurate Distances):** At the time of this study, there was not any reliable list of GPS coordinates for the facility locations. The only available information at Ornge was the facilities' postal codes, which did not provide the exact geographical location of the sending facilities. Therefore, some of the estimated distances between facilities are likely not highly accurate. While this limitation existed during this study, the gap has been addressed, and Ornge Research and Development team has created a reliable list of GPS coordinates that can be used for future analyses.

- **Lack of Information on Potential Delays:** Although ACRV is the most detailed source for tracing a patient transfer; it does not include potentially useful time intervals such as crew waiting times for local land ambulances. This issue will be further discussed in sections 5.1.5 and 5.1.6.
- **Lack of Information on Potentially Significant Factors:** Information on potentially influential factors, such as traffic and historical weather conditions in Ontario, were not available to the researcher. Currently there is no standard method at the Ornge Communications Centre (OCC) for tracking and recording the weather or traffic information. Gathering historical information on these variables, considering the large dataset and the large area of Ontario would have been extremely difficult and time consuming. Thus, the time of year and the time of day were considered as surrogate measures for weather and traffic conditions, respectively.
- **Inconsistencies in Recording of the Data:** During shadowing and field observations, some inconsistencies in paramedics' understanding of the data fields and terminologies (e.g., particular intervals) were observed. When possible, the author fixed data entry inconsistencies or removed ambiguous cases by reviewing several descriptive historical reports.

4.2 Data Analysis Strategy: Unit of Analysis

As mentioned before, the goal of this research was to design a decision support tool that accepts two points as input, i.e., sending and receiving facilities, and presents the user with estimated transfer times. As discussed previously, the transfer times that are of interest to the decision makers are time to definite care, time to sending facility, and patient out-of-hospital time.

There are two possible approaches to analyze the data and design the application. One is to conduct the analysis at the level of each sending receiving facility combination. The other approach is to split up the total time to definite care to meaningful intervals and then provide an estimate for each of these intervals according to the requested combination of sending and receiving facilities. The following example demonstrates and compares these two methods.

Example:

Consider A and B as the sending facilities in one city and C and D as the receiving facilities in another city; both sending facilities have helipads. However, receiving facilities do not have helipads, so the patients are required to be transferred to one of the landing sites (X or Y) close to the receiving facilities and then transferred to C or D using a local land ambulance. Thus, the first leg of travel would be an air transfer and the second leg would be a land transfer (Figure 4-1).

For simplification, assume that the goal is to estimate patient out-of-hospital time for each possible combination of facilities and landing sites (e.g., A-X-C, B-Y-D, etc). The limitation is that, there is not enough historical data available for some combinations.

Integrated Model: One approach is to look at the historical data for each route and provide the estimated out-of-hospital time for that. For example, assume that in the dataset, there were 50 transfers from A to C. Twenty seven of these cases used X as the receiving landing site (A-X-C) and 23 of the cases used Y as the receiving landing site (A-Y-C). The estimated travel time for A-X-C was 37 min (air leg=25 min, land leg=12 min), and for A-Y-C was 98 min (air leg=43 min, land leg= 55 min). However, if there are no data available for a specific combination, this model cannot provide any estimates (e.g., B-X-D or B-Y-D). This approach is shown on the left in Figure 4-1.

Modular Model: The other approach is to split up the combination (e.g., A-X-C) to two legs (e.g., A-X and X-C) and look at the historical data for each leg separately and provide the estimated times for those legs. For example, assume that, in the dataset, there were 627 transfers from A to X (air leg) and the travel time estimate for this interval was 21 min. Also, there were 177 transfers from X to C (land leg) and the travel time estimate for this interval was 15 min. Thus, the estimated travel time for A-X-C using this method would be 36 min (36 min = 21 min + 15 min). This method enables us to provide estimates for the combinations that do not have enough observations in the dataset. For example, the combination of B-X-D has never happened in the past, but B-X and X-D have happened. The travel time estimate for B-X based on 150 observations was 60 min and the estimate for X-D based on 600 observations was 30 min. Thus, the travel time for B-X-D should be around 90 min. This approach is shown on the right in Figure 4-1.

The modular model solves the common problem of lack or scarcity of data in many cases. However, there might still be a few legs that do not have enough observations in the data. In that case, we can utilize general models derived from statistical analyses to estimate the travel time for those legs based on predictive factors such as distance. Let's say in our example, there is another landing site called Z, and we want to estimate the time for A-Z-C. We have 200 observations for Z-C but only three observations for A-Z. Since three observations would not be reliable to generate an estimate, we use a statistical model built on the entire dataset or a subset of it to estimate the travel time for A-Z, based on explanatory factors such as distance and time of day. For Z-C, we still use the estimate obtained from the 200 observations which were collected from transfers conducted between Z-C. The out-of-hospital time would then be the sum of the estimated times for A-Z and Z-C.

This approach (i.e., splitting the total time into sub-intervals) complies with the principles of a modular design [25], where the out-of-hospital time in this example consists of two modules; sending facility-landing site and landing site-receiving facility (Figure 4-2). The subintervals are produced independently of one another, but will function together as a whole to provide an estimate for the out-of-hospital time. Splitting up the transfer time to subintervals (modules) also makes the complexity of the large data manageable and allows module estimates to be changed and improved over time independently.

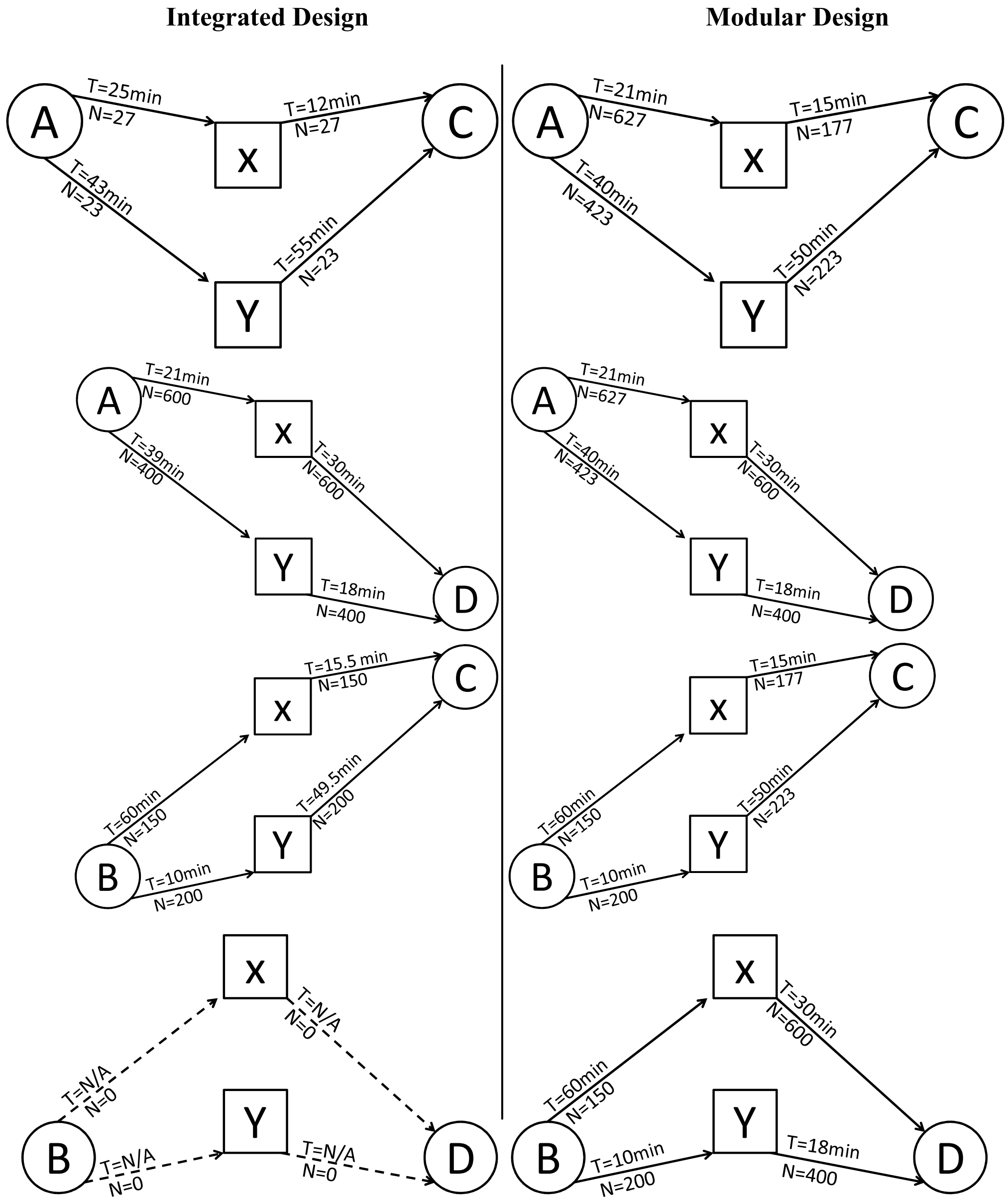


Figure 4-1 Comparison of Two Possible Approaches to Manage the Data; without Data Aggregation (left), with Data Aggregation/ Modularity Concept (right)

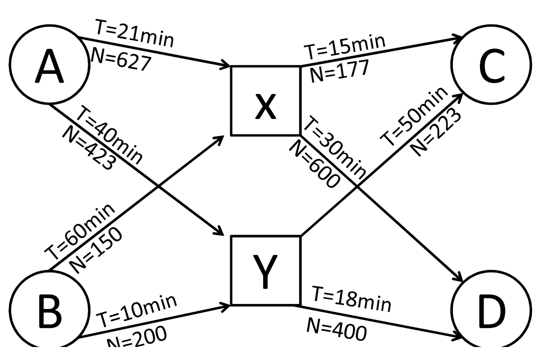


Figure 4-2 Each of the estimated intervals can be considered as an individual module. The modules can be connected together to produce a variety of time estimates for different combinations.

Accuracy: As discussed previously, the modular design of the tool is a good approach to deal with the combinations that do not have enough observations. However, one might argue that adding the estimated times of subintervals might not be correct as summing up the estimates of individual intervals may give a result that might be different than generating an overall estimate from the entire process. To compare the two methods, the sum of the estimated subinterval times ($\sum \tilde{T}_i$) can be compared with the estimated total times ($\widetilde{\sum T_i}$). Figure 4-3, shows the estimated total time to definite care for a commonly serviced route in southern Ontario (i.e., Peterborough Regional Health Centre - University Health Network General Site). With the modular method the sum of the estimated times of subintervals was 135 min ($\sum \tilde{T}_i = 135\text{min}$). With the integrated design, based on the 145 observations available for this particular route, the estimated total time was 140 min ($\widetilde{\sum T_i} = 140\text{min}$).

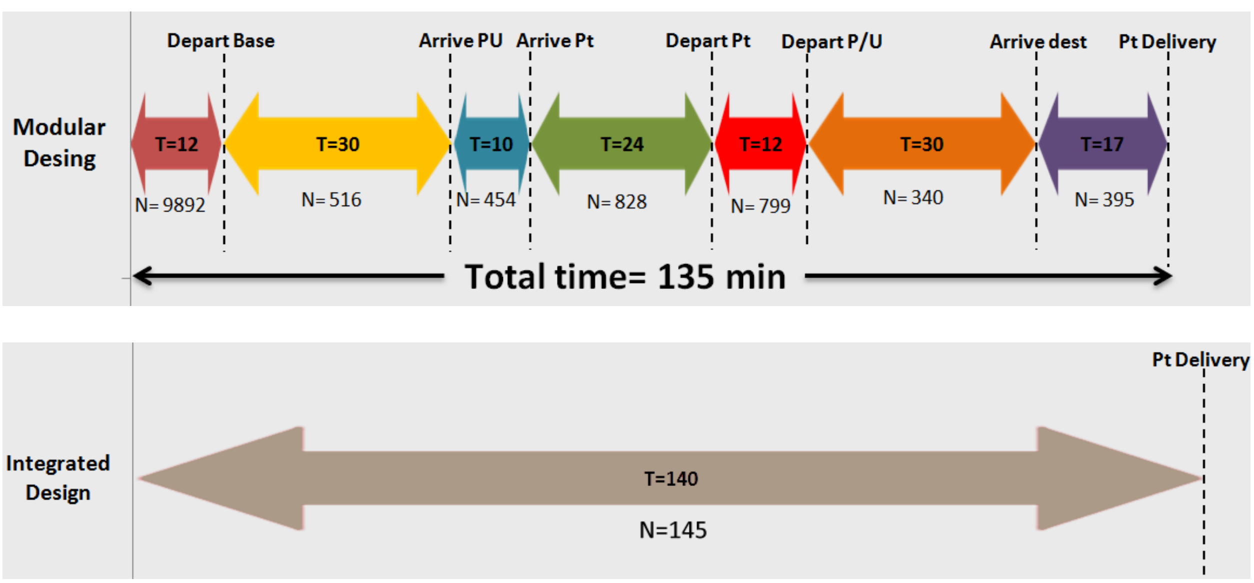


Figure 4-3 The Comparison of Total Time Estimates for a Particular Route: Modular Design (Top), Integrated Design (Bottom)

Using the dependent t-test, the outputs of the two models were then compared for 36 routes that had more than 30 observations. The results revealed that, on the average the output of the integrated model (M=117.62, SE=20.23) was 3 minutes greater than the output of the modular model (M=114.67, SE=22.15). This difference is statistically significant $t(35)=3.16$, $p<.001$, however, it is not be significant from a practical perspective.

It is worth mentioning that in this analysis, the sample median was chosen as the estimate of central tendency. The reasons for this choice will be discussed in section 6.1. Further, it was assumed that the intervals are independent of each other. This assumption was based on consultations with the paramedics and transport physicians.

Summary: In sum, there were several reasons for splitting the estimation times into intervals instead of calculating travel times for the entire duration of the transfer:

- First of all, the planners tend to make their estimates by breaking down the transfer process into components which are related to these intervals. Thus, the suggested approach is compatible with operators' mental model of the process.
- Splitting each transfer into individual intervals allows for the use of larger datasets for estimating intervals that were common between different sending-receiving facility combinations.
- As mentioned previously, there are a number of different variables that a physician considers in light of patient acuity: time to bedside, out-of-hospital time, and time to definite care. These variables can be readily calculated from individual interval estimates.
- Separate estimates would allow dispatchers to experiment with different combinations of routes between the sending and receiving facilities. Route

properties such as the base providers, pick-up, and drop-off sites can be modified depending on the current status of resources and other environmental factors. These properties would then change specific intervals while keeping other intervals constant, simplifying the decision making process by allowing for the easy calculation of transfer times for the different alternatives.

4.3 Time Intervals

This section briefly explains the intervals (modules) available for creating the decision support tool. An alphabetic coding was adopted by the researcher to shorten the names of the intervals. Figure 4-4 presents a visual representation of these intervals.

- **Interval A** (call accepted – depart base): For interfacility emergent and urgent calls, once the call is accepted by the base provider, the paramedics place the required equipment inside the vehicle and depart the base. This interval is also called the vehicle preparation time.
- **Interval B** (depart base – arrive pick-up site): For air transfers, this interval is from the time the aircraft takes off and leaves the base to the time the aircraft lands on the sending facility landing site. For land transfers, this interval is from the time the land ambulance departs the base to the time the ambulance parks at the sending facility. This interval is also called the travel time from base to sending.
- **Interval C** (arrive pick-up site – arrive patient site): For air transfers, this interval is from the time the aircraft lands on the sending facility landing site to the time the paramedics arrive at the patient's bedside. Some facilities have their own landing sites, for example, Hospital for Sick Children located in southwest

Ontario has a helipad on its roof that can be used as the landing site for this hospital and the hospitals around it (e.g., Mount Sinai Hospital). If the landing site is not within walking distance to the sending facility, an additional land leg is required to take the paramedics to the sending facility. For fixed-wing aircraft, there is always an additional land leg required to take the paramedics from the airport to the sending facility. This additional land leg can be provided by contracted taxi services or local emergency medical service (EMS) ambulances. For land transfers, this interval is from the time the land ambulance parks at the sending facility to the time the paramedics arrive at the patient's bedside.

- **Interval D** (arrive patient site – depart patient site): For all interfacility emergent and urgent calls, regardless of mode of transportation, this interval is from the time the paramedics get to the patient's bedside, to the time they move the patient to the stretcher and leave the bedside.
- **Interval E** (depart patient site – depart pick-up site): This interval is similar to interval C as it is the travel time between the patient's bed at the sending facility and the sending facility landing site for air transfers, and the sending facility parking for land transfers.
- **Interval F** (depart pick-up site – arrive destination landing site): For air transfers, this interval is from the time the aircraft takes off and leaves the sending facility landing site to the time the aircraft lands on the receiving facility landing site. For land transfers, this interval is from the time the land ambulance departs the sending facility's parking to the time the land ambulance stops at the receiving facility's parking.

- **Interval G** (arrive destination landing site – delivery patient site): For air transfers, the last interval is from the time the aircraft lands on the receiving facility landing site to the time the paramedics arrive at the receiving facility and deliver the patient to the medical team there. For land transfers, this interval is from the time the ambulance stops at the receiving facility's parking to the time the paramedics enter the receiving facility and deliver the patient to the other medical team.

As mentioned in section 1.2, there are also three import intervals that a travel planner or physician may take into consideration when deciding the mode of transportation. These intervals are "time to patient's bed at the sending facility" (a.k.a., time to sending facility); "out-of-hospital time" (a.k.a., out of hospital); and "total time to definite care" (a.k.a., total time).

- **Time to Sending Facility** (call accepted – arrive patient site): This interval is from the time the call is accepted by the base provider to the time the paramedics arrive at patient's bedside at the sending facility. Intervals A, B, and C are included in "Time to Sending Facility".
- **Out of Hospital** (depart patient site – delivery patient site): This interval is from the time the paramedics depart the patient site to the time they deliver the patient to the receiving facility. Intervals E, F, and G are included in "Out of Hospital".
- **Total Time** (call accepted – delivery patient site): This interval is from the time the call is accepted by the base provider to the time the patient is delivered to the receiving facility. All the intervals from A to G are included in "Total Time".

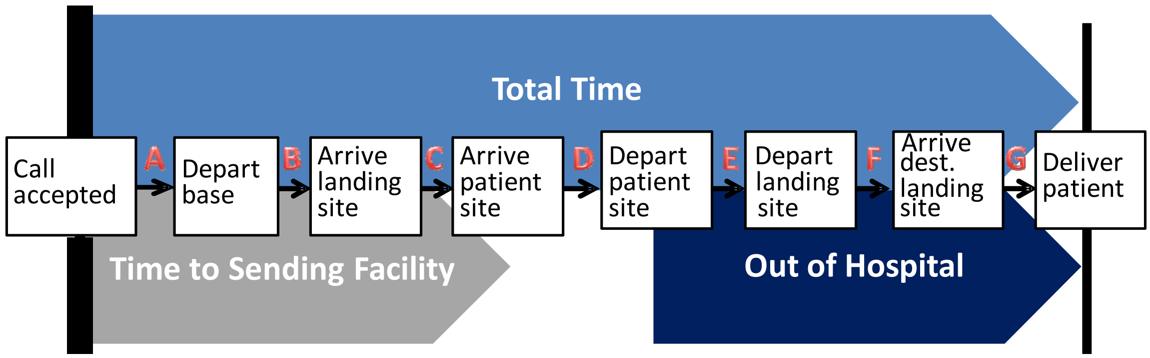


Figure 4-4 A Visual Representation of the Time Intervals

Chapter 5

Effect of Different Factors on Transfer Time

During the interviews and field observations, the front line staff (i.e., pilots, paramedics, communications officers, operations managers, and physicians) mentioned that factors such as weather, traffic, and road conditions might have significant effects on transfer times. In this chapter, the effect of some of these factors on air and land transfer times will be investigated. A hierarchical (blockwise entry) method was used for entering these factors to the statistical models.

5.1 Effect of Different Factors on Air Transfer Time

5.1.1 Base Provider Effect on Air Transfers

An air base provider consists of three elements: aircraft, pilots, and paramedics. The next section investigates the effect of the aircraft model on transfer times.

As for the pilot effect, according to Ornge policy and air traffic control regulations, pilots should fly with a consistent speed regardless of the fact that they are carrying a patient or not. Along the same line of reasoning, the pilots are not informed about patient acuity. Therefore, there is no reason to expect a systematic pilot effect on travel times. The same is true for paramedics. Ornge paramedics are always changing; based on Ornge needs, new paramedics are frequently hired at different times of the year, some are terminated, and some move to different bases. Although it is true that paramedic characteristics (age, experience, etc.) might affect transfer times, due to these frequent changes, it is not reasonable to associate the base characteristics with individual paramedics. Therefore, among the three elements of a base provider, we can only investigate the effect of the aircraft model.

5.1.2 Effect of Aircraft Model on Air Transfers

More than 10 models of aircraft are used in patient transport at Ornge. These models are different in two important time-related characteristics: 1) the amount of time it takes to prepare them for flight, 2) their flight speeds. Therefore, aircraft model can affect the first interval (A), which is call accepted to the time the aircraft departs the base, because of its preparation time, and it can affect the travel times from the base to the sending facility (B), and from the sending facility to the receiving facility (F) because of its flight speed.

Effect of Aircraft Model on Preparation Time: Using a two-way between-subject ANOVA, the effect of aircraft model on the duration of the first interval was investigated. A significant main effect of the vehicle model on interval A was found, $F (20, 16{,}755) = 283.82$, $p < .001$. Figure 5-1 compares interval A for 6 different aircraft models. The S-76 is a rotor wing and the other models are fixed-wing aircraft. The preparation time for the helicopters is much shorter than that for fixed-wing aircraft. It is worth mentioning that since 2011, Ornge has replaced some S-76 models with AW-139 helicopters. The speed and preparation time for AW-139 are slightly different than S-76. At the time of this study there were not enough historical data for this new model. Thus, AW-139 data were not included in the analysis. The other factor in this statistical analysis was time of the year (month). The effect of this variable will be discussed in the following sections.

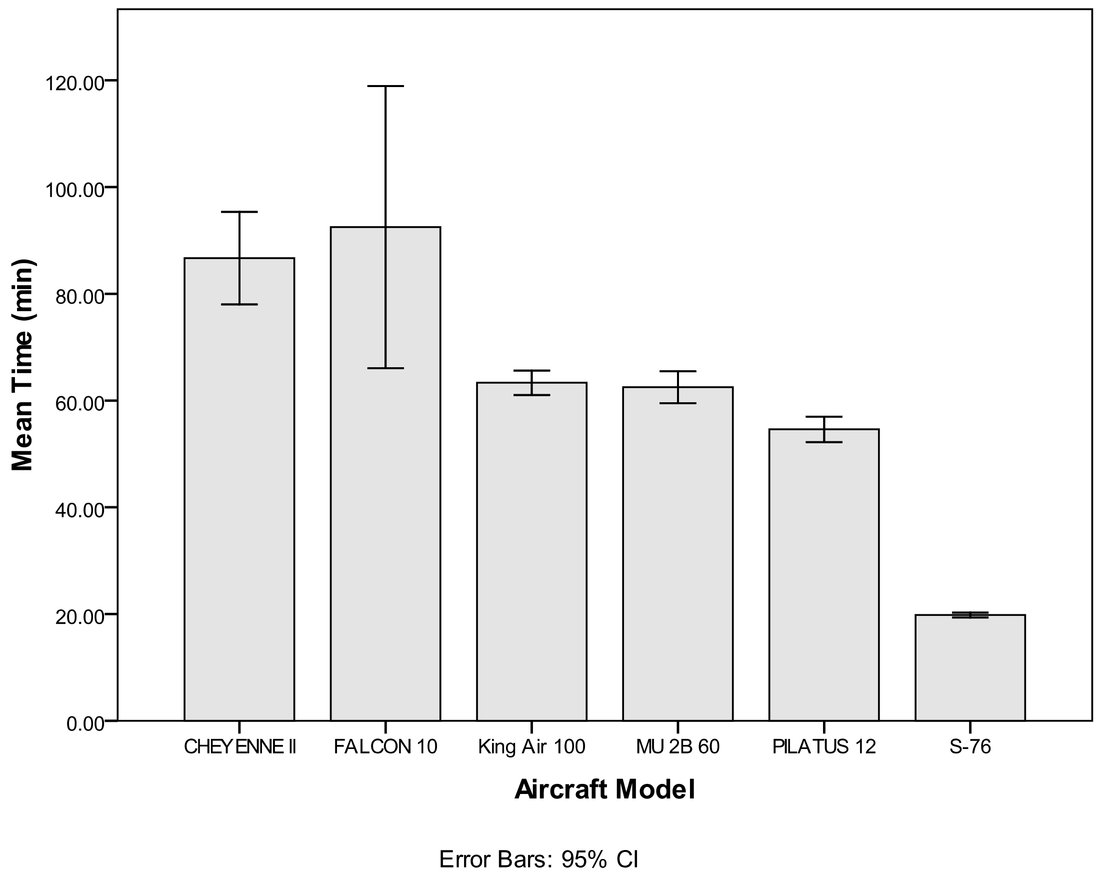


Figure 5-1 Interval A for Different Aircraft Models

Effect of Aircraft Model on Travel Time: Since different aircraft models have different specifications, such as cruise speed, cruise altitude, rate of climb, etc., it is obvious that the travel time would be different for different aircraft models. Using linear regression models, the relation between distance and travel time was investigated for different aircraft models. The regression models have the orthodromic distance (or great-circle distance [26]) as the independent variable and the historical travel time as the dependent variable. Table 5-1 shows that, different aircraft models have different regression parameters (a and b) due to the variation in aircraft characteristics, most likely speed. The large values of the adjusted R squared suggest small variability in air travel times within each aircraft model.

Table 5-1 Estimated Regression Parameters for Common Aircraft Models Used by Ornge

Aircraft Model	a	b	Adjusted R Squared
Aero Commander 700	0.18	9.83	0.89
CESSNA 441 CONQUEST II	0.12	7.08	0.91
CESSNA CARAVAN	0.20	3.73	0.95
CHEYENNE II XL	0.15	4.94	0.94
King Air 100	0.16	4.04	0.94
King Air 200	0.14	7.49	0.88
KING AIR E-90	0.14	3.86	0.96
MU 2B 36	0.15	6.50	0.72
MU 2B 36A	0.12	8.29	0.94
MU 2B 60	0.12	7.99	0.94
NAVAJO	0.19	8.07	0.92
NAVAJO CHIEFTAN	0.19	8.06	0.93
PILATUS 12	0.14	8.25	0.92
PILATUS PC12/47E NG	0.13	8.98	0.90
ROCKWELL 700	0.20	2.19	0.70
S-76	0.23	5.05	0.85
SA226-TC	0.13	5.14	0.93
Time (min) = a × Distance (km) + b			

5.1.3 Effect of Time of Year (Month) on Air Transfers

In general, and according to the paramedics and pilots during interviews, in bad weather conditions, one should expect longer aircraft preparation times, longer travel times, longer in-hospital times to prepare the patient (e.g., extra clothing needed), and longer times in loading/unloading patients to/from the ambulances. Although the transport medicine team believed that weather can have a significant effect on air transfers, historical weather conditions in Ontario were not available to the researcher. Therefore, month was considered as a surrogate measure for weather condition. The effect of month on different intervals of the transfer process was then investigated.

For each part of the air transfer, the adjusted R squared values of the statistical models were compared before and after including month in the model. Table 5-2 shows that, including month in the statistical models does not improve the models' predictive power as the adjusted R squared values do not significantly change. This finding suggests that, assuming paramedics' and pilots' perception of weather impact on transfer times is true, time of the year (month) is not a good surrogate measure for weather.

Table 5-2 Adding month in the statistical models of air transfer times does not significantly change the adjusted R squared values.

Description	Intervals	Adjusted R Squared		Other Variables in the Model
		Model Including Month	Model without Month	
Preparation Time	A	0.267	0.259	Aircraft Model
Air Travel Time	F & B	0.927	0.927	(for S-76) Distance, Time of Day
Additional Land Leg to Pick up Time	C & E	0.121	0.122	Driving Distance, Day of Week, Time of Day
Additional Land Leg to Deliver Time	G	0.255	0.255	Driving Distance, Day of Week, Time of Day

5.1.4 Effect of Time of Day (Hour) on Air Transfers

The effects of time of day on flight preparation time, air travel times, and additional land legs (e.g., from airport to hospital and vice versa) were investigated.

The paramedics and pilots believed that vehicle preparation time is not affected by time of day, because this process usually takes place indoors and the preparation steps are the same at different times of the day. Additionally, pilots believed that time of day should not affect aircraft travel times as they fly with a constant speed most of the time and regardless of time of day. However, the paramedics believed that the additional land legs from airports to the hospitals and vice versa usually take longer during rush hours.

Table 5-3 shows that similar to the month effect; including time of day in the statistical models does not improve models' predictive power (as can be seen by fairly constant R squared values). Thus, it can be concluded that as expected, the effect of time of day on aircraft preparation time and flight time was not practically significant. Regarding the effect of time of day on additional land legs, it can be concluded that time of day is either not a good surrogate measure for traffic conditions or traffic conditions do not have a practically significant effect on travel times.

Table 5-3 Adding time of day in the statistical models of air transfer times does not significantly change the adjusted R squared values.

Description	Intervals	Adjusted R Squared		Other Variables in the Model
		Model Including Time of Day	Model without Time of Day	
Preparation Time	A	0.287	0.259	Aircraft Model
Air Travel Time	F & B	0.928	0.927	(for S-76) Distance, Month
Additional Land Leg to Pick up	C & E	0.123	0.122	Driving Distance, Day of Week, Month
Additional Land Leg to Deliver Time	G	0.256	0.255	Driving Distance, Day of Week, Month

5.1.5 Effect of Distance on Air Transfers

The effect of distance on air travel times and additional land legs (e.g., from airports to hospitals and vice versa) was investigated.

The flight distance was calculated using the great-circle formula: the GPS coordinates of the base and the sending facility were used to estimate the flight distance from base to sending facility (interval B), and the GPS coordinates of the sending and the receiving facilities were used to estimate the flight distance from sending to receiving facility. Figure 5-2 shows a strong linear relation between flight distance and flight travel time for S-76 aircraft (R^2=.93). A similarly strong relation between the flight distance and the flight time was found for other aircraft models.

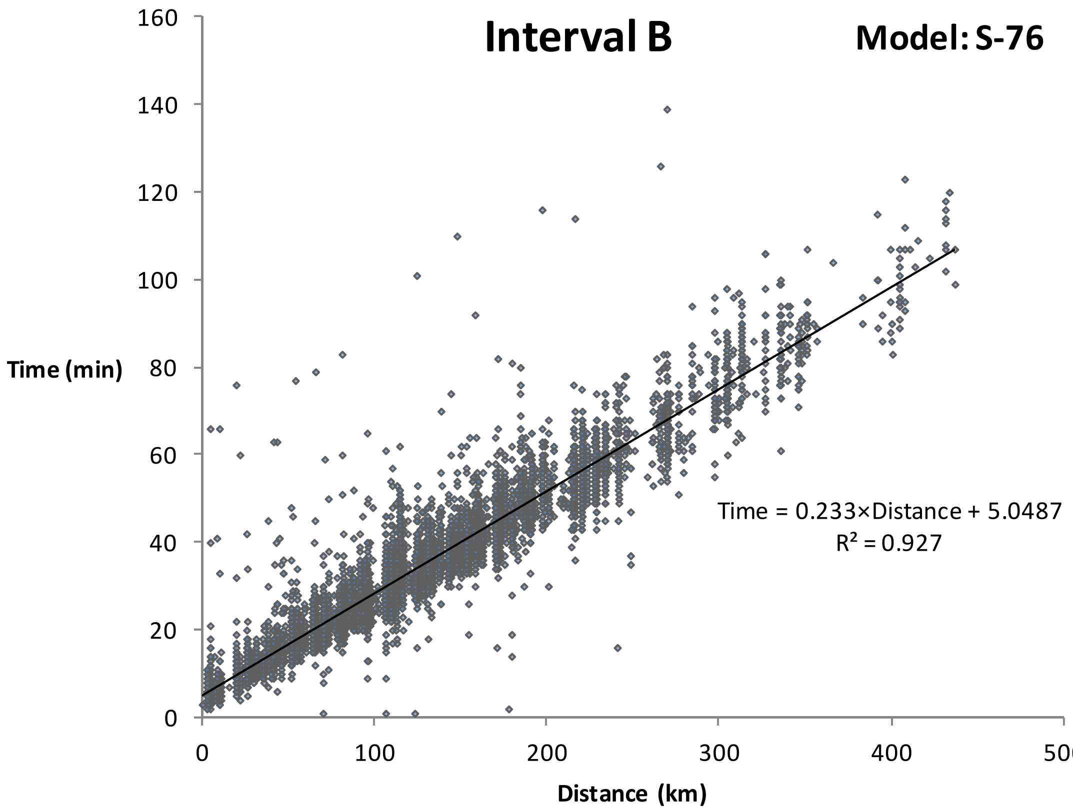


Figure 5-2 Linear Relationship between the Distance and Travel Time for S-76 Helicopters

Regarding the additional land legs, the driving distance between hospitals and airports was estimated using an online web mapping service (Bing Maps): the GPS coordinates of hospitals and airports were used as inputs. Table 5-4 shows the summary of the statistical models for the additional land legs with distance as the independent variable and time as the dependent variable. The relationship between time and distance for additional land legs is not as strong as the one for air legs; the adjusted R squared for additional land legs are much smaller compared to the ones for air legs.

Table 5-4 Poor Predictive Power of Models for Additional Land Legs

Description	Intervals	Model Including Distance	
		P- Value	Adjusted R Squared
Additional Land Leg to Pick up Time	C & E	.000	0.121
Additional Land Leg to Deliver Time	G	.000	0.255

The low predictive power of the models built for additional land legs could be due to limitations such as inaccurate GPS coordinates of the facilities, inconsistencies in recording of the data, occasional omission of pick-up/delivery location entry, and unavailability of relevant information, such as waiting times for land ambulances as well as accurate traffic and weather conditions.

As mentioned before, the GPS coordinates of the facilities were obtained through postal codes. This method is not very accurate as postal codes sometimes represent the centre of a large area (especially in the sparsely populated areas of Ontario). This could be one of the reasons that the adjusted R squared value for additional land legs carried out to deliver the patient (adjusted R^2=.255) is greater than that carried out to pick-up the patient (adjusted R^2=.121). The facilities, where the patients are delivered to, are usually large facilities located in densely populated areas; whereas the facilities that send the patients are usually small facilities located in sparsely populated areas. Therefore, deduced GPS coordinates for most of the receiving facilities are expected to be more accurate than the GPS coordinates calculated for the sending facilities.

Another limitation in investigating the additional land legs between facilities and airports was the unavailability of some important information such as crew waiting times for the local land ambulances. Two relevant time points were available in the data: arrive pick-up site (i.e., the time the aircraft lands on the pick-up site) and arrive patient site (i.e., the time the paramedics arrive at the patient's bed). This time period includes the potential waiting time for land ambulances, as well as the travel time and the time spent by the paramedics unloading the medical equipment from the vehicle and going to the patient's room. No information regarding the duration of these subintervals were available in the dataset (Figure 5-3). Considering the fact that driving distance is only directly related to the driving time, it is reasonable that the relationship between time and distance for additional land legs is not as strong as the one for air legs. One potential solution to obtain more accurate models would be to replace the effect of distance with the effect of route (combination of facility and airport). This method will be discussed in the next section.

