A GENERAL DESIGN METHODOLOGY FOR POSTPARTUM NURSE PRACTITIONER-LED CLINICS

JACQUELINE NOVOTNY

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Telfer School of Management
University of Ottawa

Abstract

Having a newborn can be a big change for families, especially for first-time parents. At hospital discharge, parents are often provided with a lot of information, which can be difficult to retain. Due to shortened postnatal lengths of stay, nurses typically have less time to educate parents, which often results in families feeling overwhelmed. After hospital discharge, it is recommended for families to see a health care provider (i.e., physician, nurse practitioner, or registered midwife) within 72 hours for a follow-up appointment. This follow-up appointment is meant to assess both the mother and newborn to ensure they are both in good health and to provide any needed support. Unfortunately, completing the appointment within this timeframe may not be possible for every family or they may not be aware of its importance.

Depending on the family's model of care, completing the follow-up appointment within 72 hours after hospital discharge can be challenging. Families that have a physician as their health care provider may experience delays in scheduling the follow-up appointment. This can be due to the physician's lack of availability, as there is a physician shortage in most communities. Furthermore, some families do not have access to a health care provider and, therefore, do not see a care provider after hospital discharge. Completing the follow-up appointment later than when it is recommended, or not at all, can result in negative health consequences for the mother and newborn and can also increase re-admission hospital rates and related costs (Cargill et al., 2007).

At the moment, postnatal lengths of stay are shortening but the service delivery has not changed to accommodate this trend (Lemyre et al., 2018). This means that the services typically provided to families in the hospital now need to be provided in the community. The follow-up appointment after hospital discharge is an opportunity to provide these services; however, timely access to a health care provider, specifically a physician, can be challenging. Thus, this thesis explores the development of a general design methodology for a postpartum nurse practitioner-led clinic. The aim of the clinic is to provide timely access to any family that needs to complete the necessary postpartum services after hospital discharge within a community.

An analytical model was developed to explore the characteristics of a postpartum nurse practitioner-led clinic and how it would operate (i.e., what services would be offered, the amount of time needed for these services, what is needed to offer these services, etc.). The model conducts a simulation of the appointment scheduling process based on the input values entered into it and evaluates a number of performance metrics (e.g., number of diversions, patient wait times, resource idle time, clinic overtime, number of appointments provided within 72 hours and number of appointments provided beyond 72 hours). The findings from the model can support the potential implementation of a postpartum nurse practitioner-led clinic in any community. Implementing such clinics could increase awareness, further educate parents and increase access to postpartum services.

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Introduction

Context

Having a newborn can be a big change for families and can be quite challenging when families have difficulty accessing postpartum care services, which are services provided immediately after childbirth and that continue after hospital discharge (Ontario Prenatal Education, 2020). This thesis explores the postpartum care services provided to families once they are transitioned home. Families should complete a follow-up appointment with their health care provider shortly after hospital discharge; however, depending on their model of care, they may experience delays. This could be due to limited access to their health care provider, where receiving an appointment may take some time, or due to families being unaware of the exams they need to complete during the postpartum period (Cantin & Rivard, 2017). The first follow-up appointment after hospital discharge is essential because it is meant to examine the newborn's health and provide support to the family (Ontario Prenatal Education, 2020).

The Provincial Council for Maternal and Child Health (PCMCH) has outlined the recommended follow-up care for mothers and newborns along with the associated timeframes in their Standards of Postnatal Care Report (Provincial Council for Maternal and Child Health, 2018a). It is recommended that a mother and her newborn receive their physical follow-up appointment with a health care provider (i.e., a physician, a nurse practitioner or a midwife) within 72 hours after hospital discharge (Provincial Council for Maternal and Child Health, 2018a). Though births can occur in different settings (i.e., home, birth center or hospital), this thesis will focus on hospital births as they account for approximately 98% of births in Canada (Association of Ontario Midwives, 2020; Lemyre et al., 2018).

A reason for delayed follow-up appointments or families not completing the follow-up appointment at all could be due to the physician shortage observed in many communities, especially in rural areas (Islam, 2014). This is problematic because a newborn's health can rapidly change and needs to be closely monitored by a health care provider during the first few weeks after birth (Ontario Prenatal Education, 2020). Additionally, mothers require support, such as mental health and breastfeeding advice, during this transitional time (Provincial Council for Maternal and Child Health, 2018b). Therefore, if families cannot complete the follow-up appointment in a timely manner, it can have negative health consequences for the mother and her newborn. Also, if families cannot obtain timely access to their health care provider, then they will seek care elsewhere, such as the emergency department (Cargill et al., 2007).

Systematically, postnatal lengths of stay (the amount of time a mother and her newborn stay in the hospital after birth) have been decreasing across the globe as a way to combat increasing health care costs (Provincial Council for Maternal and Child Health, 2018b). The problem with this trend is that measures have not been put in place in the community to supplement the services that are no longer offered in hospitals (Lemyre et al., 2018). This brings with it concerns regarding the quality of the postpartum care given to mothers and newborns if the delivery of these services remains unchanged as it could result in less care or worse quality of care than what was previously provided (Provincial Council for Maternal and Child Health, 2018a). Similarly, to what is occurring globally, Ontario is not exempt from decreasing trends in postnatal lengths of stay. In Ontario, the average postnatal length of stay for a vaginal birth decreased from 3.2 days in 1993 to 2.0 days in 2012 (Lemyre et al., 2018).

This thesis largely focuses on the delivery of postpartum care services within the Ottawa area, as it is the community of interest. However, the challenges faced in the delivery of postpartum care services are not unique to the Ottawa and surrounding area. These challenges are experienced across the globe and more locally, across the province of Ontario. Both global and provincial authorities have set out objectives to help guide positive changes in the delivery of postpartum care services. These goals should be kept in mind when developing new models of care for postpartum care services. In the following subsections, both global and provincial goals were examined to help better understand what objectives should be accomplished when developing new models of care for these services.

Globally

To improve the quality of care given to mothers and their newborns, the World Health Organization (WHO) has identified a number of goals that countries can aim to achieve. These goals include the following:

1. Improve the quality of care provided to mothers and newborns because many health problems can be prevented by effective, scalable and sustainable improvements;
2. Provide equal care to everyone in order to minimize inequities between those who are rich and those who are poor. To minimize inequities between populations, quality of care needs to be complemented with specific policies that increases access to care; and,
3. Provide respectful care to women and newborns as a way to help minimize stress and reduce complications (World Health Organization, 2018).

Achieving these goals could most likely be done through policy changes that focus on improving how health care services are provided in each individual country. However, it will take the initiative of each country's Ministry of Health to take action to apply these goals (World Health Organization, 2018).

Provincially

To help overcome the problems faced by Ontario's health care system, the province has developed a number of initiatives. In 2012, an action plan was launched that includes a number of objectives that are meant to help guide the improvement of Ontario's health care system (Ministry of Health and Long-Term Care, 2015). These objectives include:

1. Improving access to services, so patients can receive care faster;
2. Providing more coordinated and integrated care in the community;
3. Further educating patients so that they can make the right decisions about their health; and,
4. Making decisions based on value and quality in order to sustain the system for generations to come (Ministry of Health and Long-Term Care, 2015).

These objectives are meant to help guide a positive change within Ontario's health care system. Ontario seeks to transform its health care system by providing better access to services, which would consequently result in providing better care to patients (Ministry of Health and Long-Term Care, 2015). Ontario is trying to achieve this by integrating more health care services into the community. One example of Ontario trying to promote community services is the creation of Local Health Integration Networks (LHINs), which are regional organizations that oversee health services for a certain region (Ministry of Health and Long-Term Care, 2018). While still in operation, the LHINs are responsible for planning, managing, delivering and monitoring home and community care services (Ministry of Health and Long-Term Care, 2018).

The LHINs have existed for many years; however, they are slowly being suspended in Ontario because the province is currently restructuring its health care system. In 2018, a majority Progressive Conservative government party, led by Doug Ford, was elected and announced its plans for health care reform by creating Ontario Health Teams (Powers, 2018; Crawley, 2019). Ontario Health Teams will be created by merging 20 agencies together to form one large agency called Ontario Health (Crawley, 2019). The purpose of Ontario Health will be to provide a new way of organizing and delivering care that is more connected to patients in their local communities by structuring health care providers to work as one coordinated team (*Become an Ontario Health Team, 2020*). At the moment, there is limited information about Ontario Health and how Ontario Health Teams will function (Crawley, 2019). Furthermore, the implementation of Ontario Health Teams will take several years; therefore, this thesis primarily focuses on LHINs when discussing the health care system, but this information may differ after the implementation of Ontario Health (Crawley, 2019).

With Ontario seeking to improve its health care system by expanding community services and undertaking a major restructuring plan, there is an opportunity for the implementation of innovative solutions. With greater emphasis on community services, new models of care like the Monarch Center and the Postnatal Ambulatory Clinic (PNAC) in Ontario, which are both physician-led newborn follow-up clinics, have emerged as ways to improve postpartum care in the province (Provincial Council for Maternal and Child Health, 2018a). Thus, new models of care are emerging that further utilize and connect community services.

Research Objective

With shorter postnatal lengths of stay and an unchanged service delivery to accommodate this, the focus of this thesis is on the development of a general design methodology for a postpartum nurse practitioner-led clinic. This is a postpartum clinic where mothers and newborns can go to complete their follow-up appointments after hospital discharge, complete any required testing and receive any additional support. Such a clinic is unique compared to what is currently available because it is nurse practitioner-led. The research in this thesis outlines what is required to develop such a clinic and how it would operate. The aim is to create an analytical model that can be used as a capacity planning tool to evaluate the service delivery of a clinic depending on a number of factors. The model represents a general clinic design, which can be adaptable to any community.

The analytical model proposed in this thesis computes the service level offered by the clinic, along with other performance metrics, based on the predefined operational factors set in the model. The service level is defined as the percentage of follow-up appointments provided within 72 hours from hospital discharge and its results is dependent on the demand and capacity inputs entered into the model. The capacity inputs represent the daily number of appointment slots available from each resource (i.e., nurse practitioner, registered nurse, etc.), while the demand inputs represent the daily number of appointment requests. These inputs combined help create the daily schedules, which are used to simulate random appointment durations. The performance of the system is assessed through various performance measures (e.g., number of diversions, patient wait times, resource idle time, clinic overtime, number of appointments provided within 72 hours, and number of appointments provided beyond 72 hours). The results of the simulation give an indication of the expected outcomes based on the inputs entered into the model.

The model was designed based on data collected from Quinte Health Care and the Institute for Clinical Evaluative Sciences (IC/ES). Data was gathered from Quinte Health Care as their community is facing a physician shortage and receiving timely access to postpartum care can be challenging at times; therefore, they were interested in supporting a study that looked into an alternative model of care. Additionally, data was collected from IC/ES as they were the only known source of information on when families complete their follow-up appointment after hospital discharge. The data collected helped estimate the inputs of the model, which are adaptable, and to evaluate the performance of the model.

The purpose of designing a postpartum nurse practitioner-led clinic is to increase timely access to postpartum care. This clinic would be accessible to any family that wishes to visit it. The ultimate goal is to ensure that all mothers and newborns have equal and timely access to postpartum care wherever or whenever they need it.

The research question for this thesis is: *What would be the operational characteristics (i.e., service offering, what would be required to provide these services, and the optimal amount of time for offering these services) of a nurse practitioner-led clinic that would increase access to families that seek timely postpartum care services after hospital discharge in a community?*

Background

Postpartum Care in Ontario

Services Provided After Hospital Birth

To create a model for a postpartum nurse practitioner-led clinic, it is necessary to understand the services provided during this stage and their importance. The services provided during the postpartum period are critical for the health of the newborn as this is when a newborn is at greatest risk of death (Ontario Prenatal Education, 2020). Globally, newborn deaths account for 45 percent of all deaths among children under the age of 5 (Ontario Prenatal Education, 2020). Of these deaths, 36 percent occur within the first 24 hours of life and 73 percent occur during the first week of life (Ontario Prenatal Education, 2020). In Ontario, the neonatal death rate is 2.4 per 1,000 live births within the first 24 hours after birth and 0.6 per 1,000 live births within 1 to 6 days after birth (Statistics Canada, 2020). Fortunately, the neonatal death rate is relatively low in Ontario in comparison to global neonatal death rates; however, it is still a concern.

Prior to hospital discharge, a series of tests and health checks are completed on the newborn (Ontario Prenatal Education, 2020). These are completed to ensure that the newborn is healthy enough to go home. A full breakdown of the services the mother and her newborn receive prior to hospital discharge can be found in Table 1.

Table 1: Postpartum services provided prior to hospital discharge

Newborn	• *Newborn bloodspot screening:* a blood sample to screen and detect for any critical diseases is typically collected between 24 to 48 hours after birth. If newborns are discharged before 24 hours after birth, a repeat sample will need to be taken between 24 to 48 hours after birth; • *Pulse oximetry screening for critical congenital heart disease:* a test that measures the level of oxygenation in the arterial blood; • *Infant hearing screening:* newborns that are not at risk of permanent hearing loss receive an initial Automated Distortion Product Optoacoustic Emissions (ADPOAE) screening prior to hospital discharge; and, • *Newborn physical exam:* newborns receive a complete physical exam by a physician or midwife within 24 hours of birth. This exam is done to assess a newborns physical health, check for signs of jaundice, and provide feeding support (Provincial Council for Maternal and Child Health, 2018b)
Mother	• *Maternal physical assessment:* a thorough postnatal maternal physical assessment is completed on all mothers. This includes assessing the mothers physical, psychological and social wellbeing (Provincial Council for Maternal and Child Health, 2018b).

Once discharged from the hospital, families should arrange a follow-up appointment with their health care provider. Based on PCMCH standards, it is recommended to complete this follow-up appointment within 72 hours after hospital discharge (Provincial Council for Maternal and Child Health, 2018b). Typically, the mother and newborn are assessed together and the services they receive are outlined in Table 2.