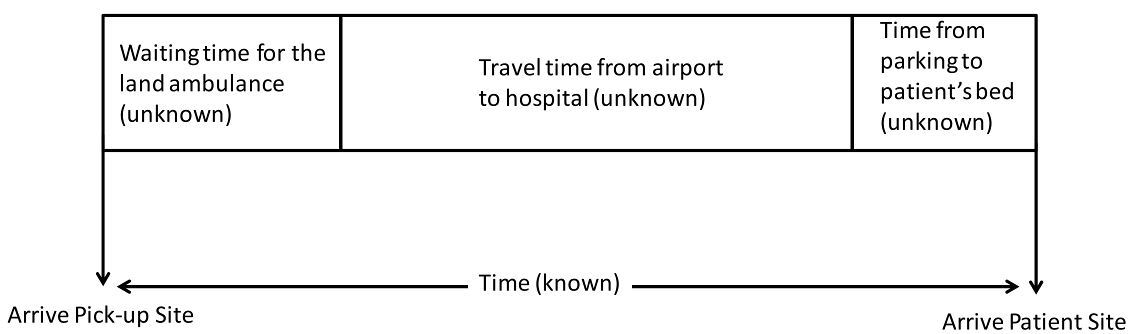


Figure 5-3 No information regarding the duration of additional land-leg subintervals were available in the dataset.

5.1.6 Effect of Route on Air Transfers

We define route as the combination of the origin and destination points of a part of a transfer. For example, for air travel times, if the base provider is Ottawa and the sending facility is Peterborough Regional Health Centre, then "Ottawa- Peterborough Regional Health Centre" would be considered as the route; or for additional land legs, if the airport is Ottawa International Airport and the facility is Ottawa General Hospital, then the route would be the combination of these two. The route effect is more specific than the distance effect; by considering the ‘distance’, we might ignore some aspects of the transfer such as road conditions for land legs (e.g., highway, street, etc.) or the waiting times that are usually associated with the local land ambulance service of a particular region. Therefore, the ‘route’ is expected to be a better predictor than the ‘distance’. However, the downside of using route as a predictor is that there are not enough historical observations for all potential routes. As discussed before, for some routes, we might have thousands of historical observations but for others, we might have none.

Summary: The statistical analyses revealed that time of year and time of day may not be good representatives of weather and traffic conditions, respectively. Therefore, the strategy for the cases that have enough observations would be to use the route effect as it is expected to provide the best specific information. The strategy for the cases that have only a few observations would be to use the next best available predictor which is distance. The aircraft model is also a significant factor that should be taken into account.

The interested readers are referred to Appendix A for additional information on the statistical models built and the analyses conducted.

5.2 Effect of Different Factors on Land Transfer Times

In this section, we will mostly focus on the effect of available factors such as time of day and time of year on ambulance driving time. Most of the land transfer intervals, except the driving times, are short and normally take less than 5 minutes. The land ambulances usually leave the base within a few minutes after accepting the call, or the time from hospital's parking to patient's bed is always recorded as 5 minutes by some of the paramedics. Since these already small values are recorded in the order of minutes and not seconds and the paramedics keep track of these times in a roughly accurate manner, the reliability of data for these short duration intervals is questionable. Although this issue of reliability is not a significant one, given the short duration of these intervals, reporting the effect of different factors on these intervals can be misleading. Thus, a detailed discussion on the analysis of short duration intervals is included in Appendix A.

5.2.1 Base Provider Effect on Land Transfers

A land base provider consists of two elements: land ambulance and paramedics. Ornge land bases use the same type of land ambulance. As for the paramedics, because of frequent staff changes, it is not reasonable to associate the base characteristics with individual paramedics. However, there are particular land bases that might show differences from other bases (Figure 5-4), such as the PAEDS teams (i.e., paramedics for the pediatric patients). For example, the average vehicle preparation time (i.e., from the time the base accepts the call to the time the vehicle departs the base) was around 7 minutes for all other land bases but was around 14 minutes for Toronto PAEDS team and around 12 minutes for Ottawa PAEDS team. The observed difference in vehicle preparation time between PAEDS and other bases could be due to the specialized equipment needed to be loaded to the ambulances or because of the added details or information the pediatric teams need to prepare for the call prior to departing the base.

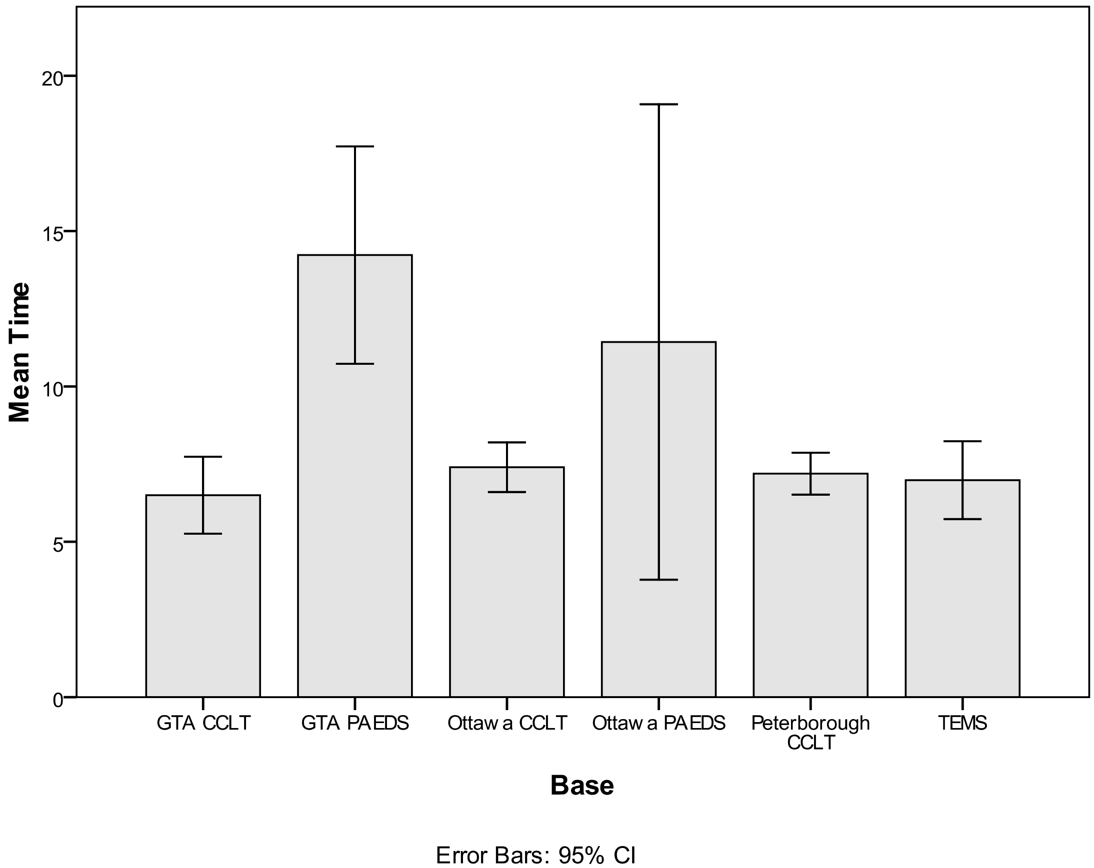


Figure 5-4 Interval A Comparison across 7 Ornge Land Bases

5.2.2 Effect of Time of Year (Month) on Land Transfers

As discussed before, time of year was selected as a surrogate measure for weather, which is believed by the paramedics to have a significant effect on the land ambulance transfer times. The paramedics believe that bad weather conditions might affect road and traffic conditions and therefore increase travel times. The adjusted R squared values obtained before and after including the effect of month in the model were compared. Table 5-5 shows that including month in the models does not improve the models' predictive power. Thus, it can be concluded that month may not be a good representative of weather conditions which were believed by the paramedics to have a significant effect on driving times.

Table 5-5 Adding month in the statistical models of land transfers does not significantly change the adjusted R squared values.

Description	Intervals	Adjusted R Squared		Other Variables in the Model
		Model Including Month	Model without Month	
Driving Time from Base to Sending	B	0.665	0.640	Driving Distance, Day of Week, Time of Day
Driving Time from Sending to Receiving	F	0.749	0.726	Driving Distance, Day of Week, Time of Day

5.2.3 Effect of Time of Day (Hour) on Land Transfers

The effect of time of day on driving times was also investigated. Table 5-6 shows that including time of day in the statistical models does not significantly improve the models' predictive power as the adjusted R squared values do not significantly differ between including time of day in the model and not including it.

Table 5-6 Adding time of day in the statistical models of land transfers does not significantly change the adjusted R squared values.

Description	Intervals	Adjusted R Squared		Other Variables in the Model
		Model Including Time of Day	Model without Time of Day	
Driving Time from Base to Sending	B	0.665	0.623	Driving Distance, Day of Week, Month
Driving Time from Sending to Receiving	F	0.749	0.724	Driving Distance, Day of Week, Month

Multiple analyses were conducted, which took into account the population of the cities, the direction of the transfer (from a big city to a small city and vice versa) and different definitions of rush hour (e.g., morning rush hour, evening rush hour, etc.). None of these methods improved models' predictive power. Thus, it was concluded that time of day may not be a good predictor of the observed variability in driving times. As discussed in section 4.1.3, the inaccurate GPS coordinates for some facilities was also a limitation of this dataset and might have influenced some of the results.

5.2.4 Effect of Distance on Land Transfers

The driving distance between base providers and sending facilities (interval B) and between sending and receiving facilities (interval F) were estimated using their GPS coordinates and an online web mapping service (Bing Maps). Regression analyses were conducted to investigate the relationship between the driving distance and the travel time (Figure 5-5 and Figure 5-6). The results suggested that driving distance was a significant predictor in estimating land ambulance driving times.

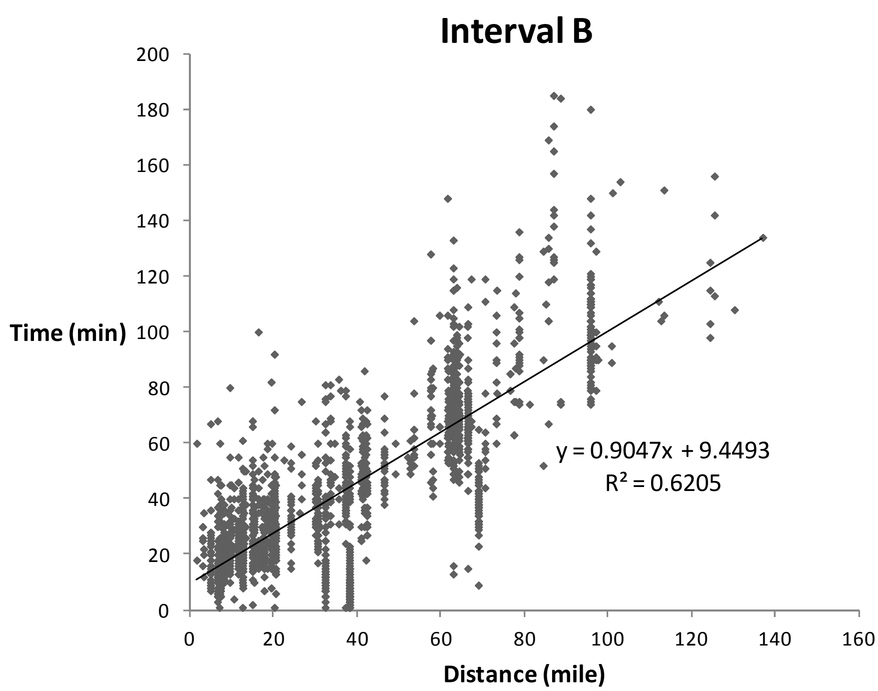


Figure 5-5 Linear Relationship between Driving Distance and Travel Time from Base to Sending Facility

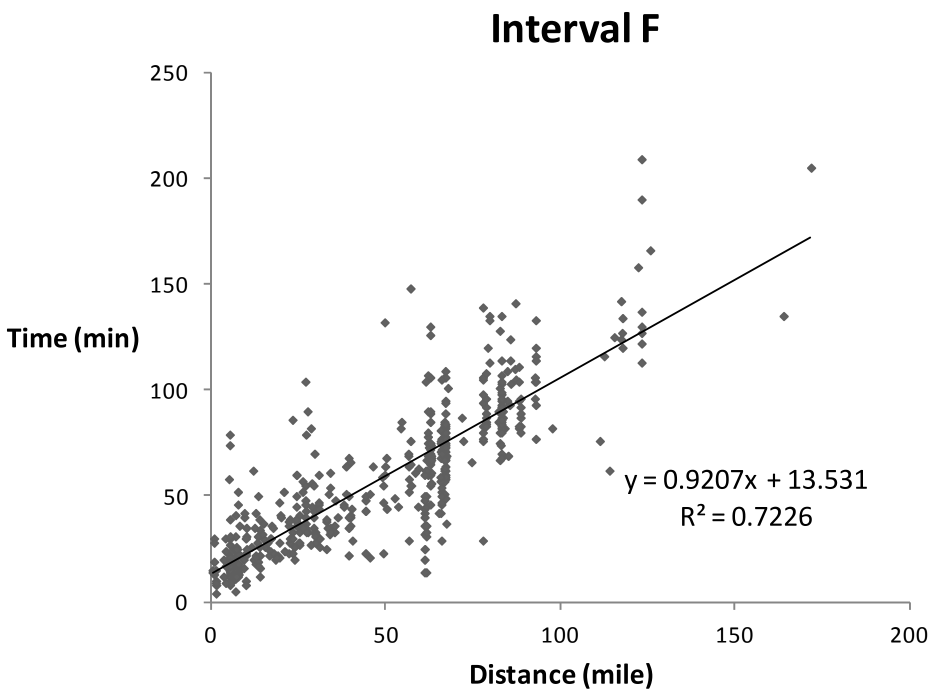


Figure 5-6 Linear Relationship between Driving Distance and Travel Time from Sending Facility to Receiving Facility

5.2.5 Effect of Route on Land Transfers

As mentioned in section 5.1.6, by considering route as a predictor for land transfer times, we can take into the account factors such as road conditions (e.g., highway/street) and route busyness. Thus, including route instead of distance would yield more accurate estimates. The problem is that there are not enough historical observations for all routes.

Summary: Since the effect of time of day and time of year on land travel times were not significant, we will only consider the effect of route or distance to estimate the time.

The "lack of data" limitation forces us to consider the route effect just for the cases that have enough observations, and use distance effect for the remaining cases.

The interested readers are recommended to read Appendix A for more detailed information regarding the statistical models built on land transfer data.

5.3 Conclusion

5.3.1 Factors for Estimating Air Transfer Intervals

It was concluded that time of day (hour) and time of year (month) were not practically significant factors for estimating durations of different air transfer intervals. Aircraft model and route were found to be the key predictors for most of the air transfer intervals. Table 5-7 shows a summary of significant factors for different intervals of air transfers, which are further discussed below.

- **Interval A** (call accepted – depart base): The aircraft model was found to be the important factor for estimating the vehicle preparation time.
- **Interval B** (depart base – arrive pick-up site): The aircraft model and the base-sending distance/route were found to be the influential factors.
- **Interval C** (arrive pick-up site – arrive patient site): The combination of sending landing site – sending facility was found to be the most useful factor for the routes that had enough historical observations, and distance shall be used for cases that do not have enough observations.
- **Interval D** (arrive patient site – depart patient site): According to the physicians and paramedics the duration of interval D, which is the in-hospital time, depends on the patient’s condition, and cannot be estimated based on available information. Thus, there are no predictors for this interval and it should be estimated using the in-hospital-time data from each facility.
- **Interval E** (depart patient site – depart pick-up site): Similar to interval C, the combination of sending landing site – sending facility was found to be the most

useful factor for the routes that had enough historical observations, and distance shall be used for cases that do not have enough observations.

- **Interval F** (depart pick-up site – arrive destination landing site): Similar to interval B, the aircraft model, and combination of sending landing site – receiving landing site (or their distance) were found to be the determining factors.
- **Interval G** (arrive destination landing site – delivery patient site): The combination of receiving facility-receiving landing site was found to be useful for the routes that had enough historical data and distance shall be used for the cases that do not have enough observations.

Table 5-7 Summary of Significant Factors for Air Transfers

Interval	Description	Significant Factors
A	Call Accepted-Depart Base	Base Provider (Aircraft Model)
B	Depart Base-Arrive P/U Site	Route (or Distance) Aircraft Model
C	Arrive P/U Site-Arrive Pt. Site	Route (or Distance)
D	Arrive Pt. Site-Depart Pt. Site	Sending Facility
E	Depart Pt. Site-Depart P/U Site	Route (or Distance)
F	Depart P/U Site-Arrive Destination	Route (or Distance) Aircraft Model
G	Arrive Destination-Delivery Pt. Site	Route (or Distance)

P/U Site: Pick-up Site

5.3.2 Factors for Estimating Land Transfer Intervals

Time of day (hour) and time of year (month) did not have significant effects on the durations of land intervals. Table 5-8 shows a summary of significant factors for different intervals of land transfers, which are further discussed below. It should be noted that, as discussed before, the short duration intervals were likely not very accurately recorded. The conclusions listed below for these intervals are based on statistical analysis reported in Appendix A. Overall, the factors identified by these analyses as influential were as expected.

- **Interval A** (call accepted – depart base): The base provider will be considered as the determining factor.
- **Interval B** (depart base – arrive pick-up site): The combination of base provider-sending facility was found to be the most useful factor for the routes that have many historical observations, and distance shall be used for cases that have few observations.
- **Interval C** (arrive pick-up site – arrive patient site): The sending facility will be considered as this interval refers to the time from sending facility's parking to the patient's bedside.
- **Interval D** (arrive patient site – depart patient site): Similar to air transfers, the effect of sending facility will be taken into account to estimate interval D.
- **Interval E** (depart patient site – depart pick-up site): Similar to interval C, the sending facility will be considered as a determining factor as this interval refers to the time from the patient's bedside to the sending facility's parking.
- **Interval F** (depart pick-up site – arrive destination landing site): The combination of sending facility-receiving facility was found to be the most useful factor for the routes that have many historical observations, and distance shall be used for cases that have few observations.
- **Interval G** (arrive destination landing site – delivery patient site): The receiving facility will be considered as the determinant factor for this interval, which refers to the time from receiving facility's parking to the patient's destination.

Table 5-8 Summary of Significant Factors for Land Transfers

Interval	Description	Significant Factors
A	Call Accepted-Depart Base	Base Provider
B	Depart Base-Arrive P/U Site	Route (or Distance)
C	Arrive P/U Site-Arrive Pt. Site	Sending Facility
D	Arrive Pt. Site-Depart Pt. Site	Sending Facility
E	Depart Pt. Site-Depart P/U Site	Sending Facility
F	Depart P/U Site-Arrive Destination	Route (or Distance)
G	Arrive Destination-Delivery Pt. Site	Receiving Facility

5.3.3 Using Online Mapping Services for Time Estimations

The statistical analysis revealed that including time of day and time of year does not improve the model's prediction ability of land travel times. Considering the fact that all land data were included in statistical analysis, these results seem reasonable as explained in the following paragraphs.

The rush hour and traffic conditions might be different in different regions of Ontario. To accurately estimate the effect of time of day on land travel times, a reasonable sample size for each region of Ontario in different times of the day is required. As mentioned before, one of the characteristics of this dataset was the occasional small number of historical observations especially for land transfers. Therefore, the only option was to analyze land transfer data at an aggregate level (without considering individual routes) and investigate the effect of distance, time of day, and time of year.

In order to take into account the effects of traffic, weather, and other external factors (e.g., road condition), one option would be to look at online information from web mapping services as these services provide real-time information on routes and traffic conditions.

Bing Maps is an online web mapping service that allows the application developers to access its online information (i.e., driving time, driving distance, etc.). Using a Visual Basic code, we generated travel time estimates corresponding to the land ambulance transfers in our dataset (interval F-Land). The historical travel times by Ornge land ambulances were then compared with the estimated travel times obtained through Bing Maps. The Bing Maps' times were produced at an arbitrary date/time (3 pm on August 03, 2012). The weather and traffic condition of southern Ontario (i.e., locations of Ornge land bases) were confirmed using online services. No unusual weather or traffic events were observed.

Figure 5-7 shows the linear relationship between the historical travel times and the estimates provided by Bing Maps. The value of R squared is .81, which suggests a strong linear relationship. The R squared value of this model (R^2=.81) is greater than the R squared value of the regression model (discussed in section 5.2.4) which used only distance as an independent variable (R^2=.72). This finding suggests that using Bing Maps to estimate the land travel times would yield more accurate results than using a linear relationship built solely on distance and time. The more accurate results could be due to the fact that, Bing Maps also considers additional information such as road type (e.g., highway, street, etc.). Given that the above evaluation was based on a single, arbitrary date/time, further study is needed to assess the value of using Bing Maps time estimates for a wider range of dates and times.

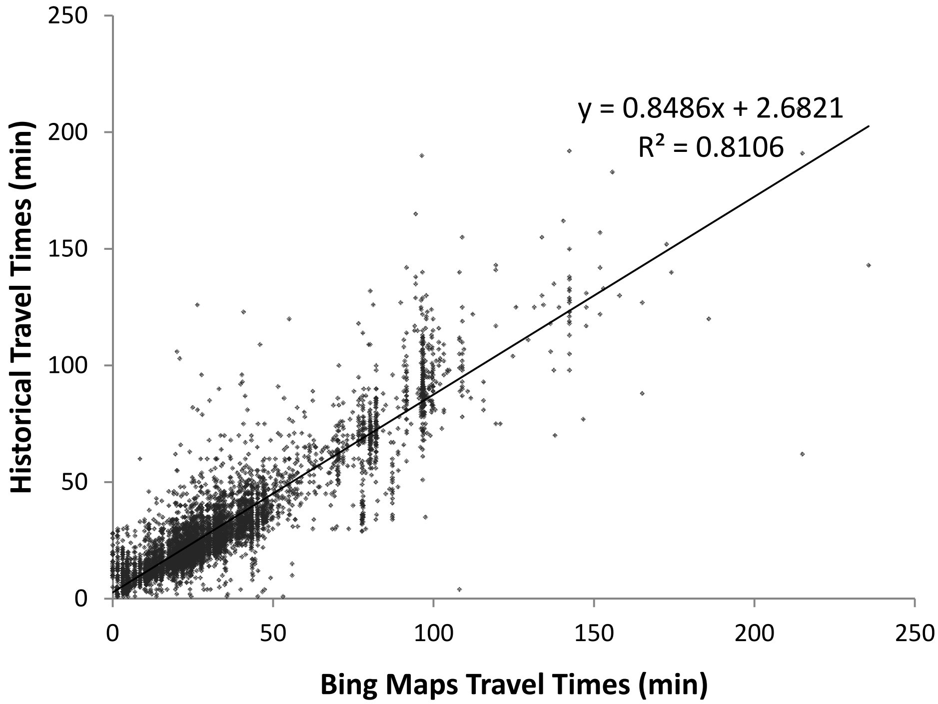


Figure 5-7 Linear Relationship between Historical Travel Times by Land Ambulances and Estimates Obtained through Bing Maps

Chapter 6
Specifying Tool Inputs and Outputs

6.1 Reporting the Median

The available dataset contained around 36,000 emergent/urgent interfacility patient transfers. Therefore, a large number of outliers were expected to be observed in the dataset that could not be explained by the available factors.

In general, most of the intervals had a positively skewed distribution (Figure 6-1). These distributions, similar to the half normal distribution, can be in part explained by the fact that time is a positive variable. It was also observed that in many cases, after removing the outliers, mean and median were almost identical.

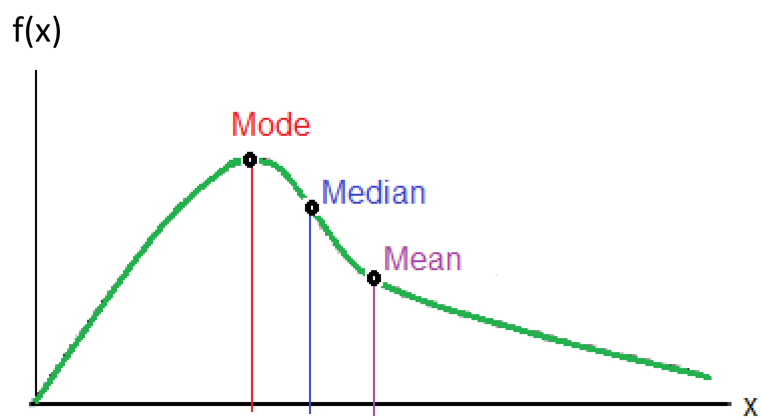


Figure 6-1 Most of the intervals had a positively skewed distribution.

Figure 6-2 shows an example of the outliers for interval C-Land for Mount Sinai Hospital. As mentioned before, the statistical analysis revealed that sending facility was the only significant predictor for interval C (i.e., from parking to patient's bedside) in land transfers. The available dataset contained 39 observations with Mount Sinai Hospital as the sending facility for land transfers. The average duration for interval C for this hospital was 7.05 minutes. However, there were some outliers in the data that affected the average time (e.g., two cases between 40 and 45 minutes which are out of the ordinary).

In order to provide better estimates, one option was to remove the outliers and re-estimate the average time. After removing the outliers, the average time became 5.2 minutes. Another option was to use median as it is affected less by outliers. The median time for interval C for Mount Sinai was 5 minutes.

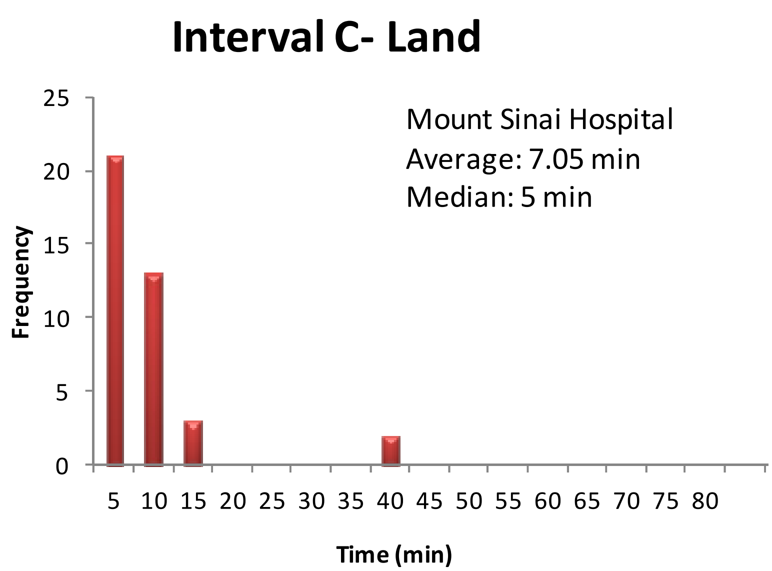


Figure 6-2 An Example of the Outliers in the Interval C-Land's Data for Mount Sinai Hospital

After identifying the significant factors for each interval, the median time for each level of these factors was selected to be reported as the tool's output. Below is the list of reasons as to why the median was selected as the measure of central tendency:

- **Similar results:** Adjusted mean (or mean after removing the outliers) and median yielded very similar results for the majority of cases.

- **Amount of data cleaning:** Estimating the adjusted means required extensive data cleaning on the large historical dataset. Also, because of the inconsistencies in data entries, some of the incorrect data entries were not easily detectable.
- **Effect of outliers:** As mentioned before, many outliers were observed in the dataset that were due to inconsistencies in terminologies, errors in recording the data, etc. Additionally, in this observational study, the sample sizes were not equal; some samples had hundreds of observations and some had less than 10 observations. Using the median reduces the effect of the outliers especially when the sample size is small.

It is worth mentioning that detailed investigations are required to find the reasons for the outliers observed in the dataset. It is possible that through these investigations potentially significant factors might be identified for which recording and keeping track of in the future would prove to be beneficial.

6.2 Lack or Scarcity of Data

As mention in section 4.1.3, lack or scarcity of data for particular facility combinations is one of the main characteristics of this dataset. The potential reasons for lack or scarcity of data in different intervals are presented below.

- **Interval A** (call accepted – depart base): For both air and land transfers, this interval had sufficient amount of data.
- **Interval B** (depart base – arrive pick-up site): For air and land transfers, the lack or sparseness of data has been observed to occur when the patient is picked-up from a location that is not one of the base's common pick-up sites.
- **Interval C** (arrive pick-up site – arrive patient site): For air transfers, the lack or sparseness of data has been observed to occur when a pick-up landing site is used

that is not commonly used for that sending facility. For land transfers, it appears to have happened for facilities that have rarely used Ornge services for transferring patients to other facilities.

- **Interval D** (arrive patient site – depart patient site): For both air and land transfers, the lack or sparseness of data for this interval has been observed to occur for facilities that have rarely used Ornge services for transferring patients to other facilities.
- **Interval E** (depart patient site – depart pick-up site): Similar to interval C, for air transfers, the lack or sparseness of data has been observed to occur when a pick-up landing site is used that is not commonly used for that sending facility. For land transfers, it was observed to have happened for the facilities that have rarely used Ornge services for transferring patients to other facilities.
- **Interval F** (depart pick-up site – arrive destination landing site): For air transfers, the lack or sparseness of data has been observed to occur when the aircraft is travelling an uncommon route between two landing sites. For land transfers, it was observed to have happened when the land ambulance is travelling between an uncommon combination of sending and receiving facilities.
- **Interval G** (arrive destination landing site – delivery patient site): For air transfers, the lack or sparseness of data has been observed to occur when a destination landing site is used that is not commonly used for that receiving facility. For land transfers, it was observed to have happened for the facilities that rarely receive patients from other facilities through Ornge transfers.

The lack or scarcity of data for different intervals had major implications for decision support design. For each interval, depending on whether the number of historical observations for the interval is smaller or greater than a cut-off value, a different estimation method will be used. This cut-off value for minimum number of observations can be selected by advanced users (e.g., operations managers) and pre-inputted to the tool as a default setting.

The algorithms built for estimating different intervals are presented in sections 6.3 and 6.4. These algorithms are based on the analysis and the associated results reported in Chapter 5. The following two sections provide a very detailed account of these algorithms and would be particularly useful for future software developers. The reader can skip these sections without a break in the continuity of the thesis.

6.3 Time Estimations for Air Transfers

6.3.1 Call Accepted – Depart Base (Interval A)

Statistical analysis revealed that aircraft model is an important factor that should be taken into account when estimating interval A for air transfers.

Figure 6-3 shows the time estimation process for interval A for air transfers. If the aircraft model is equal to X, and if there is a considerable amount of historical data, then the median of the relevant data would be reported as the time estimate. However, if the number of historical observations (i.e., N(X)) is deemed to not be enough, the median duration of interval A for all air transfers would be reported as the estimated time for interval A (T_A).

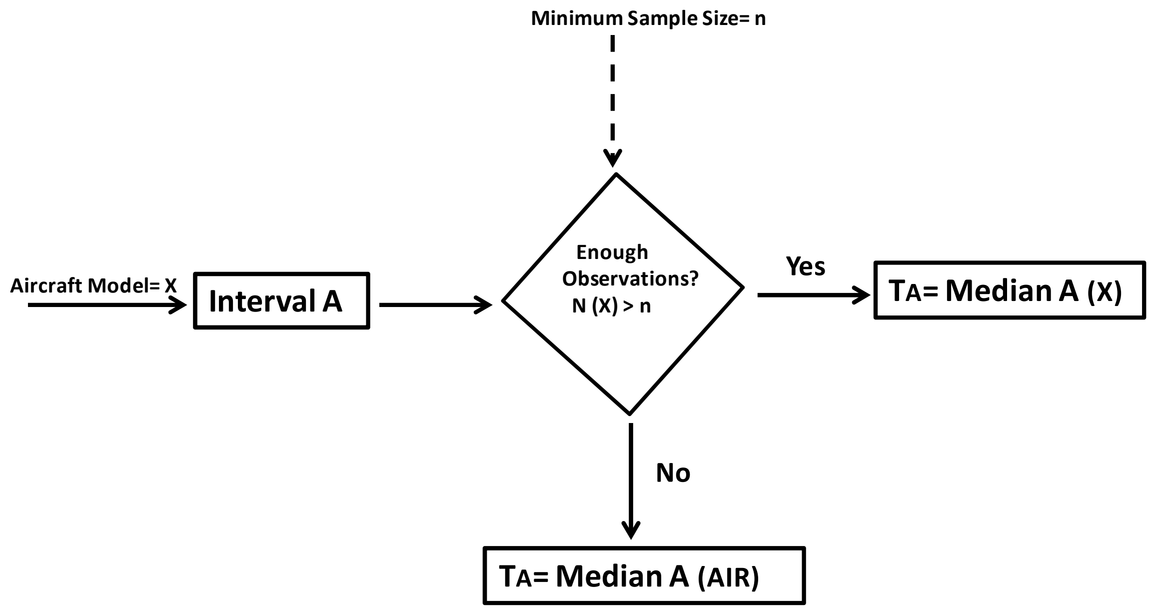


Figure 6-3 Time Estimation Process for Interval A for Air Transfers

6.3.2 Depart Base – Arrive Pick-up Site (Interval B)

Statistical analysis revealed that aircraft model and distance are two important factors that should be taken into account in order to estimate interval B for air transfers. However, by only considering these two conditions, some route-related factors (e.g., busy air routes) might be ignored. If there is a considerable amount of historical data, it would be more reasonable to replace the factor 'distance' with the factor 'route' (i.e., combination of the base provider name and the pick-up landing site name).

Figure 6-4 shows the time estimation process for interval B for air transfers. If the base provider is equal to W, the aircraft model is equal to X, the sending landing site is equal to U, and if there is a considerable amount of historical data, then the median of the relevant data would be reported as the time estimate. However, if the number of historical observations is deemed to be not enough, the distance between the base provider location and the sending facility landing site (S_B) would be calculated, and entered in the associated time-distance regression equation (f_x) for that aircraft model (Please see section 5.1.2).

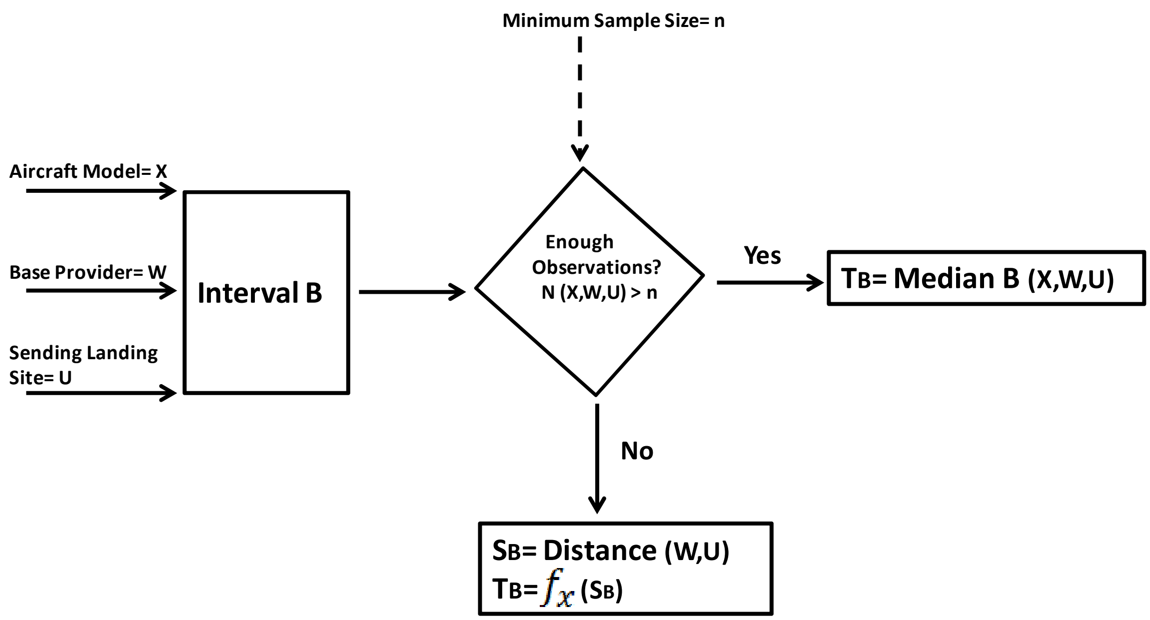


Figure 6-4 Time Estimation Process for Interval B for Air Transfers

6.3.3 Arrive Pick-up Site – Arrive Patient Site (Interval C)

Statistical analysis revealed that distance was an only influential factor that should be used to estimate interval C. Similar to interval B, if there is a considerable amount of historical data, it would be more reasonable to replace the factor 'distance' with the factor 'route' (i.e., combination of the pick-up landing site name and sending facility name). However, if the number of historical observations is deemed to be not enough, it is not best to use the distance-based regression equation reported in section 5.1.5, as the predictive power for this model was poor (only 12% of the variation in interval C could be explained by distance; please see Table 5-4). For these cases, another option is to report the median time of similar cases. The cases which have similar distance values (not necessarily the exact same distance value) can be utilized to calculate a median.

Figure 6-5 shows the time estimation process for interval C for air transfers. If the sending facility name is equal to P, and the sending landing site is equal to U, and if there is a considerable amount of historical data, then the median of the relevant data would be reported as the time estimate. However, if the number of historical observations is deemed to be not enough, the distance between the sending facility and the sending landing site can be calculated (S_c). Then, if there is a considerable amount of historical data when the distance is equal to S_c, the median of the relevant data would be reported as the time estimate for that case. If the number of historical observations is deemed to be not enough at this distance, then the median time of similar cases (i.e., cases for which the sending facility- sending landing site distance falls between $S_c - \varepsilon$ and $S_c + \varepsilon$) can be reported. . The value of ε can be determined and inputted automatically or by advanced users (e.g., operations managers).

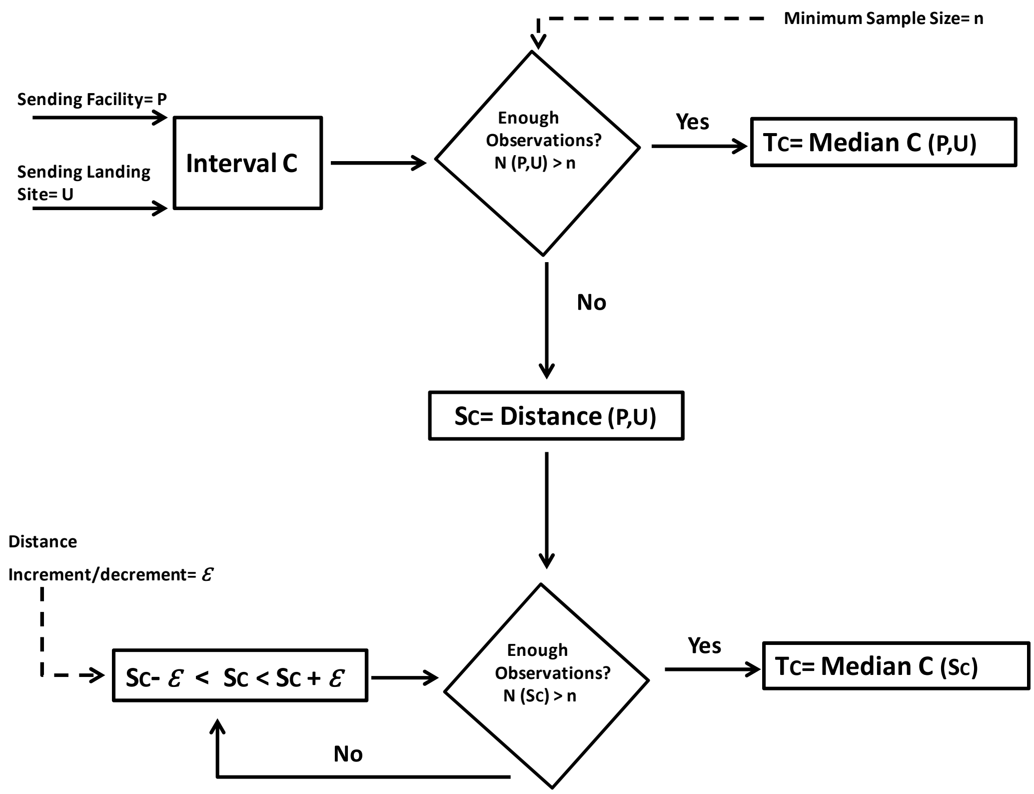


Figure 6-5 Time Estimation Process for Interval C for Air Transfers

6.3.4 Arrive Patient Site – Depart Patient Site (Interval D)

The effect of sending facility was taken into account to estimate interval D for both air and land transfers.

Figure 6-6 shows the time estimation process for interval D for air and land transfers. If the sending facility name is equal to P and if there is a considerable amount of historical data for this facility, then the median of the relevant data would be reported as the time estimate. However, if the number of historical observations is deemed to be not enough, the median of all in-hospital times would be used (~22 min).

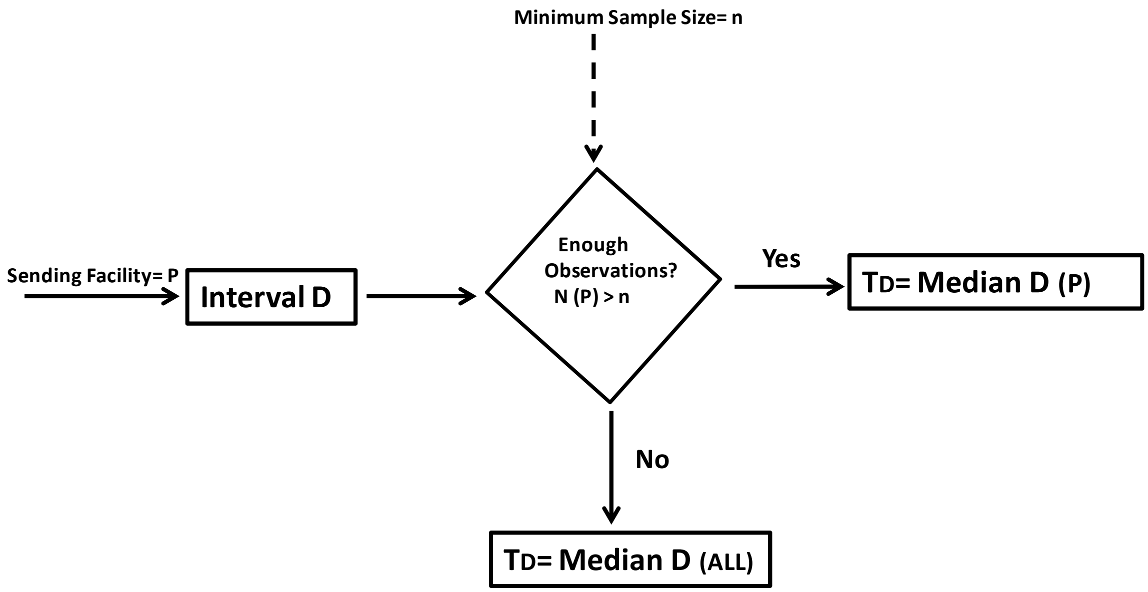


Figure 6-6 Time Estimation Process of Interval D for Air and Land Transfers

6.3.5 Depart Patient Site – Depart Pick-up Site (Interval E)

The time estimation process for this interval is similar to the one for interval C. If there is a considerable amount of historical data, the median time of the specified combination of the pick-up landing site and sending facility would be reported. If the number of historical observations is deemed to be not enough, the median time of the similar cases (similarity based on distance) would be reported.

Figure 6-7 shows the time estimation process for interval E for air transfers. If the sending facility name is equal to P, the sending landing site is equal to U, and if there is a considerable amount of historical data, then the median of the relevant data would be reported as the time estimate. However, if the number of historical observations is deemed to be not enough, the distance between the sending facility and sending landing site (SE) can be calculated. Then, if there is a considerable amount of historical data when the distance is equal to SE, the median of the relevant data would be reported as the time estimate. If the number of historical observations is deemed to be not enough for this distance, then the median time of the similar cases (i.e., cases for which the sending facility- sending landing site distance falls between $S_C - \mathcal{E}$ and $S_C + \mathcal{E}$) can be reported. The value of $\mathcal{E}$ can be determined and inputted automatically or by the users.

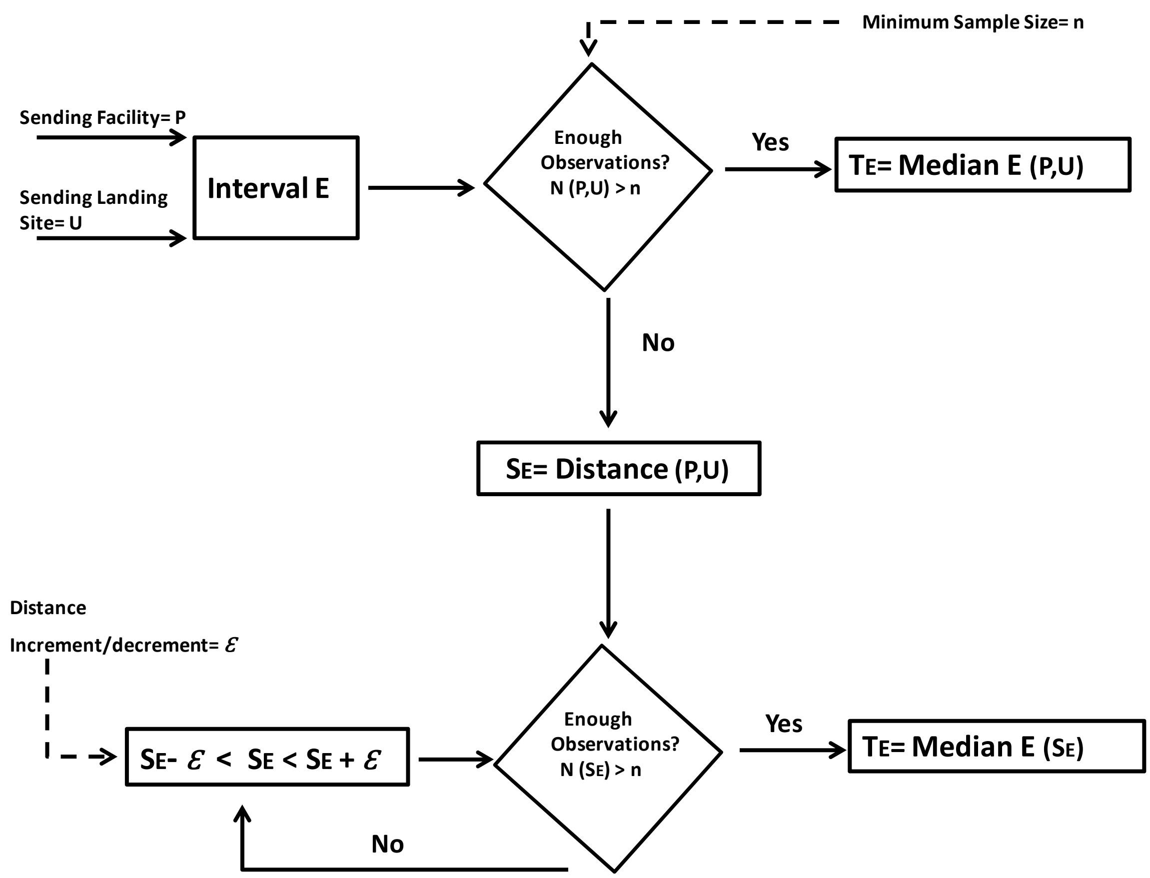


Figure 6-7 Time Estimation Process for Interval E for Air Transfers

6.3.6 Depart Pick-up Site – Arrive Destination Landing Site (Interval F)

Statistical analysis revealed that aircraft model and distance are two important factors that should be taken into account when estimating interval F for air transfers. However, by only considering these two conditions, some route-related factors (e.g., busy air routes) might be ignored. If there is a considerable amount of historical data, it would be more reasonable to replace the factor 'distance' with the factor 'route' (i.e., combination of the pick-up landing site name and destination landing site name).

Figure 6-8 shows the time estimation process for interval F for air transfers and is similar to the one for interval B. If the aircraft model is equal to X, the sending landing site is equal to U, the receiving landing site is equal to V, and if there is a considerable amount of historical data, then the median of the relevant data would be reported as the time estimate. However, if the number of historical observations is deemed to be not enough, the distance between the sending facility landing site and the receiving facility landing site would be calculated, and entered in the associated regression equation for that aircraft model (Please see section 5.1.2).

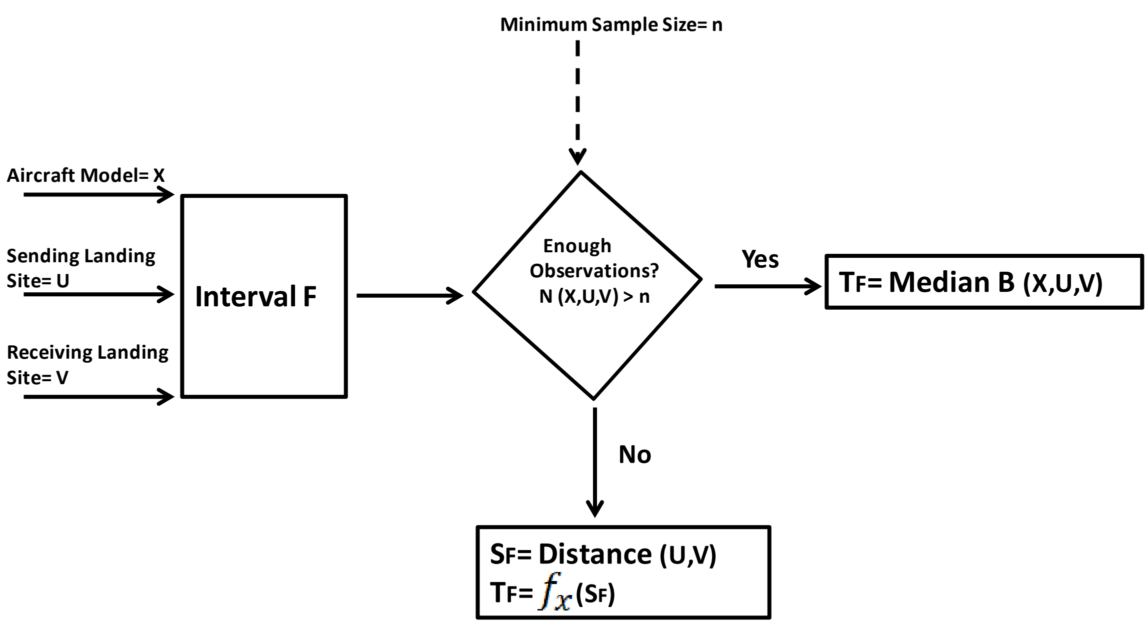


Figure 6-8 Time Estimation Process of Interval F for Air Transfers

6.3.7 Arrive Destination Landing Site – Delivery Patient Site (Interval G)

Statistical analysis revealed that distance was an influential factor that should be used when estimating interval G. If there is a considerable amount of historical data, it would be more reasonable to replace the factor 'distance' with the factor 'route' (i.e., combination of the destination landing site and receiving facility). However, if the number of historical observations is deemed to be not enough, it is not best to use the distance-based regression equation reported in section 5.1.5, as the predictive power for this model was poor (only 26% of the variation in interval G could be explained by distance; please see Table 5-4). For these cases, another option is to report the median time of similar cases (similarity based on distance).

Figure 6-9 shows the time estimation process of interval G for air transfers. If the receiving facility name is equal to Q, and the destination landing site is equal to V, and if there is a considerable amount of historical data when these two conditions are met, then the median of the relevant G data would be reported as the time estimate. However, if the number of historical observations is deemed to be not enough, the distance between the receiving facility and the destination landing site can be calculated(S_G). Then, if there is a considerable amount of historical data when the distance is equal to S_G, the median of the relevant data would be reported as the time estimate for that case. If the number of historical observations is deemed to be not enough for this distance, then the median time of similar cases (i.e., cases for which the receiving facility- destination landing site distance falls between $S_G- \varepsilon$ and $S_G+ \varepsilon$) can be reported. The value of ε can be determined and inputted automatically or by the users.

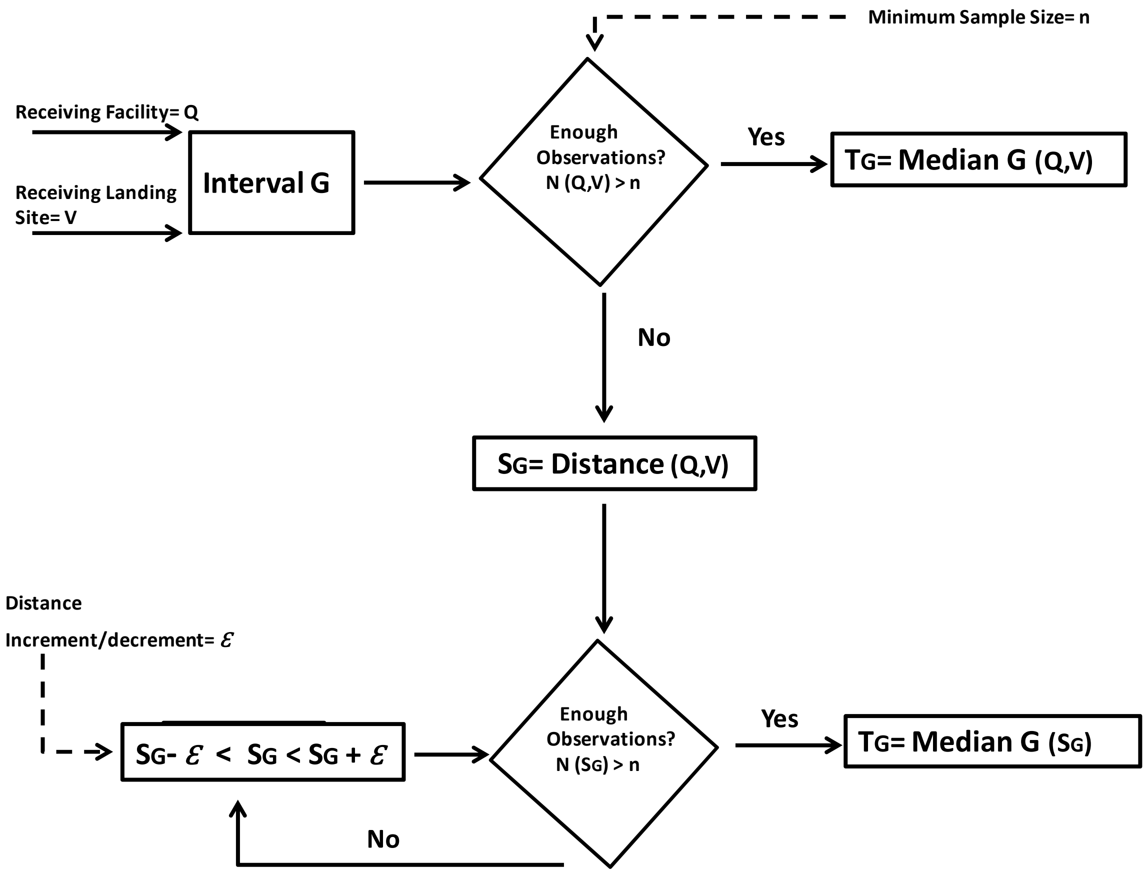


Figure 6-9 Time Estimation Process for Interval G for Air Transfers

6.4 Time Estimations for Land Transfers

6.4.1 Call Accepted – Depart Base (Interval A)

The effect of base provider was taken into account in order to estimate interval A for land transfers.

Figure 6-10 shows the time estimation process for interval A for land transfers. If the base provider name is equal to L and if there is a considerable amount of historical data, then the median of the relevant data would be reported as the time estimate. However, if the number of historical observations (i.e., N(L)) is deemed to not be enough, the median duration of interval A for all land transfers would be reported as the estimated time for interval A ($T`_A$; ~5 min).

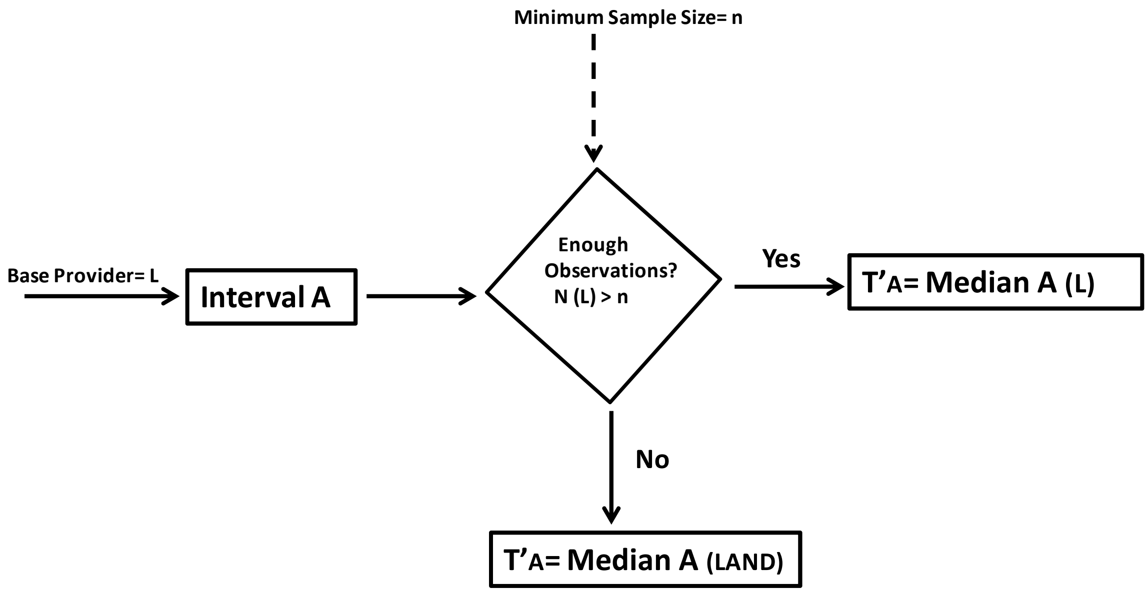


Figure 6-10 Time Estimation Process for Interval A for Land Transfers

6.4.2 Depart Base – Arrive Pick-up Site (Interval B)

Statistical analysis revealed that distance is an important factor that should be taken into account in order to estimate interval B for land transfers. However, by only considering this factor, some route-related factors (e.g., busy land routes) might be ignored. If there is a considerable amount of historical data, it would be more reasonable to replace the factor 'distance' with the factor 'route' (i.e., combination of the base provider name and sending facility name).

Figure 6-11 shows the time estimation process for interval B for land transfers. If the base provider is equal to L, the sending facility is equal to P, and if there is a considerable amount of historical data, then the median duration of interval B for all relevant data would be reported as the time estimate. However, if the number of historical observations is deemed to be not enough for these two conditions, the distance between the base provider location and the sending facility would be calculated, and entered in the time-distance regression equation reported in section 5.2.4.

Another option for dealing with lack or scarcity of data for this interval is to utilize times estimated by Bing Maps (see Section 5.3.3).

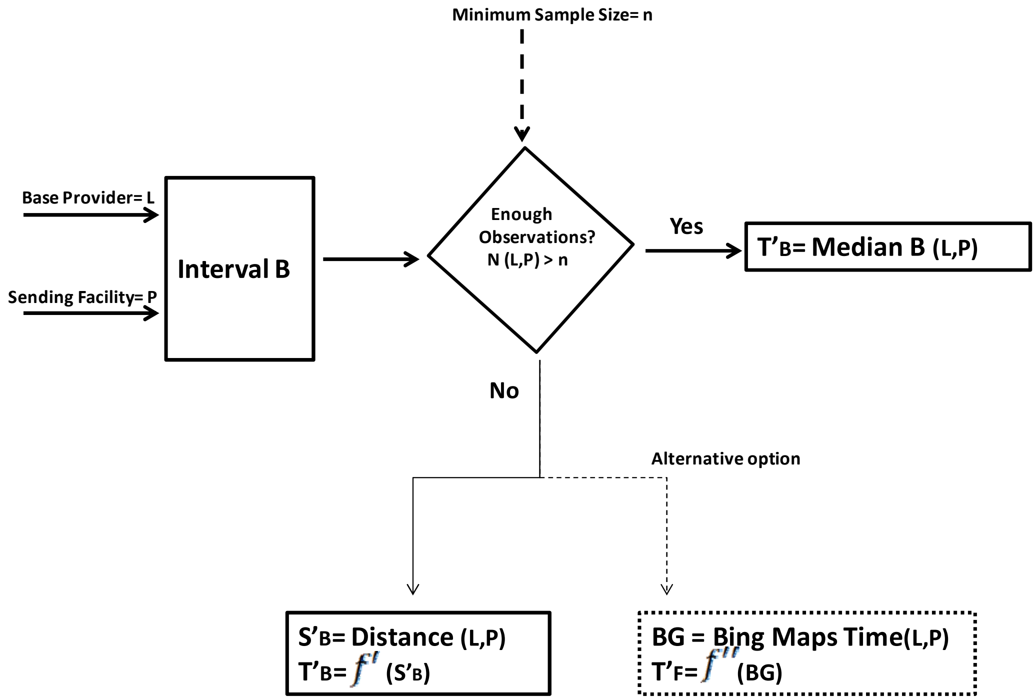


Figure 6-11 Time Estimation Process for Interval B for Land Transfers

6.4.3 Arrive Pick-up Site – Arrive Patient Site (Interval C)

The effect of sending facility was taken into account in order to estimate interval C for land transfers.

Figure 6-12 shows the time estimation process for interval C for land transfers. If the sending facility name is equal to P and there is a considerable amount of historical data, then the median of the relevant data would be reported as the time estimate. However, if the number of historical observations is deemed to be not enough, the median duration of interval C for all land transfers would be reported as the estimated time for interval C (~5 min).

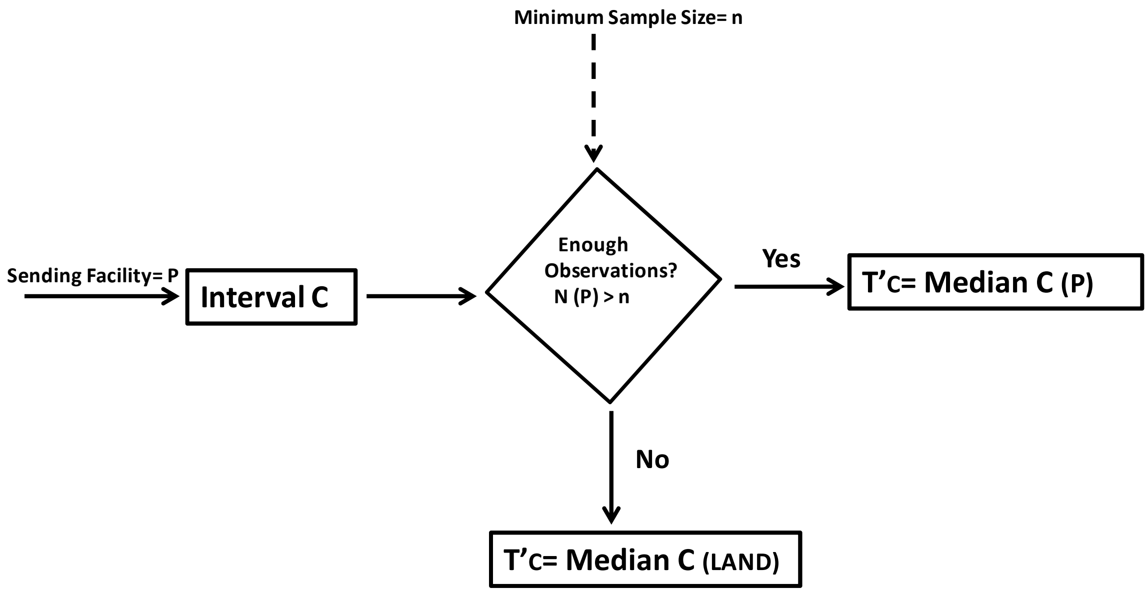


Figure 6-12 Time Estimation Process for Interval C for Land Transfers

6.4.4 Depart Patient Site – Depart Pick-up Site (Interval E)

Similar to interval C, the effect of sending facility was taken into account in order to estimate interval E for land transfers.

Figure 6-13 shows the time estimation process for interval E for land transfers. If the sending facility name is equal to P, and if there is a considerable amount of historical data, then the median of the relevant data would be reported as the time estimate. However, if the number of historical observations is deemed to be not enough, the median duration of interval E for all land transfers would be reported as the estimated time for interval E (~5 min).

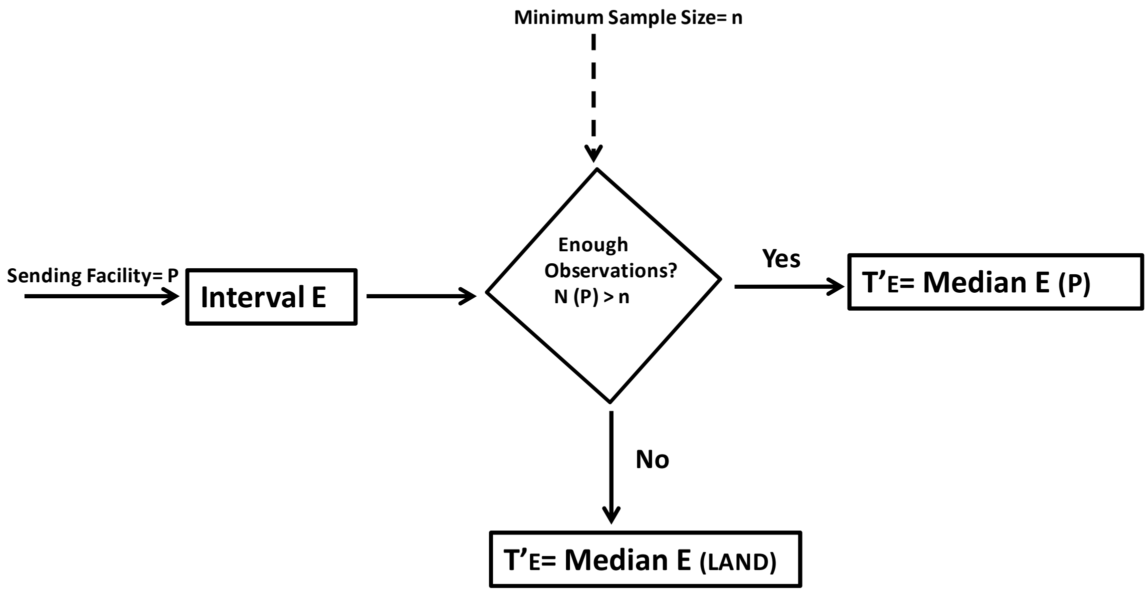


Figure 6-13 Time Estimation Process for Interval E for Land Transfers

6.4.5 Depart Pick-up Site – Arrive Destination Landing Site (Interval F)

Statistical analysis revealed that distance is an important factor that should be taken into account in order to estimate interval F for land transfers. However, by only considering this factor, some route-related factors (e.g., busy land routes) might be ignored. If there is a considerable amount of historical data, it would be more reasonable to replace the factor 'distance' with the factor 'route' (i.e., combination of the sending facility name and receiving facility name).

Figure 6-14 shows the time estimation process for interval F for land transfers. If the sending facility is equal to P, the receiving facility is equal to Q, and there is a considerable amount of historical data, then the median of the relevant data would be reported as the time estimate. However, if the number of historical observations is deemed to be not enough, the distance between the sending facility and the receiving facility would be calculated, and entered in the time-distance regression equation for land transfers.

Another option for dealing with lack or scarcity of data for this interval is to look at times estimated by Bing Maps (Section 5.3.3).

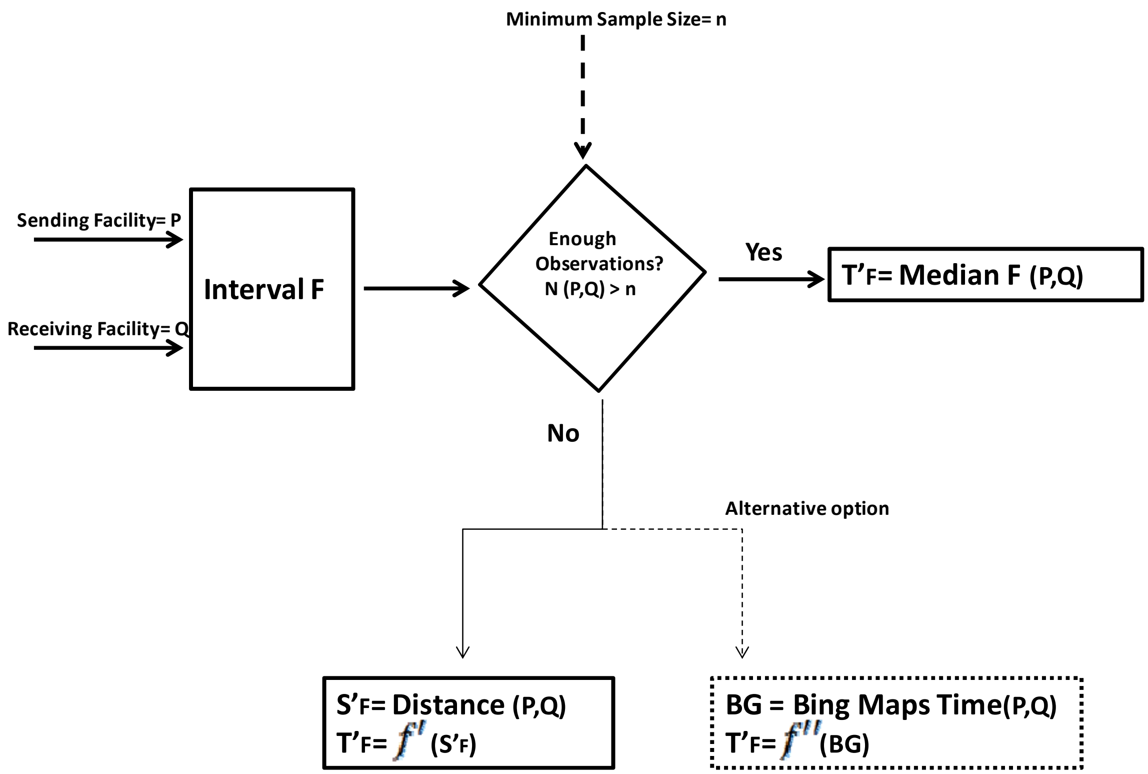


Figure 6-14 Time Estimation Process for Interval F for Land Transfers

6.4.6 Arrive Destination Landing Site – Delivery Patient Site (Interval G)

The effect of receiving facility was taken into account in order to estimate interval G for land transfers.

Figure 6-15 shows the time estimation process for interval G for land transfers. If the receiving facility name is equal to Q and there is a considerable amount of historical data, then the median of the relevant data would be reported as the time estimate. However, if the number of historical observations is deemed to be not enough, the median duration of interval G for all land transfers would be reported as the estimated time for interval G (~6 min).