Table 2: Postpartum services provided at the first follow-up appointment

Newborn	• *Jaundice and Hyperbilirubinemia Screening:* all newborns receive a bilirubin screening, which is completed by taking a blood sample. It tests for hyperbilirubinemia, which is the result of the diminished ability to conjugate and excrete excess bilirubin in the blood. High bilirubin levels can cause jaundice, which can lead to brain damage and other serious complications; • *Newborn physical exam:* this is a second exam that is very similar to that performed prior to being discharged from the hospital; • *Weight check:* this entails weighing the newborn as it is important to ensure that the newborn is expectantly gaining the appropriate amount of weight for its age; and,

	• *Complete any screenings tests that have not been completed:* this entails completing any tests that were not completed prior to discharge (Ontario Prenatal Education, 2020; Provincial Council for Maternal and Child Health, 2018b; *Hyperbilirubinemia Toolkit*, 2017).
Mother	• *Feeding support*: this is meant to assess how feeding is going for the mother and her newborn; • *Postpartum assessment*: this entails providing wound care, assess any bleeding, and examine the mother's mental health; • *Ask how the family is adjusting to life with a newborn:* this is meant to provide any support to the family with the adjustment of having a newborn at home; and, • *Answer any questions that the parent(s) may have:* this is meant to ease any concerns that parents may have (Ontario Prenatal Education, 2020; Provincial Council for Maternal and Child Health, 2018b).

Based on the newborn's health and concerns, they may or may not return for another follow-up appointment. The number of appointments a newborn requires can vary where some may only require one while others may require multiple. If they return for a subsequent visit, they may return for the same services or for other specific services. For example, some newborns may return further monitoring, some may need several bilirubin samples, and some mothers may return for additional breastfeeding support. The services provided to the family and the newborn depend on what is required.

To complete the follow-up appointments, families can visit a variety of different health care providers, including a physician (i.e., obstetrician, family physician, pediatrician or neonatologist), a registered midwife, or a nurse practitioner (Cantin & Rivard, 2017). More details will be provided in the following sub-section that describes the clinical pathway that families can follow to complete their follow-up appointments. Generally, the clinical pathway can vary and is dependent on the family's primary health care provider.

The clinic pathway for higher risk newborns can differ from that for those who are at a lower risk. For instance, preterm newborns will have a follow-up plan with their health care provider prior to hospital discharge (Caring for Kids, 2019). Furthermore, the family will be educated about early signs or symptoms to look for to help identify any problems, if they occur (Caring for Kids, 2019). Thus, higher risk newborns may not follow the same follow-up pathway, as they may require more intervention. Therefore, the postpartum care services discussed in this thesis relate to lower-risk births, as they are more likely to follow the standard pathway.

In addition to the follow-up appointments, families may receive a phone call from a public health nurse within the first 48 hours after discharge (Ontario Prenatal Education, 2020). This is part of the Government of Ontario's Healthy Babies Healthy Children program, where a public health nurse will offer support and information and discuss how the family is doing (Ontario Prenatal Education, 2020). If they do not want to receive a phone call, families can opt to call their local public health unit themselves as the program is voluntary (Ontario Prenatal Education, 2020). The purpose of the program is to help families transition home with their newborn and to provide them with information about community resources (Ontario Prenatal Education, 2020).

After completing all the necessary follow-up appointments after hospital discharge, newborns will continue to visit their primary health care provider on a regular basis. Most families with young children will have ongoing contact with their primary health care provider because they will attend well-baby care visits until their child is 18 months old (Ministry of Children, Community and Social Services, 2005). These visits will occur when the child is two months, four months, six months, nine months, 12 months, 15 months and 18 months old (Ministry of Children, Community and Social Services, 2005). After 18 months, children will have another visit at 2 years and then once every year until they are 5 years old (Ministry of Children, Community and Social Services, 2005). The purpose of these visits is to assess the child's physical health, ensure they are meeting milestones for their physical growth (i.e., height and weight), identify any serious physical or developmental delays, and provide immunizations against a number of diseases (Ministry of Children, Community and Social Services, 2005). Furthermore, many primary health care providers will use these visits to offer support and education to parents and connect them with community services (Ministry of Children, Community and Social Services, 2005). Unfortunately, this practice is not universal among all primary health care providers in Ontario and, therefore, can differ from family to family (Ministry of Children, Community and Social Services, 2005).

Health Care Providers Providing Postpartum Care

The health care provider a family has to complete the follow-up appointment with can differ, as there are a number of different health care providers that offer newborn care. Furthermore, the specific pathway and experience can differ based on the chosen health care provider. For example, the timing of when families receive postpartum care can differ, as different health care providers provide services at different timeframes (Provincial Council for Maternal and Child Health, 2018b). Health care providers providing newborn care in the postpartum period can include physicians, midwives and nurse practitioners (Cantin & Rivard, 2017).

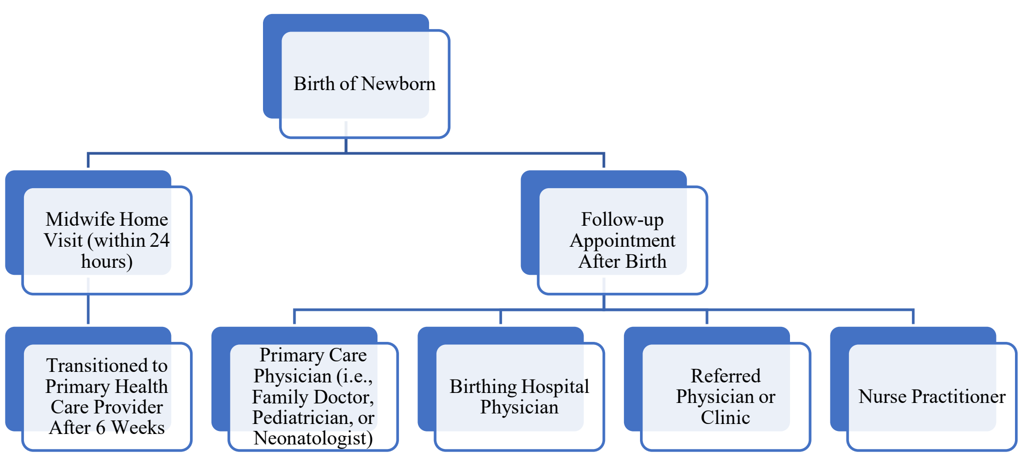
For families that choose a midwife, they will continue to receive care from their midwife for 6 weeks after birth (Association of Ontario Midwives, 2020). Regardless of the birthplace (i.e., home, birth center or hospital), midwives will complete a follow-up appointment within 24 hours after birth in the family's home (Association of Ontario Midwives, 2020). After the initial appointment, families will most likely have several follow-up appointments with their midwife during the first week after birth (Association of Ontario Midwives, 2020). During these appointments, midwives will provide the same postpartum services (e.g., physical examination, weight check and breastfeeding support) and, for services they cannot complete themselves (i.e., bilirubin samples), they will refer the family to the appropriate health care provider (Association of Ontario Midwives, 2020). After six weeks, families will be discharged from midwifery care and will be transitioned to their primary health care provider (Association of Ontario Midwives, 2020).

For families that do not choose midwifery care, they will receive postpartum services from either a physician or a nurse practitioner. For the first follow-up appointment after birth, families will complete the appointment with their primary health care provider, a referred health care provider (i.e., a referred physician or clinic that provides postpartum services) or by the physician at the birthing hospital (Caring for Kids, 2018). The chosen health care provider depends on each family's circumstances and preferences, as some may have timely access to a primary health care provider while others may not. Furthermore, geographical location can also impact the availability of health care providers to complete the follow-up appointment (Caring for Kids, 2018).

Though it is recommended for families to receive the follow-up appointment within 72 hours after hospital discharge, families under physician care may receive their appointment anytime within the first week after hospital discharge (Caring for Kids, 2018). This could be due to dated guidelines and physicians being unaware of the new recommendations. It could also be due to the physician's limited appointment availability. Families with a nurse practitioner will complete the follow-up within the first week after hospital discharge; however, the specific timeframe is less well-defined (Caring for Kids, 2016). Nevertheless, families should receive the follow-up appointment within 72 hours after hospital discharge to dismiss any major health concerns; however, in practice, not every family will receive the follow-up appointment within this timeframe.

If multiple follow-up appointments are required, they are typically done by the same health care provider, but they will refer the family for services they cannot complete themselves. Furthermore, it is possible that the family will complete the follow-up appointment with one health care provider and then be transitioned to another. The pathway can vary but, overall, the aim is to ensure that the newborn receives the appropriate care. With multiple providers offering follow-up appointments, Figure 1 illustrates the different pathways families can take.

Figure 1: Health Care Providers Delivering Follow-up Appointments After Birth



Once families complete all the necessary follow-up appointments, they will continue to regularly see their primary care provider. If families have difficulty finding a primary health care provider, they can try finding a physician or nurse practitioner through word of mouth, where they can ask friends and family members if their primary health care provider is accepting new patients

(Caring for Kids, 2018). Furthermore, there are provincial programs, such as Health Care Connect, that connect families to primary health care providers who may be accepting new patients in Ontario (Ministry of Health and Long-Term Care, 2017b). Ideally, families would already have a primary health care provider prior to birth; however, this may not always be the case.

Benefits of Newborn Follow-up Appointments

As previously mentioned, not every family has access or timely access to a family physician to complete the follow-up appointment within 72 hours after hospital discharge. This is even despite the fact that early follow-up appointments are important and can provide many benefits. For one, any changes in a newborn's health can be caught early on. For example, bilirubin levels peak between 3 to 5 days after birth and, therefore, early follow-ups allow these bilirubin levels to be closely monitored, as high levels could be life-threatening (Cargill et al., 2007). In addition, early follow-up appointments can be beneficial to the overall health care system by lowering hospital readmission rates. For example, a study conducted in Ohio, USA, found that newborns seen within a few days (less than four days) after hospital discharge were less likely to be readmitted to the hospital compared to those who completed the follow-up after four days (Cargill et al., 2007).

Another benefit of early follow-up appointments is that families may be informed of the community services available to them sooner (Ministry of Children, Community and Social Services, 2005). They may be able to access these services sooner and receive the appropriate support, which could greatly benefit them during this transitional period. Currently, however, some families may not be informed of the importance of these community services for the overall health and development of their child, or they are simply too busy to take the time to search for these services on their own (Ministry of Children, Community and Social Services, 2005). Furthermore, some families may be unaware of these services due to language, cultural and educational barriers (Ministry of Children, Community and Social Services, 2005).

Completing frequent and timely follow-up appointments is also important for the long-term health of the newborn. Furthermore, it could reduce the long-term health care costs associated with poor child development because children are closely monitored for any serious health issues and can receive timely treatment (Ministry of Children, Community and Social Services, 2005). For example, without follow-up appointments, children may be at a greater risk of developing high blood pressure, Type 2 diabetes and mental health problems (Ministry of Children, Community and Social Services, 2005). Thus, it is important that newborns complete the necessary follow-up appointments early on and continue to complete the necessary check-ups thereafter to ensure they are in good health.

State of Postpartum Care in Ontario

To better understand how to improve the delivery of postpartum care services in Ontario, the current state of how these services are delivered must first be known. A study done by the Champlain Maternal Newborn Regional Program (CMNRP) surveyed a sample of 200 women to assess their postpartum experience (Cantin & Rivard, 2017). This study was conducted through an online survey that was disseminated to new parents through social media platforms (i.e., Facebook and Twitter) in 2016. The survey was shared by parent representatives and community partners and was promoted through CMNRP's Weekly News email (approximately 1,000 recipients) (Cantin & Rivard, 2017). The majority of the respondents were middle to high income parents, married and between the ages of 26 and 35 (Cantin & Rivard, 2017). From this survey, it was found that 92.7% of the respondents were able to book a follow-up appointment for their newborn as instructed at hospital discharge; however, the timing of when it was completed differed (either within 1-2 days, 2-3 days or 1-week after discharge) (Cantin & Rivard, 2017). Furthermore, 7.3% of the respondents experienced difficulties in booking a timely follow-up appointment due to multiple barriers (e.g., receptionist would only schedule the follow-up appointment 1-week after discharge) (Cantin & Rivard, 2017). Due to the non-response bias experienced in this study, the percentage of families that experienced difficulties in scheduling a follow-up appointment may be greater than 7.3% (Cantin & Rivard, 2017). Furthermore, it was found that approximately 10% of the respondents were told to complete their follow-up appointment within a week after going home, instead of within 72 hours, and about 1.1% of the respondents were not even told about the first follow-up appointment and its importance (Cantin & Rivard, 2017). Those who were able to book a follow-up appointment expressed that they experienced many complications, including weekend delays, the inability to register their newborn with their physician until they were born, and not being able to get an appointment sooner than what was provided (Cantin & Rivard, 2017). Given that the majority of the respondents in the survey were middle to high income parents, there may also be some selection bias in the survey; thus, other lower income levels may not be well represented, and the values obtained in this survey could be lower than actually concluded.

To better understand the current state of postpartum care in Ontario, Ontario newborn follow-up data from 2012 to 2017 was processed and analyzed with the assistance of IC/ES. Further details about the data collected from IC/ES will be provided in the *Data Collection* sub-section of this thesis. From this dataset, it was found that approximately 66% of the newborns did not receive a follow-up appointment with their physician within 72 hours after hospital discharge (IC/ES, 2020). Furthermore, it appeared that the majority of the newborns, approximately 75% of them, received their follow-up appointment within 34 days after birth (IC/ES, 2020). Additionally, the mean number of days to the completion of the follow-up appointment was 29 days, while the median was 8 days (IC/ES, 2020). The values above suggest that newborns do not receive timely follow-up appointments with their physician, which could be attributed to long wait-times or due to misinformation on when families need to complete the follow-up appointment.

The data obtained from IC/ES also provided information about the mother's age at admission, number of multiple births and the mother's income quintile at birth. The summary statistics are provided for those who completed the follow-up appointment and those who did not. A statistical analysis was performed to determine any relationships between these variables and whether or not newborns completed their follow-up appointment.

The results of the statistical analysis can be found in Table 3. The first variable analyzed was the mother's age at admission. To determine whether there is evidence of a difference in the mother's age at admission between those who completed the follow-up appointment or not, a two-sample t-test was conducted. The $p - value$ associated with this test was less than 0.05.

Thus, the results suggest that there is a difference in the mean mother's age at admission between families who completed the follow-up appointment and those who did not. Looking at the data obtained, the average mother's age at admission for those who completed the follow-up appointment was 30.3 years old, while the average age of those who did not complete the follow-up appointment was 31.3 years old (IC/ES, 2020).