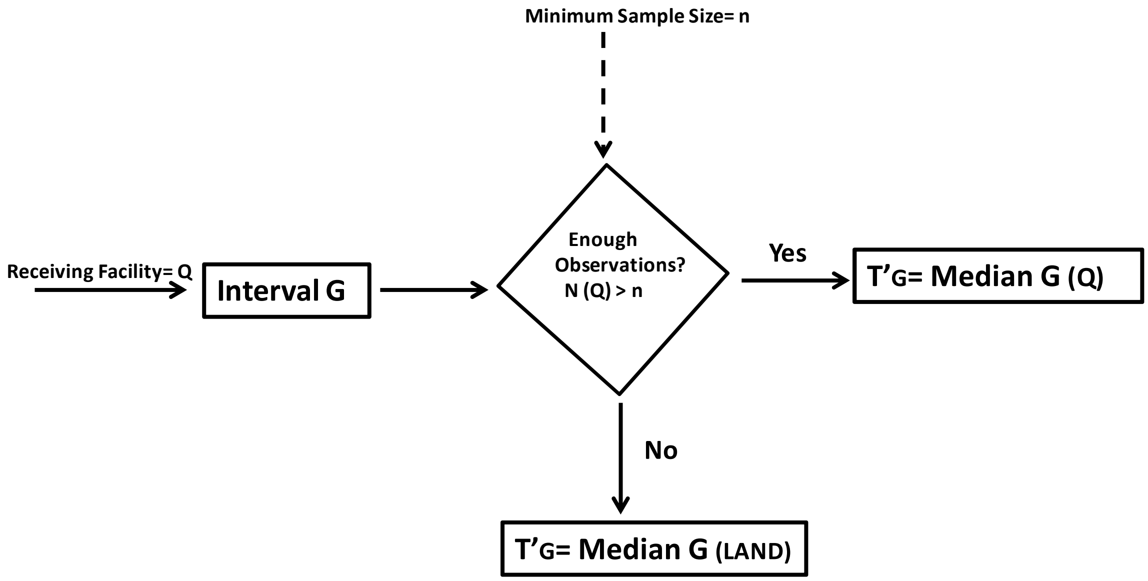


Figure 6-15 Time Estimation Process for Interval G for Land Transfers

Chapter 7
Interface Design

7.1 Preliminary Design of the Tool

Although there are severe limitations associated with using Excel as a platform to build an interface, Ornge requested an Excel tool for the preliminary version, as it could be easily implemented and tested in the communications centre.

Figure 7-1 shows the suggested preliminary design. The original idea for the tool design came from Gantt charts: horizontal bar charts developed as a production control tool in 1917 by Henry L. Gantt [27]. Gantt charts are known to be simple to understand and easy to construct; they are used by most project managers for all but the most complex projects. These charts can be applied in project planning and scheduling. Example applications in the healthcare system include the design of complex projects such as hospital construction [27]. Further, the tool has been designed with relevant human factors principles and research in mind. For example, [28] conducted a series of experiments to examine the effects of presentation format and time pressure on decision making. It was concluded that graphics are better than tables under increased time pressure [28]. Thus, the prototype design incorporated graphics in addition to tables and was evaluated through a usability study.

The tool interface consists of 4 major sections:

- Input table
- Output table
- Visual representation of the results

- Histograms (accessed through additional tabs)

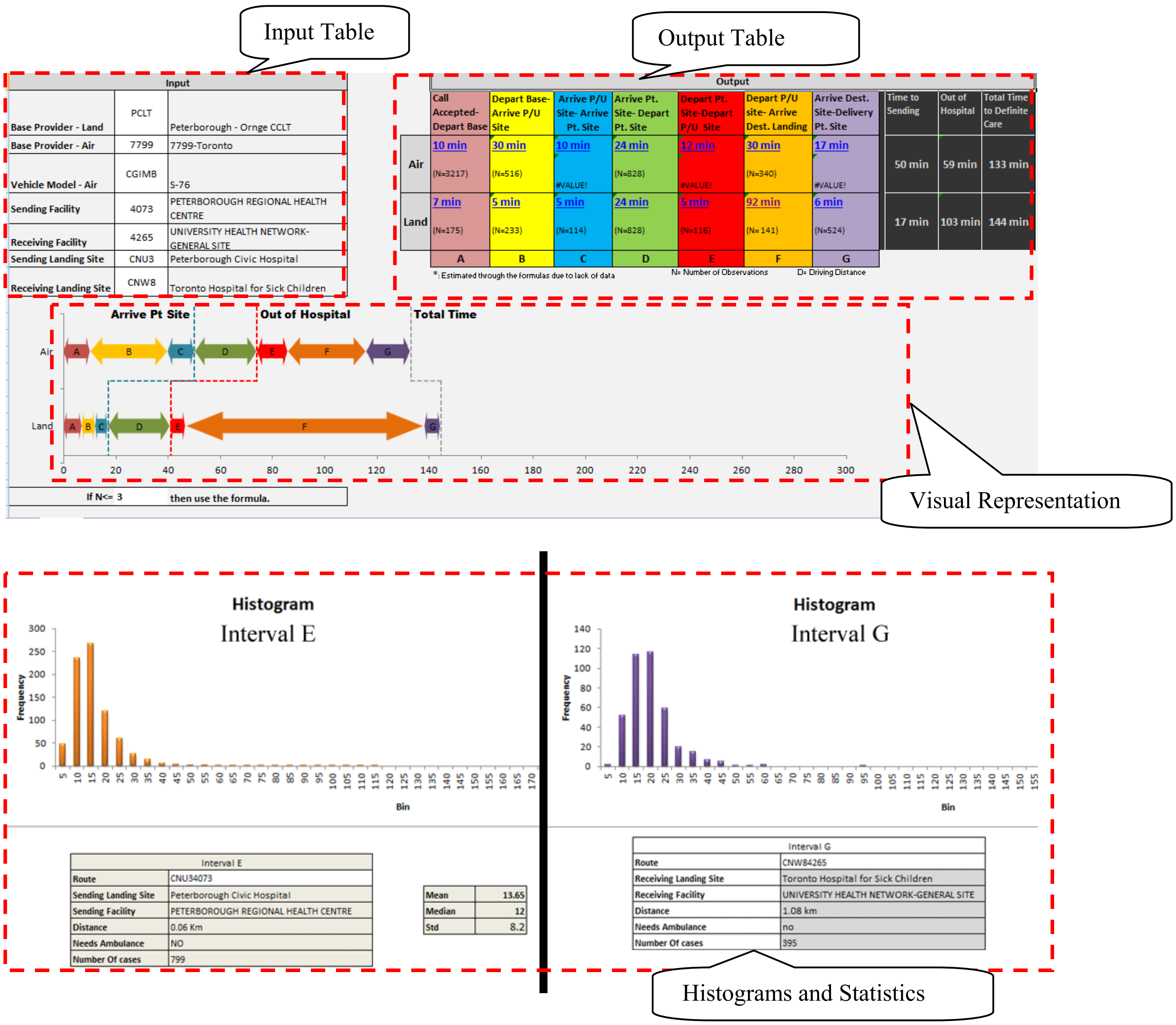


Figure 7-1 Preliminary Design of the Excel Version of the Tool (Histograms are presented in different Excel tabs).

7.1.1 Input Table

The users input the following information in the tool:

- Base provider code for land (four-letter code)
- Base provider code for air (four-digit code)
- Vehicle code (for aircraft): aircraft registration code

- Sending facility code (four-digit code)
- Receiving facility code (four-digit code)
- Sending landing site code (four-letter code)
- Receiving landing site code (four-letter code)
- Minimum number of observations for reporting the median (to be selected by advanced users such as operations managers potentially as a default setting)

Figure 7-2 presents the input section. In the current version of the tool, the users need to enter the code for each facility. Some drop-down menus have been designed to facilitate data entry; however, the ideal method would be an auto-complete feature, which will be discussed in section 7.3.

Input		
Base Provider - Land	PCLT	Peterborough - Ornge CCLT
Base Provider - Air	7799	7799-Toronto
Vehicle Model - Air	CGIMB	S-76
Sending Facility	4073	PETERBOROUGH REGIONAL HEALTH CENTRE
Receiving Facility	4265	UNIVERSITY HEALTH NETWORK-GENERAL SITE
Sending Landing Site	CNU3	Peterborough Civic Hospital
Receiving Landing Site	CNW8	Toronto Hospital for Sick Children

Figure 7-2 Tool's Input Section

7.1.2 Output Table

Figure 7-3 presents the output table. This table provides the user with the time estimate for each interval for different modes of transportation. Additional information, such as distance, number of available observations, and the estimation method can all be included in this table; however, there is concern that providing too much information to the end-users, who have limited time to process this information, might have a detrimental effect on their decision making.

	Output									
	Call Accepted-Depart Base	Depart Base-Arrive P/U Site	Arrive P/U Site- Arrive Pt. Site	Arrive Pt. Site- Depart Pt. Site	Depart Pt. Site-Depart P/U Site	Depart P/U site- Arrive Dest. Landing	Arrive Dest. Site-Delivery Pt. Site	Time to Sending	Out of Hospital	Total Time to Definite Care
Air	10 min (N=3217)	30 min (N=516)	10 min #VALUE!	24 min (N=828)	12 min #VALUE!	30 min (N=340)	17 min #VALUE!	50 min	59 min	133 min
Land	7 min (N=175)	5 min (N=233)	5 min (N=114)	24 min (N=828)	5 min (N=116)	92 min (N= 141)	6 min (N=524)	17 min	103 min	144 min
	A	B	C	D	E	F	G			

*: Estimated through the formulas due to lack of data N= Number of Observations D= Driving Distance

Figure 7-3 Tool's Output Table

7.1.3 Visual Presentation

Figure 7-4 presents the visual representation of time estimates. Different colors have been used for each interval to make the comparison easier for the end-users. For example, yellow has been used for interval B, which represents the travel time from the base to the sending facility. This color coding would help a user who might be only interested in comparing the travel time to the sending facility for different modes of transportation.

It should be noted that, the alphabetic coding of the intervals was adopted by the researcher to shorten the names of the intervals. This coding should be modified in the later versions of the tool to make the intervals easier to comprehend.

Dashed lines have been used to separate three estimates that are particularly important for the physicians: 1) time to bed-side 2) out of hospital time and 3) time to definite care (Total Time).

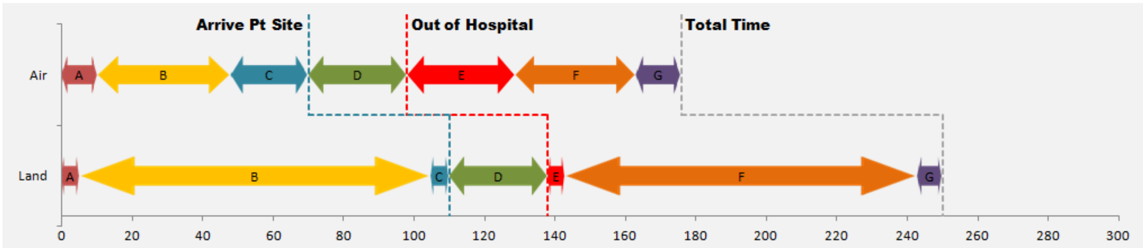
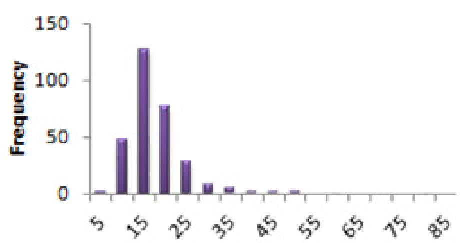


Figure 7-4 Visual Representation of Estimates

7.1.4 Histograms

For each interval, the histogram of historical data can also be presented to the interested users. By clicking on the name of the interval, the users can see the related histogram and the associated summary statistics. This information would be useful to advanced users such as operations managers and physicians. Figure 7-5 shows the histogram for interval G-Air for one of the facilities in Ottawa.



Interval G-Air	
Receiving Landing Site	Ottawa Civic Hospital
Receiving Facility	UNIVERSITY OF OTTAWA HEART INSTITUTE
Number of Cases	298
Distance (miles)	0.36

Mean	14.46
Median	13
Std	7.51

Figure 7-5 Histogram for Interval G-Air for one of the Facilities in Ottawa

7.2 Usability Study

A simple usability study was conducted in order to evaluate the Excel tool and its preliminary design. Seven participants from Ornge communications centre (OCC) were interviewed: four communications officers, three physicians, and one operations manager (Please see Appendix B for the guidelines designed for the participants). Due to time constraints, all of the participants were interviewed when they were on duty and were engaged in their primary tasks. The tool and the estimation method were briefly explained to the participants and then the participants were asked to answer a predetermined set of questions. The questions were mostly about the time estimation methods previously utilized by the operators, the tool's accuracy, and the interface design of the tool including the visualization of the information provided. At the end of the interview session, the participants were asked to share their suggestions to improve the tool.

7.2.1 Previous Methods

The first question was about the previous methods that the participants used to estimate the times for air and land transfers and to select the mode of transportation. Due to inaccurate estimations (discussed in chapter 3), Ornge put a hold on operator estimations, and provided guidelines (using our preliminary results) for some air versus land decisions (Appendix C). The participants were asked to recall the previous estimation methods that they used before this policy went into effect.

The communications officers stated that in order to estimate the time to definite care for land transfers, they mostly looked at Google Maps to find the geographical locations of the facilities and the associated times. For air transfers, they mostly estimated the travel time by considering the distance and the speed of the aircraft using the information provided to them by the dispatching software tools. Some of the more experienced communications officers also tried to consider factors such as route type (e.g., highway, street, etc.) or traffic conditions.

The three physicians who participated in the study were asked how they used the time estimates they received from the communications officers. One of the physicians reported trusting these estimates and using them as they were. The other physician reported using the time estimates provided by the communications officers, but also stated being uncomfortable with these estimates while being aware that they might be wrong. The third physician said that he did not use the time estimates provided by the communications officers as he did not find the methods used to be accurate.

This question was not applicable to the operations managers as they are not involved in the time estimation process.

7.2.2 Questions about the Tool's Outputs

The tool was presented and explained to the participants (inputs, outputs, and visual representation of the time estimates). One of the common cases of patient transfers (sending facility: Peterborough Regional Health Centre, receiving facility: University Health Network-General Site) was used as an example. The introduction of the tool took about 2 minutes and then the participants were asked if they required any additional information about the tool.

Comments on the tool's output: The tool's output for some common combinations (Appendix B) of sending-receiving facilities were presented to the communications officers. The participants were then asked to use their experience to comment on the estimates provided by the tool. All of the participants said that the estimated times "make sense" to them and are "as expected". This question was not applicable to the physicians and operation managers as they were not directly involved in time estimations.

Acquiring additional information: The participants were then asked about how they would proceed to make a decision after seeing the tool's output. In the 2-minute introduction, it was explained to the participants that the tool is not taking into account external factors, such as traffic and weather conditions. This question was asked to see if the participants would refer to additional sources (such as live traffic information) to validate the estimates provided by the tool. All of the participants stated that they would make their air versus land decisions based on the estimates provided by the tool.

The same question was asked again, this time the participants were reminded that the tool is not taking into account external factors such as traffic or weather. It was also reminded to them that the estimated times that are presented to them are medians and the actual times in practice might be shorter or longer than the medians. After reminding these additional points, two of the communications officers and one physician stated that they might look at additional sources (e.g., traffic updates, Google Maps) to validate the estimates. The others stated that they will still rely on the tool's output as gathering traffic and weather information is time-consuming and acquiring accurate information is not guaranteed.

Visual representation of the results: The participants were asked if they found the visual representation of the results helpful. Most of them said that the visual representation is useful and would help them make quicker decisions.

Additional Information: The participants were then asked what additional information they expected to see which was not presented in the current version of the tool. Most of the participants said that no additional information is required and stated that they are basically interested in three time estimates: time to patient bedside (sending facility), out of hospital time, and total time to definite care.

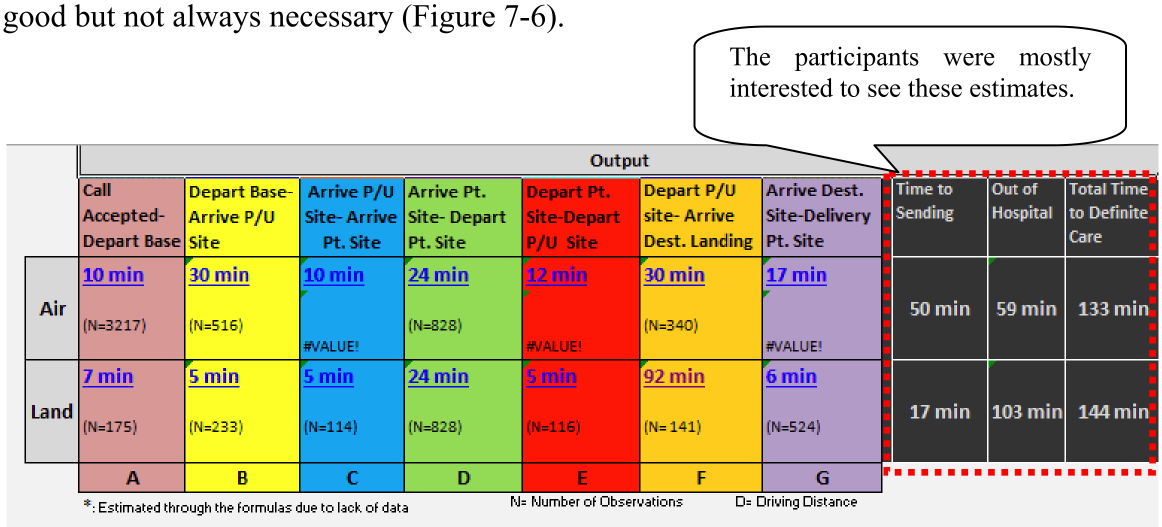
Histograms: The histograms of different intervals were shown and explained to the participants. Communications officers stated that they are not interested to see the histograms and do not find them useful. The physicians and operations managers stated that histograms might be useful for them and they are interested to see them.

Comments on tool's limitations: One of the tool limitations (reliability of the estimates) was explained to the participants with an example. Two histograms were presented to the participants. Both histograms had a median equal to 30 minutes but one of them had 26 observations and the other one had only 3 observations. It was then explained to them that the tool estimates 30 minutes for both of these cases without differentiating between the one with 3 cases and the one with 30 cases. Participants had different opinions about this limitation. Some communications officers said they would still use the tool even if the estimates are based on a few number of observations, as they believed "anything is better than nothing". One of the physicians said that he is concerned about this limitation, but he would like to work with the tool to find the minimum number of observations required to trust the tool. The other physician said that an alert can be provided for the cases that do not have enough observations, so for those cases the users can refer to additional sources. The operations manager had a similar idea: he suggested printing off the tool's output for the suspicious cases and discussing them in the communications centre.

7.3 Open-ended Comments and Recommendations

The participants were also told to feel free to share their ideas and recommendations to improve the tool for the final versions. The following recommendations were made.

Important time estimates: All of the participants stated that they are mostly interested to see three time estimates: 1) time to sending facility (patient bedside) 2) out of hospital time and 3) total time to definite care. They believed seeing all the other sub-intervals are good but not always necessary (Figure 7-6).



	Call Accepted-Depart Base	Depart Base-Arrive P/U Site	Arrive P/U Site- Arrive Pt. Site	Arrive Pt. Site- Depart Pt. Site	Depart Pt. Site-Depart P/U Site	Depart P/U site- Arrive Dest. Landing	Arrive Dest. Site-Delivery Pt. Site	Time to Sending	Out of Hospital	Total Time to Definite Care
Air	10 min (N=3217)	30 min (N=516)	10 min #VALUE!	24 min (N=828)	12 min #VALUE!	30 min (N=340)	17 min #VALUE!	50 min	59 min	133 min
Land	7 min (N=175)	5 min (N=233)	5 min (N=114)	24 min (N=828)	5 min (N=116)	92 min (N= 141)	6 min (N=524)	17 min	103 min	144 min
	A	B	C	D	E	F	G			

*: Estimated through the formulas due to lack of data N= Number of Observations D= Driving Distance

Figure 7-6 Participants believed seeing all the other sub-intervals are good but not always necessary.

Data entry: In the current Excel version, the users are required to either type the sending/receiving facility codes as input or they can select them from a drop down menu. Most participants found these methods time-consuming; they expected an auto complete feature similar to the ones used in web search engines (e.g., Figure 7-7).

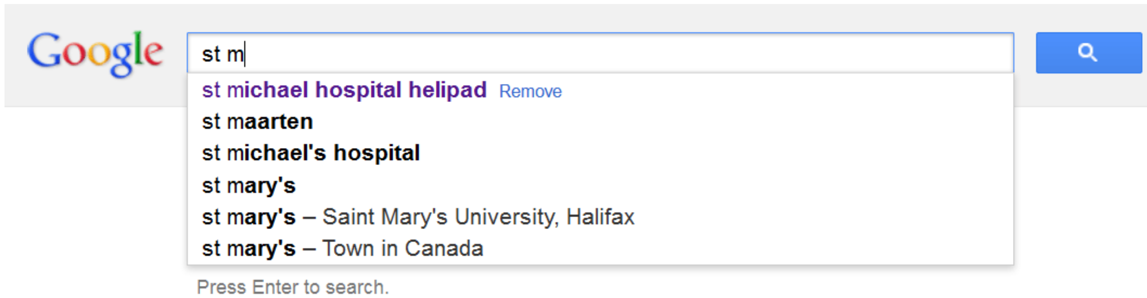


Figure 7-7 Participants expected an auto-complete feature similar to the ones used in web search engines.

Output page layout: Figure 7-1 shows the preliminary version of the tool. Some participants stated that there is a distance between the output table and the visual representation of the results which causes a lot of "back and forth". According to the proximity compatibility principle, and considering that these two sources of information are used within the same task, the location of these outputs should be adjusted [16]. One of the expert participants suggested placing the output table below the graph, but keeping the important results (i.e., time to sending, out-of-hospital time, and total time) at the top of the page. This suggested design is shown in Figure 7-8. This way, the users can see the required results (main intervals) without any distractions (sub-intervals) and refer to the sub-interval information if interested.

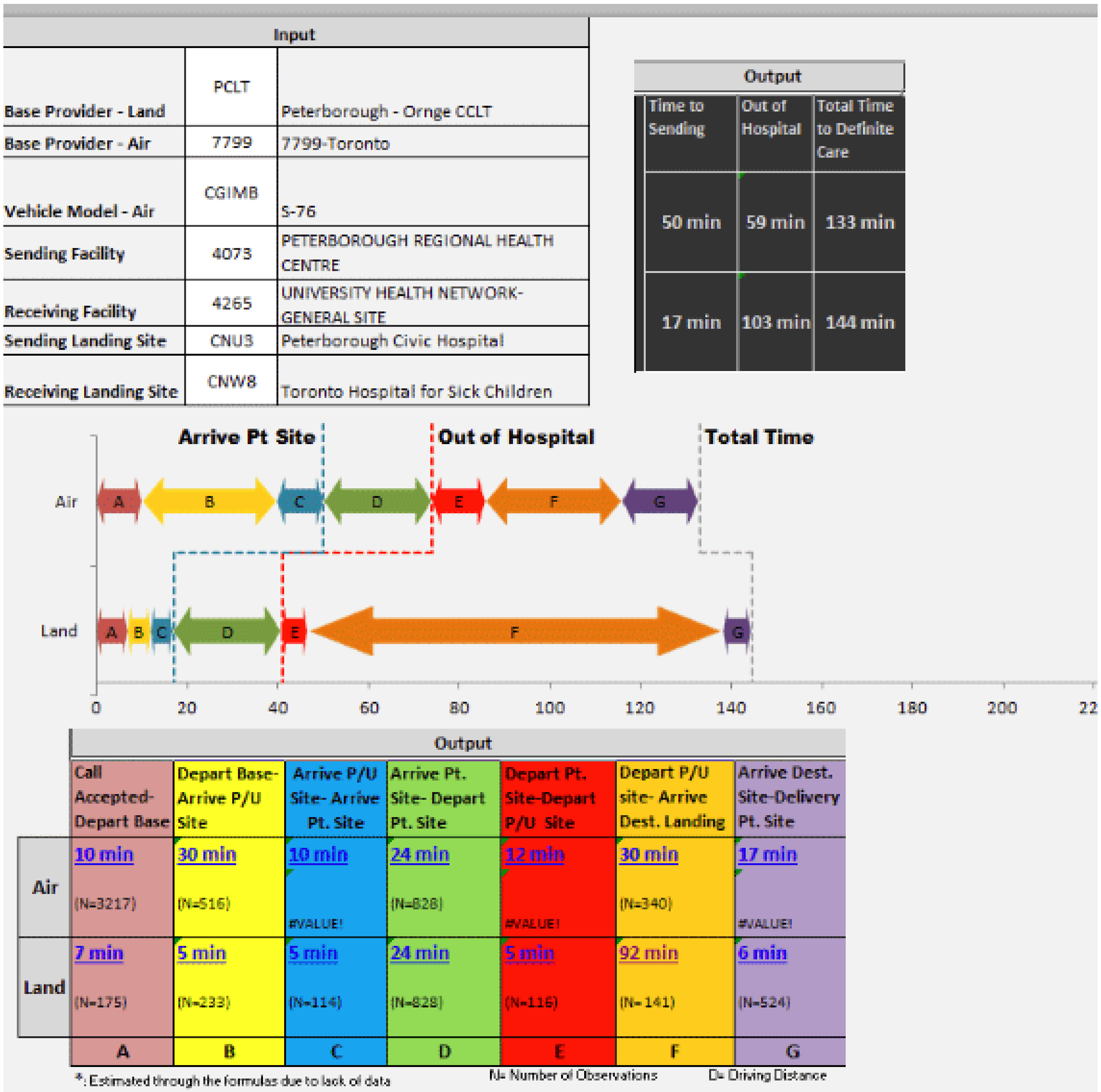


Figure 7-8 An Interface Revision Suggest by a Participants

Histograms: The participants did not want to see the histograms on the tool's main tab. The ones who were interested to analyze the histograms wanted the ability to click on the interval and see its histogram. This feature is included in a newer version of the tool.

Regarding the three important time estimates (i.e., time to sending, out of hospital time, and total time to definite care), one of the physicians was also interested to know which mode of transportation is faster and by how many minutes (e.g., the total time out of hospital for air transfer is shorter by 44 minutes).

Other suggestions: Some participants suggested including other inputs for the later versions of the tool, such as potential fuel stops or the level of care required for transferring the patient.

Chapter 8

Conclusion and Recommendations

Selecting the mode of transportation (air versus land) is known to be an important decision in emergency transport medicine. This decision has a direct effect on time to definite care that is referred to as "the golden hour" in recognition that transport to a designated trauma centre positively impacts patient outcome. In order to select the best transportation option, several factors such as weather, patient condition, distance, etc., should be considered. Despite the complexity, these decisions are often made under time pressure. Research has shown that time-pressure reduces the quality of decision making when humans have to acquire and process information from multiple sources [12]. Analysis of a historical dataset on emergency patient transfers conducted in Ontario between 2010 and 2011 revealed that, time to definite care estimates deviate significantly from observed times. These results are presented in Chapter 3 as well as in [29].

In order to mitigate the negative impact of time pressure on land versus air choice decisions, a decision support tool was created. This tool uses Ornge (transport medicine system in Ontario) dispatch historical data and estimates the transfer times for land and air options. Extensive data cleaning was performed on a large historical dataset (2007-2011). Around 35,000 transfers were then used in data analysis.

In this observational dataset, many factors, such as scarcity or lack of observations for some combinations of sending-receiving facilities were outside the control of the investigator. For some combinations, there were thousands of historical data available, while for some, there were only a few historical data records. The lack of data for particular facility combinations was a major characteristic of this dataset and significantly guided the design of the algorithms used to generate travel time estimates. Further, a limitation of the dataset was the unavailability of potentially useful historical information, such as road, traffic, and weather conditions which may have a significant influence on transfer times.

A method was applied to leverage information from frequent routes in order to estimate the transfer times for non-common routes. The process was first split into subcomponents (or time intervals), and through statistical analyses and field observations, the significant factors for each interval were identified. The time estimates for each interval were then generated based on historical data. In order to reduce the impact of outliers, median times were reported for the cases that had a sufficient number of historical data and regression equations (obtained from statistical analyses) or medians from similar conditions were utilized for cases with a few observations. Separate algorithms were then developed to aggregate the interval estimates of each interval and determine transfer times for all combinations of sending and receiving facilities. This methodology allowed the use of larger datasets for estimating intervals that were common between different sending-receiving facility combinations. Another benefit was the ability to readily calculate and present the time estimates that are deemed important by the operators: time to bedside, out of hospital time, and total time to definite care.

A preliminary interface was designed in Excel and was evaluated by the end users. Some issues were found regarding the preliminary design that should be fixed in later versions. Additionally, further investigation is required to find out how the end-users (specifically transport physicians) interpret the results in practice, and how much they rely on and trust the tool's outputs.

This decision support tool will replace functions that were originally performed by humans (i.e., information acquisition, time estimations, mode comparison, etc.). While eliminating human errors, such as the estimation errors discussed in Chapter 3, automation of tasks can also invite problems [30]. One major issue related to automation is the inappropriate reliance of the human operator on the automation, which is guided by the reliability of the automation as well as the calibration of trust in the automation. Perceived reliability is important, because if an operator distrusts the tool, he might abandon it, even if the tool is useful [31]; on the other hand, an operator who becomes complacent by over-relying on the tool will be less likely to question and monitor the quality of the output provided by the automation [32]. Further research is needed to investigate the actual reliability of this tool as well as how this information should be presented to the decision makers to facilitate trust calibration and hence appropriate reliance.

The estimates generated by the proposed tool should be validated. One way of achieving validation is employing experienced dispatchers who are familiar with particular routes to comment on the accuracy of these estimates. A more objective, and arguably a better way to evaluate the accuracy of the tool, is to utilize a test data set. The test data should be selected from historical transfer data in a way to ensure that a variety of situations are represented (e.g., varying levels of weather and traffic). The accuracy of the tool then should be compared to the estimates generated by dispatchers without using the tool.

It should be noted that, the current version of the tool does not provide variability information aside from the histograms which are considered by the end users to be non-central to the functionality of the tool. However, in order to make an informed air versus land decision it is appears that one should know the spread, or dispersion in the historical data. There are different options to present the variability information, such as presenting standard deviations or quartiles. Further investigation is required to select an appropriate method to provide the variability information to time-pressed end users without causing information overload.

As mentioned before, the tool does not take into account the effect of potentially important factors, such as weather or traffic conditions. Currently, there is no standard method for monitoring and tracking the weather/traffic information in Ornge Communications Centre. This limitation should be made clear to the end-users. Implementing advanced systems that track and record this information will provide useful data for investigating the effect of these potentially significant variables.

Although some factors which were tested in statistical models were statistically significant, they were considered to be practically non-significant by the researcher. Further interviews with end-users are warranted to more accurately identify the limits above which an observed difference should be considered as practically significant.

Finally, although Excel is a very widely used tool for numerical calculations and graphing, it is far from being the best available option for an interface design platform. Some tasks and functions (e.g., creating animated graphs, implementing automatic text completion for data entry, and generating easy to use navigation options) that can be easily built using an html-based tool are either not possible in Excel or require extra programming effort. It is recommended to add a software developer to the research team to create a customized tool based on the algorithms provided in this thesis.

The preliminary version of the tool (Excel) will be released for testing and use in the Ornge Communications Centre in February 2013. Follow-up interviews should be conducted with the users to further improve this tool.

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Appendices

Appendix A
Statistical Analyses

The purpose of the statistical analyses in this section is to identify the significant factors for estimating each of the important intervals. For each interval the significance of several factors was tested using analysis of variance (ANOVA). SPSS and SAS were used to analyze the data.

A.1 Identifying Significant Factors for Air Transfers

A.1.1 Call Accepted – Depart Base (Interval A)

For air transfers, the effect of the following factors on interval A`s duration were investigated:

- Aircraft model
- Month

A two way between subjects ANOVA was run to investigate the significance of these factors on the interval's duration. Table A-1 shows the results of the between subject ANOVA with the above mentioned factors. The dependent variable was the first interval's duration (A); from the time the call is accepted by the base, to the time the air ambulance departs the base.

Table A-1 Results of the between subject ANOVA

Tests of Between-Subjects Effects

Dependent Variable:Time

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	5.232E6	209	25033.731	30.498	.000
Intercept	1541540.375	1	1541540.375	1878.017	.000
Month	11494.361	11	1044.942	1.273	.233
Model	4659390.835	20	232969.542	283.821	.000
Month * Model	277824.843	178	1560.814	1.901	.000
Error	1.375E7	16755	820.834		
Total	3.459E7	16965			
Corrected Total	1.899E7	16964			

a. R Squared = .276 (Adjusted R Squared = .267)

There was a significant main effect of the vehicle model on interval A's duration, $F(20, 16755) = 283.821$, $p<0.001$. Figure A-1 compares the interval A's durations of 6 different aircraft models. S-76 is a rotor wing and the other models are fixed wing aircraft.

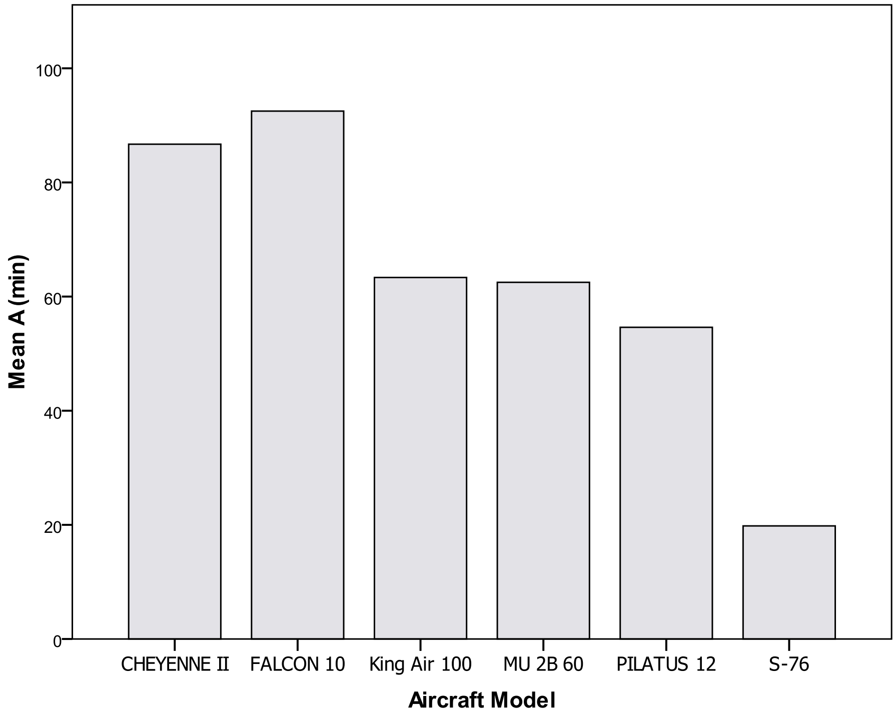


Figure A-1 Interval A's duration Comparison between 6 different aircraft models

The effect of the month on interval's duration (A), F (11, 16755) =1.273, p<.05 was not significant.

A.1.2 Depart Base – Arrive Pick-up Site (Interval B)

For air transfers, this interval is from the time the aircraft takes off and leaves the base to the time the aircraft lands on the sending facility landing site. The effects of the following factors on the interval B's duration were investigated:

- Distance from the base provider to the sending facility landing site
- Month
- Hour of departure
- Aircraft Model

These factors were selected based on the interviews of pilots and paramedics. For the future research, the effect of weather condition on the travel time can also be investigated. At the time of this study, historical weather condition of Ontario was not available to the researcher. Additionally, it was argued that acquiring the weather conditions and inputting them to the system to get the estimated time, would be time-consuming for the users.

Since different aircraft models have different specifications such as cruise speed, cruise altitude, rate of climb etc., for each of the aircraft models a separate analysis was run.

Aircraft Model S-76: Using the GPS coordinates of the landing sites and the great-circle distance formula the distances between landing sites were calculated. Distance was entered into the statistical model as the first predictor. Table A-2 reports the summary of this model; R has a value of .963 which shows the strong correlation between the distance and travel time for helicopters. The value of R square is .927, which tells that distance can account for 92.7% of the variation in travel time by helicopters. Table A-3 also reports an analysis of variance (ANOVA) for this model.

Table A-2 ANOVA model Summary

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.963[a]	.927	.927	4.997

a. Predictors: (Constant), DIST

Table A-3 Results of the between subject ANOVA

Tests of Between-Subjects Effects

Dependent Variable:B

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3.757E6	1	3757024.677	150482.227	.000
Intercept	102603.178	1	102603.178	4109.623	.000
Distance	3757024.677	1	3757024.677	150482.227	.000
Error	297351.819	11910	24.967		
Total	1.471E7	11912			
Corrected Total	4054376.496	11911			

a. R Squared = .927 (Adjusted R Squared = .927)

As the second predictor, month was entered into the model. Table A-4 shows the results of the analysis of covariance (ANCOVA) with distance as the covariate and month as the categorical variable with 12 levels for S-76 helicopters. The main effect of month is significant $F(11,11899)=1.410$, $p=.005$. However, when month was included to the previous model the R squared or adjusted R square (.927) did not change. Therefore adding month to the model does not improve the model's predictability.

Table A-4 Results of the between subject ANOVA

Tests of Between-Subjects Effects

Dependent Variable:B

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3.758E6	12	313140.462	12558.719	.000
Intercept	103077.939	1	103077.939	4134.014	.000
Distance	3731267.163	1	3731267.163	149645.105	.000
Month	660.872	11	60.079	2.410	.005
Error	296690.947	11899	24.934		
Total	1.471E7	11912			
Corrected Total	4054376.496	11911			

a. R Squared = .927 (Adjusted R Squared = .927)

As the third predictor, hour of departure was entered into the model. Table A-5 shows the results of the analysis of covariance (ANCOVA) with distance as the covariate and month (12 levels) and hour (24 levels) as the categorical variables. Similar to the month effect, the main effect of hour is significant $F(23,11623)=180.596$, $p<.001$. Yet, including hour into the model does not improve the predictability; the adjusted R squared changes from .927 to .928 which tells that month and hour account for 0.1% of the variation in travel times by S-76 helicopters.

Table A-5 Results of the between subject ANOVA

Tests of Between-Subjects Effects

Dependent Variable:B

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3.769E6	288	13088.055	533.732	.000
Intercept	96595.564	1	96595.564	3939.174	.000
Distance	3591896.025	1	3591896.025	146477.764	.000
Month	673.090	11	61.190	2.495	.004
Hour	4153.713	23	180.596	7.365	.000
Month*Hour	6776.403	253	26.784	1.092	.153
Error	285016.690	11623	24.522		
Total	1.471E7	11912			
Corrected Total	4054376.496	11911			

a. R Squared = .930 (Adjusted R Squared = .928)

Figure A-2 shows average travel times by helicopters for a particular distance (112 km) in different months. The observed difference between these travel times in different months is, in most of the cases, less than one minute.

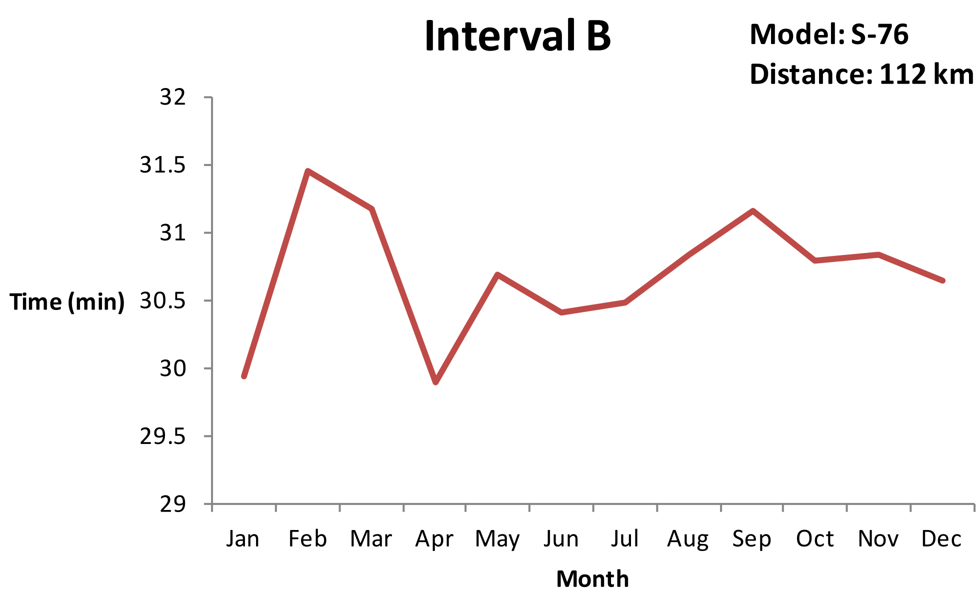


Figure A-2 Travel times by helicopters in different months- 112 Km

Figure A-3 shows average travel times by helicopters for a particular distance (112 km) in different hours. The difference between these travel times in different hours is around 2 minutes (between 30 min and 32 min). However, since there were not enough observations for all levels of hour of departure, some of these averages might not be reliable.

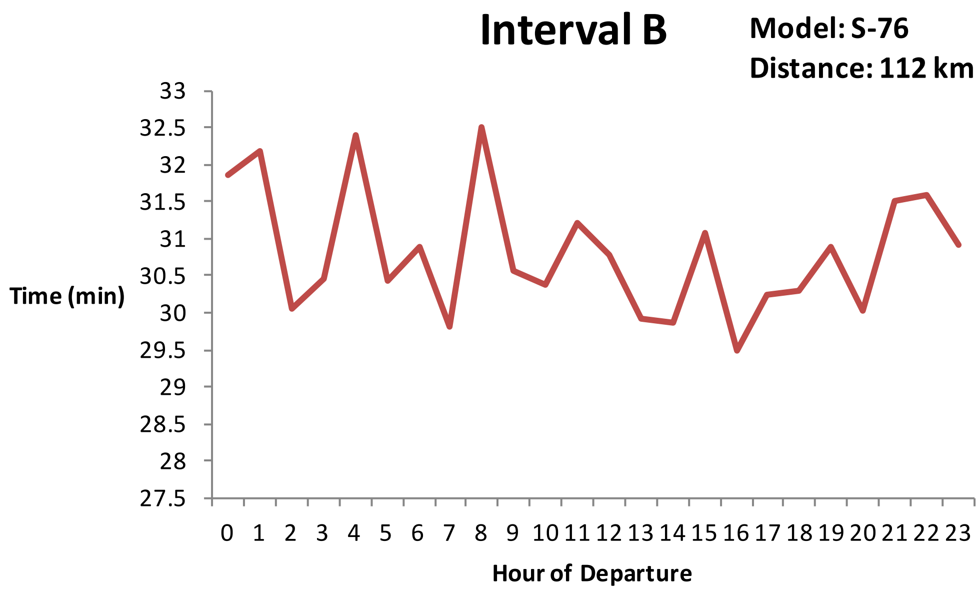


Figure A-3 Travel times by helicopters in different hours- 112 Km

Figure A-4 compares the average travel times by helicopters in particular distances (81 km, 112km and 133km) and in different months. In particular distance, the travel time slightly changes throughout the year. However, these minor changes are not predictable as this observational study is not controlling many factors such as weather condition; additionally some averages might not reliable due to lack of observation for particular conditions (e.g. there were only 5 observations for 133 km on December for S-76 helicopters).

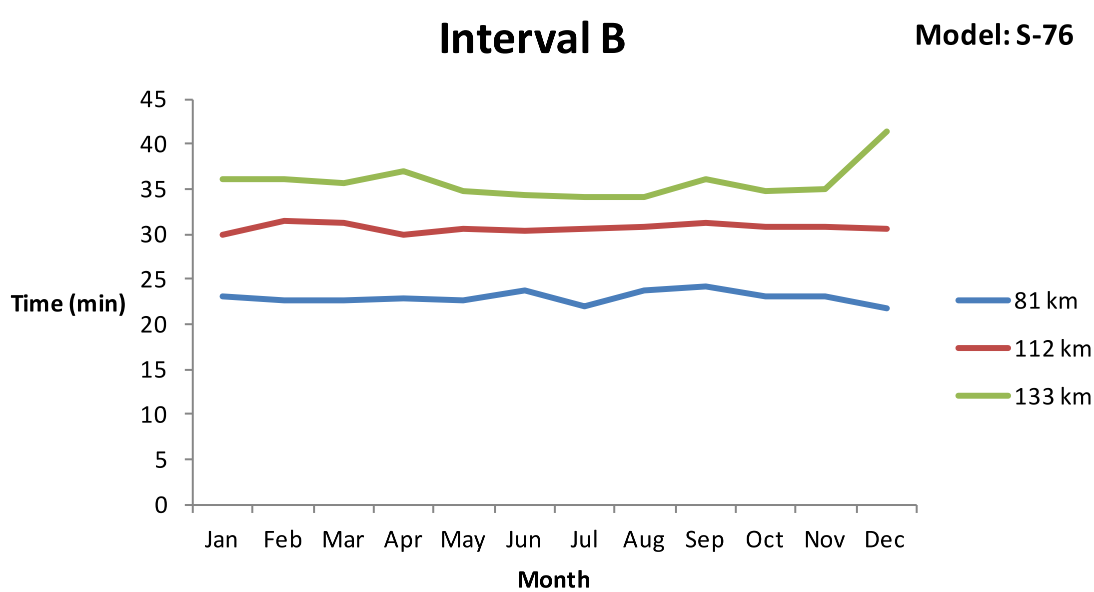


Figure A-4 Comparison of average travel times by helicopters in different distances in different months

Due to lack of observations for some levels of hour of departure, a comparison of travel time in different hours and different distances could not be made.

Thus month and hour were excluded from the model since these factors did not improve the model's predictability in estimating the travel time and did not have enough observation for all of their levels.

Figure A-5 shows the linear relationship between the distance and travel time for S-76 helicopters.

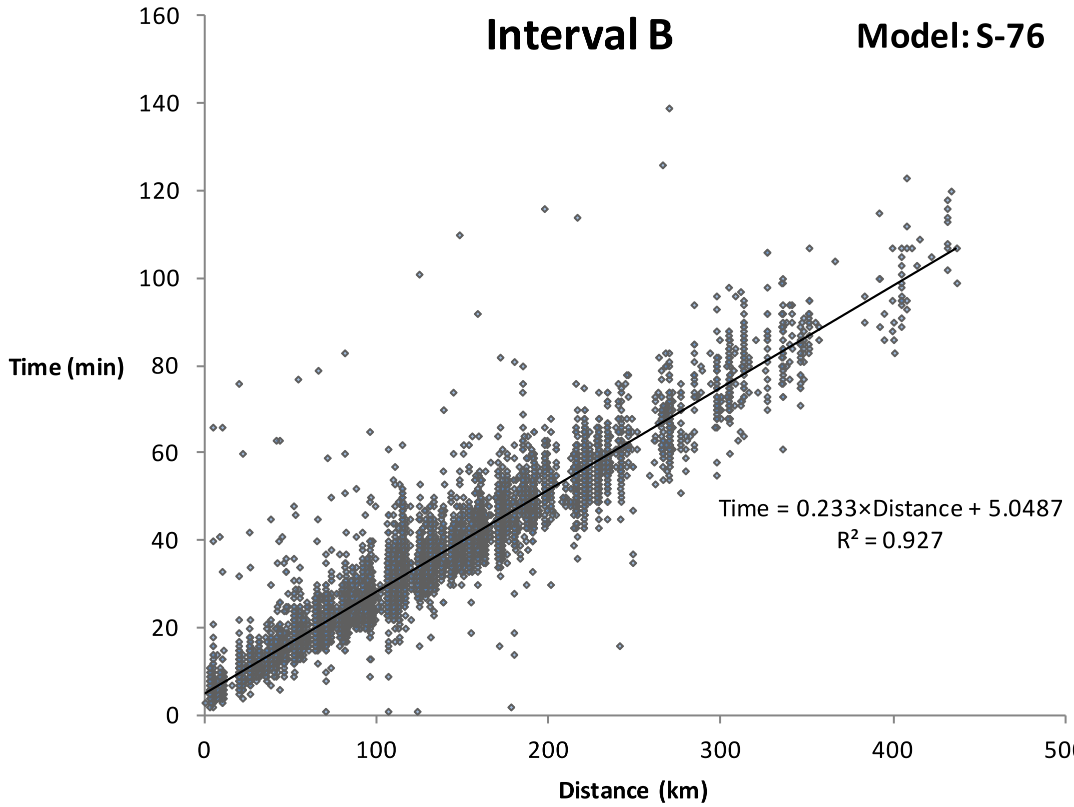


Figure A-5 the linear relationship between the distance and travel time for S-76 helicopters

Aircraft Model King Air 200: King Air 200 is a fixed-wing aircraft that is commonly used by some Ornge base providers. A statistical model was developed to estimate the interval B's duration for this aircraft. Great-circle distance was entered into the statistical model for King Air 200 as the first predictor. Table A-6 ANOVA Model Summary reports the summary of this model; R has a value of .946 which shows the strong correlation between the distance and travel time for helicopters. The value of R square is .895, which tells that distance can account for 89.5% of the variation in travel time by King Air 200. Table A-7 Results of the between subject ANOVA also reports an analysis of variance (ANOVA) for this model.

Table A-6 ANOVA Model Summary

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.946[a]	.895	.895	6.212

a. Predictors: (Constant), Distance

Table A-7 Results of the between subject ANOVA

Tests of Between-Subjects Effects

Dependent Variable:B

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	901159.110[a]	1	901159.110	23355.569	.000
Intercept	27081.951	1	27081.951	701.890	.000
Distance	901159.110	1	901159.110	23355.569	.000
Error	106029.754	2748	38.584		
Total	7018000.000	2750			
Corrected Total	1007188.864	2749			

a. R Squared = .895 (Adjusted R Squared = .895)

As the second predictor, month was entered into the model. Table A-8 shows the results of the analysis of covariance (ANCOVA) with distance as the covariate and month as the categorical variable with 12 levels for King Air 200 aircraft. The main effect of month is significant $F(11,2737)=4.487$, $p<.001$. However, there was a minor increase (.001) in adjusted R squared when month was included to the previous model. Therefore adding month to the model slightly improved the model's predictability.

Table A-8 Results of the analysis of covariance (ANCOVA)

Tests of Between-Subjects Effects

Dependent Variable:B

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	903037.181[a]	12	75253.098	1977.575	.000
Intercept	27127.216	1	27127.216	712.876	.000
Distance	897905.271	1	897905.271	23596.035	.000
Month	1878.071	11	170.734	4.487	.000
Error	104151.683	2737	38.053		
Total	7018000.000	2750			
Corrected Total	1007188.864	2749			

a. R Squared = .897 (Adjusted R Squared = .896)

As the third predictor, hour of departure was entered into the model. Table A-9 shows the results of the analysis of covariance (ANCOVA) with distance as the covariate and month (12 levels) and hour (24 levels) as the categorical variables. The main effect of hour was also significant $F(23,2469)=1.596$, $p<.05$. Yet, including hour into the model does not improve the predictability; the adjusted R squared changes from .895 to .898 which tells that month and hour account for 0.3% of the variation in travel times by King Air 200 aircraft.

Table A-9 Results of the analysis of covariance (ANCOVA)

Tests of Between-Subjects Effects

Dependent Variable:B

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	914478.515[a]	280	3265.995	86.978	.000
Intercept	21827.916	1	21827.916	581.306	.000
Distance	821227.321	1	821227.321	21870.377	.000
Month	993.438	11	90.313	2.405	.006
Hour	1378.396	23	59.930	1.596	.036
Month * Hour	10026.602	245	40.925	1.090	.172
Error	92710.349	2469	37.550		
Total	7018000.000	2750			
Corrected Total	1007188.864	2749			

a. R Squared = .908 (Adjusted R Squared = .898)

Figure A-6 shows average travel times by King Air 200 aircraft for a particular distance (330 km) in different months. The difference between travel times in different months in most cases is smaller than 3 minutes. Some averages might not reliable due to lack of observation for particular conditions (e.g. there were only 5 observations for 330 km on January for King Air 200 aircraft).

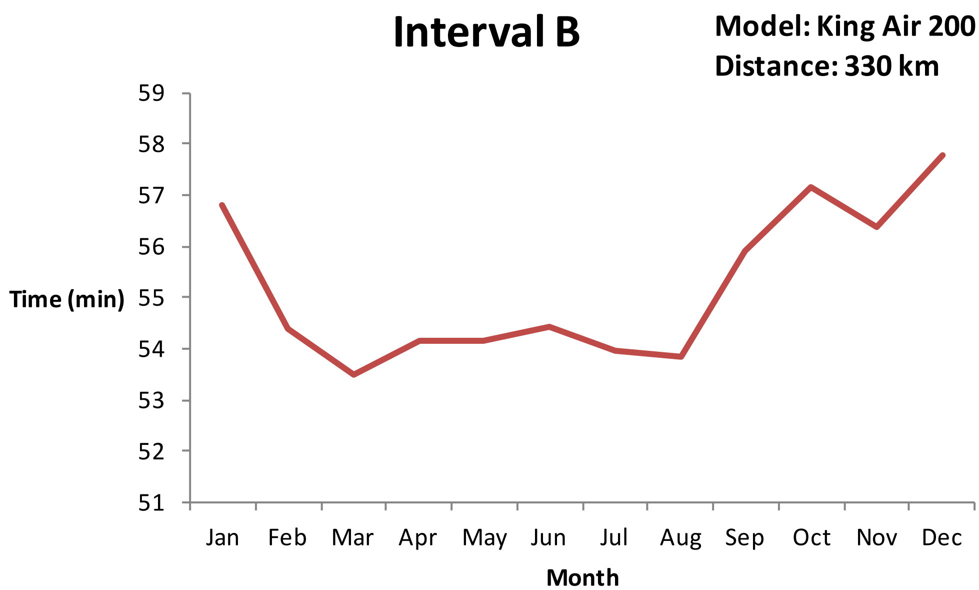


Figure A-6 Travel times by King Air 200 aircraft in different months- 330 Km

Figure A-7 shows average travel times by King Air 200 aircraft for a particular distance (330 km) in different hours. The difference between these travel times in different hours is around 4 minutes. However, since there were not enough observations for all levels of hour of departure, some of these averages are missed (e.g. 3 A.M.) and some might not be reliable (e.g. there were only 2 observations for 330 km at 5 P.M for King Air 200 aircraft).

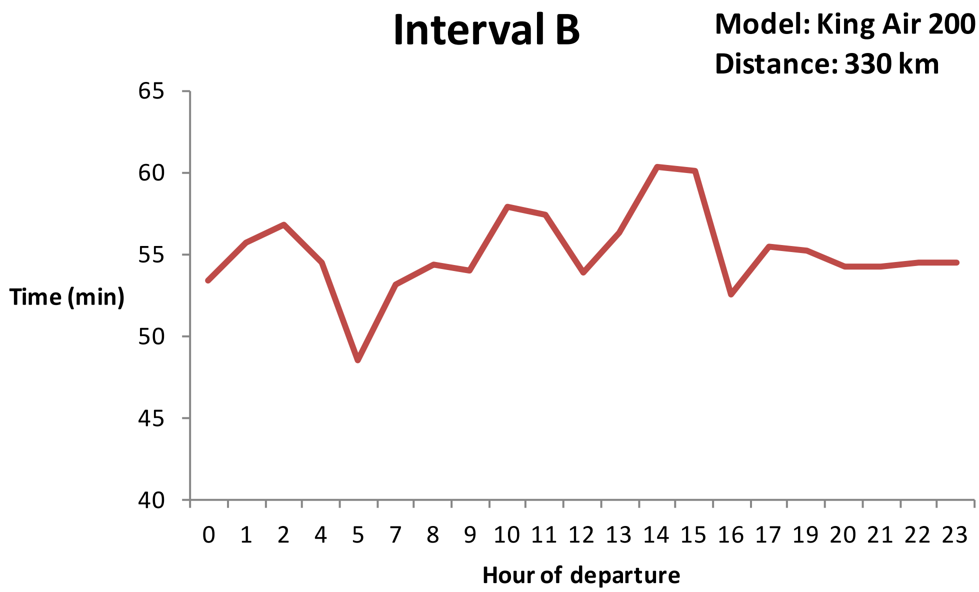


Figure A-7 Travel times by King Air 200 aircraft in different hours- 330 Km

Due to lack of observations for some levels of hour of departure/month, a comparison of travel time in different hours/months and different distances could not be made.

Month and hour were excluded from the model since these factors did not improve the model's predictability in estimating the travel time and did not have enough observation for all of their levels.

Figure A-8 shows the linear relationship between the distance and travel time for King Air 200 aircraft.

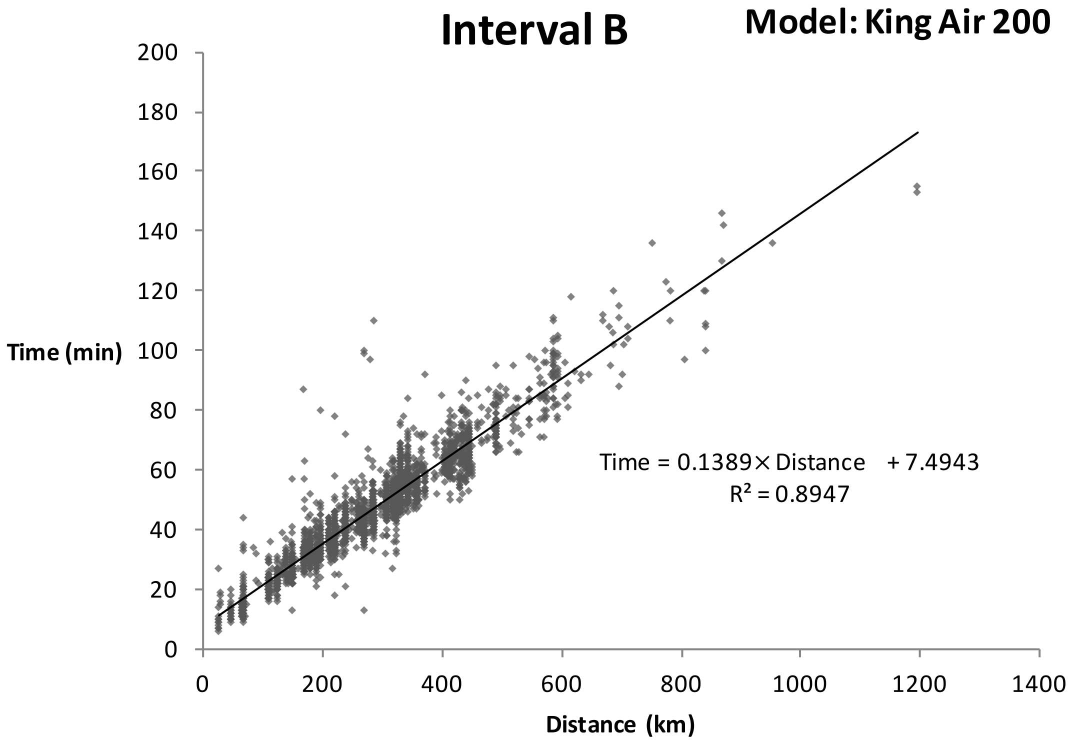


Figure A-8 Linear relationship between the distance and travel time for King Air 200 aircraft

Summary: The statistical results revealed that distance is the only useful factor for estimating the travel times by aircraft. The statistical significance of month and hour of departure effects were due to the large sample sizes, as when these factors were included into the model, the model's predictability did not improve. Also there were not enough observations for all levels of these factors in the available dataset which yield to unequal and incomplete sample sizes.

Table A-10 shows the derived parameters for common aircraft models at Ornge.

Table A-10 Derived parameters for common aircraft models at Ornge

Aircraft Model	a	b	Adjusted R Squared
Aero Commander 700	0.18	9.83	0.89
CESSNA 441 CONQUEST II	0.12	7.08	0.91
CESSNA CARAVAN	0.20	3.73	0.95
CHEYENNE II XL	0.15	4.94	0.94
King Air 100	0.16	4.04	0.94
King Air 200	0.14	7.49	0.88
KING AIR E-90	0.14	3.86	0.96
MU 2B 36	0.15	6.50	0.72
MU 2B 36A	0.12	8.29	0.94
MU 2B 60	0.12	7.99	0.94
NAVAJO	0.19	8.07	0.92
NAVAJO CHIEFTAN	0.19	8.06	0.93
PILATUS 12	0.14	8.25	0.92
PILATUS PC12/47E NG	0.13	8.98	0.90
ROCKWELL 700	0.20	2.19	0.70
S-76	0.23	5.05	0.85
SA226-TC	0.13	5.14	0.93
Time (min) = a × Distance (km) + b			

A.1.3 Arrive Pick-up Site – Arrive Patient Site (Interval C)

This interval is from the time the aircraft lands on the sending facility landing site to the time the paramedics arrive to the patient's bed. The duration of this interval depends on the geographical locations of the sending landing site and sending facility. Some facilities have their own landing sites, for example Hospital for Sick Children located at South West Ontario has a helipad on its roof that can be used as the landing site for this hospital and the hospitals around it (e.g. Mount Sinai Hospital). If the landing site is not within walking distances to the sending facility, an additional land leg is required to take the paramedics to the sending facility; for the fixed-wing aircraft, there is always an additional land leg required to take the paramedics from the airport to the sending facility. This additional land leg can be provided by contracted taxi services or local emergency medical service (EMS) ambulances.

Limitations: The land vehicles for transferring the paramedics from the landing site to the patient site are not always on-time and available. Therefore, sometimes the paramedics have to wait at the landing site for the taxi or EMS ambulance. These delays can have several reasons such as weather condition, traffic, unavailability of resources or, dispatchers' errors in scheduling. Currently, only the arrival times to the sending landing site and patient site are recorded by the paramedics and the waiting times are reported only when they are greater than one hour. Therefore it's not easy to detect and analyze these waiting times.

Another limitation is that, currently there is not a reliable list of GPS coordinates of the facilities. The only available information at Ornge is the sending facilities' postal codes which do not provide the exact geographical locations of the sending facilities when converted to the GPS coordinates.

Also, in order to reduce the waiting time and the total time to definite care sometimes the patients are brought to the sending landing sites by EMS ambulances. This is not considered as a common practice for emergent and urgent Ornge transfers; however historical data shows that it has sometimes happened. If Ornge paramedics receive the patient at the airport, they are required to record it. However, inconsistencies are observed in the data in terms of recording the pick-up location (i.e. Hospital or Airport). There are doubts on whether the paramedics follow the same rules in recording the data.

In summary, the available data for this interval (also interval E and G) might be a combination of the travel times and waiting times. The estimated distances obtained from the GPS coordinates of the facilities might not be all accurate as the GPS coordinates of the facilities are obtained from converting the postal codes to GPS coordinates. In addition some of the transfers that their pick-up locations were airports might be mistakenly reported as picked up at hospital and vice versa.

The effects of the following factors on the interval C's duration were investigated:

- Driving distance from the sending facility landing site to the sending facility
- Month
- Day of week
- Hour of arrival to the sending facility landing site

To obtain the driving distances, the GPS coordinates of the sending landing sites and sending facilities were inputted in Bing Maps using Excel and the driving distances were calculated.

Driving distance was entered into the statistical model as the first predictor. Table A-11 reports the summary of this model; R has a value of .348 which shows a weak correlation between the driving distance and travel time for this interval. The value of R square is .121, which tells that driving distance can account for 12.1% of the variation in interval C's duration. Table A-12 also reports an analysis of variance (ANOVA) for this model. The weak correlation between the distance and time for this interval could be due to one of the above mentioned limitations.

Table A-11 ANOVA Model Summary

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.348[a]	.121	.121	14.127

a. Predictors: (Constant), Distance

Table A-12 Results of the between subject ANOVA

Tests of Between-Subjects Effects

Dependent Variable:C

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	249118.512[a]	1	249118.512	1248.212	.000
Intercept	1185903.515	1	1185903.515	5941.986	.000
Distance	249118.512	1	249118.512	1248.212	.000
Error	1813386.833	9086	199.580		
Total	4731575.000	9088			
Corrected Total	2062505.345	9087			

a. R Squared = .121 (Adjusted R Squared = .121)

As the next steps the other variables were entered into the model one by one and then together. Table A-13 reports a summary of the models; it appears that including new variables to the model does not improve the model's predictability as the adjusted R squared does not increase.

Table A-13 Summary of the models

Model	Variables in the model	P- Value	R Squared	Adjusted R Squared
1	Distance	.000	.121	.121
2	Distance	.000	.123	.122
	Month	.009		
3	Distance	.000	.125	.123
	Hour	.002		
4	Distance	.000	.123	.122
	Day of Week	.001		
5	Distance	.000	.148	.120
	Month	.020		
	Hour	.023		
	Month * Hour	.961		
6	Distance	.000	.131	.123
	Month	.018		
	Day of Week	.001		
	Month * Day of Week	.758		
7	Distance	.000	.137	.121
	Hour	.001		
	Day of Week	.026		
	Hour * Day of Week	.990		
8	Distance	.000	.292	.108
	Month	.027		
	Hour	.031		
	day of Week	.105		
	Month * Hour	.996		
	Month * Day of Week	.834		
	Hour * Day of Week	.987		
	Month* Hour * Day of Week	.954		

Model 8 with month, hour and day of week as the factors and distances as the covariate has the maximum number of variables, yet it has the minimum value for the adjusted R squared. It appears that model 8 is highly over fitted; this could be due to the large number of levels in the model (2016 Model levels= 12 Month levels × 24 Hour levels × 7 Day of Week levels) considering the number of observations (9088 observations).

Summary: Only 12% of the variation in interval C's duration can be explained by the statistical models with the available factors. The poor model's predictability could be due to inaccurate GPS coordinates of the facilities, paramedic's inconsistencies in recording the data and unavailability of some information such as waiting times, traffic and weather conditions.

A.1.4 Arrive Patient Site – Depart Patient Site (Interval D)

This interval is from the time the paramedics get to the patient's bed, to the time they move the patient to the stretcher and leave the bedside. It usually takes between 25 to 40 minutes to prepare the patient for the transfer. However, according to the paramedics and physicians, the duration of this interval for both air and land, depends on the patient's condition when the paramedics get to his/her bed, and also the amount of the drug required for getting the patient ready. The patients' medical information was not available to the researcher. Additionally, medical experts claimed that having patients' medical information in the historical data would not yield to better estimates of the interval's duration, as patient's condition and the amount of required drug, when the paramedics get to the bedside is not predictable for emergent and urgent calls.

The effects of sending facility on this interval's duration was investigated, as Ornge physicians believed the time in the hospital might be different for different facilities.

Effects: A one way between subjects ANOVA was run to investigate the significance of sending facility on the interval D's duration. Table A-14 shows the results of the between subject ANOVA with the sending facility as the predictor. The dependent variable was the interval D's duration (i.e from the time paramedics arrive to the patient bed to the time the patient is moved to the stretcher is ready for transfer).

Table A-14 Results of the between subject ANOVA

Tests of Between-Subjects Effects

Dependent Variable:Time

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1.879E6	257	7311.477	8.848	.000
Intercept	1321802.665	1	1321802.665	1599.581	.000
Sending	1879049.585	257	7311.477	8.848	.000
Error	2.600E7	31460	826.343		
Total	5.747E7	31718			
Corrected Total	2.788E7	31717			

a. R Squared = .067 (Adjusted R Squared = .060)

The results shows that this statistical model is a better prediction of interval D's duration than if the mean value of interval D's durations were used, F(257,31460)=8.848, p=<.001. However the adjusted R squared is .060 which shows that only 6.0% of the variation in interval D's duration can be explained by this model.

There was a significant main effect of the sending facility on the interval D's duration, F(257,381460)=8.848, p<.001. This indicates that there are some differences in interval D's duration between the sending facilities. Figure A-9 compares the interval D's durations of some sending facilities.

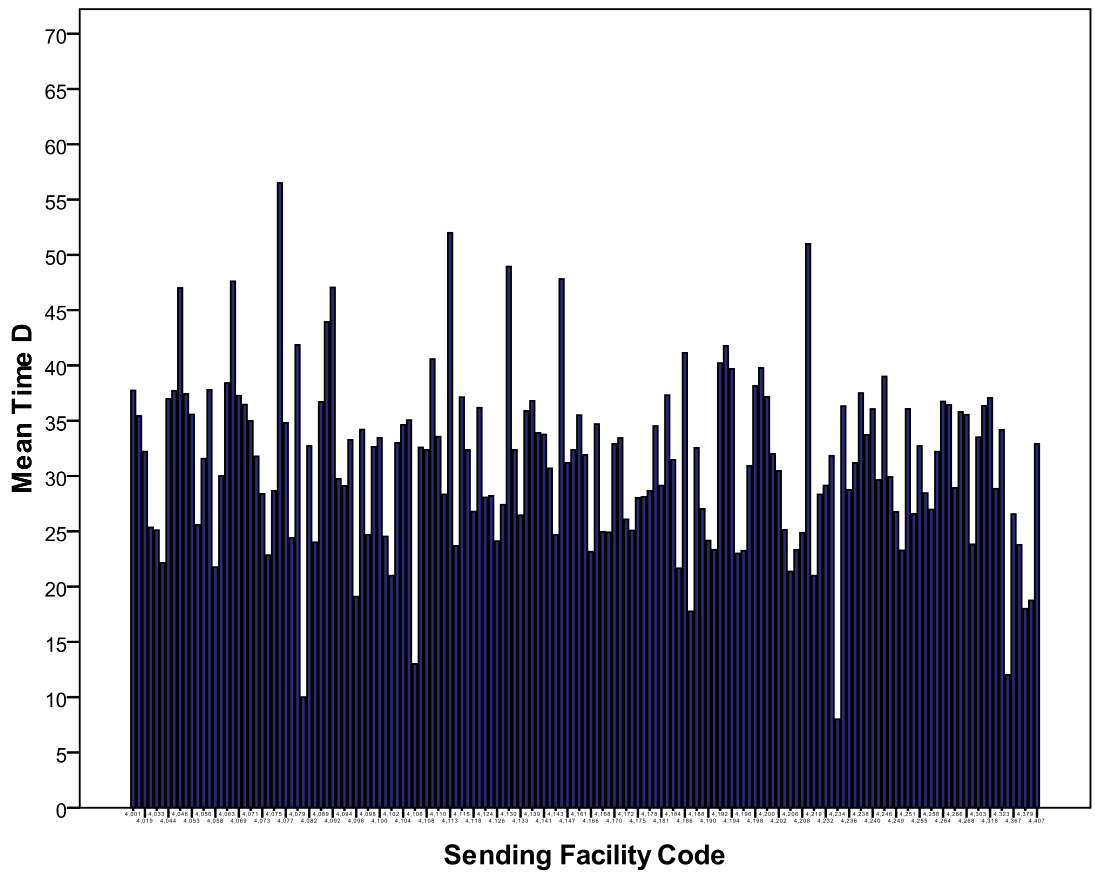


Figure A-9 Interval D duration comparison between some sending facilities

The observed difference between sending facilities in interval D's duration, could be due to factors such as hospital's efficiency in emergency patient transfer procedures, the type of patient that is usually being transferred from certain sending facilities, or because of some limitations such as lack of observations for some of the sending facilities. However, as mentioned before according to the medical experts the duration of this interval is not predictable for emergent and urgent calls, as it depends on the patient's condition and the amount of required drug, when the paramedics get to the bedside.