Table 3: Statistical Analysis

Variable	Test	P-Value	Significant/Non-Significant
Mother's Age at Admission (missing vs. non-missing appointments)	Two sample t-test	$p < 0.0001$	Significant
Income Quintile (missing vs. non-missing appointments)	Chi-Square Test of Independence	$p < 0.0001$	Significant
Multiple-Birth (missing vs. non-missing appointments)	Chi-Square Test of Independence	$p < 0.0001$	Significant

The next variable analyzed is income quintile. Based on the family's income at birth, the newborn would be counted and classified under one of five quintiles. From the data obtained, the number of newborns in each income quintile was computed. To determine whether or not there is an association between family income and whether or not the follow-up appointment was completed, a chi-square test of independence was conducted. The $p - value$ for this test was less than 0.05, suggesting there is a difference in the family's income distribution between those who completed the follow-up appointment and those who did not. Looking at the dataset, there was an increase in the proportion of newborns that missed follow-up appointments in income quintile 1, with an increase of 2.3%, and quintile 5, with an increase of 0.7% (IC/ES, 2020). To determine whether or not these increases are statistically significant, two-sample proportion tests were completed comparing newborns who missed follow-up appointments to those who did not in income quintile 1 and 5. The $p - value$ for both tests were less than 0.05, meaning there is evidence of a difference in the proportion of newborns in income quintile 1 and income quintile 5 who missed the follow-up appointment after hospital discharge compared to those who did not.

The last variable analyzed was multiple births. It counts and classifies newborns into single (i.e., one baby born at birth) and multiple births (i.e., more than one baby born at birth). Looking at the dataset obtained from IC/ES, it was found that 3.08% of all births were multiple births (IC/ES, 2020). To determine whether or not there is an association between multiple births and whether or not the follow-up appointment was completed, a chi-square test of independence was conducted. The $p - value$ for this test was less than 0.05, suggesting there is a difference in the proportion of multiple births between those who completed the follow-up appointment and those who did not.

The statistical analysis described above provides some context on what variables may or may not impact families completing the follow-up appointment after hospital discharge. For example, the findings on income quintiles suggests that families of lower socioeconomic status may be more likely to miss follow-up appointments after hospital discharge. The information gathered from this analysis can help support the improvement of postpartum care in Ontario and in turn help support the development of models like the one proposed in this thesis.

Nurse Practitioners in Ontario

To better understand the nurse practitioner role, the following section describes how the profession came to be, the benefits nurse practitioners provide, and the challenges they face. This information is valuable for understanding the role of nurse practitioners in relation to the model and clinic design proposed in this thesis.

History of Nurse Practitioners in Ontario

The role of nurse practitioners is still relatively new, not just in Ontario but all across Canada, as this health care profession has not been around for very long. In 1970, Ontario introduced a provincial education program for those who wanted to become a qualified nurse practitioner (van Soeren et al., 2009). Unfortunately, the profession did not grow because it lacked supporting legislation (van Soeren et al., 2009). Due to the lack of support for the profession and funding for the nurse practitioner program, the program was eliminated in the 1980's; however, it was revitalized in the mid 1990's (van Soeren et al., 2009).

After the mid 1990's, the nurse practitioner profession gained more support from the government through education and legislation support (van Soeren et al., 2009). In 1998, legislation was passed that allowed nurse practitioners to be certified Registered Nurses, Extended Class category, with the College of Nurses of Ontario (CNO) (van Soeren et al., 2009). This legislation increased nurse practitioner's responsibility as they could now independently communicate a diagnosis of a disease or disorder to patients, order certain diagnostic tests (ultrasounds, radiographs, or laboratory tests), and prescribe a limited range of pharmaceutical drugs (van Soeren et al., 2009). Furthermore, recent changes to the legislation have protected the "Nurse Practitioner" title and have allowed for specializations in the field, where nurse practitioners can decide to specialize in Primary Care, Adult Care, Pediatric Care or Anaesthesia (van Soeren et al., 2009). Thus, the nurse practitioner profession has come a long way from when it was first introduced; however, many challenges still remain and need to be overcome to have the profession properly integrated within the health care system.

About Nurse Practitioners

To be qualified for the nurse practitioner program in Ontario, individuals first need to complete a four-year Baccalaureate degree in Nursing and obtain at least two years of full-time clinical practice experience to become a registered nurse (RN) (Nurse Practitioners' Association of Ontario [NPAO], 2019). Upon completing the requirements to become an RN, individuals can complete a master's program to become a nurse practitioner (NPAO, 2019). The nurse practitioner program takes approximately 24 months to complete and consists of coursework and clinical practice (NPAO, 2019). Once these requirements are fulfilled, nurse practitioners must take a final exam and an Objective Structured Clinical Evaluation (OSCE) to confirm they have acquired the necessary skills and knowledge to be competent, safe and ethical nurse practitioners (NPAO, 2019). After completing all these steps, individuals become qualified nurse practitioners and are recognized as registered nurses with additional education and qualifications.

Once nurse practitioners complete their education, then they can begin practicing either at hospitals or community clinics. They can provide a variety of healthcare services in primary care, acute care, rehabilitative care, curative and supportive care, and palliative care (*Practice Standard: Nurse Practitioner*, 2019). Presently, they are authorized to diagnose, order and interpret diagnostic tests, prescribe medications and other treatments for patients (*Practice Standard: Nurse Practitioner*, 2019). Under the *Nurse Act*, the full detailed scope of practice for nurse practitioners is the following:

1. Communicate to a patient, or a patient's representative, a diagnosis;
2. Perform a procedure below the dermis of a mucous membrane;
3. Put an instrument, hand or finger:
    a. Beyond the external ear canal;
    b. Beyond the point where the nasal passages normally narrow;
    c. Beyond the larynx;
    d. Beyond the opening of the urethra;
    e. Beyond the labia majora;
    f. Beyond the anal verge; or,
    g. Into an artificial opening of the body.
4. Apply and order the application of a prescribed form of energy;
5. Set or cast a bone fracture or joint dislocation;
6. Administer a substance by injection or inhalation;
7. Prescribe, dispense, sell or compound a medication; and,
8. Treat, by means of a psychotherapy technique delivered through a therapeutic relationship, an individual's serious disorder of thought, cognition, mood, emotional regulation, perception or memory that may seriously impair the individual's judgment, insight, behaviour, communication or social functioning (*Practice Standard: Nurse Practitioner*, 2019).

The scope of practice outlined above is for nurse practitioners practicing in Ontario and there may be some variation across provinces and territories, as each one independently regulates them (NPAO, 2019). Nevertheless, the aim of nurse practitioners across Canada is to help improve the health of individuals in diverse and different communities where health care services may be harder to access (*Practice Standard: Nurse Practitioner*, 2019). Nurse practitioners focus on communicating health promotion/disease prevention, treatment of minor injuries, maintenance/monitoring of chronic diseases and palliative care (van Soeren et al., 2009).

In terms of work settings, most nurse practitioners work alongside a physician. According to a research study that surveyed 371 nurse practitioners, only 1.3% of nurse practitioners do not work with a physician (van Soeren et al., 2009). For those who work with a physician, 66% do it in a collaborative practice in a shared facility, while 23% do it in a separate facility (van Soeren et al., 2009). It is possible that only a low percentage of nurse practitioners work independently from a physician because of the many limitations they face in their role.

Within Ontario, the majority (approximately 82%) of nurse practitioners are compensated by the Ministry of Health and Long-Term Care (van Soeren et al., 2009). However, the amount that nurse practitioners are paid as well as their pension and benefits can widely vary across geographical locations and work settings (i.e., hospital vs. community, unionized vs. non-unionized). Based on a survey conducted by the Canadian Federation of Nurses Unions (CFNU) in 2018, it was found that the average annual income of a full-time nurse practitioner in Ontario was $103,822 per year while the average annual income of a part-time nurse practitioner was $60,000 (Little, 2018). It is worth noting that these figures may be different in other provinces and territories. Furthermore, it was found that nurse practitioners across Canada working in a community-health setting made an average annual income of $103,000, while those working in a hospital setting made an average annual income of $107,000 (Little, 2018).

The drawback of varying remuneration levels for nurse practitioners is that it discourages them from working in certain settings, as they would prefer to attain positions in more favourable ones. The salary differences and benefit gaps for nurse practitioner positions has created competition between different health care settings, particularly between acute and primary care (Little, 2018). Furthermore, nurse practitioners experience some dissatisfaction with their current remuneration levels, which has an impact on their overall job satisfaction and retention. To help improve this, proper remuneration needs to be provided as it is one of the most important factors for nurse practitioners in terms of job satisfaction (Little, 2018).

Benefits of Nurse Practitioners

The nurse practitioner profession is still relatively new and is still growing; however, it can add a tremendous amount of value to the health care system. For one, nurse practitioners can help fill the gap in underserved areas with limited access to health care services. Based on a study conducted by van Soeren that surveyed 371 nurse practitioners, it was found that 57% of them worked in underserved areas and were geographically dispersed across Ontario (van Soeren et al., 2009). The respondents of the survey reported that they worked with marginalized populations that included low-income earners, unemployed persons, substance abusers and mentally ill patients (van Soeren et al., 2009). Furthermore, cultural minorities and recent immigrants were also reported as common populations that nurse practitioners serve (van Soeren et al., 2009).

To further support nurse practitioners working in underserved areas, a study conducted in 2013 surveyed 817 nurse practitioner patients in rural communities and found that each of these patients were previously unattached to a health care provider (Hunter et al., 2016). From this study, it was found that nurse practitioners improved access to primary care services in rural and urban areas (Hunter et al., 2016). Increasing access to primary care services can help improve the overall health of the population as it addresses mental health and chronic disease management service gaps (Hunter et al., 2016). However, in terms of recruitment, it was found that nurse practitioners who have a connection with the community are most likely to serve these underserved areas (Hunter et al., 2016). Regardless of their geographical location, patients report high levels of satisfaction with nurse practitioners because they have greater access to health services and find nurse practitioners provide quality care through effective counselling (Little, 2018).

Since nurse practitioners achieve high levels of patient satisfaction and provide quality care, they could be considered as substitutes for physicians in certain circumstances. According to a systematic literature review, nurse practitioners provide care that is equal to or of better quality than that provided by a family physician and probably achieve equal or better health outcomes for patients (Randall et al., 2017). Furthermore, in comparison to family physicians, it was also found that nurse practitioners probably achieve slightly higher levels of patient satisfaction (Laurant et al., 2018). These results are probably due to the fact that nurse practitioners provide more health advice to patients, which can result in better health outcomes (Laurant et al., 2018). Overall, nurse practitioners could not entirely replace family physicians; however, they could be utilized in certain circumstances where family physicians have limited availability.

Challenges Faced by Nurse Practitioners

Though there are many benefits to nurse practitioners, there are also a number of challenges they face in their role. These can include barriers in their everyday practice, a lack of understanding of their role in the health care system and a lack of funding from the government. These challenges can create disadvantages to the profession because they can impact job satisfaction and retention. Identifying these challenges can help gain an understanding on how they can be overcome or minimized when creating health care models involving nurse practitioners.

One frustration frequently expressed by nurse practitioners is the everyday limitations that they face in their practice, which impact their capability as health care providers. For one, a commonly frustrating limitation that nurse practitioners experience is the limited drug and laboratory list that they can prescribe from (van Soeren et al., 2009). Nurse practitioners are regulated by the government on the types of drugs and laboratory tests that they can prescribe, but this list can be rather limiting because they cannot utilize many common diagnostic tests or treatments (van Soeren et al., 2009). Furthermore, nurse practitioners may require a physician's signature for certain referrals, limiting their autonomy (van Soeren et al., 2009). To overcome these limitations, nurse practitioners refer their patients to other health care providers, who can prescribe them the appropriate test or drug.

Another challenge that nurse practitioners experience is the lack of understanding about the nurse practitioner role within the health care sector. The nurse practitioner profession is still relatively new and so can pose challenges for public understanding and acceptance of its role (van Soeren et al., 2009). Currently, there is a lack of understanding on what nurse practitioners do and their full scope of practice, which hampers their integration within the health care system (van Soeren et al., 2009). This issue primarily concerns other health care providers, as they have a limited understanding of what nurse practitioners are capable of (Little, 2018). This results in nurse practitioners not realizing their fullest potential. According to a nurse practitioner survey, it was found that 26% of nurse practitioners do not work within their full scope of practice (Little, 2018).

Another frustration that nurse practitioners experience is the lack of funding they receive from the government in relation to their salary and work operations. Nurse practitioner wages did not increase for almost 10 years prior to a recent increase in 2016 (NPAO, n.d.). Though, even with current remuneration levels, nurse practitioners continue to be dissatisfied because their scope of practice continues to increase (Little, 2018). This translates into, on average, an additional 3-4 hours of unpaid overtime a week (Little, 2018). These frustrations are further fueled by the lack of equality compared to other health professionals in terms of remuneration levels for comparable work (van Soeren et al., 2009). For example, physicians receive financial incentives for work that is done or could be done by a nurse practitioner, such as immunizations and well-baby reviews (van Soeren et al., 2009). Finally, nurse practitioners receive minimal administrative and operational funding and often have concerns over job security as many positions are not funded as permanent positions (van Soeren et al., 2009).

A potential solution to these challenges is to implement policy changes that emphasize team-based primary health care or to simply increase funding for nurse practitioners (Little, 2018). At the moment, nurse practitioners are still funded by the LHINs. LHINs manage a local budget and determine the number of funded nurse practitioners in different areas (Little, 2018). Making policy changes would entail changing the way in which health care providers are currently funded, in order to create a financial environment that supports more collaborative care (Little, 2018). This change may occur as part of the expected implementation of Ontario Health Teams, as they are meant to encourage more collaborative care; however, this information is currently not known. An alternative solution would be to increase the funding provided to the LHINs for nurse practitioners. With increased funding, LHINs could hire more nurse practitioners in the community (Little, 2018). This, unfortunately, also poses challenges as LHINs are disincentivized to hire nurse practitioners because, unlike physicians, their salaries come directly from their budget (Little, 2018).

The challenges that nurse practitioners face are not unique to Ontario and are experienced all around the world. According to a recent study conducted by the Organization of Economic Cooperation and Development (OECD), nurse practitioners in most countries around the world face similar barriers that include opposition from certain stakeholders, government legislative barriers and financing and reimbursement issues (Little, 2018). These challenges can hopefully be overcome through changes made by local governments. The nurse practitioner profession is still relatively new, but it is slowly growing as more nurse practitioner-led models are being implemented.

Nurse Practitioner-Led Clinics in Ontario

With a better understanding of the role and importance of nurse practitioners, the next important aspect for designing a postpartum clinic is to understand how nurse practitioner-led clinics are created in Ontario. That is, to better understand the application process involved in having a nurse practitioner clinic and, if approved, the process followed to open it. Understanding this process is important for this thesis because it illustrates what is required to open a nurse practitioner-led clinic. Furthermore, outlining this process also provides insight on the steps required to implement such a clinic in a community, if it were ever to be implemented in the future.