The Ornge medical experts also believed that for similar patient, the duration of this interval would be the same for land and air transfers. The hypothesis that the times in hospital for air and land transfers are equal for similar patients, could not be investigated, Since the patients' medical information was not available to the researcher.

Summary: The average duration for this interval seem to be between 25 and 40 minutes. Considering the sending facility for predicting the interval's duration, as opposed to using the total average, might slightly improve the estimates. However, the medical experts believe that the in-hospital time is not predictable for emergent and urgent patients without knowing the patient's condition when the paramedics arrive at his/her bed.

A.1.5 Depart Patient Site – Depart Pick-up Site (Interval E)

This interval is similar to interval C for air transfers as it is the time between two points of sending facility and sending landing site. Once the patient is ready, the paramedics take the patient to the sending facility landing site and load him/her into the aircraft. Similar to interval C, this interval's duration depends on the distance between the sending landing site and sending facility. However, there are some differences between interval C and E that yield in different durations.

One major difference is that, while there is no patient involved in interval C, the paramedics are carrying the patient in interval E. This means that interval E involves some extra steps that are not included in interval C, such as loading the patient to the aircraft. The extra steps can increase the interval E's duration. On the other hand, there are some factors that might decrease the interval E's duration , for example if an additional land leg is required to transfer the patient from the sending facility to the sending landing site and the patient is emergent, the local land ambulance can turn on its sirens and go faster.

Another difference between interval C and E, is in the possibility of unavailability of resources if additional land legs are required; while usually a taxi or an EMS ambulance can be used to transfer the paramedics from the sending landing site to the sending facility, the only option for transferring an emergent/urgent patient from the sending facility to the sending landing site is an EMS ambulance. The variability of resources can decrease the possibility of unavailability and consequently decrease the waiting time in interval C. On the other hand, since the facilities are the destination points for many patient transfers, there is high possibility of having available EMS ambulances for interval E.

Limitations: The limitations for this interval are similar to what were mentioned for interval C and include: Inaccurate GPS coordinates of the facilities, paramedic's inconsistencies in recording the data and unavailability of some information such as waiting times, traffic and weather conditions.

The effects of the following factors on the interval E's duration were investigated:

- Driving distance from the sending facility landing site to the sending facility
- Month
- Day of week
- Hour of departure from sending facility

To obtain the driving distances, the GPS coordinates of the sending landing sites and sending facilities were inputted in Bing Maps using Excel and the driving distances were calculated.

Driving distance was entered into the statistical model as the first predictor. Table 1 reports the summary of this model; R has a value of .347 which shows a weak correlation between the driving distance and travel time for this interval. The value of R square is .120, which tells that driving distance can account for 12.0% of the variation in interval E's duration. Table A-16 also reports an analysis of variance (ANOVA) for this model. The weak correlation between the distance and time for this interval could be due to one of the above mentioned limitations.

Table A-15 ANOVA Model Summary

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.347[a]	.120	.120	13.694

a. Predictors: (Constant), Distance

Table A-16 Results of the between subject ANOVA

Tests of Between-Subjects Effects

Dependent Variable:E

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	244805.514[a]	1	244805.514	1305.396	.000
Intercept	2127882.331	1	2127882.331	11346.673	.000
Distance	244805.514	1	244805.514	1305.396	.000
Error	1789445.496	9542	187.534		
Total	6366731.000	9544			
Corrected Total	2034251.010	9543			

a. R Squared = .120 (Adjusted R Squared = .120)

As the next steps the other variables were entered into the model one by one and then together. Table A-17reports a summary of the models; it appears that including new variables to the model does not improve the model's predictability as the adjusted R squared slightly changes.

Table A-17 Summary of the models

Model	Variables in the model	P- Value	R Squared	Adjusted R Squared
1	Distance	.000	.120	.120
2	Distance	.000	.123	.121
	Month	.014		
3	Distance	.000	.129	.127
	Hour	.000		
4	Distance	.000	.121	.120
	Day of Week	.210		
5	Distance	.000	.158	.131
	Month	.000		
	Hour	.000		
	Month * Hour	.070		
6	Distance	.000	.130	.122
	Month	.015		
	Day of Week	.332		
	Month * Day of Week	.274		
7	Distance	.000	.141	.126
	Hour	.000		
	Day of Week	.165		
	Hour * Day of Week	.866		
8	Distance	.000	.311	.140
	Month	.002		
	Hour	.000		
	day of Week	.284		
	Month * Hour	.025		
	Month * Day of Week	.113		
	Hour * Day of Week	.637		
	Month* Hour * Day of Week	.043		

Summary: Only 12% of the variation in interval E's duration can be explained by the statistical model with distance as the predictor. Entering other factors to the model slightly improved the model's predictability; the adjusted R squared changed from .120 to .140 after adding 2016 levels to the model. The poor model's predictability could be due to inaccurate GPS coordinates of the facilities, paramedic's inconsistencies in recording the data and unavailability of some information such as waiting times, traffic and weather conditions.

A.1.6 Depart Pick-up Site- Arrive destination landing site (Interval F)

The time estimates for this interval were very similar to the ones in Interval B Air. Ornge pilots have been instructed to fly with a consistent speed regardless of either they are carrying a patient or not. According to Ornge policy and air traffic control regulations, pilots should not be aware of patient acuity.

A.1.7 Arrive destination landing site – Delivery patient Site (Interval G)

The last interval is from the time the aircraft lands on the receiving facility landing site to the time the paramedics arrive to the receiving facility and deliver the patient to the medical team at the receiving facility. Similar to intervals C and E, the duration of this interval depends on the geographical locations of the landing site and facility. If the receiving facility landing site is not within walking distances to the receiving facility, an additional land leg is required to transfer the patient and Ornge paramedics to the receiving facility; for the fixed-wing aircraft, there is always an additional land leg required to take the patient and Ornge paramedics from the airport to the receiving facility. This additional land leg can be provided by contracted taxi services or local emergency medical service (EMS) ambulances.

Limitations: The limitations mentioned for intervals C and E also exist for interval G. These limitations were: Inaccurate GPS coordinates of the facilities, paramedic's inconsistencies in recording the data and unavailability of some information such as waiting times, traffic and weather conditions.

Similar to interval C, in order to reduce the waiting time and increase the resources availability sometimes the patients are delivered to the local EMS paramedics at the receiving landing site. This is not considered as a common practice for emergent and urgent Ornge transfers; however historical data shows that it has sometimes happened. Unlike interval C, the transfer of care's location is not reported by the paramedics. Therefore with the available information, it's not possible to determine if the delivery location was the sending facility landing site or sending facility.

Moreover, for the fixed-wing aircraft, especially during rush hours, instead of a local land EMS ambulance for the additional leg from the receiving facility landing site to the receiving facility, a helicopter might be used. The mode of transportation for the additional leg is not recorded by the paramedics. Therefore with the available information for the fixed-wing aircraft, it's not possible to determine if the mode of transportation for the additional leg was a helicopter or the patient was delivered at the airport.

The effects of the following factors on the interval G's duration were investigated:

- Driving distance from the receiving facility landing site to the receiving facility
- Month
- Day of week
- Hour of arrival to the receiving facility landing site

To obtain the driving distances, the GPS coordinates of the receiving landing sites and receiving facilities were inputted in Bing Maps using Excel and the driving distances were calculated.

Driving distance was entered into the statistical model as the first predictor. Table A-18 reports the summary of this model; R has a value of .505 which shows a moderate correlation between the driving distance and travel time for this interval. The value of R square is .255, which tells that driving distance can account for 25.5% of the variation in interval G's duration. Table A-19 also reports an analysis of variance (ANOVA) for this model. The moderate correlation between the distance and time for this interval could be due to one of the above mentioned limitations.

Table A-18 ANOVA Model Summary

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.505[a]	.255	.255	15.403

a. Predictors: (Constant), Distance

Table A-19 Results of the between subject ANOVA

Tests of Between-Subjects Effects

Dependent Variable:G

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1.058E6	1	1058398.953	4460.879	.000
Intercept	1788385.390	1	1788385.390	7537.584	.000
Distance	1058398.953	1	1058398.953	4460.879	.000
Error	3096749.032	13052	237.262		
Total	9477146.000	13054			
Corrected Total	4155147.985	13053			

a. R Squared = .255 (Adjusted R Squared = .255)

As the next steps the other variables were entered into the model one by one and then together. Table A-20 reports a summary of the models; it appears that including new variables to the model does not improve the model's predictability as the adjusted R squared does not increase.

Table A-20 Summary of Models

Model	Variables in the model	P- Value	R Squared	Adjusted R Squared
1	Distance	.000	.255	.255
2	Distance	.000	.255	.255
	Month	.439		
3	Distance	.000	.257	.256
	Hour	.005		
4	Distance	.000	.255	.255
	Day of Week	.055		
5	Distance	.000	.271	.255
	Month	.785		
	Hour	.023		
	Month * Hour	.808		
6	Distance	.000	.260	.255
	Month	.442		
	Day of Week	.062		
	Month * Day of Week	.398		
7	Distance	.000	.265	.256
	Hour	.014		
	Day of Week	.144		
	Hour * Day of Week	.672		
8	Distance	.000	.361	.249
	Month	.754		
	Hour	.086		
	day of Week	.154		
	Month * Hour	.758		
	Month * Day of Week	.975		
	Hour * Day of Week	.644		
	Month* Hour * Day of Week	.964		

Model 8 with month, hour and day of week as the factors and distances as the covariate has the maximum number of variables, yet it has the minimum value for the adjusted R squared. It appears that model 8 is highly over fitted; this could be due to the large number of levels in the model (2016 Model levels= 12 Month levels × 24 Hour levels × 7 Day of Week levels) considering the number of observations (13054 observations).

Summary: Only 26% of the variation in interval C's duration can be explained by the statistical models with the available factors. The poor model's predictability could be due to inaccurate GPS coordinates of the facilities, inconsistencies in recording the data and unavailability of some information such as waiting times, delivery locations, modes of transportation for the additional legs, traffic and weather conditions.

A.2 Identifying Significant Factors for Land Transfers

A.2.1 Call Accepted – Depart Base (Interval A)

Once the call is accepted by the land base, the paramedics put the equipment inside the vehicle and depart the base. In most cases, this process takes less than 7-8 minutes. The effects of two factors on this intervals' duration were investigated. These factors were:

- Base provider

- Month

Since land bases use similar land ambulance vehicles, the vehicle model was not included in the model.

Limitation: Interviews with paramedics revealed that patient's specifications might also have a significant effect on this interval's duration; for some patients, additional equipments are required to be loaded in the ambulance. In this study the patient's information were not available to the researcher.

Effects: A two way between subjects ANOVA was run to investigate the significance of these factors on the interval A's duration. Table A-21 shows the results of the between subject ANOVA with the base provider and month factors. The dependent variable was the interval A's duration for land transfers (i.e. from the time the call is accepted by the base, to the time the land ambulance departs the base).

Table A-21 Results of the between subject ANOVA

Tests of Between-Subjects Effects

Dependent Variable:Time

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	11315.582[a]	66	171.448	1.018	.439
Intercept	25569.480	1	25569.480	151.823	.000
Month	2692.929	11	244.812	1.454	.143
Base	3619.103	5	723.821	4.298	.001
Month * Base	5614.721	50	112.294	.667	.965
Error	234435.420	1392	168.416		
Total	327064.000	1459			
Corrected Total	245751.002	1458			

a. R Squared = .046 (Adjusted R Squared = .001)

The results shows that this statistical model does not result in significantly better prediction of interval A's duration than if the mean value of interval A's durations were used, F(66,1392)=1.018, p=.439.

There was a significant main effect of the base provider on the interval A's duration, F(5,1392)=4.298, p<.01. This indicates that there are some differences in interval A's duration between the land base providers. Figure A-10compares the interval A's durations of 7 Ornge bases.

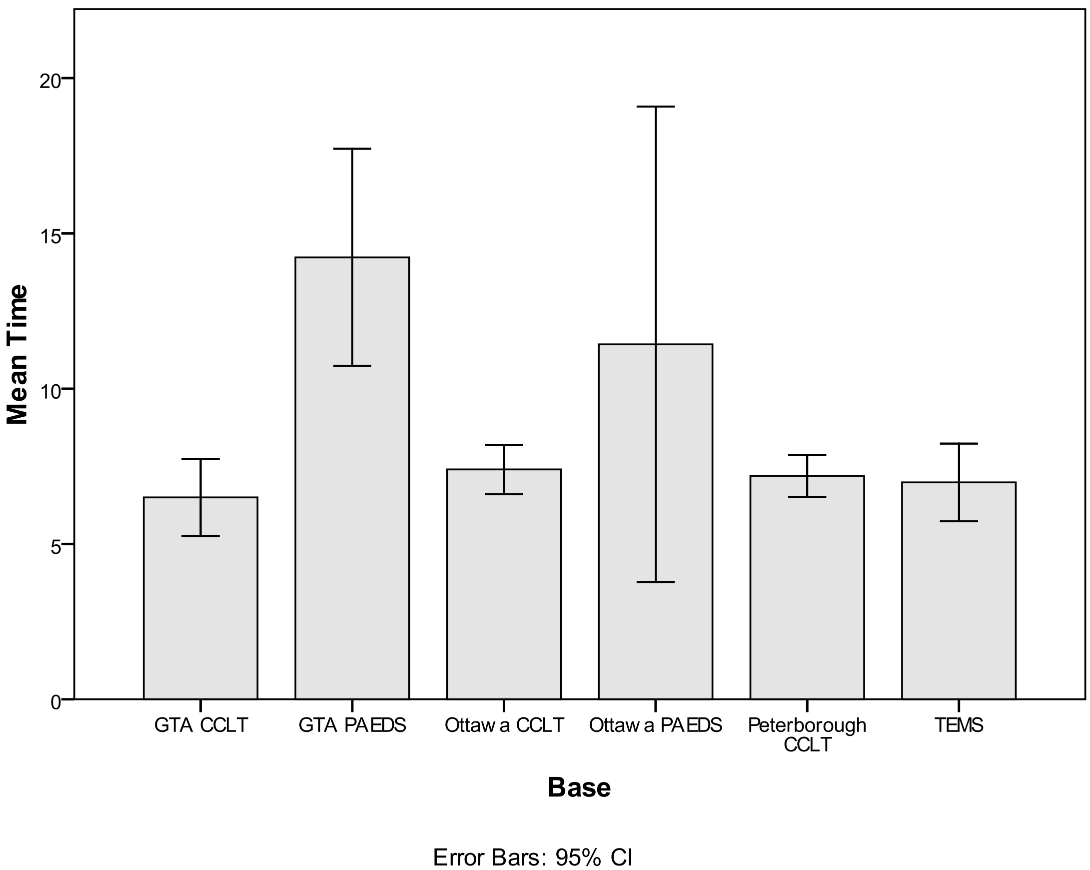


Figure A-10 Interval A duration comparison between 7 Ornge bases

The average interval A's durations for GTA CCLT, Ottawa CCLT, Peterborough CCLT and TEMS bases are approximately equal to each other and around 7-8 minutes. These bases are considered as the main land resources for patient transfers and have the highest number of historical observations.

The average interval A's durations for Toronto PAEDS and Ottawa PAEDS were greater than the other bases. Toronto PAEDS and Ottawa PAEDS have the same locations of GTA CCLT and Ottawa CCLT bases. The difference is that, the PAEDS paramedics are responsible for transferring pediatric patients. The observed difference in interval A's duration between PAEDS and other bases could be because of different equipments are needed to be loaded into ambulances for pediatric patients.

The effect of month on interval A's duration was not significant $F(11,1392)=1.454$, $p=.143$. The ambulances are kept in indoor parking facilities, and if a land base accepts the call, it means that the vehicles can depart the base within minutes. Therefore unlike air transfers, time of the year has no effect on the interval A's duration.

The interaction effect of month and base provider on interval A's duration was not significant $F(50,1392)= .667$, $p=.965$. Figure A-11compares the interval A's duration of three busy Ornge land providers in different months. For each base, the difference between the interval A's durations in different months are around 1 minute. Since there were not enough observations for all levels of month, some of these averages might not be reliable (e.g. there were only 5 Peterborough CCLT on April).

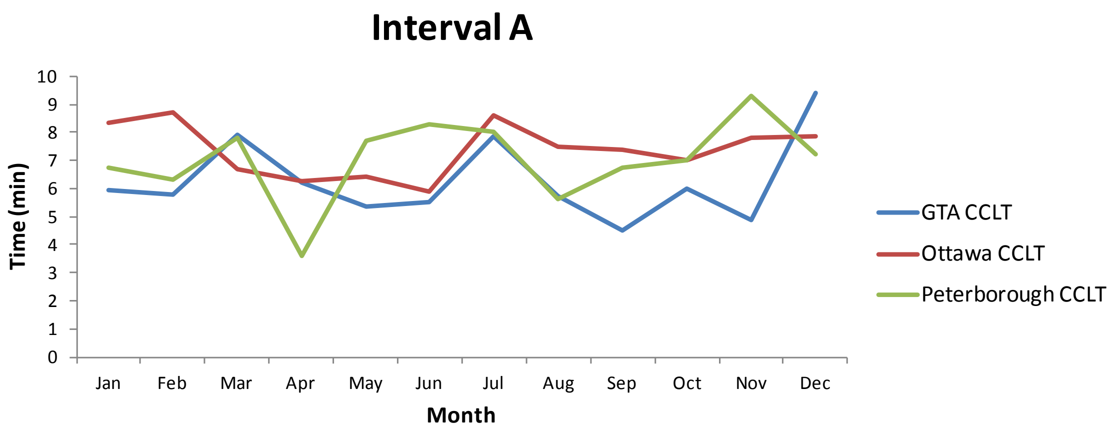


Figure A-11 Interval A's duration comparison of three busy Ornge land providers in different months

Since month did not have an effect on the interval A's duration for land transfers, it was removed from the statistical model. Table A-22 shows the results of the between subjects ANOVA with the base provider as the factor. It appears that removing month from the model improves the model's predictability, $F(5,1453)=5.045$, $p<.001$. However the adjusted R squared is .014 which shows that only 1.7% of the variation in interval A's duration can be explained by the base provider.

Table A-22 Results of the between subject ANOVA

Tests of Between-Subjects Effects

Dependent Variable:Time

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	4193.540[a]	5	838.708	5.045	.000
Intercept	29051.872	1	29051.872	174.751	.000
Base	4193.540	5	838.708	5.045	.000
Error	241557.462	1453	166.247		
Total	327064.000	1459			
Corrected Total	245751.002	1458			

a. R Squared = .017 (Adjusted R Squared = .014)

There was a significant main effect of the base provider on the interval A's duration, $F(5,1453)=5.045$, $p<.001$.

The model's improvement after removing month could be due to lack of observations in some levels of month for some bases. Similar to other intervals, the unequal sample sizes in this observational study can produce some issues such as multicollinearity or over-fitting which can yield to unreliable results.

Summary: The average duration for this interval seem to be between 7 and 8 minutes. Considering the base provider for predicting the interval's duration, as opposed to using the total average, might slightly improve the estimates.

A.2.2 Depart Base – Arrive Pick-up Site (Interval B)

For land transfers this interval is from the time the land ambulance departs the base to the time the ambulance stops at sending facility's parking. This interval thus refers to the travel time by the land ambulances and is highly affected by factors such as geographic location of the base and sending facility, road type, weather condition and traffic.

Unlike similar intervals in air transfers (i.e. C Air, E Air), this interval solely refers to the travel time by the land ambulance and does not include other times such as waiting times or patient loading/unloading times.

Limitations: Some of distances might not be reliable, as currently there is not a reliable list of GPS coordinates of exact locations of the facilities. The only available information at Ornge is the facilities' postal codes which do not provide the exact geographical locations of the sending facilities when converted to the GPS coordinates.

- Factors
- The effects of the following factors on the interval B's duration were investigated.
- Distance from the base to the sending facility
- Month
- Hour of departure
- Day of week

To obtain the driving distances, the GPS coordinates of the bases and sending facilities were inputted in Bing Maps using Excel and the driving distances were calculated.

Driving distance was entered into the statistical model as the first predictor. Table A-23 reports the summary of this model; R has a value of .788 which represents the large effect of driving distance on the travel time for this interval. The value of R square is .621, which tells that driving distance can account for 62.1% of the variation in interval B's duration. Table A-24 also reports an analysis of variance (ANOVA) for this model. There was a significant main effect of the distance on the interval B's duration, F(1,2036)=3329.316, p<.001.

Table A-23 Model Summary

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.788[a]	.621	.620	18.652

a. Predictors: (Constant), Distance

Table A-24 Results of the between subject ANOVA

Tests of Between-Subjects Effects

Dependent Variable:Time

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1.158E6	1	1158270.116	3329.316	.000
Intercept	59829.624	1	59829.624	171.973	.000
Distance	1158270.116	1	1158270.116	3329.316	.000
Error	708325.101	2036	347.900		
Total	5725089.000	2038			
Corrected Total	1866595.217	2037			

a. R Squared = .621 (Adjusted R Squared = .620)

As the second predictor, month was entered into the model. Table A-25 shows the results of the analysis of covariance (ANCOVA) with distance as the covariate and month as the categorical variable with 12 levels. The main effect of month is significant F(11,2025)=3.062, p<.001. However, there was a minor increase (.005) in adjusted R squared when month was included to the previous model. Therefore adding month to the model slightly improved the model's predictability.

Table A-25 Results of the between subject ANOVA

Tests of Between-Subjects Effects

Dependent Variable:Time

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1.170E6	12	97488.296	283.341	.000
Intercept	59995.149	1	59995.149	174.371	.000
Distance	1152020.070	1	1152020.070	3348.243	.000
Month	11589.435	11	1053.585	3.062	.000
Error	696735.667	2025	344.067		
Total	5725089.000	2038			
Corrected Total	1866595.217	2037			

a. R Squared = .627 (Adjusted R Squared = .625)

As the third predictor, hour of departure was entered into the model. Table A-26 shows the results of the analysis of covariance (ANCOVA) with distance as the covariate and month (12 levels) and hour (24 levels) as the categorical variables. The main effect of hour was significant $F(23,1758)=4.478$, $p<.001$. hour into the model slightly improved the predictability; the adjusted R squared changed from .620 (model with only distance) to .649 which tells that month and hour account for 2.9% of the variation in travel times by land ambulances..

Table A-26 Results of the between subject ANOVA

Tests of Between-Subjects Effects

Dependent Variable:Time

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1.301E6	279	4663.381	14.497	.000
Intercept	24464.392	1	24464.392	76.052	.000
Distance	962383.838	1	962383.838	2991.751	.000
Month	9153.662	11	832.151	2.587	.003
Hour	33129.453	23	1440.411	4.478	.000
Month * Hour	94802.776	244	388.536	1.208	.021
Error	565511.882	1758	321.679		
Total	5725089.000	2038			
Corrected Total	1866595.217	2037			

a. R Squared = .697 (Adjusted R Squared = .649)

As the forth predictor, day of week was entered into the model. Table A-27 shows the results of the analysis of covariance (ANCOVA) with distance as the covariate and month (12 levels), hour (24 levels) and day of week (7 levels) as the categorical variables. The main effect of day of week was not significant $F(6,853)=.859$, $p=.525$. Including day of week into the model slightly improved the predictability; the adjusted R squared changed from .620 (model with only distance) to .665 which tells that month, hour and day of week account for 4.5% of the variation in travel times by land ambulances.

Table A-27 Results of the between subject ANOVA

Tests of Between-Subjects Effects

Dependent Variable:Time

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1.605E6	1184	1355.419	4.417	.000
Intercept	16585.838	1	16585.838	54.044	.000
Distance	421948.533	1	421948.533	1374.907	.000
Month	7390.305	11	671.846	2.189	.013
Hour	34518.168	23	1500.790	4.890	.000
DayofWeek	1581.838	6	263.640	.859	.525
Month * Hour	98796.863	242	408.252	1.330	.002
Month * DayofWeek	21325.694	66	323.117	1.053	.367
Hour * DayofWeek	48749.388	134	363.801	1.185	.088
Month * Hour * DayofWeek	231749.095	699	331.544	1.080	.141
Error	261779.186	853	306.892		
Total	5725089.000	2038			
Corrected Total	1866595.217	2037			

a. R Squared = .860 (Adjusted R Squared = .665)

Table A-28 reports a summary of the models; it appears that including new variables to the model slightly improves the model's predictability as the adjusted R squared has minor changes compared to the first model. Although model 8 has a better predictability compared to the other ones, it is highly over fitted; there are large number of levels in the model (2016 Model levels= 12 Month levels × 24 Hour levels × 7 Day of Week levels) compared to the number of observations (2038 observations).

Table A-28 Summary of Models

Model	Variables in the model	P- Value	R Squared	Adjusted R Squared
1	Distance	.000	.621	.620
2	Distance	.000	.627	.625
	Month(12)	.000		
3	Distance	.000	.641	.636
	Hour(24)	.000		
4	Distance	.000	.622	.621
	Day of Week(7)	.106		
5	Distance	.000	.697	.649
	Month(12)	.003		
	Hour(24)	.000		
	Month(12) * Hour(24)	.021		
6	Distance	.000	.639	.623
	Month(12)	.000		
	Day of Week(7)	.080		
	Month(12) * Day of Week(7)	.806		
7	Distance	.000	.670	.640
	Hour(24)	.000		
	Day of Week(7)	.661		
	Hour(24) * Day of Week(7)	.160		
8	Distance	.000	.860	.665
	Month(12)	.013		
	Hour(24)	.000		
	day of Week(7)	.525		
	Month(12) * Hour(24)	.002		
	Month(12) * Day of Week(7)	.367		
	Hour(24) * Day of Week(7)	.088		
	Month(12) * Hour(24) * Day of Week(7)	.141		

In a separate analysis and in order to reduce the number of levels and increase the number of observations in the levels, hour was entered to the model with 4 categories. Table A-29 provides a summary of these 4 categories. The first category refers to the midnight to 6 AM that traffic is expected to be at its lowest levels. The second category is from 6 AM to 10 AM which refers to the rush hour in the morning. The third category refers to two non rush hour intervals of (10 AM to 3 PM) and (8 PM to 12 PM). The fourth category is from 3 PM to 8 PM which refers to the rush hour in night.

Table A-29 Categorization of time of day

Category	Description	From	To
1	Non-rush-hour Morning	12:00 PM	6:00 AM
2	Rush-hour Morning	6:00 AM	10:00 AM
3	Non-rush-hour Day and Night	10:00 AM 8:00 PM	3:00 PM 12:00 PM
4	Rush-hour Night	3:00 PM	8:00 PM

Table A-30 reports a summary of the models for the new analysis; hourtype factor with 4 above mentioned levels was replaced with hour with 24 levels to resolve the problem of over fitting. There are 336 levels in model 8 of this table and the adjusted R squared is .641. The minor changes in the adjusted R squared compared to the first model, suggest that adding new variables to the model slightly improves the model's predictability.

Table A-30 Summary of Models

Model	Variables in the model	P- Value	R Squared	Adjusted R Squared
1	Distance	.000	.621	.620
2	Distance	.000	.627	.625
	Month(12)	.000		
3	Distance	.000	.632	.631
	HourType(4)	.000		
4	Distance	.000	.622	.621
	Day of Week(7)	.106		
5	Distance	.000	.645	.636
	Month(12)	.020		
	HourType(4)	.000		
	Month(12) * HourType(4)	.322		
6	Distance	.000	.639	.623
	Month(12)	.002		
	Day of Week(7)	.080		
	Month(12) * Day of Week(7)	.806		
7	Distance	.000	.641	.636
	HourType(4)	.000		
	Day of Week(7)	.263		
	HourType(4) * Day of Week(7)	.005		
8	Distance	.000	.697	.641
	Month(12)	.142		
	HourType(4)	.000		
	day of Week(7)	.017		
	Month(12) * HourType(4)	.703		
	Month(12) * Day of Week(7)	.463		
	HourType(4) * Day of Week(7)	.355		
	Month(12) * HourType(4) * Day of Week(7)	.235		

Effects: Figure A-12 shows average travel times by land ambulances for a particular distance (134 km) in different months. The difference between travel times in different months in most cases is smaller than 7 minutes. Some averages might not reliable due to lack of observation for particular conditions.

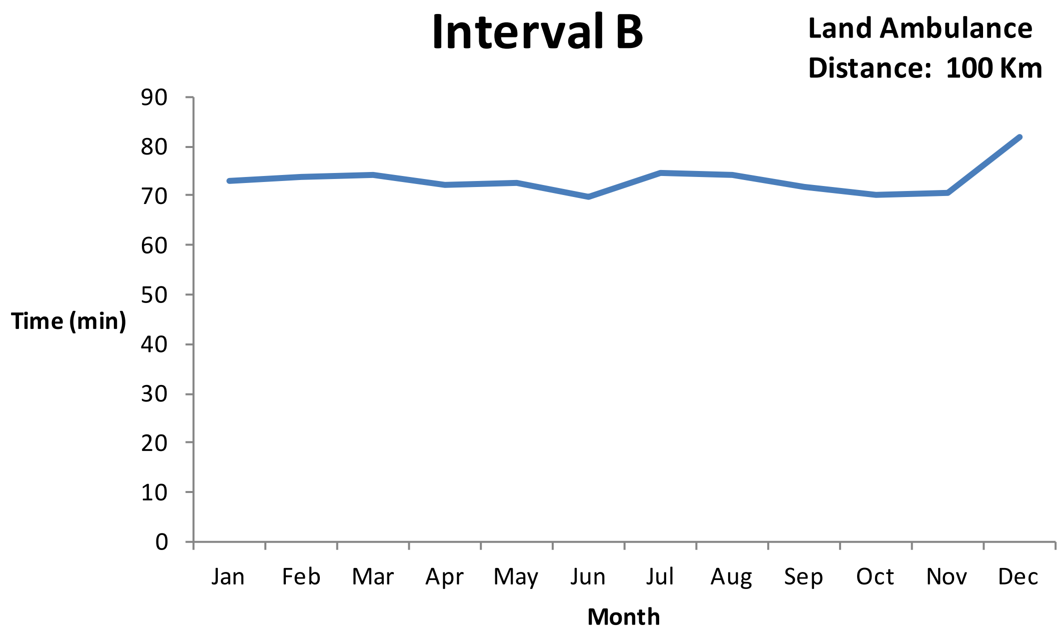


Figure A-12 Travel times by land ambulances in different months- 134 Km

Figure A-13compares the average travel times by land ambulances in particular distances with enough observations (32 km, 100km and 153km) and in different months. Different trends are observed for different distances; while there is no variability for 32 km and 100 km, for 150 km variability is observed throughout the year. These trends are not predictable as this observational study is not controlling for many factors such as weather condition; additionally some averages might not reliable due to lack of observation for particular conditions (e.g. there were only 2 land observations for 153 km on April).

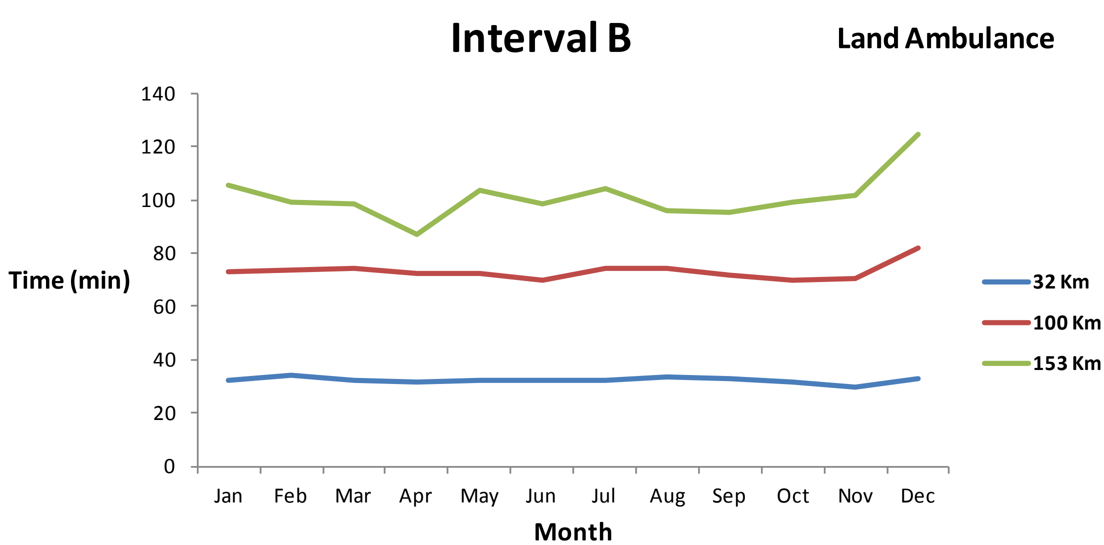


Figure A-13 comparison of travel times by land ambulances in different distances and in different months

Figure A-14 compares the average travel times by land ambulances in 3 distances (32 km, 100km and 153km) and in different times of the day. The travel time changes are observed in different times of the day. However, these changes are not predictable as they do not follow similar patterns. Additionally, this observational study is not controlling for many factors such as weather condition or traffic. Some averages might not be reliable due to lack of observation for particular conditions (e.g. there were only 5 land observations for 153 km between 12:00 PM to 6:00 AM).

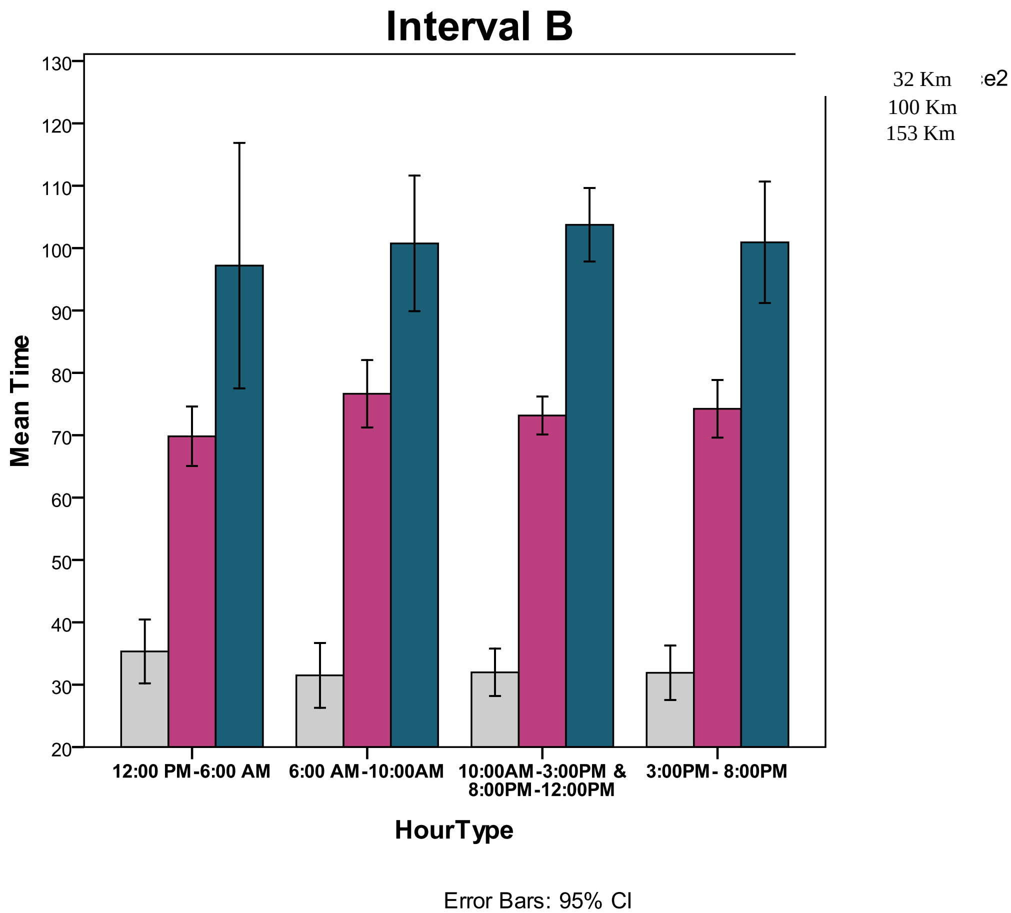


Figure A-14 comparison of travel times by land ambulances in different distances and in different times of the day

Figure A-15 compares the average travel times by land ambulances in 3 distances (32 km, 100 km and 153 km) and in different days of week. Minor differences are observed in travel times in different days of week. However, these changes are not predictable as they do not follow similar patterns. Additionally, this observational study is not controlling for many factors such as weather condition or traffic. Some averages might not be reliable due to lack of observation for particular conditions (e.g. there were only 5 land observations for 153 km on Saturday).

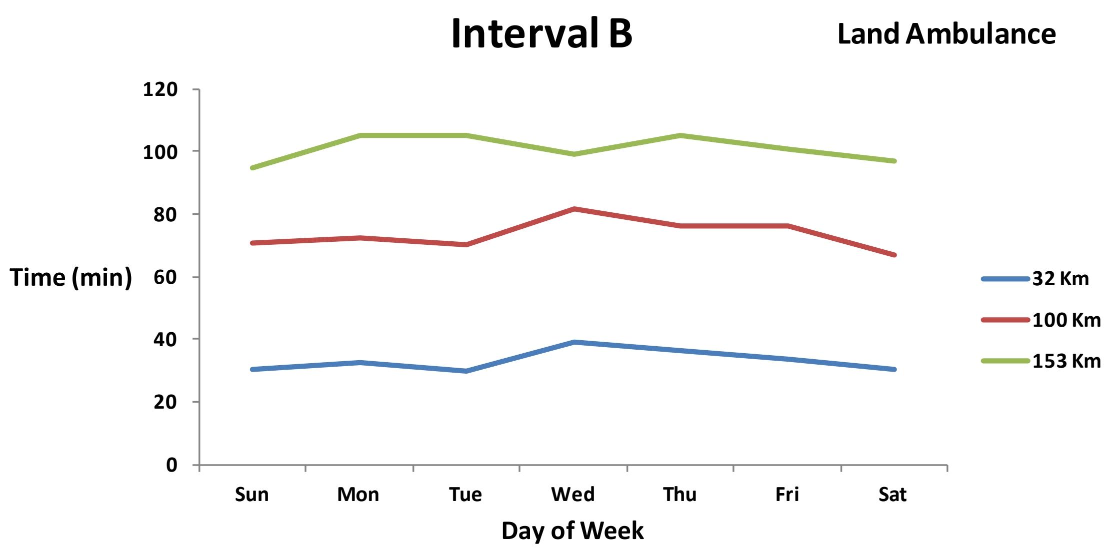


Figure A-15 comparison of travel times by land ambulances in different distances and in different days of week

Summary: The statistical results revealed that distance has a strong effect on travel time by land ambulances. The statistical significance of month, hour of departure, and day of week effects could be due to the large sample sizes, as when these factors were included into the model, the model's predictability had minor improvements. Some results are not 100% reliable because of some limitations in the study such as lack of observations for all levels of the factors in the available dataset, inaccurate GPS coordinates of the facilities, and unavailability of some information such as waiting times, traffic and weather conditions.

A.2.3 Arrive Pick-up Site – Arrive Patient Site (Interval C)

This interval is from the time the land ambulance stops at the sending facility's parking the time the paramedics arrive to the patient's bed. In most cases, this process takes less than 5-7 minutes. The effects of two factors on this intervals' duration were investigated. These factors were:

- Sending facility
- Month (Season)

Limitation: For some of the sending facilities there were not enough historical data. There were around 5300 land observations recorded in the dataset, and there were 84 facilities recorded as the sending facility in the available dataset. For most of these facilities there were not enough observations for all levels of month.

Effects: A two way between subjects ANOVA was run to investigate the significance of these factors on the interval C's duration. Table A-31 shows the results of the between subject ANOVA with the sending facility and month factors. The dependent variable was the interval C's duration for land transfers (i.e. from the time ambulance arrive to the sending facility to the time the paramedics arrive to the patient's bed).

Table A-31 Results of the between subject ANOVA

Tests of Between-Subjects Effects

Dependent Variable:C

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	17005.772[a]	596	28.533	1.341	.000
Intercept	18416.521	1	18416.521	865.640	.000
Sending	4636.439	83	55.861	2.626	.000
Month	266.862	11	24.260	1.140	.325
Sending * Month	10720.770	502	21.356	1.004	.471
Error	81142.997	3814	21.275		
Total	228677.000	4411			
Corrected Total	98148.769	4410			

a. R Squared = .173 (Adjusted R Squared = .044)

The results shows that this statistical model is a better prediction of interval C's duration than if the mean value of interval C's durations were used, F(596,3814)=1.341, p=<.001. However the adjusted R squared is .044 which shows that only 4.4% of the variation in interval C's duration can be explained by this model.

There was a significant main effect of the sending facility on the interval C's duration, F(83,3814)=2.626, p<.001. This indicates that there are some differences in interval C's duration between the sending facilities. Figure A-16 compares the interval C's durations of some sending facilities.

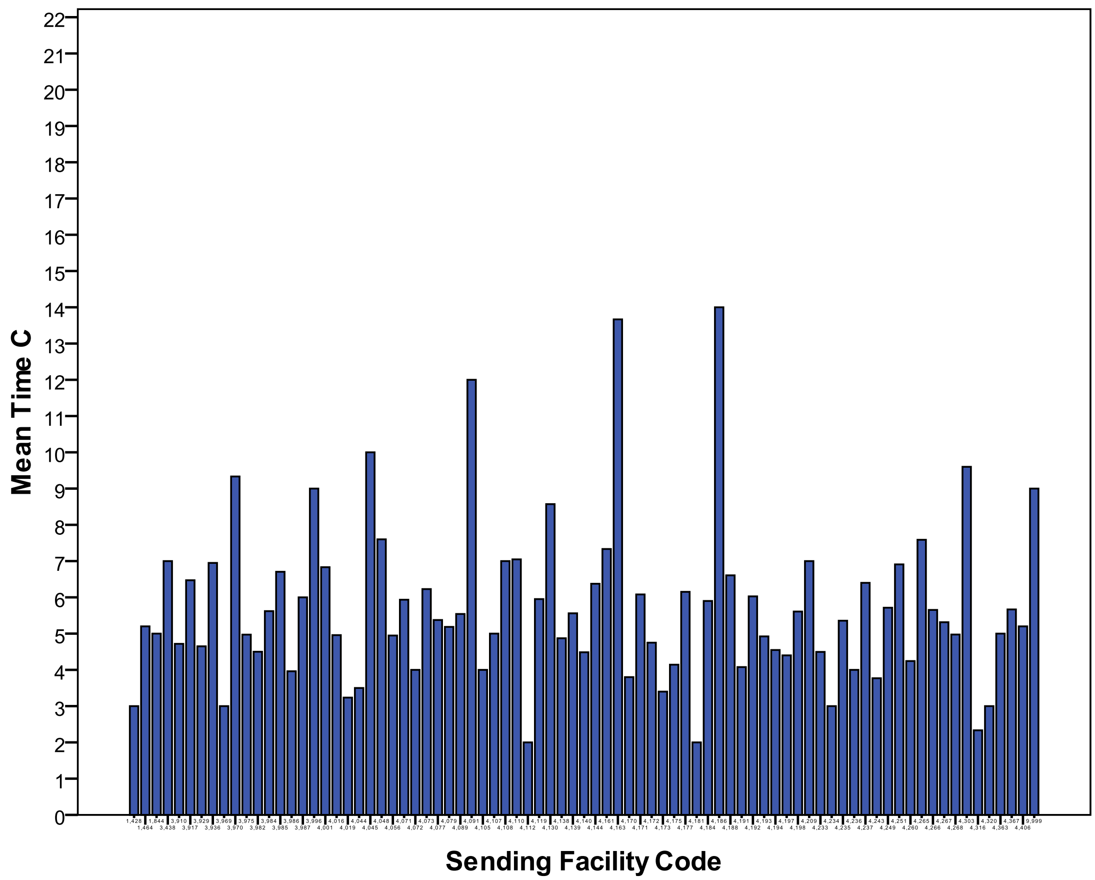


Figure A-16 Interval C's durations comparison of some sending facilities

The average interval C's durations for most of the sending facilities are approximately equal to each other and around 5-7 minutes. The significant effect of the sending facility shows that, the duration of this interval depends on factors such as the distance between parking and the patient's bed and hospital's efficiency in emergency patient transfer procedures.

The effect of month on interval C's duration was not significant $F(11,3814)=1.140$, $p=.325$. The only action that might happen outside the hospital is getting the equipment out of the ambulance and going inside the hospital, therefore the month related factors such as weather, do not impact the interval C's duration for land transfers.

The interaction effect of month and sending facility on interval C's duration was not significant $F(502,3814)= 1.004$, $p=.471$. Figure A-17compares the interval C's duration of three busy sending facilities in different months. For each sending facility, the difference between the interval C's durations in different months are around 1 minute.

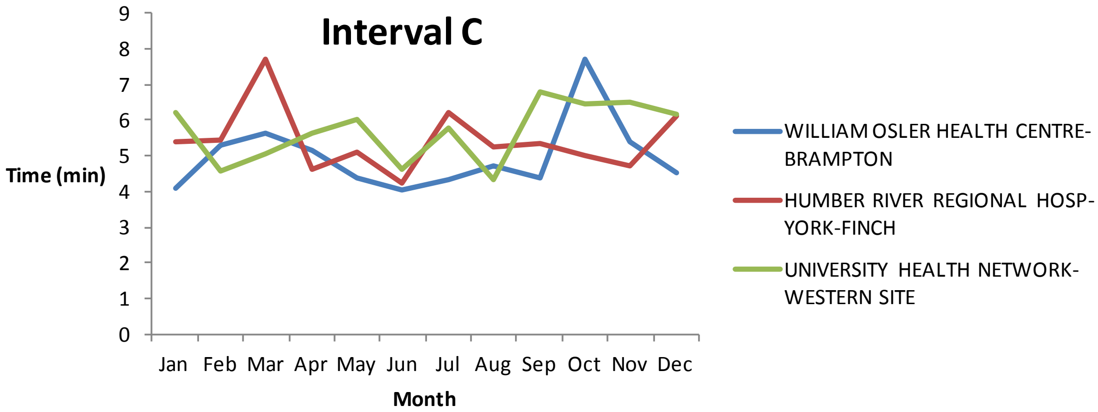


Figure A-17 Interval C's duration comparison of three busy sending facilities in different months

Since month did not have an effect on the interval C's duration for land transfers, it was removed from the statistical model. Table A-32 shows the results of the between subjects ANOVA with the sending facility as the factor. It appears that removing month from the model did not change the model's predictability as the adjusted R squared remained .044.

Table A-32 Results of the between subject ANOVA

Tests of Between-Subjects Effects

Dependent Variable:C

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	6063.177[a]	83	73.050	3.433	.000
Intercept	11685.967	1	11685.967	549.111	.000
Sending	6063.177	83	73.050	3.433	.000
Error	92085.592	4327	21.282		
Total	228677.000	4411			
Corrected Total	98148.769	4410			

a. R Squared = .062 (Adjusted R Squared = .044)

Summary: The average duration for this interval seem to be between 5 and 7 minutes. Considering the sending facility for predicting the interval's duration, as opposed to using the total average, might slightly improve the estimates.

A.2.4 Arrive Patient Site – Depart Patient Site (Interval D)

This interval is similar to interval D for Air transfers. According to the paramedics and physicians, the in hospital time is regardless of the mode of transportation. However, future research can identify the average in hospital time for different types of patients (e.g. patients who need surgery, critically ill patients, etc).

A.2.5 Depart Patient Site – Depart Pick-up Site (Interval E)

This interval is similar to interval C for land transfers as it is the time between two points of patient's bed and parking. Once the patient is ready, the paramedics take the patient to the land ambulance at parking, and load him/her into the vehicle. Similar to interval C, this interval's duration depends on distance between parking and the patient's bed and hospital's efficiency in emergency patient transfer procedures. The difference is that, while there is no patient involved in interval C, the paramedics are carrying the patient in interval E. The effects of two factors on this intervals' duration were investigated. These factors were:

- Sending facility
- Month (Season)

Limitation: For some of the sending facilities there were not enough historical data. There were around 5300 land observations recorded in the dataset, and there were 83 facilities recorded as the sending facility in the available dataset. For most of these facilities there were not enough observations for all levels of month.

Effects: A two way between subjects ANOVA was run to investigate the significance of these factors on the interval E's duration. Table A-33 shows the results of the between subject ANOVA with the sending facility and month factors. The dependent variable was the interval E's duration for land transfers (i.e. from the time the patient is moved to the stretcher to the time the land ambulance departs the sending facility).

Table A-33 Results of the between subject ANOVA

Tests of Between-Subjects Effects

Dependent Variable:E

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	25340.619[a]	577	43.918	2.144	.000
Intercept	19967.710	1	19967.710	974.665	.000
Sending	5349.869	82	65.242	3.185	.000
Month	1442.094	11	131.099	6.399	.000
Sending * Month	19364.435	484	40.009	1.953	.000
Error	75247.836	3673	20.487		
Total	221826.000	4251			
Corrected Total	100588.455	4250			

a. R Squared = .252 (Adjusted R Squared = .134)

The results shows that this statistical model is a better prediction of interval E's duration than if the mean value of interval E's durations were used, $F(577,3673)=2.144$, $p=<.001$. However the adjusted R squared is .134 which shows that only 13.4% of the variation in interval E's duration can be explained by this model.

There was a significant main effect of the sending facility on the interval E's duration, $F(82,3673)=3.185$, $p<.001$. This indicates that there are some differences in interval E's duration between the sending facilities. Figure A-18 compares the interval E's durations of some sending facilities.

Similar to Interval C, the average interval durations for most of the sending facilities are approximately equal to each other and around 5-7 minutes. The significant effect of the sending facility shows that, the duration of this interval depends on factors such as the distance between parking and the patient's bed and hospital's efficiency in emergency patient transfer procedures.

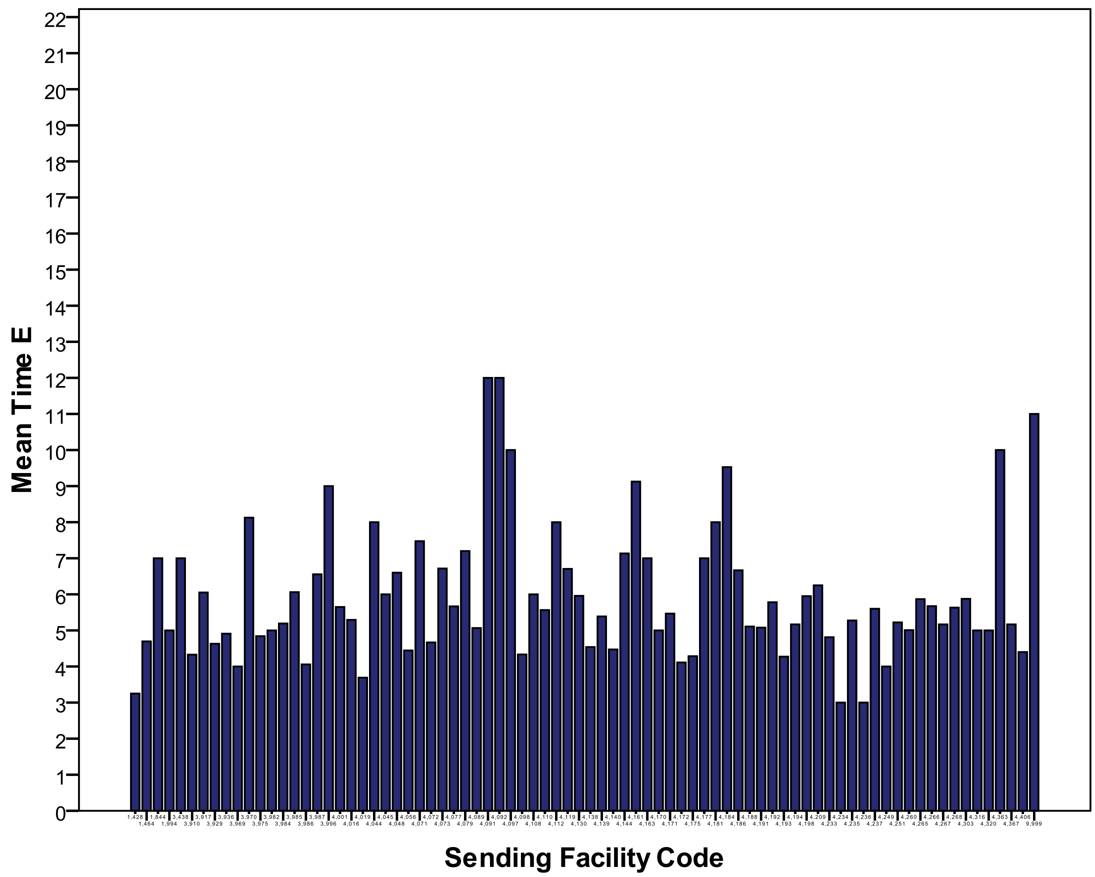


Figure A-18 Comparison of interval E's durations between some sending facilities

The effect of month on interval E's duration was significant $F(11,3673)=6.399$, $p<0.001$. This indicates month related factors such as weather, might impact the interval E's duration for some sending facilities. Figure A-19 compares the interval E's durations of different months. It appears that interval E's duration is longer in some months compared to the others. This could be due to extra actions required in some months to load the patient inside the ambulance such as safety procedures.

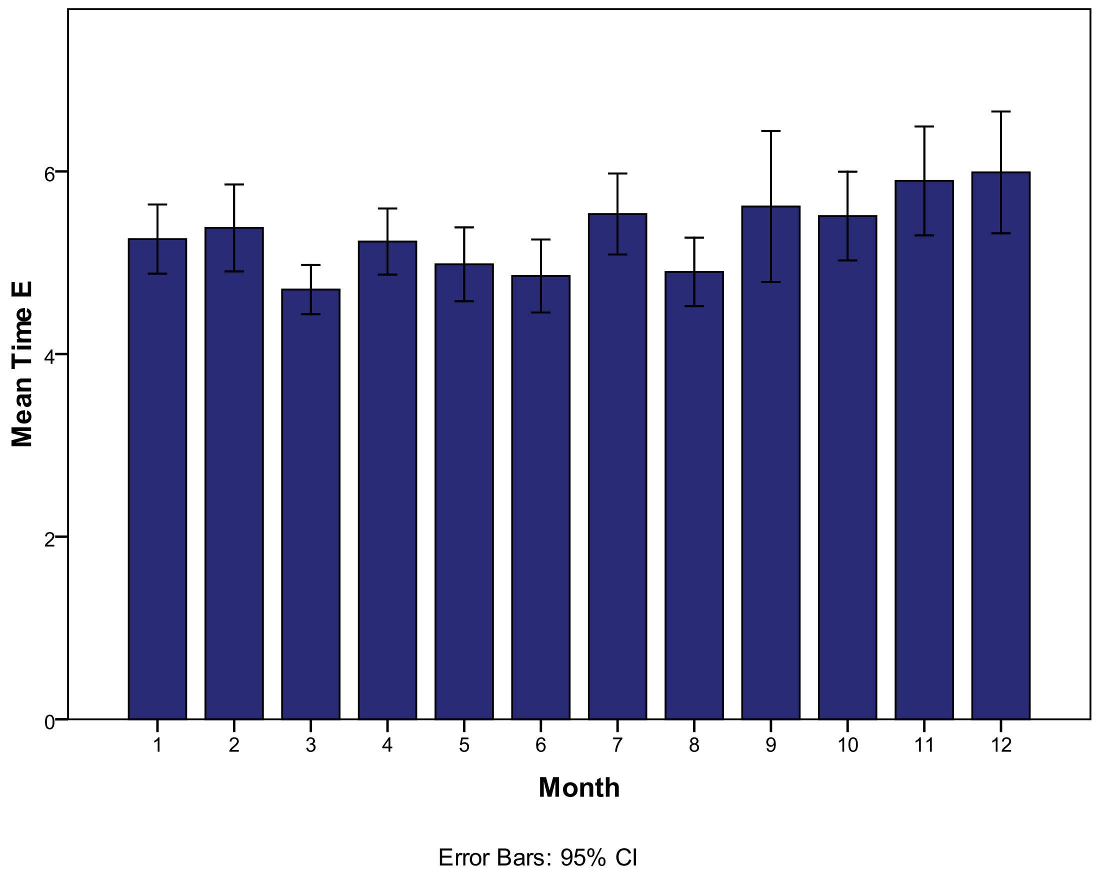


Figure A-19 Comparison of interval E's durations in different months

The interaction effect of month and sending facility on interval E's duration was significant F(484,3673)= 1.953, p<0.001. Figure A-20compares the interval E's duration of three busy sending facilities in different months. Different trends are observed; for example, for the facilities that have indoor parking less variability is expected to be observed in different times of the year, compared to those that have outdoor parking. The information regarding the type of the parking was not available to the researcher.

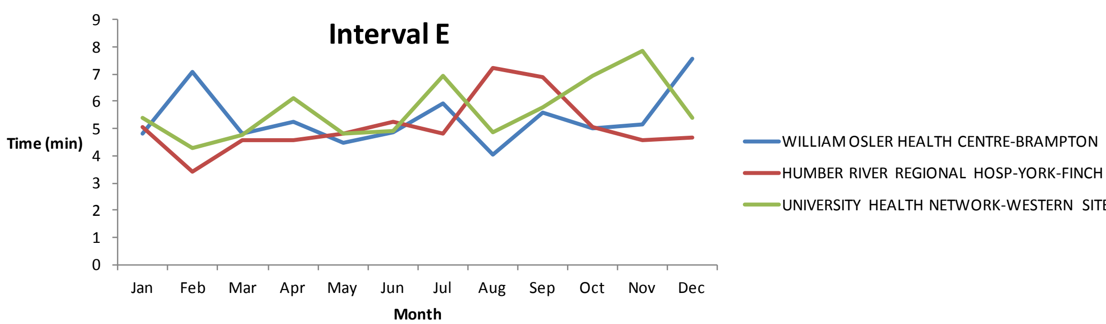


Figure A-20 Comparison of interval E's duration of three busy sending facilities in different months

As mentioned before, for most of these facilities there are not enough observations for all levels of month. Therefore, it's not possible to use the derived statistical model for the cases that do not have enough observations. For these cases, only one factor can be considered as the predictor for the interval's duration. Table A-34 reports a summary of the models with one or two predictors; the adjusted R squared for the model with sending facility as the predictors (.036) is greater than adjusted R squared for model with month as the predictor (.004). Therefore for the cases that there is not enough historical observations, sending facility should be used as the only predictor.

Table A-34 Summary of Models

Model	Variables in the model	P- Value	R Squared	Adjusted R Squared
1	Sending Facility	.000	.055	.036
2	Month	.003	.007	.004
3	Sending Facility	.000	.252	.134
	Month	.000		
	Sending Facility*Month	.000		

Summary: The average duration for this interval seem to be between 5 and 7 minutes. Considering the sending facility and month for predicting the interval's duration, as opposed to using the total average, might slightly improve the estimates. However sending facility should be used as the sole predictor for the facilities that do not have enough observations for all levels of month.

A.2.6 Depart Pick-up Site – Arrive Destination Landing Site (Interval F)

For land transfers, this interval is from the time the land ambulance departs the sending facility's parking to the time the land ambulance stops at the receiving facility's parking. This interval thus refers to the travel time by the land ambulances and is highly affected by factors such as geographic location of the facilities, road type, weather condition and traffic. The difference between this interval and interval B for land transfers, is that while there is no patient involved in interval B, the ambulance is transferring the patient in Interval F. To reduce the patient's out-of-hospital time, the land ambulance might have a greater speed in interval F compared to interval B.

Also, it's worth mentioning that, this interval is not comparable with intervals E or G for air transfers. As mentioned before for air transfers if the landing site is not within walking distances to the sending facility an additional land leg is required to transfer the patient from the facility to the landing site. While interval F for land transfers solely refers to the travel time by the land ambulance, interval E or G also include other times such as waiting times for the local land ambulances, times for loading/unloading the patient to/from the ambulance and, the walking time from parking to the patient's bed. Therefore in the equal distances and situations, interval E or G's durations would be greater than interval F's duration. Additionally, more variability is expected to be observed in interval E or G compared to interval F.

Limitations: Some of distances might not be reliable, as currently there is not a reliable list of GPS coordinates of exact locations of the facilities. The only available information at Ornge is the facilities' postal codes which do not provide the exact geographical locations of the sending facilities when converted to the GPS coordinates. Figure A-21 shows the 4 kilometer distance between the actual location of the Kemptville district hospital and its recorded postal code using Google Maps.

There are usually long distances between sending and receiving facilities while the distances between facilities and their landing sites are usually short. Therefore, for this interval and interval B-Land, the errors resulting from using the postal codes of the facilities for estimating the distances are not as influential as they are for other intervals such as C,E and G for air transfers.

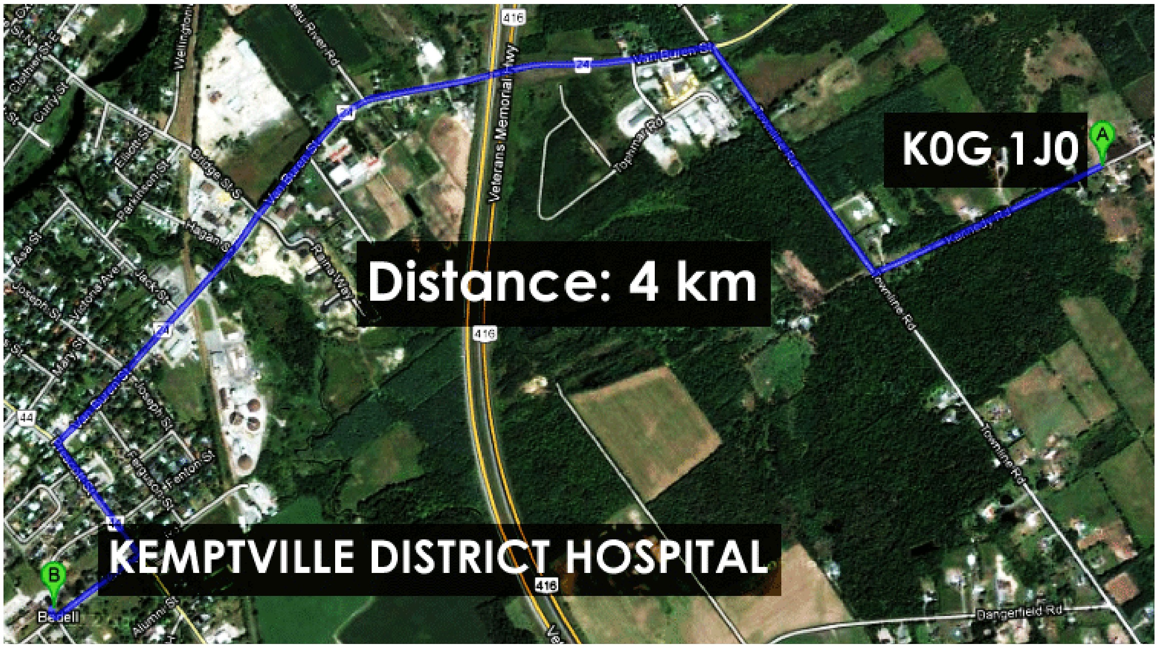


Figure A-21 Inaccurate GPS coordinates of facilities

Factors: The effects of the following factors on the interval F's duration were investigated.

- Distance from the sending facility to the receiving facility
- Month
- Hour of departure
- Day of week

To obtain the driving distances, the GPS coordinates of the sending facilities and receiving facilities were inputted in Bing Maps using Excel and the driving distances were calculated.

Driving distance was entered into the statistical model as the first predictor. Table A-35 reports the summary of this model; R has a value of .850 which represents the large effect of driving distance on the travel time for this interval. The value of R square is .723, which tells that driving distance can account for 72.3% of the variation in interval F's duration. Table A-36 also reports an analysis of variance (ANOVA) for this model. There was a significant main effect of the distance on the interval F's duration, F(1,2971)=7753.586, p<.001.

Table A-35 ANOVA Model Summary

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.850[a]	.723	.723	17.503

a. Predictors: (Constant), Distance

Table A-36 Results of the between subject ANOVA

Tests of Between-Subjects Effects

Dependent Variable:Time

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2.375E6	1	2375301.648	7753.586	.000
Intercept	259040.172	1	259040.172	845.573	.000
Distance	2375301.648	1	2375301.648	7753.586	.000
Error	910162.274	2971	306.349		
Total	1.192E7	2973			
Corrected Total	3285463.922	2972			

a. R Squared = .723 (Adjusted R Squared = .723)

As the second predictor, month was entered into the model. Table A-37 shows the results of the analysis of covariance (ANCOVA) with distance as the covariate and month as the categorical variable with 12 levels. The main effect of month is significant F(11,2960)=2.263, p<.05. However, there was a minor increase (.001) in adjusted R squared when month was included to the previous model. Therefore adding month to the model slightly improved the model's predictability.

Table A-37 Results of the between subject ANOVA

Tests of Between-Subjects Effects

Dependent Variable:Time

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2.383E6	12	198574.331	651.228	.000
Intercept	254195.836	1	254195.836	833.640	.000
Distance	2355075.506	1	2355075.506	7723.510	.000
Month	7590.327	11	690.030	2.263	.010
Error	902571.947	2960	304.923		
Total	1.192E7	2973			
Corrected Total	3285463.922	2972			

a. R Squared = .725 (Adjusted R Squared = .724)

As the third predictor, hour of departure was entered into the model. Table A-38 shows the results of the analysis of covariance (ANCOVA) with distance as the covariate and month (12 levels) and hour (24 levels) as the categorical variables. The main effect of hour was not significant F(23,2694)=1.437, p=.081. Including hour into the model does not improve the predictability; the adjusted R squared changes from .724 to .727 which tells that month and hour account for 0.4% of the variation in travel times by land ambulances.

Table A-38 Results of the between subject ANOVA

Tests of Between-Subjects Effects

Dependent Variable:Time

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2.473E6	278	8895.566	29.495	.000
Intercept	152001.400	1	152001.400	503.992	.000
Distance	2129192.328	1	2129192.328	7059.775	.000
Month	6518.654	11	592.605	1.965	.028
Hour	9968.784	23	433.425	1.437	.081
Month * Hour	79228.085	243	326.042	1.081	.195
Error	812496.704	2694	301.595		
Total	1.192E7	2973			
Corrected Total	3285463.922	2972			

a. R Squared = .753 (Adjusted R Squared = .727)

As the forth predictor, day of week was entered into the model. Table A-39 shows the results of the analysis of covariance (ANCOVA) with distance as the covariate and month (12 levels), hour (24 levels) and day of week (7 levels) as the categorical variables. The main effect of day of week was not significant $F(6,1694)=.902$, $p=.493$. Including day of week into the model slightly improved the predictability; the adjusted R squared changed from .723 (model with only distance) to .749 which tells that month, hour and day of week account for 2.6% of the variation in travel times by land ambulances.

Table A-39 Results of the between subject ANOVA

Tests of Between-Subjects Effects

Dependent Variable:Time

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2.816E6	1278	2203.639	7.956	.000
Intercept	112353.452	1	112353.452	405.629	.000
Distance	1181137.056	1	1181137.056	4264.252	.000
Month	8518.175	11	774.380	2.796	.001
Hour	8289.177	23	360.399	1.301	.154
Day	1498.387	6	249.731	.902	.493
Month * Hour	88338.636	240	368.078	1.329	.001
Month * Day	13678.196	66	207.245	.748	.934
Hour * Day	51769.325	132	392.192	1.416	.002
Month * Hour * Day	277552.415	796	348.684	1.259	.000
Error	469213.841	1694	276.986		
Total	1.192E7	2973			
Corrected Total	3285463.922	2972			

a. R Squared = .857 (Adjusted R Squared = .749)

Table A-40 reports a summary of the models; it appears that including new variables to the model slightly improves the model's predictability as the adjusted R squared has minor changes compared to the first model. Although model 8 has a better predictability compared to the other ones, it is highly over fitted; there are large number of levels in the model (2016 Model levels= 12 Month levels × 24 Hour levels × 7 Day of Week levels) compared to the number of observations (2973 observations).

Table A-40 Summary of Models

Model	Variables in the model	P- Value	R Squared	Adjusted R Squared
1	Distance	.000	.723	.723
2	Distance	.000	.725	.724
	Month(12)	.010		
3	Distance	.000	.726	.724
	Hour(24)	.042		
4	Distance	.000	.724	.723
	Day of Week(7)	.348		
5	Distance	.000	.753	.727
	Month(12)	.028		
	Hour(24)	.081		
	Month(12) * Hour(24)	.195		
6	Distance	.000	.732	.724
	Month(12)	.011		
	Day of Week(7)	.449		
	Month(12) * Day of Week(7)	.622		
7	Distance	.000	.741	.726
	Hour(24)	.119		
	Day of Week(7)	.895		
	Hour(24) * Day of Week(7)	.141		
8	Distance	.000	.857	.749
	Month(12)	.001		
	Hour(24)	.154		
	day of Week(7)	.493		
	Month(12) * Hour(24)	.001		
	Month(12) * Day of Week(7)	.934		
	Hour(24) * Day of Week(7)	.002		
	Month(12) * Hour(24) * Day of Week(7)	.000		

In a separate analysis and in order to reduce the number of levels and increase the number of observations in the levels, hour was entered to the model with 4 categories. **Error! Reference source not found.** provides a summary of these 4 categories. The first category refers to the midnight to 6 AM that traffic is expected to be at its lowest levels. The second category is from 6 AM to 10 AM which refers to the rush hour in the morning. The third category refers to two non rush hour intervals of (10 AM to 3 PM) and (8 PM to 12 PM). The fourth category is from 3 PM to 8 PM which refers to the rush hour in night.

Table A-41 Time of day Categories

Category	Description	From	To
1	Non-rush-hour Morning	12:00 PM	6:00 AM
2	Rush-hour Morning	6:00 AM	10:00 AM
3	Non-rush-hour Day and Night	10:00 AM	3:00 PM
		8:00 PM	12:00 PM
4	Rush-hour Night	3:00 PM	8:00 PM

Table A-40 reports a summary of the models for the new analysis; hourtype factor with 4 above mentioned levels was replaced with hour with 24 levels to resolve the problem of over fitting. There are 336 levels in model 8 of this table and the adjusted R squared is .729. The minor changes in the adjusted R squared compared to the first model, suggest that adding new variables to the model slightly improves the model's predictability.