Nurse practitioner clinics are a primary care model that have nurse practitioners as the lead care providers (Ministry of Health and Long-Term Care, 2010a). These clinics function by working collaboratively with multiple care providers (i.e., registered nurses, registered practical nurses, collaborating family physicians and/or other health care providers) that work together to provide comprehensive, accessible, and coordinated care to people that do not have access to or have difficulty accessing primary care services (Ministry of Health and Long-Term Care, 2010a). The creation of nurse practitioner-led clinics in Ontario is a multi-step process that can take several months to complete and each clinic must be approved by the Ministry of Health and Long-Term Care (Ministry of Health and Long-Term Care, 2010a).

The first step in forming a nurse practitioner-led clinic in Ontario is to complete the application form provided by the Ministry of Health and Long-Term Care. The application contains numerous sections that entail the applicants to provide information about themselves, about the community where the clinic would be located, about the clinic, about the patients and programs offered by the clinic, about community partnerships, and about the requirements to operate the clinic (Ministry of Health and Long-Term Care, 2010a). Once submitted, the application is evaluated based on the following five criteria:

1. **The demand for primary care services in the proposed community**: this criterion evaluates the need for the clinic in the proposed community by reviewing the health needs of the population in that community. Furthermore, it evaluates existing primary care services available in the area to help determine the need for the clinic;
2. **Commitment of providers for the proposed nurse practitioner-led clinic**: this criterion evaluates the planned number of providers involved in the clinic (i.e. registered nurses, nurse practitioners, collaborating physicians and/or other health care providers) and their role;
3. **Meeting the health needs in the proposed community**: this criterion evaluates how the proposed clinic would meet the health needs of the population it intends to serve by outlining the services they will offer;
4. **Community partnerships**: this criterion evaluates the level of collaboration with other community partners, such as their role with the clinic and how they will support the clinic; and,
5. **Operations of the clinic**: this criterion evaluates the length of time required to open the clinic, the amount of space required and the resources (i.e., human resources and materials/equipment) needed to operate the clinic (Ministry of Health and Long-Term Care, 2010a).

To complete the application, which also requires a number of documents to be submitted along with it, can take approximately 3 months (Ministry of Health and Long-Term Care, 2010a). Once submitted, applications are reviewed by a panel that includes government representatives from Primary Health Care, Financial Management, Nursing, Information Technology, and Provincial Programs (Ministry of Health and Long-Term Care, 2010a). If the application is selected, then the applicant is given a letter of confirmation and the applicants can continue planning the nurse practitioner-led clinic (Ministry of Health and Long-Term Care, 2010a). However, they are not automatically approved for funding and will need to complete other forms (Ministry of Health and Long-Term Care, 2010a). Once approved, it can take 12 months to have the clinic fully operational, if everything is in order (Ministry of Health and Long-Term Care, 2010a). The required steps to open a clinic can be found in the *Nurse Practitioner-Led Clinic Implementation Roadmap*, which is shown in Appendix A (Ministry of Health and Long-Term Care, 2010a).

After the application has been approved, the next step is to attend a meeting with the ministry to discuss the process of opening the clinic (Ministry of Health and Long-Term Care, 2010b). This meeting is a teleconference meeting that typically occurs within 1 to 2 weeks from the time the application has been approved (Ministry of Health and Long-Term Care, 2010b). During this meeting, next steps are discussed along with the timeline for steps to be completed. Furthermore, preliminary funding guidelines are discussed, which can help fund these next steps (Ministry of Health and Long-Term Care, 2010b).

Once the initial meeting is completed, there are a number of tasks that need to be done prior to beginning the process of opening the clinic, which can be quite costly. Due to this, the ministry provides preliminary funding of up to $10,000 to help applicants with start-up costs (Ministry of Health and Long-Term Care, 2010b). The aim of this funding is to help expedite the process of opening the clinic and to have it fully operational within 12 months (Ministry of Health and Long-Term Care, 2010b).

A second meeting with the Ministry takes place within 1-2 months from the initial meeting as a progress report update (Ministry of Health and Long-Term Care, 2010b). By this meeting, the tasks that are typically completed include: identifying barriers to opening the clinic, retaining legal services, beginning to create the governance structure, arranging visits for potential locations for the clinic, further developing the service offering of the clinic, identifying what is required to deliver these services and the proposed funding for opening the clinic (Ministry of Health and Long-Term Care, 2010b).

As planning progresses, applicants must complete the *Business and Operational Plan*, which outlines the services and programs expected to be offered by the clinic and the detailed funding for operating the clinic for a fiscal year (Ministry of Health and Long-Term Care, 2010b). In this plan, the following should be included: a full description of the programs and services offered by the clinic, a list of providers, job descriptions, and recruitment plans required for these programs and services, space planning requirements, site location and necessary renovations, information technology needs, and a realistic timeline of when the clinic will be fully operational (Ministry of Health and Long-Term Care, 2010b). Completing this step in the planning process is done with the assistance of the ministry and typically takes 2-3 months (Ministry of Health and Long-Term Care, 2010b).

After the approval of the *Business and Operational Plan*, the pre-operational steps can begin (Ministry of Health and Long-Term Care, 2010b). This entails finalizing the governance structure of the clinic and beginning preparations for renovating the selected location (Ministry of Health and Long-Term Care, 2010b). For developing the governance structure, a guide is provided but legal and financial advice is typically required to finalize it (Ministry of Health and Long-Term Care, 2010b). Establishing the governance structure is essential because it outlines how the clinic will be managed and supervised (Ministry of Health and Long-Term Care, 2010b). This entire pre-operational stage can take approximately 3-6 months to complete.

The final stage in opening a clinic is the operational stage, which entails finalizing the operational components of the clinic and can take anywhere between 6 to 12 months to complete

(Ministry of Health and Long-Term Care, 2010b). Prior to becoming fully operational, applicants can apply for operational funding from the ministry. To do so, they must provide a detailed plan regarding existing and proposed staff, timelines for implementing said staff, outlining financial contributions from partners and estimating the funds needed for one fiscal year (Ministry of Health and Long-Term Care, 2010b). Once everything is agreed upon and approved, a final business agreement known as the *Nurse Practitioner-Led Clinic Operational Agreement* is signed between the Nurse Practitioner-Led Clinic and the ministry. Upon completion of this final step, the nurse practitioner-led clinic is fully operational.

The process of opening a nurse practitioner-led clinic in Ontario is quite rigorous and lengthy; however, it is meant to ensure that the clinic is properly established and provides adequate care to the community. The various steps taken for opening a nurse practitioner-led clinic can differ for other provinces/territories, as they are independently regulated by each regional authority. Once fully operational, the nurse practitioner-led clinic can add great value to the community, as they can increase access to primary care services.

Literature Review

To carry out a literature review on postpartum nurse-led clinics, a number of databases were explored: The University of Ottawa Library Database, Google Scholar, PubMed and the Nursing & Allied Health Database. Furthermore, the "Search for Similar Articles" tool available in PubMed was utilized to obtain additional relevant articles. Within these databases, the main keywords used to review the literature on postpartum nurse practitioner-led clinics included the following: model, design, nurse-led clinics, early discharge, community-based health clinics, and maternal and newborn follow-up. A detailed description of the search strategy can be found in Appendix B.

The objective of this literature review was to obtain information about postpartum nurse practitioner-led clinics, specifically about how they operate and how they are designed. Unfortunately, this search strategy was not able to identify any published articles related to postpartum nurse practitioner-led clinics. More specifically, none of the articles found discussed/analyzed the different factors to consider when designing a nurse practitioner-led clinic (i.e., services to provide, demand for services, nurse availability, geographical access, appointment scheduling, etc.) or the service delivery process for follow-up appointments after hospital discharge. This area may not be popular and therefore limited research has been done on the topic, or there may not be any postpartum nurse practitioner-led clinics in existence. This finding is insightful because it could suggest that the model proposed in this thesis is unique and potentially not previously studied.

Without any published articles on postpartum nurse practitioner-led clinics, other topics were researched to gain an understanding about nurse practitioner-led clinics and postpartum care. In relation to nurse practitioner-led clinics, topics selected included the history, leadership, performance evaluation and patient satisfaction for these types of clinics. In relation to understanding the service delivery, articles about postpartum care, trends in postnatal length of stay, and the characteristics of patients who completed follow-up appointments after hospital discharge were selected. From the literature review, only 1 article considered a postpartum clinic. A detailed description of the different article categories can be found in Appendix C.

For this literature review, a total of 22 articles were chosen. During the review, articles were filtered based on date (published in the last 20 years) and the type of review process. The articles selected originated from various countries, with the largest proportion originating from Canada. A full breakdown of the origin of the selected studies can be found in Appendices D & E. The 22 articles chosen were selected because they either evaluated the operations of a nurse practitioner-led clinic of any type, examined nurse practitioners providing postpartum care in different capacities (i.e., home visits, community clinic, etc.) or evaluated the impact of shortened postnatal lengths of stay in relation to postpartum care after hospital discharge (i.e., newborn health, readmission rates, etc.). With very limited research available on postpartum care in nurse practitioner-led clinics, articles providing any insight about the operations of nurse practitioner-led clinics, especially within Canada, the performance of these clinics or on the follow-up process after hospital discharge (i.e., the services provided, the timing of these services) were selected for review.

As mentioned above, only one article evaluates a postpartum clinic. The article assesses the performance of a physician-led postpartum clinic in Ontario (Hardy et al., 2018). This study outlines the benefits of the clinic, which largely centers on shortening hospital postnatal lengths of stay (Hardy et al., 2018). It was found that eighteen months after the implementation of the clinic the average length of stay for a caesarean birth decreased by 20 hours and the average length of stay for vaginal births decreased by 6 hours (Hardy et al., 2018). This study concluded that there is a strong association between the implementation of a community-based postpartum clinic and the reduction in hospital postnatal lengths of stay (Hardy et al., 2018). Unfortunately, the study does not provide any insight on the structure of the clinic nor about what is required to operate it. Though, the study does illustrate that a postpartum clinic can contribute to shortening postnatal lengths of stay in hospitals by providing the necessary postpartum care services in the community.

Articles relating to the operations of nurse practitioner-led clinics outline potential challenges that could arise and other factors to consider when designing a nurse practitioner-led clinic. The challenges stated in multiple articles relate to the recruitment and retention of nurse practitioners. For instance, one study found that nurse practitioner recruitment and retention in primary health centres was quite challenging due to the competitive salaries offered by other organizations (Heale, James & Garceau, 2016). Due to high turnover, this resulted in high nurse practitioner burnout as the remaining nurses had to take on more patients (Heale et al., 2016). Another challenge faced by nurse-led clinics is that the clinics are often situated in rural areas that are far away from major centers (Heale et al., 2016). This poses many challenges for these nurses, who are not compensated with additional incentives (Heale et al., 2016). To help combat these challenges, the Government of Ontario in 2016 committed $85 million to help with the recruitment and retention in nurse-led clinics (Heale et al., 2016).

Other studies that evaluate the performance of nurse practitioner-led clinics in various care settings reveal a number of benefits relating to the care provided by these clinics. One study evaluates maternal and neonatal health outcomes after implementing a nurse practitioner-led model for diabetes in pregnancy (Murfet et al., 2014). The model decreased negative health outcomes in newborns with the information and support provided, something found to be particularly beneficial in rural areas (Murfet et al., 2014). Two other studies examine the benefits of nurse practitioner-led models and conclude their positive impact on health outcomes, patient satisfaction and access to care (Shiu et al., 2012). The positive impact could be the result of the delivery of patient centered care and being strongly connected with community services (Shiu et al., 2012). Furthermore, one study identified a reduction in emergency room costs in rural areas because of the increased access to care offered by these clinics (Sofer, 2018).

Studies that examine postnatal lengths of stay primarily focus on the impact of early discharge. One article studies the readmission rates of newborns that were discharged early (within 48 hours after birth) and completed the follow-up appointment within 3 days after hospital discharge (Gupta et al., 2006). For those who were readmitted, which was 8.3% of newborns, it was due to neonatal jaundice, dehydration, and feeding difficulties (Gupta et al., 2006). Another study analyzed the financial impact of shortened postnatal lengths of stay as a way for hospitals to decrease costs. The study concluded that cost savings could be realized if the same quality and access to services were maintained and could be achieved with the implementation of community based postpartum care clinics (Bowers & Cheyne, 2015). Furthermore, the study did identify that cost savings would not be realized by cutting staffing costs (Bowers & Cheyne, 2015). Thus, based on these studies, it could be inferred that shortened postnatal lengths of stay are acceptable but with the appropriate models in place to accommodate for it.

Other articles assessing shortened postnatal lengths of stay discuss the positive benefits family's experience. One study interviewed 22 women about their hospital experience after birth (Beake et al., 2005). The results discovered that most women wanted to leave the hospital and return home quickly because they felt more relaxed and in control at home (Beake et al., 2005). Interestingly, the women interviewed stated that they expected their time at the hospital to be a time of rest and support; however, they found it was not that (Beake et al., 2005). Another study evaluates the experience families had with early discharge and having a follow-up appointment shortly after (Chen et al., 2018). The study discovered that families had a positive experience and enjoyed the care model, especially first-time parents, as they felt more secure and confident in themselves with the support provided (Chen et al., 2018).

Finally, articles relating to follow-up appointments study the timing and frequency of these appointments after hospital discharge. A study conducted in California analyzed the number of newborns discharged early (less than one night for vaginal births and less than three nights for caesarean births) who did not receive a timely follow-up appointment within 2 days after discharge (Galbraith et al., 2003). Of the newborns considered in this study, the authors found that 49.4% of them were discharged early, and of these, 67.5% received untimely follow-up appointments (after 2 days from hospital discharge) (Galbraith et al., 2003). Additionally, they identified that newborns of low income households were more likely to be discharged early and not receive a timely follow-up; however, this could differ in Canada as this study was conducted in the United States (Galbraith et al., 2003). Furthermore, another study considered newborns discharged early from a hospital in South Africa and the number who completed the follow-up within 1 week after discharge (Milambo et al., 2018). Out of 972 newborns, 794 completed the follow-up within 1 week after discharge (Milambo et al., 2018). Those who did not have their follow-up appointment within a week was due to maternal illness, lack of money for transportation, or the mother thought that the follow-up appointment was not necessary because the newborn was healthy (Milambo et al., 2018).

This literature review provided us with valuable information about nurse practitioner-led clinics and postpartum care; however, it did not provide us with information about the design of postpartum nurse-led clinics as there is limited literature available on this topic. Thus, this thesis could provide more insight on the design of postpartum nurse practitioner-led clinics as it illustrates how this new delivery model of postpartum care services could work. The research presented in this thesis can assist researchers and policy makers in the field; therefore, the findings from this thesis could contribute to the existing literature in the area and practice in the field.