Table A-42 Summary of Models

Model	Variables in the model	P- Value	R Squared	Adjusted R Squared
1	Distance	.000	.723	.723
2	Distance	.000	.725	.724
	Month(12)	.010		
3	Distance	.000	.724	.723
	HourType(4)	.036		
4	Distance	.000	.724	.723
	Day of Week(7)	.348		
5	Distance	.000	.732	.727
	Month(12)	.007		
	HourType(4)	.009		
	Month(12) * HourType(4)	.002		
6	Distance	.000	.732	.724
	Month(12)	.011		
	Day of Week(7)	.449		
	Month(12) * Day of Week(7)	.622		
7	Distance	.000	.728	.726
	HourType(4)	.027		
	Day of Week(7)	.567		
	HourType(4) * Day of Week(7)	.001		
8	Distance	.000	.758	.729
	Month(12)	.010		
	HourType(4)	.076		
	day of Week(7)	.813		
	Month(12) * HourType(4)	.023		
	Month(12) * Day of Week(7)	.313		
	HourType(4) * Day of Week(7)	.058		
	Month(12) * HourType(4) * Day of Week(7)	.350		

Effects: Figure A-22 shows average travel times by land ambulances for a particular distance (134 km) in different months. The difference between travel times in different months in most cases is smaller than 7 minutes. Some averages might not reliable due to lack of observation for particular conditions.

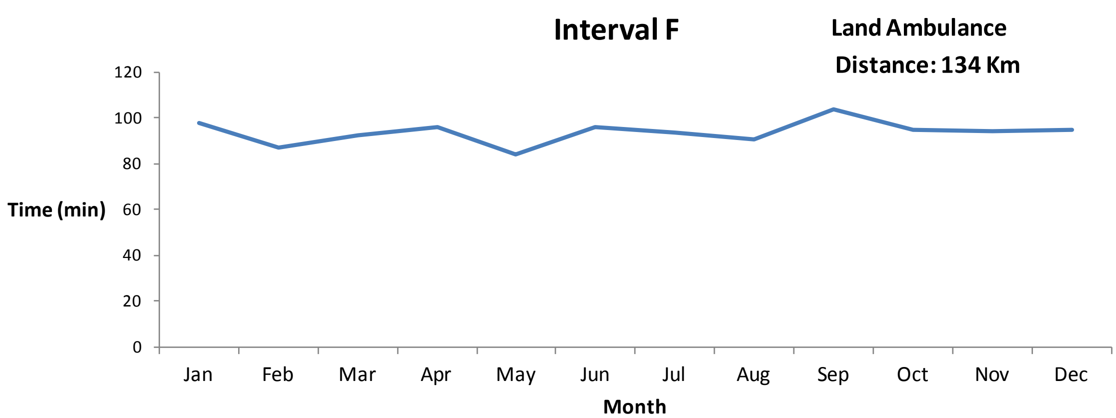


Figure A-22 Travel times by land ambulances in different months- 134 Km

Figure A-23 compares the average travel times by land ambulances in particular distances with enough observations (43 km, 100km and 134km) and in different months. In particular distance, the travel time changes are observed throughout the year. However, these changes are not predictable as this observational study is not controlling many factors such as weather condition; additionally some averages might not reliable due to lack of observation for particular conditions (e.g. there were only 4 land observations for 43 km on May).

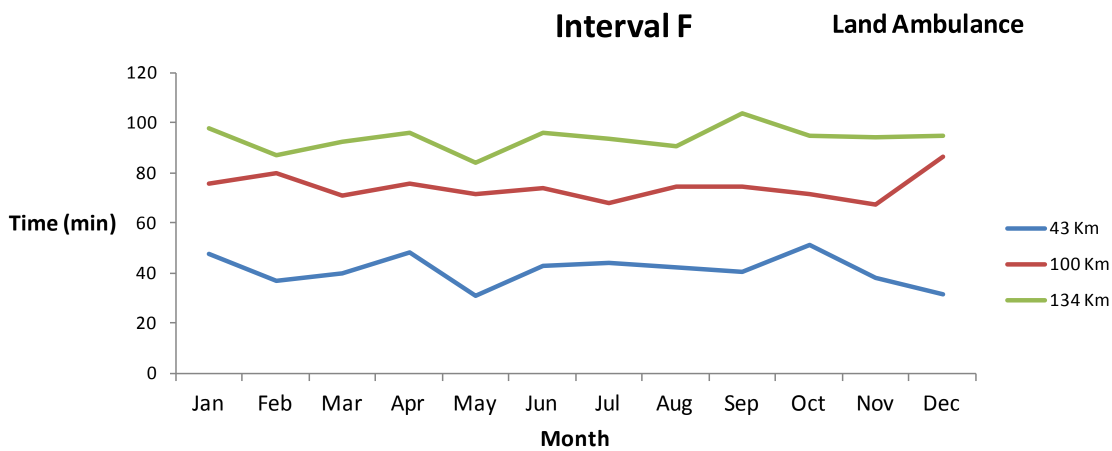


Figure A-23 Comparison of travel times by land ambulances in different distances and in different months

Figure A-24 compares the average travel times by land ambulances in 3 distances (43 km, 100km and 134km) and in different times of the day. The travel time changes are observed in different times of the day. However, these changes are not predictable as they do not follow similar patterns. Additionally, this observational study is not controlling for many factors such as weather condition or traffic. Some averages might not be reliable due to lack of observation for particular conditions (e.g. there were only 4 land observations for 100 km between 12:00 PM to 6:00 AM).

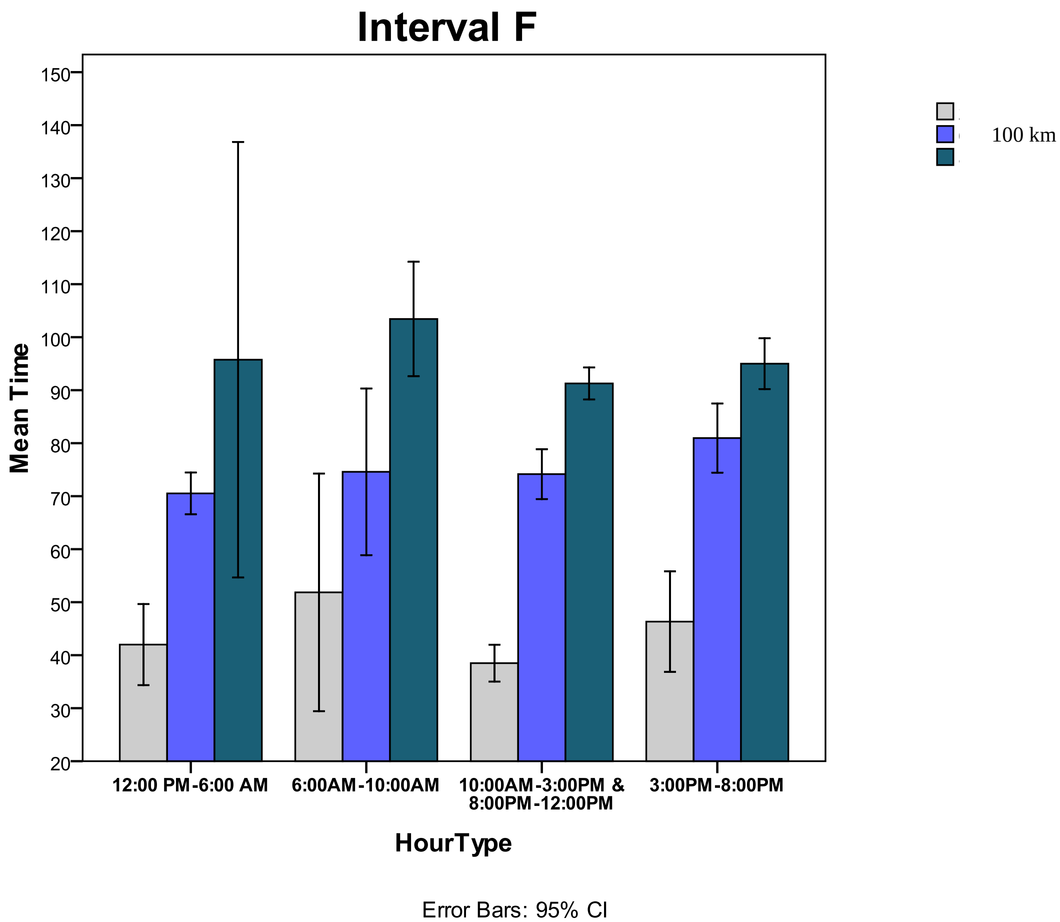


Figure A-24 Comparison of travel times by land ambulances in different distances and in different times of the day

Figure A-25 compares the average travel times by land ambulances in 3 distances (43 km, 100km and 134km) and in different days of week. Minor differences are observed in travel times in different days of week. However, these changes are not predictable as they do not follow similar patterns. Additionally, this observational study is not controlling for many factors such as weather condition or traffic. Some averages might not be reliable due to lack of observation for particular conditions (e.g. there were only 7 land observations for 43 km on Saturday).

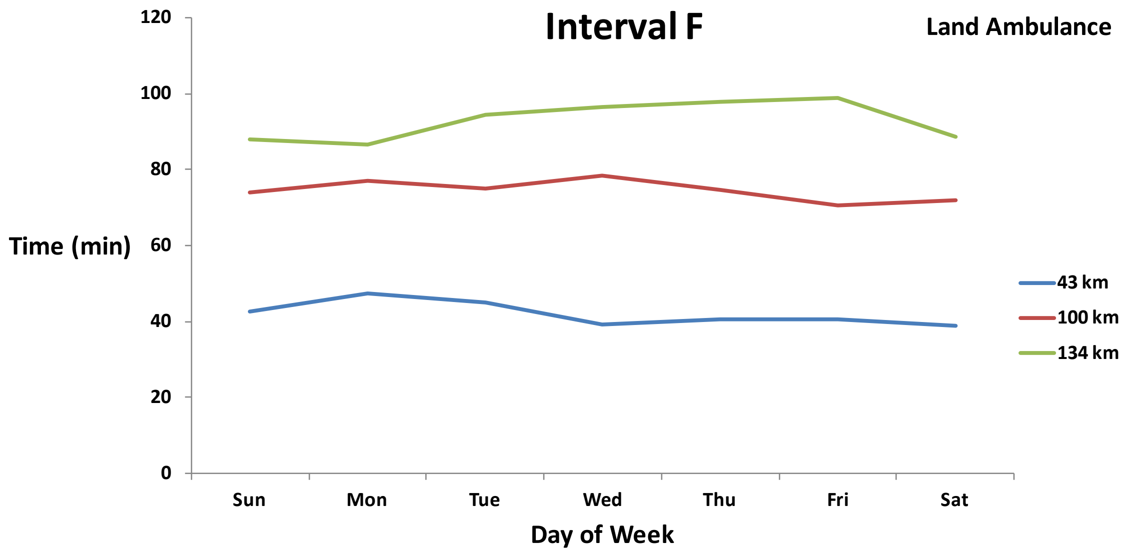


Figure A-25 Comparison of travel times by land ambulances in different distances and in different days of week

Summary: The statistical results revealed that distance has a strong effect on travel time by land ambulances. The statistical significance of month, hour of departure, and day of week effects were due to the large sample sizes, as when these factors were included into the model, the model's predictability had minor improvements. Some results are not 100% reliable because of some limitations in the study such as lack of observations for all levels of the factors in the available dataset, inaccurate GPS coordinates of the facilities, and unavailability of some information such as waiting times, traffic and weather conditions.

A.2.7 Arrive destination landing site – Delivery patient Site (Interval G)

The last interval is from the time the ambulance stops at the receiving facility's parking to the time the paramedics go inside the receiving facility and deliver the patient to the medical team. Similar to intervals C and E, the duration of this interval depends on distance between parking and the patient's assigned bed at the receiving facility, hospital's efficiency in emergency patient transfer procedures and/or other factors. The effects of two factors on this intervals' duration were investigated. These factors were:

- Receiving facility
- Month (Season)

Limitation: Similar to interval C and E, for some of the receiving facilities there were not enough historical data. There were around 4084 land observations recorded in the dataset, and there were 55 facilities recorded as the receiving facility in the available dataset. For some of these facilities there were not enough observations for all levels of month.

Effects: A two way between subjects ANOVA was run to investigate the significance of these factors on the interval G's duration. Table A-43 shows the results of the between subject ANOVA with the receiving facility and month factors. The dependent variable was the interval G's duration for land transfers (i.e. from the time the ambulance arrives to the receiving facility to the time the paramedics deliver the patient to the receiving facility).

Table A-43 Results of the between subject ANOVA

Tests of Between-Subjects Effects

Dependent Variable:G

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	84407.442[a]	435	194.040	3.763	.000
Intercept	41673.598	1	41673.598	808.204	.000
Receiving	23845.245	54	441.579	8.564	.000
Month	4305.644	11	391.422	7.591	.000
Receiving * Month	58621.073	370	158.435	3.073	.000
Error	188102.668	3648	51.563		
Total	579235.000	4084			
Corrected Total	272510.110	4083			

a. R Squared = .310 (Adjusted R Squared = .227)

The results shows that this statistical model is a better prediction of interval G's duration than if the mean value of interval G's durations were used, $F(435,3648)=3.763$, $p=<.001$. The adjusted R squared is .227 which shows that only 22.7% of the variation in interval G's duration can be explained by this model.

This interval is in many aspects similar to intervals C and E (i.e. times spent between patient's bed at sending facility and parking). However, comparing the adjusted R squares reveals that, the model's predictability for this interval (adjusted R squared= .227) is better than the predictabilities of the models for intervals C (adjusted R squared= .044) and E (adjusted R squared=.134). This better predictability can be explained by the number of facilities and their types.

There is smaller number of receiving facilities (55 receiving facilities) compared to the number of sending facilities (84 facilities). The receiving facilities are mostly large and standard facilities while the sending facilities are mostly nursing homes or small hospitals. The variability of tasks' durations in small and non-standard facilities seems to be greater than that for large and standard facilities.

There was a significant main effect of the receiving facility on the interval G's duration, $F(54,3648)=8.564$, $p<.001$. This indicates that there are differences in interval G's duration between the receiving facilities. Figure A-26 compares the interval G's durations of some receiving facilities. Compared to interval C and E, this interval also includes some paperwork requirements with the receiving facility that might add some extra minutes to the intervals' durations. The average interval durations for most of the receiving facilities are approximately equal to each other and around 7-9 minutes. The significant effect of the receiving facility shows that, the duration of this interval depends on factors such as the distance between parking and the patient's dedicated bed and hospital's efficiency in emergency patient transfer procedures.

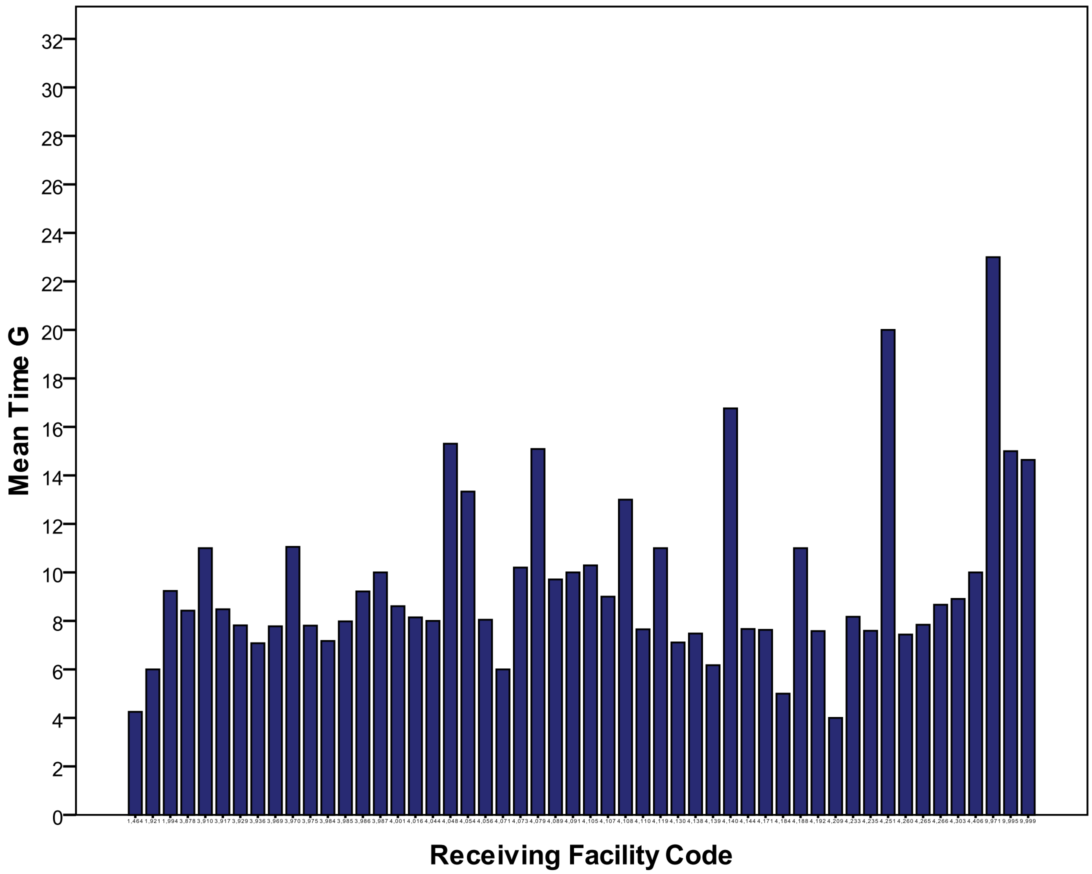


Figure A-26 Comparison of the interval G's durations between some receiving facilities

The effect of month on interval E's duration was significant F(11,3648)=7.591, p<0.001. This indicates month related factors such as weather, might impact the interval G's duration for some receiving facilities. Figure A-27compares the interval G's durations of different months. It appears that interval G's duration is longer in some months compared to the others. This could be due to extra actions required in some months to load the patient inside the ambulance such as safety procedures.

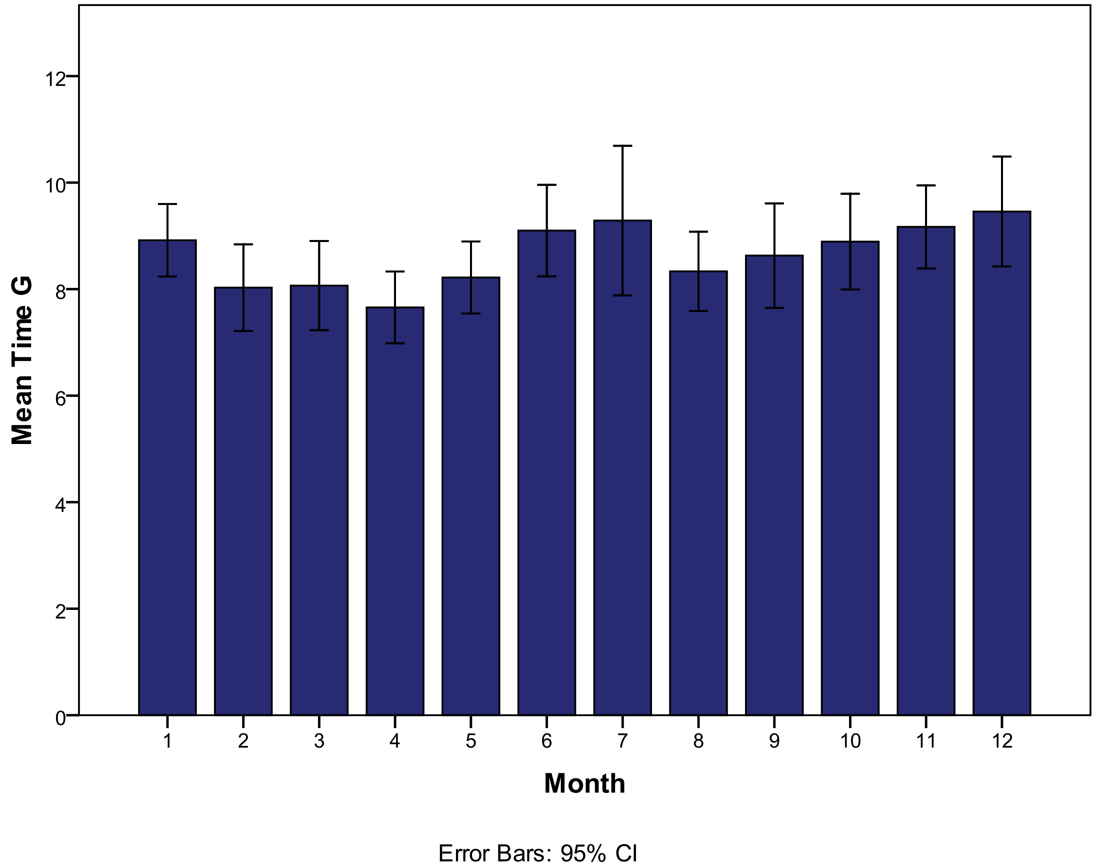


Figure A-27 Comparison of the interval G's durations between different months

The interaction effect of month and sending facility on interval G's duration was significant F(370,3648)= 3.073, p<0.001. Figure A-28 compares the interval G's duration of three busy receiving facilities in different months. Different trends are observed; for example, for the facilities that have indoor parking less variability is expected to be observed in different times of the year, compared to those that have outdoor parking. The information regarding the type of the parking was not available to the researcher.

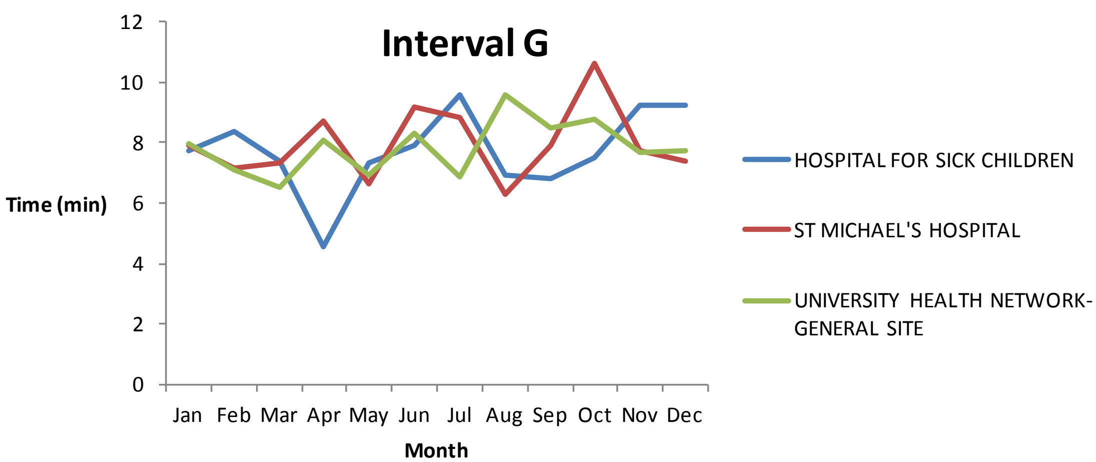


Figure A-28 Comparison of the interval G's duration of three busy receiving facilities in different months

As mentioned before, for some of the facilities there are not enough observations for all levels of month. Therefore, it's not possible to use the derived statistical model for the cases that do not have enough observations. For these cases, only one factor can be considered as the predictor for the interval's duration. Table A-44 reports a summary of the models with one or two predictors; the adjusted R squared for the model with sending facility as the predictors (.079) is greater than adjusted R squared for model with month as the predictor (.002). Therefore for the cases that there is not enough historical observations, receiving facility should be used as the only predictor.

Table A-44 Summary of Models

Model	Variables in the model	P- Value	R Squared	Adjusted R Squared
1	Receiving Facility	.000	.091	.079
2	Month	.080	.004	.002
3	Receiving Facility	.000	.310	.227
	Month	.000		
	Receiving Facility*Month	.000		

Summary: The average duration for this interval seem to be between 7 and 9 minutes. Considering the receiving facility and month for predicting the interval's duration, as opposed to using the total average, might slightly improve the estimates. However, receiving facility should be used as the sole predictor for the facilities which do not have enough observations for all levels of month.

Appendix B

Short Term Planning Decision Support Tool

Land versus Air Decisions

This decision support application uses historical dispatch (ACRV) and call data (OPTIMAS) to generate relevant time estimates for hospital pairs. This tool will enable the OCC decision-makers (flight planner, operations manager, physician) to make evidence-based decisions on vehicle allocation based on patient needs.

How does the tool Work?

A preliminary design of the tool is shown below (figure 1). The tool receives some information about the trip such as base provider name for air and land transfers, aircraft model, etc and provides time estimates for the different time intervals (e.g. call accepted to depart base, depart base to arrive pick-up site, etc).

Inputs		
Vehicle Model - Air	cfabh	S-76
Base Provider - Air	7791	7791-Ottawa
Base Provider - Land	OCLT	Ottawa - Ornge CCLT
Sending Facility	4071	PEMBROKE REGIONAL HOSPITAL INC.
Receiving Facility	4091	CHILDREN'S HOSPITAL OF EASTERN ONTARIO
Sending Landing Site	CYTA	PEMBROKE AIRPORT
Receiving Landing Sit	CPK7	Ottawa Children's Hospital

Minimum Number for Median	3

	Output						
	Call Accepted-Depart Base	Depart Base-Arrive P/U Site	Arrive P/U Site-Arrive Pt. Site	Arrive Pt. Site-Depart Pt. Site	Depart Pt. Site-Depart P/U Site	Depart P/U site- Arrive Dest. Landing	Arrive Dest. Land Site-Delivery Pt.
Air	10	38	22	27	31	34	9
Land	5	100	5	35	5	97	8
	A	B	C	D	E	F	G

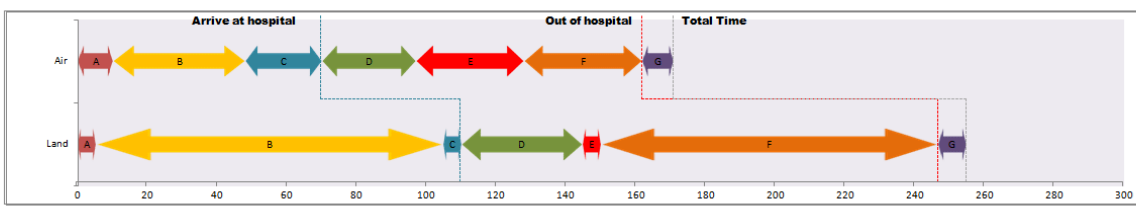
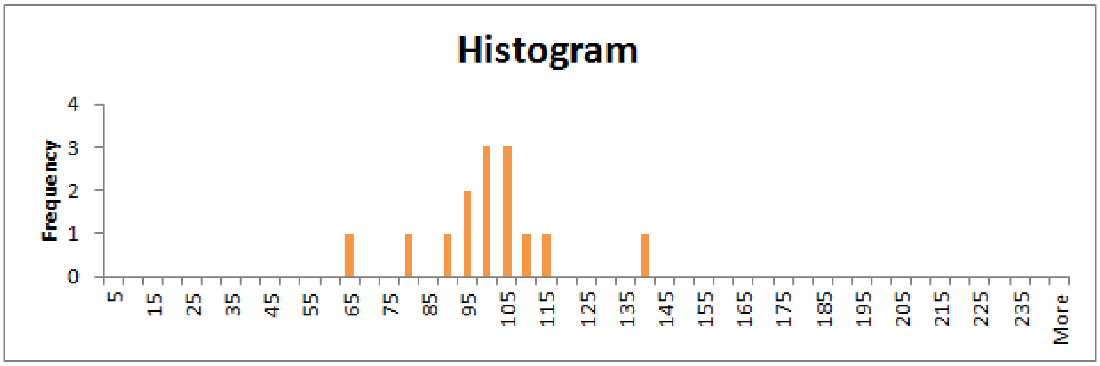


Figure 1

How are the times estimated?

The time estimates are the medians of the available historical data. To estimate the time for each interval we looked at the available Ornge historical data from 2007 to 2011 for that particular interval, based on the inputted information. For example in order to estimate the land travel time from Pembroke regional hospital to Children's hospital of Eastern Ontario we looked at 14 available historical observations (figure 2) The median time based on these 14 observations was 97 minutes; this time will be reported as the time estimate for the travel time between Pembroke regional hospital to Children's hospital of Eastern Ontario.



Interval F	
Sending Facility	PEMBROKE REGIONAL HOSPITAL INC.
Receiving Facility	CHILDREN'S HOSPITAL OF EASTERN ONTARIO
Number of Cases	14

Mean	97.5
Median	97

Figure 2

Why median?

Median is the middle value in a list of numbers; 50% of the values are below the median and 50% of the values are above it. Median was selected, because unlike the average median is not sensitive to the extreme values.

Your feedback:

The sole purpose of this survey is to evaluate the tool's efficiency and usability and prepare for the tool's training program in the future.

- 3 questions have been designed to assess the tool's features and understand the users' needs and expectations.
- Answering all these questions should take less than 15 minutes.
- The users' names or positions should not be recorded.

Question 1- Pervious Methods

a) We are interested to know more about the pervious land versus air decision making strategies at Ornge Communication Centre. Imagine that you are requested to estimate the time to definite care for a patient transfer from Peterborough regional health centre to University health network- general site. Could you please explain the steps taken to estimate the time to definite care for this transfer (land and air)?

b) Now imagine that you are requested to estimate the time to definite care for a patient transfer from Niagara health system-st Catharines (4045) to Hamilton Health Sciences Corporation (3878), would you go through the same process?

Question 2- Results page

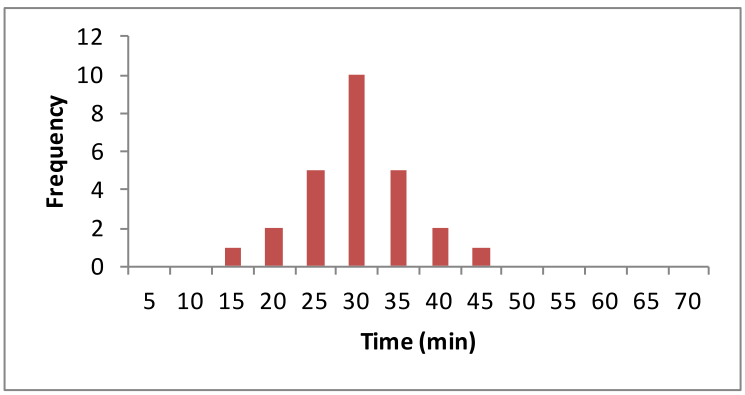
The tool’s results for the patient transfers from Peterborough regional health centre to University health network- general site are shown here (Researcher shows the output results to the user).

- Based on your experience, what do you think about the accuracy of these results?
- What would be your next step after seeing the tool’s results?
- What would be your next step after seeing the tool’s results? Considering the fact that this tool is still not taking into the account some factors such as weather or traffic and is built based on the medians.
- Is the visual presentation of results (the graph) useful?
- What other information you’d like to see on the results page?
- (The researcher shows the advanced version of the tool), which one do you prefer the simple version or the advance version? Why?

Question 3- Histograms

In addition to estimating the time estimates, this tool also provides the histogram of the historical data for each interval (Researcher shows the histograms to the user and explains the values).

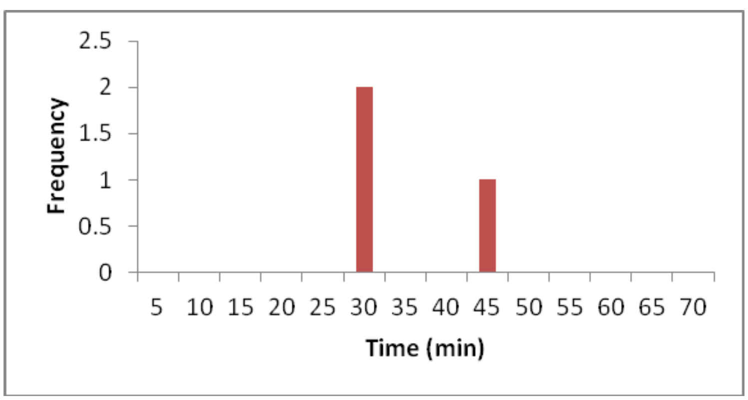
- Do you find these histograms useful? If yes, how?
- The tool has provided the same results (30 minutes) for two sets of historical data. Does seeing these histograms affect the way you interpret the 30 min time estimate?



Histogram A

Number of observations: 26

Median: 30 min



Histogram B

Number of observations: 3

Median: 30 min

Location	791 Time		CCLA Time		Decision
	Total time (minutes) from sending to receiving (Out of hospital time)	Total Time (minutes) to Difinitive Care	Total time (minutes) from sending to receiving (Out of hospital time)	Total Time (minutes) to Difinitive Care	Decision Matrix
Alexandria	52 to 70 minutes depending on destination site	115 to 140 minutes depending on destination site	70 to 89 minutes depending on destination site	175 to 195 minutes depending on destination site	**791 first choice for all calls. CCLA is a limited second choice where other resources are not available.**
Almonte	40 to 42 minutes depending on destination site	86 to 92 minutes depending on destination site	48 to 59 minutes depending on destination site	155 to 165 minutes depending on destination site	**791 first choice for Code 4. CCLA second choice. CCLA is a consideration for Code 3. The benefit in time for air would be diminished where the landing sites included Carp Airport or Ottawa Airport.**
Arnprior	40 to 42 minutes depending on destination site	122 to 128 minutes depending on destination site	54 to 78 minutes depending on destination site	152 to 172 minutes depending on destination site	**791 first choice for Code 4. CCLA second choice. CCLA is a consideration for Code 3.**
Brockville	50 to 55 minutes depending on destination site	135 to 138 minutes depending on destination site	80 to 115 minutes depending on destination site	195 to 256 minutes depending on destination site	**791 first choice for all calls. CCLA is a limited second choice where other resources are not available.**
Carleton Place	63.5	91	45.5	91	**CCLA first choice for all calls. 791 second choice**
Cornwall	71.5	145	81 minutes	195 minutes	**791 first choice for Code 4. CCLA second choice. CCLA is a consideration for Code 3.**
Hawkesbury	71	147	88	195	**791 first choice for Code 4. CCLA second choice. CCLA is a consideration for Code 3.**
Kemptville	29	90	50	135	**791 first choice for Code 4. CCLA second choice. CCLA is a consideration for Code 3.**
Kingston					**791 first choice for all calls. CCLA estimated time to definitive care nears 5 hours**

Pembroke	54.5	140	121 minutes	260 minutes	**791 first choice for all calls. CCLA is a limited second choice where other resources are not available.**
Perth	39 to 47 minutes depending on destination site	110 to 115 minutes depending on destination site	80 to 115 minutes depending on destination site	188 to 193 minutes depending on destination site	**791 first choice for all calls. CCLA is a limited second choice where other resources are not available.**
Renfrew	42	115	88	195 minutes	**791 first choice for all calls. CCLA is a limited second choice where other resources are not available.**
Smiths Falls	43 to 51 minutes depending on destination site	117 to 124 minutes depending on destination site	62 to 79 minutes depending on destination site	155 to 173 minutes depending on destination site	**791 first choice for all calls. CCLA is a limited second choice where other resources are not available. CCLA should be considered for Priority 3 calls.**
Winchester	38	105	52	130	**791 first choice for Code 4. CCLA second choice. CCLA is first choice for Code 3.**

Note that not all transfer of care times at the pickup location are the same. The data is based upon actuals. Where numbers are small, and the transfer of care time is longer for land vs. air, the average times for the transportation would be extended.