Stakeholder Engagement

With limited literature available on the operations and service delivery of a postpartum nurse practitioner-led clinic, especially within Ontario, discussions were held with stakeholders at a postpartum clinic, a nurse practitioner-led clinic and a hospital. The objective of these discussions was to better understand each stakeholder's field of work, which could help in the design of the model proposed in this thesis. The information gathered was very valuable, as it provided insight about the delivery of postpartum care and the operations of nurse practitioner-led clinics in Ontario.

Observational Visit at a Postpartum Clinic

For this thesis, an opportunity was provided to visit a local maternal-newborn follow-up clinic for a day to observe its operations and gain insight about the delivery of newborn care. The follow-up clinic operates two locations; however, only one location was visited for this observational visit. During the visit, primarily the office administrator was shadowed as she largely deals with the operations of the clinic; however, numerous staff members were interviewed to gain an understanding about the clinic and the services it provides. The primary roles of the office administrator included: coordinating families (i.e., registering families with the clinic, scheduling their appointments, directing families to their appointments and discharging them from the clinic), coordinating staff for their scheduled appointments and completing a number of administrative duties (i.e., ordering medical supplies, organizing paperwork, requesting lab results, etc.).

About the Maternal-Newborn Follow-up Clinic

The follow-up clinic is an innovative multi-disciplinary maternal and newborn health clinic that provides care to mothers and their newborns within 48 hours after hospital discharge. It was created in response to shorter hospital lengths of stay after birth, with vaginal deliveries typically being one night in the hospital and caesarean sections typically being two nights in the hospital. The clinic helps families with their transition from the hospital to at home by providing a wide array of services through their extensive team of health care providers. On a typical day, the clinic staffs one office administrator, one family physician with a specialization in maternal and newborn care, and two registered nurses who are International Board-Certified Lactation Consultants (full-time and/or part-time). Once the health care providers at the clinic believe a family is doing well and no longer need services from them, the family is discharged from the clinic and transitioned to their primary health care provider.

Referral Process

To gain access to the services provided by the follow-up clinic, families are referred from the local hospital. Any family can be referred to the clinic, however, those who cannot obtain a follow-up appointment within 48 hours after hospital discharge are most commonly referred. Furthermore, even those families who complete the follow-up appointment elsewhere may be referred to the clinic. For example, this can occur for families who have a physician that cannot complete bilirubin samples, jaundice assessments, and breastfeeding support themselves. Additionally, some families with a midwife might be referred to the clinic for episodic care (i.e., to provide the family with additional breastfeeding support, provide support for complex case management or whenever the newborn requires a bilirubin sample).

Appointment Scheduling

The follow-up clinic is open 6 days a week from Monday to Saturday from 8:00 am to 4:00 pm and is closed during statutory holidays. Scheduled appointments begin at 8:00 am and finish by 4:00 pm. Staff work within these scheduled hours, except for Mondays when additional administrative tasks are scheduled, and staff work until 5:00 pm. The clinic maintains consistent hours, even though they are faced with the unique challenge of scheduling last minute appointments as families must receive services within a specific timeframe. To accommodate these appointments, the clinic schedules additional staff to manage the extra workload and avoid overtime costs.

For families that are discharged from the hospital between 8:00 am and 4:00 pm, their follow-up appointment is scheduled by the hospital upon discharge. As the family is being discharged, the nurse at the hospital will phone the clinic to arrange an appointment for the family. For families that are discharged outside these hours, a referral form is faxed to the clinic and the clinic must contact the family to arrange an appointment time.

For scheduling appointments, the clinic uses a scheduling software that keeps track of the appointment slots allocated to families that visit the clinic each day. If the family is new to the clinic, then a patient chart is created in order to keep track of the services provided to the family. Prior to the mother and newborn's first appointment, the clinic must complete their patient chart by obtaining their medical information from a separate software known as Epic, which is an Electronic Medical Record (EMR) software used by the local hospital. Epic is used to keep track of the health status and medical services provided to the mother and her newborn throughout the duration of their hospital stay. From this software the newborn's weight, time of birth, delivery type, blood type, labour record, delivery record and discharge summary are obtained to complete the patient chart. This information is reviewed by the nurse and the physician at the clinic, so that they are informed of any complications and/or concerns that occurred during pregnancy and delivery.

To obtain information from Epic, a patient ID number is used to find the patient's record within the software. The patient ID number is a Medical Record Number (MRN), which is assigned to the mother upon her first admission to the hospital. Typically, the clinic receives the patient ID number on the referral form provided by the local hospital. With the patient ID number available, the patient chart can be created in approximately 15 minutes. Unfortunately, the patient ID number is not always provided. In this situation, the office administrator must search for the mother's information by her name within Epic. This can be a long and tedious task as there could be multiple patients with the same name. Without the patient ID number available, an additional 10 to 15 minutes is needed to create the patient chart. Typically, patient charts are created the day before the family is scheduled to visit the clinic.

Appointments are usually scheduled the day before; however, they could be scheduled 2 to 3 days in advance if required. The clinic manages a short-term appointment schedule because families must receive health services within a specific timeframe. At times, some appointments are scheduled one week in advance if the family needs to return to have their newborn's health status examined. Occasionally, pre-scheduled appointments may be cancelled if the newborn's symptoms improve. For instance, this can occur for bilirubin sample appointments. If a newborn's bilirubin levels improve, and they no longer need monitoring, pre-scheduled appointments are cancelled. Overall, appointment cancellations rarely occur, and if there is a cancellation, it is typically done by the clinic because the family is no longer required to return.

Families are asked to arrive at the clinic 15 minutes before their scheduled appointment in order to complete the check-in process. This time is allocated to provide any required documentation (e.g., OHIP card) to the office administrator and complete any necessary forms. If a family is 15 minutes late to their appointment, a member from the clinic will phone the family to provide them with a reminder about their appointment and will ask about their estimated time of arrival. During the visit, it was observed that the office administrator had to phone one family, as they were running late for their appointment; however, the family's appointment was only arranged a few hours prior. Once a family arrives to the clinic, they are allocated 30 minutes for their appointment no matter the appointment type (i.e., well-baby care visit, breastfeeding support, a bilirubin sample or any other type of service offered by the clinic).

The number of appointments scheduled on a given day can vary but the busiest days are Mondays because the clinic is closed on Sundays. Due to this, the clinic leaves one hour unscheduled on Mondays because they often receive last minute appointment requests. Overall, the clinic is consistently busy, but it is unusually busy before and after holidays as they are closed on statutory holidays. During busy days, the clinic will double book every second appointment until 12:30 pm because part-time nurses finish their workday at 1:30 pm. On average, the clinic will see between 15 to 20 dyads in a day at their primary location, as they have more capacity. The largest number of mother-baby dyads booked in one day is 24.

Appointment Types

The clinic offers a wide array of services to help support mothers and newborns. Typically, families will complete a well-baby care visit during their first appointment with the clinic;

however, this can vary because families may be referred to receive other services. Specific details of the services provided at the well-baby care visit are outlined further in the *Appointment Process* sub-section, but in general, a physical examination is conducted on the mother and the newborn, a bilirubin sample is taken (if required) from the newborn, and breastfeeding and mental health support is provided to the mother. If clinically indicated, some newborns may receive a tongue-tie release procedure at their well-baby care visit. After the initial visit, families may return to the clinic for similar services, such as another well-baby care visit, a bilirubin sample, a breastfeeding support appointment and/or for a tongue-tie release procedure/follow-up. Whether a family returns for any of these appointments is based on their specific needs. Finally, the clinic also offers vaccination visits for pregnant mothers. The scheduling of each of these services is described in more detail below based on appointment type.

Well-Baby Care Visits

The main service provided by the clinic are well-baby care visits, as their objective is to help families transition from the hospital to the community. The clinic will schedule well-baby care visits as soon as possible but no later than 48 hours after hospital discharge. It commonly occurs that the clinic will provide follow-up appointments to families in less than 24 hours after hospital discharge. The clinic ensures that families can receive timely follow-up appointments according to recommended postnatal standards.

The number of times a family visits the clinic can vary based on their specific needs. If a family does not have a primary health care provider, then they may visit the clinic 2 to 3 times; however, the number of visits could be higher if the family requires more support. Furthermore, subsequent appointments may be scheduled within 1 to 7 days from the previous visit. For instance, if a newborn is not gaining weight as expected based on his/her age, the family will be scheduled to return to the clinic within 1 or 2 days from their previous visit. However, for families that have a primary health care provider, they may visit the clinic less. For example, the family may complete their initial visit with the clinic but will complete subsequent visits with their primary health care provider. Once again, this varies as families that have a primary health care provider may choose to continue receiving services with the clinic. Thus, the number of times a family visits the clinic can vary based on their situation but, overall, most families will have multiple visits.

Bilirubin Sample Visits

Some families may visit the clinic for a bilirubin sample appointment. The clinic will schedule these appointments in the morning, with the last bilirubin sample scheduled at 12:30 pm. The purpose of this is to ensure that sample results are received by the end of the day from the lab. If samples are ready in the morning, the clinic will order a 2-hour courier, so they can be delivered to the lab within 2 hours; however, if samples are ready in the afternoon, they will order a 1-hour courier. Once delivered to the hospital, it takes approximately 1 hour to receive the lab results; however, this can vary based on how busy the hospital is. Once the lab results are in, the office administrator will review the results in Epic; however, if it is urgent, they will receive a phone call from the lab. The office administrator will then document the results on each patient's bilirubin risk factor chart. Once this is done, she will provide the charts to the nurse and physician who will then decide which patients need to return (if any).

How to assess the bilirubin levels in a newborn is dictated by the clinic's internal bilirubin guide, which is informed by the Ministry of Health and Long-Term Care's bilirubin guide the *Clinic Pathway Handbook for Hyperbilirubinemia in Term and Late Pre-Term Infants (>=35 weeks).* If a newborn is exhibiting signs of jaundice, this step-by-step guide informs the health care provider on how to monitor a newborn's bilirubin levels. The first step in the guide helps healthcare providers determine how a newborn's bilirubin levels will be measured. If a newborn is less than two weeks old and did not previously complete phototherapy, then he/she will have his/her bilirubin levels measured with a bilimeter. A bilimeter is pressed on the newborn's sternum five times to take the average bilirubin measure. The measurement is used to assess whether or not the newborn requires a bilirubin blood sample, which is collected by pricking the newborn's heel. A bilirubin blood sample is taken if the newborn's bilimeter reading is at or within 50umol of the newborn's treatment line curve, which is plotted on the graph found in Appendix F. If the newborn is less than two weeks old but has previously completed phototherapy or is older than two weeks old, then she/he will have a bilirubin sample taken.

If a bilirubin sample is taken, then the results will determine whether or not the newborn requires phototherapy treatment. The newborn's bilirubin sample result is plotted on the graph illustrated in Appendix F. This graph contains three different risk curves and the one used to measure a newborn's bilirubin results is based on a number of different risk factors. These risk factors include:

- Gestational age 35 to 37 + 5 weeks
- Isoimmune hemolytic disease or other known hemolytic disease (G6PD deficiency, spherocytosis, DAT positive and/or any positive antibodies)
- Current and significant lethargy, asphyxia
- Unsolved temperature instability (requiring current and active treatment)
- Sepsis currently being treated, ongoing acidosis (not just low cord pH)
- Albumin < 30g/L (if measured)

These various risk factors will determine which treatment curve will be utilized on the graph, which will be used to evaluate the newborn's bilirubin results. If the newborn's bilirubin levels are above the treatment line curve, then the newborn will be referred to a pediatrician for readmission and for phototherapy. If the newborn's bilirubin levels are not above the treatment line curve, then the newborn does not require phototherapy but will need to be monitored. For these cases, the health care provider at the clinic needs to determine the newborn's follow-up plan.

The follow-up plan is determined based on the risk zones from the Hour Specific Nomogram graph and the Follow-Up Algorithm chart, which can be found in Appendices G & H. The first step is to determine which risk zone the newborn falls under in the Hour Specific Nomogram graph. This is determined by plotting the newborn's bilirubin levels on the graph. After this, the next step is to use a number of different risk factors to decide which Category (A, B or C) on the

Follow-Up Algorithm needs to be used to determine the newborn's follow-up plan. The risk factors used are the following:

- Gestational Age 35 to 37 + 5 weeks (newborn's gestational age is an independent risk factor for follow-up as per algorithm)
- Isoimmune/Hemolytic Disease/DAT positive
- Sibling with Jaundice Requiring Phototherapy
- Cephalohematoma/Bruising
- Ethnic Background – East Asian or Black race
- Weight loss > 10%

The evaluation of these different risk factors will determine whether the newborn must follow a plan in category A, B or C in the Follow-Up Algorithm chart. Based on the specific category and risk zone identified in the Hour Specific Nomogram, the algorithm determines when the newborn needs to return for a follow-up. The time to the follow-up can vary between a few hours to a few days and it is defined on a case-by-case basis. Furthermore, some newborns may only require one bilirubin sample while others may require several. For every bilirubin sample, the clinic follows the same steps outlined in their internal bilirubin guide.

At the end of the day, the clinic will contact every family to inform them of the newborn's bilirubin results. Based on the results, they will either be re-admitted to the hospital for phototherapy, have a follow-up with the clinic in 1 to 3 days for a repeat sample, or be discharged from the clinic. If a family requires a bilirubin sample when the clinic is closed, they are referred to the local hospital to complete the bilirubin sample. If a referral is received from a midwife, the clinic will only accept it if the midwife has privileges at the local hospital as samples are tested at the hospital's lab.

Once all the bilirubin sample appointments have been scheduled, then any other type of appointment can be scheduled throughout the day. The only appointment slot that is reserved each day is a late-morning slot in order to accommodate for any overnight referrals or last-minute appointment requests. If this slot remains unscheduled, then at that time the clinic will try to reschedule the last family of the day. According to the clinic, most families agree to the appointment change.

Breastfeeding Support Visits

Breastfeeding support is provided at the well-baby care visit, but if mothers continue to have difficulties, then they will be scheduled to return as needed. Breastfeeding appointments are allocated 30 minutes but if mothers require more time, then they will be asked to return the following day. According to some studies, short and frequent appointments are more effective than long visits because mothers can better retain the information provided to them. During the clinic visit, it was observed that one mother stayed approximately one and a half hours for her breastfeeding appointment; however, this could have been an unusual circumstance because the clinic had some extra capacity available that day. Typically, most families are transitioned to a primary health care provider when the newborn is 2 to 3 weeks old; however, the clinic will provide support as long as needed, as they have a family physician that is a lactation specialist.

Tongue-Tie Release Procedure

Some families may return to the clinic for a tongue-tie release procedure, which consists of cutting the newborn's band of tissue below the tongue (frenulum) to increase the tongue's range of motion (*Tongue-Tie (Ankyloglossia) - Symptoms and Causes*, 2018). The purpose of completing this procedure is to help with breastfeeding, as it helps the newborn latch (*Tongue-Tie (Ankyloglossia) - Symptoms and Causes*, 2018). In this case, it is up to the physician and the nurse to determine when the family should be scheduled to visit the clinic to complete the procedure. After completing the procedure, newborns that are appropriately gaining weight will return for a follow-up within 2-3 days; however, slow weight gaining newborns may be scheduled earlier. During the clinic visit, it was observed that one family came in for a tongue-tie release appointment and stayed at the clinic for approximately 30-50 minutes.

Vaccination Visits

Finally, the clinic also provides vaccinations (flu and TDaP) to pregnant women. These are typically drop in's and do not require a scheduled appointment because they are quickly administered. For TDaP vaccinations, women require a referral from their primary health care provider, while for regular flu vaccinations they do not. The mother only visits the clinic for the singular appointment and does not need to return.

Appointment Process

Upon Arrival

Upon arrival, the office administrator will review the patient's information to ensure that everything is correct and will enter any missing information into the system. Thereafter, the office administrator directs the family to an examination room. The family is then instructed to undress their newborn and have him/her wear a clean diaper for the weight measurement. Altogether, this entire process only takes a few minutes.

During the Appointment

Once the family is ready, they will proceed with having their newborn weighed. The newborn is weighed on a scale without a diaper on because it is additional weight. After being weighed, the newborn is assessed for jaundice if they are visiting the clinic for a well-baby care appointment or for a subsequent bilirubin sample appointment. If jaundice is present, then the newborn's bilirubin levels will be measured. Once this is all completed, the family is instructed to return to the examination room, where they will wait for the nurse. Overall, this process takes approximately 5 to 10 minutes.

The family will first see a nurse for their appointment, who will assess both the mother and the newborn. An assessment is completed at each appointment, no matter the type. The only circumstance where a family may not see a nurse is when the visit is for a quick follow-up and they do not need any breastfeeding support or bloodwork to be done. During the appointment, the mother is assessed for output, lochia, pain, breasts, incision, mental health, blood pressure and any other concerns. As part of the assessment, the nurse will ask the mother about feeding, as they are Lactation Consultants and can provide support. The newborn will be assessed for weight, jaundice, intake, output and any other concerns. After the examination, the nurse will take a bilirubin sample from the newborn, if required. Once the nurse finishes their examination, he/she will document the information in the patient's chart and provide it to the physician.

The physician will complete a detailed physical examination on the newborn and will further investigate any concerns. Once the examination is finished, the physician will educate the family about their newborn and discuss any additional concerns. Based on the assessment, the family will be instructed on when and what they will need to return for. The physician's role during this appointment is to determine the family's pathway to discharge and what steps are required to get there. The amount of time the physician requires to complete the appointment can vary because it depends on the newborn's needs. Once the appointment is over, the physician will document the information about the mother and her newborn in the patient's chart.

Once the appointment is over, the family is free to leave. Some families take approximately 5 minutes to leave the examination room, while others may take a little longer. It has been observed that more experienced families will leave quicker than those that are less experienced. If the mother is having difficulties breastfeeding, they may stay an extra 30 minutes in the examination room to try breastfeeding their newborn, if there is availability in the schedule. Once the family leaves, a staff member will reset the examination room, which consists of cleaning/disinfecting and changing the paper on the examination bed.

Discharge

Families are discharged from the clinic whenever newborns are gaining weight and there are no concerns regarding the newborn and the mother's health. Families will only be discharged from the clinic if the physician and the nurse feel confident that they no longer require close medical attention, and a proper follow-up plan is set up elsewhere. Typically, families stay on as patients of the clinic for 1 to 10 days from their initial visit; however, certain families may stay on longer. Once the family is discharged from the clinic, they are given a discharge package at the front-desk. This package is meant for the family's primary health care provider as it outlines the services they received at the clinic. They are also given discharge instructions and a list of community resources in case they would like to have additional support.

Most families have their own primary health care provider to be transitioned to, which is most commonly a family physician. If upon discharge a family does not have a primary health care provider, then the clinic will provide a list of providers that are accepting new patients and some recommendations; however, it is ultimately the family's decision on who they would like to choose. If a family is having difficulties finding a physician, then the clinic will help them by utilizing their own network. This is done by contacting physicians the clinic is acquainted with and asking them if they can accept new patients. This is not common practice by the clinic; however, it does occasionally occur, as the clinic wants to ensure that every family has access to a primary health care provider.

Staffing

One of the greatest challenges that the clinic faces is appropriately scheduling staff. With the clinic being in operation for many years now, they are beginning to appropriately schedule staff; however, they continue to still experience some challenges as there is a lot of variability in the number and type of appointments scheduled. At the clinic, the staff scheduled are nurses, office administrators and physicians.

Nurses

Depending on how busy the clinic is, either multiple full-day and/or half-day nurses will be scheduled. A full-day nurse will work a 7–hour shift from 9:00 am to 4:00 pm, while a half-day nurse will work a 4-hour shift from 9:30 am to 1:30 pm. Within these shifts, a 30-minute lunch break is scheduled; however, nurses usually decide to work through this break and take their lunch whenever they find a time window. Typically, the number of nurses scheduled throughout the week (Monday to Saturday) at the clinic's primary location is the following:

Table 4: Weekly Nurse Staffing Schedule

Weekday	Nurse Schedule
Monday	Two full-day nurses
Tuesday	One full-day & one half-day nurse
Wednesday	One full-day nurse
Thursday	One full-day & one-half day nurse
Friday	One full-day & one-half day nurse
Saturday	Two full-day nurses

On average, a full-day nurse can see approximately 12 families during his/her shift and a half-day nurse can see approximately 6 families. Based on the scheduled nursing capacity, the clinic may need to call-in an additional nurse if there are more appointments scheduled than there is capacity for. This is done whenever there are double bookings, meaning that two families are scheduled at the same appointment time. If this occurs, nurses on the clinic's roster are contacted to see who is available to work.

Office Administrators

From Monday to Friday, there is only one full-time office administrator scheduled from 8:00 am to 4:00 pm at each location. On Mondays, however, there are two office administrators scheduled at the main location. There is one part-time office administrator scheduled from 12:00 pm to 5:00 pm to complete regular office duties, while a full-time office administrator completes other tasks. These tasks can include ordering any items that may need to be restocked (i.e., wipes, diapers, formula, nipple shields, office supplies, etc.), following-up with families that have rented breast pumps, and cleaning breast pump rentals that have been returned. Furthermore, a part-time office administrator is scheduled on Saturdays for the entire day at the main location. Finally, on Sundays, a part-time office administrator works remotely to schedule appointments for Monday, a task that can take anywhere between 2 to 7 hours to complete.

Physicians

Lastly, physicians also need to be scheduled at the clinic. Normally, there is one physician scheduled at each location every day for the entire day from Monday to Saturday, and the particular physician scheduled can vary each day. Physicians will typically work from 9:15 am to 4:00 pm.

Takeaways

The follow-up clinic is a very quick pace environment, which requires a lot flexibility and multitasking from its staff. The clinic encounters many challenges including receiving last-minute referrals that need to be seen the same day and accommodating families that arrive late for their appointments. However, during the visit to the clinic, it was observed that the staff work very hard to overcome these challenges and adjust to the circumstances. The clinic provides high quality, comprehensive, and timely care to families, even though it makes staff scheduling quite challenging. The work that this unique clinic does is outstanding and is highly valuable to the community as it fills an important gap in early postpartum care and support. Visiting the clinic was a very valuable opportunity and provided a unique opportunity to understand the operations of a postpartum follow-up clinic.

Discussions with a Nurse Practitioner Working at A Nurse Practitioner-Led Clinic

A telephone meeting was organized on April 23, 2019 with a nurse practitioner currently working in a nurse practitioner-led clinic in Ontario. This was an important opportunity to gather information about nurse practitioner-led clinics and about the newborn care they provide. During this discussion, the operations of the clinic as well as the duties of the nurse practitioner were discussed.

The community where the nurse practitioner-led clinic is located receives postpartum care from the local hospital after hospital discharge (i.e., bilirubin, feeding assessment, weight check, etc.). Families will return to the hospital within 48 hours after hospital discharge for a follow-up appointment and a bilirubin sample, if needed. After completing the early follow-up appointment at the hospital, families that choose to be patients of the nurse practitioner-led clinic will be transitioned to it. Families will typically visit the clinic for a follow-up appointment within 1 week after birth. Once the family has completed their follow-up at the clinic, they are scheduled to return when the newborn is 1 month old if everything is normal. This is approximately 3 weeks after the initial visit. Of course, if there are any concerns or the family requires additional support, they will be scheduled earlier and may visit the clinic more frequently. This may occur if the newborn is not appropriately gaining weight.

In terms of scheduling, newborn follow-up appointments are scheduled for 1 hour and the mother and her newborn are assessed together. The clinic follows advance access guidelines for scheduling appointments, where a part of the day is blocked for same-day appointments. This allows for timely access to the nurse practitioner-led clinic. During the discussion, the details of the services provided at the follow-up appointment were not discussed; however, the clinic most likely provides the services outlined by the province (i.e., newborn physician assessment, weight check, jaundice, feeding, maternal assessment, output, incision, etc.). Though, the specific details of what is provided at the follow-up appointments were not discussed, information was obtained about bilirubin samples, mental health assessments and lactation support.

Bilirubin Assessments

At the appointment, a bilirubin assessment is conducted on the newborn. If jaundice is present, a nurse practitioner will refer the family to the local hospital for a bilirubin sample as the clinic does not have a bilirubin meter. For these instances, the nurse practitioner will contact a pediatrician at the local hospital to inform them that a family will be visiting the hospital for a bilirubin sample.

Mental Health Assessments

A mental health assessment is provided to mothers at the follow-up appointment. The mother is left alone to be evaluated according to the Edinburgh Postnatal Depression Scale, which involves answering a 10-question questionnaire. While the mother completes the questionnaire, the newborn and spouse will step out for a short period of time.

Lactation Support

The nurse practitioners also provide lactation support to families. In order to do this, nurse practitioners must complete additional training. This is done by first completing an online training module and then completing in-person training to gain practical experience.

Steps Following Postpartum Care

In addition to postpartum care, the clinic provides primary care to patients of all ages. Since the birth rate is relatively low in the region where the clinic operates, the clinic cannot sustain itself by solely providing newborn care. This is necessary because nurse practitioners must see a certain number of patients within a year, which is a mandated rule by the government. Due to this rule, newborns that come to the clinic for postpartum care will typically stay on as patients and have a nurse practitioner as their primary care provider. Furthermore, the clinic itself is primarily a nurse practitioner-led clinic; however, physicians are included in the clinic's business model as the nurse practitioners do not have privileges at the hospital in the event that a newborn needs readmission. It is important to note that the ability for nurse practitioners to re-admit patients to the hospital depends on the community they live in, as it is dependent on the hospitals by-laws.

Takeaways

The discussion held with the nurse practitioner working at a nurse practitioner-led clinic was very valuable. It provided an understanding about the operations of a nurse practitioner-led clinic in Ontario and many considerations to account for. More specifically, about the potential challenges a nurse practitioner-led clinic may face. Furthermore, insightful information was provided about their model of care, specifically the delivery of postpartum care.

Quinte Health Care

For this thesis, a partnership was created with Quinte Health Care with the help of CMNRP. This partnership provided an opportunity to learn about the delivery of postpartum care in the Quinte region. Through discussions with the hospital, it was evident that providing postpartum care in a timely manner is a challenge within the region. This is due to an increasing shortage of family physicians and paediatricians, with fewer physicians moving to the area and the ones currently available are beginning to retire. Due to this, some families and newborns cannot find a primary care provider. Quinte Health Care estimates that approximately 12% of newborns in the area do not have a primary care provider. Through discussions, it was evident that receiving timely newborn care can be quite challenging with the current model of care.

For families that struggle in finding a physician, the hospital tries to help by contacting physicians directly to arrange a follow-up. The hospital maintains a list of family physicians who have capacity to take on newborns and knows how many they can accommodate at any given time. However, the problem with this strategy is that the family physician will only care for the newborn and not for the rest of the family. This then results in segmented care, as the family will have to visit multiple health care providers, which is inconvenient and prevents the mother and the newborn from being cared for together. This problem is especially prevalent in military families, which constitutes a large portion of the population in the area. Family members of a military member must find their own health care provider because the military does not provide medical care to them.

To deal with this problem, Quinte Health Care partnered with Hastings Prince Edward Public Health to create a solution. Once a week there is a half-day public health nurse available to see newborns at the Public Health Unit. Nurses can see families within 1 week after hospital discharge, as they are currently not equipped to see families within 72 hours after hospital discharge. Unfortunately, they cannot complete the well-baby care follow-up appointment or any bilirubin samples; however, they can provide lactation and feeding support, and support in postpartum feelings. At the current time, only low-risk newborns of a certain weight can visit the Public Health Unit for newborn care. This means the clinic will not see any newborns that exhibit signs of jaundice, are born before 37 weeks, have any major health concerns or are multiples (i.e., twins or triplets). This new model of care is relatively new and is still being developed; however, it is an innovative solution to help address the physician shortage in the area.

For newborns that cannot be seen by the Public Health Unit, an agreement has been established with the pediatricians in the area, where they will see high-risk newborns as needed. Additionally, if a newborn seen at the Public Health Unit requires additional support or requires further assessment, they will be referred to the paediatrician group. If it is very urgent, then the newborn will be referred to the hospital and the nurse practitioner will phone a pediatrician directly to inform them that a family is on their way to see them.
Conclusively, Quinte Health Care has been dealing with the physician shortage in a creative way. Partnering with the Public Health Unit and utilizing nurse practitioners is an innovative approach to the circumstance. When this partnership was described, it was still relatively new and as such no evaluation outcomes were available; however, it is expected to be quite successful. Quinte

Health Care found a unique solution to the problem but, unfortunately, it most likely will continue to worsen. As a result, the community keeps looking for innovative ways to help with this problem and, therefore, decided to collaborate with this thesis.

Methodology

Introduction

The data characterizing the current delivery of postpartum care in the region suggest that the region may not be meeting the recommended PCMCH standards for postpartum care. These findings prompted an opportunity to conduct research on how to improve the delivery of postpartum care in Ontario's health care system. As previously mentioned, the main objective of this research was to develop a general design methodology for postpartum nurse practitioner-led clinics. These are postpartum clinics where mothers and their newborns can go to complete their follow-up appointments (this can consist of one or multiple appointments), complete any required testing, and receive any additional support. The aim was to create an operational design that could be adaptable to any region to ensure that all mothers and newborns have access to timely and quality postpartum care wherever and whenever they need it.

This was achieved by developing and implementing an analytical model. Based on the predefined external and operational factors, the model computes the associated service level, along with other outputs, through Monte Carlo simulation. These factors include the demand for postpartum care, the clinic capacity, and the predefined scheduling rule, among others, which combined are used to simulate the daily operations of the clinic for 250 days. The current version of the model can be used as a high-level capacity planning tool, which can be further expanded on to incorporate other features to increase its functionality. The model, along with the research presented in earlier sections, constitute a preliminary step needed to support the development of postpartum nurse practitioner-led clinics in the region.

In this chapter of the thesis, the steps taken to create the analytical model are described. The *Data Collection* sub-section outlines the data obtained for this thesis. The data was used to estimate the input values entered into the model and evaluate the performance of different clinic configurations through simulation. The *About the Model* sub-section provides a brief overview of the analytical model before fully detailing the steps taken to create it in the *Model Creation* sub-section, which discusses the structure of the model and the formulas used. Lastly, the *Practical Application* sub-section illustrates the usability of the model by presenting the results obtained for various clinic configurations.

Data Collection

To create the analytical model and test its application, a mixture of observational and quantitative data was used. The observational data is based on information gained from stakeholder engagements, specifically that conducted at the postpartum clinic. The quantitative data was obtained from Quinte Health Care and IC/ES. Data obtained from IC/ES also helped in evaluating the results of the model as it provided a benchmark on the current percentage of follow-up appointments provided by a physician within 72 hours after hospital discharge.

Quinte Health Care Data

To obtain data from Quinte Health Care, an ethics application was submitted. Ethics approval was granted by the Quinte Health Care's (QHC) Research Ethics Board (REB) and the University of Ottawa's Ethics Board. Data from 2014 to 2018 was retrieved from the Better Outcomes Registry & Network (BORN) database by two employees at Quinte Health Care. The data extracted included: 1) birthing volume, 2) number of singleton births, 3) number of vaginal births, and 4) number of caesarean births.

IC/ES Data

The data collection process with IC/ES took several months (approximately May to December of 2019). It began with the submission of a data request through their standard data request process to check if the data needed for this thesis, specifically follow-up data, was available. After a few meetings, it was unclear whether the required data would be available. Through further investigation, it was discovered that the data collection process was not feasible because of time and cost considerations. The secondary avenue explored was a data collection process solely reserved for health care organizations. Since this thesis was completed in collaboration with CMNRP, it could have potentially qualified. This process seemed promising because it would have been funded by the Ministry of Health and Long-Term Care. However, while gathering information about the application process, it was revealed that applications were reviewed during certain times of the year and more likely approved at the start of the year due to budgetary constraints. At the time, the application would have been submitted in August of 2019; thus, it seemed unlikely to be approved in a timely manner and there were still many unknowns about the process (i.e., timeline, collection process, etc.). The final attempt to collect data from IC/ES consisted of a meeting with an IC/ES manager at the IC/ES uOttawa location, which was arranged by a colleague from the University of Ottawa. This meeting was informative because it was discovered that IC/ES would most likely have access to physician follow-up data for newborns. However, once again, the collection process was costly and lengthy. Furthermore, it would have required us to collect the data ourselves at IC/ES uOttawa. Luckily, a contact at The Ottawa Hospital was willing to assist us in attaining data from IC/ES. Fortunately, with her help, an arrangement was established with IC/ES to utilize data from a previous project. This was feasible because it appropriately fit the timeline of this thesis and the available budget.

The data obtained from IC/ES was collected from a previous project that studied immunizations within a newborn's first few years of life. Since the data was taken from a previous project, ethics approval had already been granted, and the data had been processed and analyzed. Thus, ethics approval was not required by IC/ES but an application was reviewed and approved by the University of Ottawa's Ethics Board. To use the data for this thesis, permission was needed from the principal researcher of the project. With her approval, the data was permitted to be shared and collected.

For the data to be collected, specific data variables were given to the IC/ES data analyst. This process began by corresponding with the IC/ES data analyst via email about the data variables that could be extracted. We provided a list of variables that we would like to collect, and the analyst assessed the feasibility, time, and cost for collecting them. Based on this, we narrowed our data collection to four data variables, which included: 1) number of days to the first follow-up appointment after birth with a physician care provider, 2) mother's age at hospital admission, 3) number of births, and 4) mother's income quintile at hospital admission. The data is Ontario wide data collected for five years from fiscal year 2012-2013 to 2016-2017. To extract data for these variables, a criterion had to be specified to the analyst (i.e., fee codes for follow-up data, yes/no criteria for multiple births, type of income quintiles, and criteria for mother's age at admission). To understand which criteria to use, specifically the fee codes to request for follow-up appointment data, weeks of correspondence was had with the IC/ES data analyst. The data analyst did not provide much clarity; therefore, the principal researcher of the previous project was contacted to gain a better understanding of the dataset. This step took several months to complete and created unexpected delays in the data collection process.

The follow-up data obtained from IC/ES required some additional analysis as physician follow-up data is not readily accessible. Based on OHIP data, it was estimated when newborns completed their first follow-up appointment after hospital discharge. This was done by taking the first reported well-baby care visit. The first reported appointment was obtained based on the newborn's or mother's OHIP number, depending if the newborn was assigned an OHIP number by the time of the appointment. Since the data collected is from OHIP, our estimates may be biased because they are computed with the exclusion of aboriginals, refugees, and non-residents. The information about these populations is not reflected in the dataset because their health services are not billed to OHIP. It is important to note that this could affect the analysis of the dataset but would not affect the validity of the model.

To extract data on when newborns completed their first follow-up appointment with a physician, the fee code A007 with code 916 was pulled from OHIP, as this is the fee code used for well-baby care visits. Only the date associated with the first reported well-baby care visit was considered; therefore, subsequent well-baby care visits were omitted. Furthermore, only physician data was included, as the previous project primarily focused on the amount of time after hospital discharge newborns must wait for a follow-up appointment with a physician. Other health care providers, such as midwives, are part of a different care pathway and do not bill OHIP, meaning, follow-up data for these health care providers was not collected.

The data obtained from IC/ES provides an estimate on the amount of time newborns wait to complete their first follow-up appointment with a physician after hospital discharge. There are, however, some limitations to the data. Firstly, it is possible that the date of the appointment is not accurate as physicians commonly bill OHIP in "batches". Physician offices may bill OHIP a few days after when the appointment occurred because they may submit their billing a few times a week rather than every day. A difference of a few days makes a large difference in this study because of the short timeframe being considered. It is possible that a higher proportion of newborns received their follow-up appointment within the recommended timeframe of 72 hours after hospital discharge, but this is not properly reflected in the dataset.

Secondly, there may be some missing data due to incorrect fee codes being used by physicians. Speaking to the researcher that initially collected the data for her project, it was mentioned that there could be some unreliability in the appointment coding due to inconsistent fee-coding. That is, certain services may be wrongly coded and therefore, not be captured in the dataset. For example, newborns may visit the physician for a jaundice assessment or a consultation shortly after hospital discharge; however, these services would not be coded under a well-baby care visit. This is due to physicians being able to decide on the fee codes to bill OHIP, which are outlined in the Schedule of Benefits (*Schedule of Benefits,* 2020). Thus, a newborn may have received an assessment from a physician shortly after hospital discharge, but it may have been billed under a different fee code. Nevertheless, the data obtained from IC/ES provided some indication about the wait for newborn follow-up appointments in Ontario and was valuable to this thesis.

About the Model

For this thesis, a simulation model for a postpartum nurse practitioner-led clinic was designed and developed. Simulation refers to a broad collection of methods and applications used to mimic the behaviour of real systems, usually on a computer with the appropriate software (Kelton et al., 2015). In this case, the model was created in Microsoft Excel along with an add-in software called @Risk by Palisade. The Microsoft Excel workbook was created on a Microsoft Windows computer using a paid student version of the @Risk program. @Risk is a Monte Carlo simulation software that samples data based on different inputted probability distributions and calculates thousands of possible future outcomes (*@Risk*, n.d.).

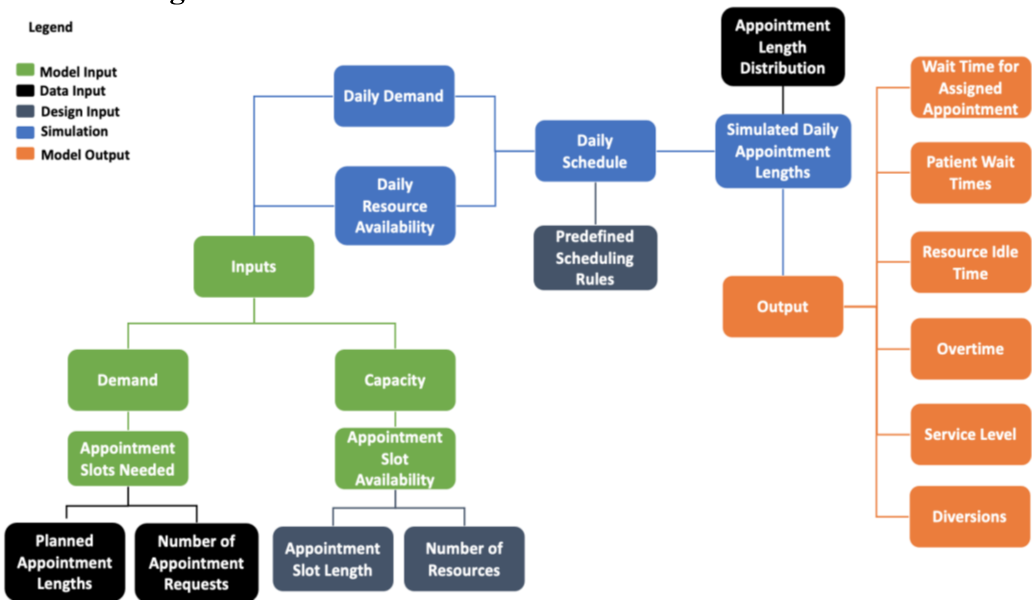
The purpose of simulation is to study systems by either measuring how they perform based on improvements made to its operations or by creating designs of it that do not already exist (Kelton et al., 2015). One way a system can be studied is by directly experimenting with it and observing the resulting impact on its performance based on different configurations; however, this approach can be rather costly, time consuming and/or difficult to implement (Kelton et al., 2015). Consequently, another way in which a system can be studied, which can be far less costly and time consuming, is by building a model of the system and observing how it reacts to different changes made to it (Kelton et al., 2015). Typically, a computer software is used to create these models, which imitate the operations and characteristics of the system under study (Kelton et al., 2015). The purpose of simulation is to observe the main effects and possible interactions between the elements of the model and how different inputs impact the outputs being analyzed (Kelton et al., 2015).

Simulation is done through random number generation from specific probability distributions using specialized algorithms (Kelton et al., 2015). The random number generation is meant to provide a flow of input values that reflect the inherent uncertainty in relation to the different factors that affect the behaviour of a system and consequently its performance (Kelton et al., 2015). Simulation was best suited for this thesis as it involves the modelling of a system that does not currently exist and thus could not be directly observed. Specifically, a logical (also known as a mathematical) model was used. This type of model considers a set of simplifications and assumptions, both structural and numerical, about how the system will work (Kelton et al., 2015). The main simplifications and assumptions for the model in this thesis are described later.

Simulation can be performed through different simulation methods. In this thesis, the simulation type used was Monte Carlo simulation as the goal was to design a high-level capacity planning tool. Discrete-event simulation could have been used; however, this simulation method is typically used to model patient flows through systems, which was not the aim of this thesis. Furthermore, there is limited research available on postpartum nurse practitioner-led clinics, where certain steps in the patient flow are unknown. Without appropriate research and data to better understand a patient's flow through the clinic (at the operational level), discrete-event simulation would have been challenging to use. Additionally, it was never our goal to consider uncertainty, for example, in interarrival times. The model identifies that an appointment is scheduled; however, it does not need to know when families arrive and depart, meaning this is not a classical queuing system. Therefore, the aim of this thesis was to design and develop a general capacity planning tool based on Monte Carlo simulation that computes the service level, which did not require a detailed description of the patient flow.

The model computes various simulated outputs based on predefined external and operational factors. The predefined factors include the demand for care, resource capacity, and predefined scheduling rules used to schedule appointments, which combined are used to create daily appointment schedules. Based on the daily schedules, the daily appointment durations are simulated to assess the clinics performance. The results of this simulation are evaluated based on various performance measures (daily number of diversions, daily number of appointment slots each resource is idle for, daily average patient wait time, daily resource idle time, daily clinic overtime, daily number of appointments provided within 72 hours, and daily number of appointments provided beyond 72 hours). The performance measures are then used to compute various outputs (the average number of days families must wait for their scheduled appointment, average patient wait times prior to their appointment, average resource idle time, average overtime, average rate of diversions and the service level). The primary output of the model is the service level, which is defined as the percentage of follow-up appointments provided within 72 hours from when they are requested. Based on the inputs entered, the resulting average service level is determined, or a pre-specified average service level can be achieved through trial-and-error. As previously mentioned, the model was designed to be adaptable; therefore, the defined operational factors can be adjusted to achieve a desired service level. Figure 2 presents a visual depiction of the model, which outlines the inputs and process followed to compute the various outputs.

Figure 2: Model Diagram



The model will be further explained in the following *Model Creation* sub-section, but a quick overview of it is provided in Figure 2. As shown, the inputs of the model include the demand for care and the resource capacity. These inputs can be manually adjusted and are based on a five-day cycle. As per the diagram in Figure 2, the demand inputs, specifically the number of requested appointments and defined planned appointment lengths, are determined based on data. From these two inputs, the number of requested appointment slots is computed, which allows the model to reserve the amount of time required from a resource in the schedule. Resource availability is determined from the number of resources and specified appointment slot lengths, which defines the number of appointment slots available. These are known as design inputs. The values of the design inputs could be driven by the demand inputs but are ultimately decided on by the decision maker of the clinic. Based on the demand and resource capacity inputs, the daily demand and the daily service capacity are determined to create daily schedules. A daily schedule is generated based on predefined scheduling rules stating the order in which appointments are scheduled. The scheduling rule is also a design input that is manually adjusted in the model. From the daily schedule, each scheduled appointment has its appointment duration simulated based on a predefined probability distribution (a normal distribution in the case of the numerical results presented later). This is a data input and is represented as the appointment length distribution input in Figure 2. The daily appointment durations are then used to compute the various outputs in the model.

Model Creation

In this section, a detailed description is given on the model design and the steps taken to create it. To do so, a number of simplifications and assumptions were made. These were not only made due to limitations faced regarding research and data availability on postpartum nurse practitioner-led clinics but also due to the type of decisions being supported. Certain assumptions were decided based on observations made at the postpartum clinic during the stakeholder engagements. A summary of the assumptions can be found below.

1. **Operating days**: the clinic operates five days a week from Monday to Friday and is closed during weekends. The model was built for one operational year, resulting in 250 operating days. This seems reasonable to accommodate for any seasonal fluctuations (if any).
2. **Demand & capacity inputs**: the demand and capacity inputs are entered into the model for five days to accommodate for any variability during the week. This seems reasonable as it was observed at the postpartum clinic that there was some fluctuation in the demand and capacity throughout the week.
3. **Daily demand:** the daily demand for each demand type is simulated through a Poisson distribution, which is a common probability distribution for this type of process. Furthermore, the daily demand is represented in number of appointment slots rather than number of appointment requests. This is computed based on the simulated daily demand and the planned durations for each demand type. This can be seen as a limitation when scheduling appointments in the daily schedule.
4. **Scheduling order:** appointments are scheduled following a priority order to create daily schedules. Based on a research study conducted by Klassen & Rohleder (1996), appointments are scheduled based on the standard deviation of the durations (lowest to highest) to minimize delays. This can be seen as a limitation as the scheduling order cannot be easily changed in the model.
5. **Resource scheduling:** multiple care providers are present at each appointment and each of them must stay for the entire duration of the appointment. This is based on observations made at the postpartum clinic where multiple care providers were required. Consequently, the minimum capacity across all resources needs to be considered in the daily scheduling process to ensure each resource is present. This characteristic of the model could be seen as a limitation because it utilizes more resource capacity than strictly required and could be less applicable in practice. However, in practice, resources could perform other tasks during this "idle" time.
6. **Appointment lengths:** appointment lengths must be a multiple of one another (i.e., 30, 60, 90, 120 minutes). Additionally, the length of the shortest appointment (i.e., 30 minutes) must match the defined appointment slot length from resources (i.e., 30 minutes). This could be seen as a limitation as there is less flexibility in scheduling appointment slots for resources.
7. **Advance booking:** families must have a scheduled appointment prior to visiting the clinic; therefore, the model does not consider walk-ins. This is based on observations made during the stakeholder engagements, where families had a scheduled appointment prior to visiting the clinic. Furthermore, appointments must be scheduled at least one day in advance, which does not allow for same-day appointment scheduling. This aspect can be seen as a limitation as same-day appointments are typically provided, which was observed during stakeholder engagements.
8. **Diversions:** appointments can be scheduled up to five days in advance, however, if an appointment cannot be scheduled within this timeframe, the family is diverted to another health care provider. This seems reasonable as it is well beyond the recommended 72 hours and would allow families to receive timelier postpartum care elsewhere.
9. **Family arrival for appointment:** families will arrive as scheduled for their appointments and will arrive on time to minimize any delays in the schedule. This was

observed during the stakeholder engagements, where families arrived for their appointments on time. Therefore, the model does not accommodate for no-shows.

10. **Appointment transition:** appointments are scheduled back-to-back without incorporating a transitional time from one appointment to the next. Once one appointment is completed, the next begins. This should be considered in the appointment durations as this is a planning model.
11. **Appointment scheduling changes:** families will not cancel or re-schedule their appointments. This seems reasonable as during the observational visit at the postpartum clinic, families did not change their appointments. This could be due to the small timeframe used to schedule and fulfill appointments.
12. **Simulated appointment durations:** appointment durations are simulated through Normal Distributions because they involve a number of different tasks. The mean values are 2/3rds of the planned appointment lengths of 30 minutes, which is the base case scenario, and the standard deviation values are 2/3rds of the mean values. More specifically, the mean values used include 20 minutes for Demand #1, 40 minutes for Demand #2, 60 minutes for Demand #3, and 79 minutes for Demand #4. While the standard deviation values used include 13 minutes for Demand #1, 26 minutes for Demand #2, 40 minutes for Demand #3, and 52 minutes for Demand #4. These values remain unchanged in the model. This seem reasonable as the values were estimated based on observational data.

The next step is to outline the steps taken to design the model, which beings with a description of the inputs. More details about the inputs can be found in Table 5.

Table 5: Input Variables

Variable	Description
Demand for Follow-ups	Demand is the daily number of requested appointments. This is represented as the number of requested appointments for both follow-up appointments that need to be completed within 72 hours after hospital discharge and any subsequent appointments following the follow-up appointment
Resource Capacity (System Service Capacity)	Resource capacity is the daily number of appointment slots available across all resources

The demand is the number of appointments requested from families. This includes the initial follow-up appointment within 72 hours after hospital discharge as well as any subsequent visits. Any subsequent appointments are provided within 72 hours from the previous appointment. The number of appointments that can be scheduled within a day depends on the system service capacity, which depends on the resources' availability. Resources, in this case, are defined as nurse practitioners and any other assistive staff, such as registered nurses. This distinction is based on observations made at the postpartum clinic, where multiple care providers were present at each appointment to assist one another. The primary care provider completing the appointment is, however, the nurse practitioner.

Based on the demand and capacity, daily schedules are created. As previously mentioned, daily schedules are used to simulate the daily operating lengths, which is done by simulating the actual duration of each scheduled appointment in a day. Thereafter, a number of performance measures are computed, which are then used to calculate the different outputs shown in Table 6.

Table 6: Output Variables

Variable	Description
Service Level	The percentage of appointments provided within 72 hours across all demand types. Also calculated for each demand type (1 to 4)
Average Patient Wait Time	The average time (in minutes) a family has to wait until they see a nurse practitioner for their appointment
Average Resource Idle Time	The average time (in minutes) nurse practitioners have to wait between appointments until they see their next scheduled appointment
Average Overtime	The average amount of extra time (in minutes) nurse practitioners must work each day to fulfill all scheduled appointments. This occurs when there are delays and the day runs longer than scheduled
Average Number of Diversions	The average number of appointment slots that cannot be scheduled within 5 days from when requested
Average Wait Time to Assigned Appointment	The average number of days from when an appointment slot is requested until it is scheduled

The goal is to increase or meet a pre-specified service level, while lowering the remaining outputs and performance measures. To illustrate the development of the model in a visual way, four different flow charts were created to outline how some outputs were calculated. These flow charts can be found in Appendices I, J, K & L. To further understand how the model was developed, the following sub-sections (*Demand*, *Resource Capacity*, *Scheduling*, *Evaluation* and *Outputs*) describe in detail each element of the model.

Demand

The first step in developing the model was to determine the inputs, first being the demand. The demand was segmented into four categories to accommodate for different appointment types. The different demand types are numbered 1 through 4 (i.e., Demand #1, Demand #2, etc.). Depending on the type of appointment requested by the family, their appointment would be scheduled under one of four demand types. This is due to the amount of time allocated to each demand type, which is illustrated in Table 7.

Table 7: Allocated Appointment Length & Slots per Demand Type

Demand Type	Appointment Length (minutes)	Required Number of Appointment Slots
Demand 1	30	1
Demand 2	60	2
Demand 3	90	3
Demand 4	120	4

The allocated appointment lengths were determined based on observational data, where the amount of time required for different appointments was observed. As previously mentioned, appointment lengths and appointment slot lengths can be adjusted accordingly. A change in the appointment lengths directly impacts the number of appointment slots needed, depending on the defined appointment slot length. As seen in Table 7, each appointment slot is allocated 30 minutes. The number of appointment slots reserved in the schedule differs for each demand type as it depends on the amount of time allocated to each demand type. The appointment slots represent the amount of time required from each resource. The specific details about resource availability will be further discussed in the following *Resource Capacity* section.

With the demand types established, the next step is to determine the daily demand, which is the number of appointment requests per demand type. Since daily follow-up data could not be obtained, the daily demand for each demand type was simulated using a Poisson Distribution. All that was required was the daily average number of appointment requests per demand type, which represents the mean values. To account for variability (seasonality) in the daily demand, a different mean value was considered for each day for five days. Five days was chosen as it was assumed that clinics would operate five days a week. Therefore, the mean values used to generate random demand can be adjusted in the model. Adjusting these values has a direct impact on the model's output. A screenshot of the mean values inputted into the model for a practical application described in a later section can be found in Appendix M. The values were estimated from observational data obtained from stakeholder engagements as explained in further detail in the *Practical Application* sub-section.

The daily number of appointment requests per demand type is simulated for 250 days. A simulation of one year was chosen to accommodate for any seasonal changes in the demand, if any are present. Furthermore, it was assumed that the clinic operates 5 days a week from Monday to Friday. A warm-up period of 30 days is considered to appropriately reflect the appointment availability on Day 1. A warm-up period of 30 days assumed to be sufficient as the time window to book appointments is very small. Excluding the warm-up period would, otherwise, create a biased output as the schedule would look very favourable at the start.

With the daily demand determined, the next step is to identify the amount of time required from the different resources to fulfill the appointments requested. This was done by identifying the number of appointment slots needed to fulfill the requested appointments. This is done for each demand type by simply multiplying the simulated number of appointments requested by the respective number of appointment slots required. For example, if on Day 1 there are 3 appointment requests for Demand #3, the number of appointment slots required to fulfill these requests is 9 (3x3). A full break down of how the daily demand is represented in the model can be found in Appendix N. The daily demand values are then used to create daily schedules together with the daily resource capacity, which is further explained in the following *Resource Capacity* section.

Resource Capacity

The system service capacity corresponds to the number of appointment slots available from resources each day. The number of appointment slots available on a given day depends on the number of resources scheduled. The number of resources represents the number of full-time or part-time care providers scheduled to work. It is assumed that full-time resources work 7.5 hours in a day, while part-time resources work 4 hours. Furthermore, the number of appointment slots a resource has available on a given day depends on the value chosen for the length of each appointment slot and the length of the resource's workday.

The model allows for changes in the daily capacity of each resource for 5 days. This can be done by changing the number of appointment slots each resource has available each day. To determine the number of appointment slots a resource has available on a given day, the number of minutes a resource is scheduled for in a day is divided by the number of minutes allocated to each appointment slot. This computation is completed for each resource (of the same type) and the summation is the total resource capacity available on that day. For this thesis, the number of resources and appointment slot lengths were estimated based on observational data. Appendix O illustrates how the resource capacity input is represented in the model.

Based on observational data, it was determined that each appointment slot is 30 minutes long. This can, however, be adjusted. A full-time resource would be available for 450 minutes in a day, which corresponds to 15 appointment slots being available. While a part-time resource would be available for 240 minutes in a day, which is equivalent to 8 appointment slots being available. The model has the ability to consider multiple resources because usually, there are multiple care providers present at the follow-up appointment. Though, it is worth noting that this could differ for a nurse practitioner-led model compared to other care models. Nonetheless, based on observational data, a mixture of full-time and part-time resources were considered. More details will be provided in the *Practical Application* section of this thesis.

Scheduling

Based on the defined inputs (i.e., demand, resource capacity, and scheduling policy), daily schedules are created. A daily schedule outlines the daily number of appointments scheduled at the clinic, by demand type, based on the daily number of appointment slots available from resources. Daily schedules are directly impacted by the model inputs because they determine the number of appointments scheduled each day at the clinic. Additionally, daily schedules are used to simulate daily appointment durations, which are then used to compute the various performance measures and outputs of the model.

Daily schedules are created using a number of formulas. To assist in the explanation of these formulas, the model notation is provided in Table 8, which outlines the various variables used in these formulas.

Table 8: Notation Table

Variable	Description
	Indices
r	Resources
n, k	A day in the booking horizon
t	A day in the planning horizon
i, j	A type of demand

m	A patient on a specific day
Parameters	
R	Number of resources
N	Number of days in the booking horizon
T	Number of days in the planning horizon
I	Number of demand types
C_{rt}	Clinic capacity of resource r on day t of the planning horizon [slots]
C_t	Clinic capacity on day t of the planning horizon [slots]
d_{it}	Number of appointment requests of type i on day t of the planning horizon [slots]
y_m^t	Planned duration of appointment m on day t [slots]
x_m^t	Random duration of appointment m on day t [slots]
Variables	
B_{in}^t	Number of appointments of type i already booked on day n of the booking horizon at the beginning of day t [slots]
A_{in}^t	Number of additional appointments of type i to book on day n of the booking horizon at the beginning of day t [slots]
E_i^t	Number of appointments of type i to divert at the beginning of day t [slots]
Q_t	Number of appointments scheduled on day t [slots]
M_t	Number of appointment visits scheduled on day t
U_r^t	Number of unscheduled appointments for resource r on day t [slots]
W_m^t	Waiting time for appointment m on day t
S_m^t	Idle time associated with appointment m on day t
O_t	Overtime on day t
S_t	Number of appointments booked in a timely manner on day t (i.e., service level on day t) [slots]
L_t	Number of appointments booked late on day t [slots]
$\bar{W}_t$	Average within-day waiting time on day t
$\bar{W}$	Average within-day waiting time over the planning horizon
$\bar{S}$	Average resource idle time over the planning horizon
$\bar{O}$	Average overtime over the planning horizon
SL	Service level over the planning horizon
$\bar{D}$	Average wait to assigned appointment over the planning horizon [days]
$\bar{E}$	Average number of appointments diverted over the planning horizon [slots]

When creating daily schedules, the first step is to determine the system service capacity. This is done by computing the minimum number of appointment slots available across all resources. The purpose of this is to ensure that all resources are available for each appointment as multiple resources are needed to conduct the appointment. For example, a registered nurse may be needed to assist the nurse practitioner during appointments. Therefore, the resource with the lowest capacity determines the number of appointment slots available for each particular day. The formula used to determine the minimum resource capacity over the planning horizon is the following:

$$C_t = min\{C_{1t}, \dots, C_{Rt}\} \ \forall t$$

The daily number of appointment slots available from resources is pre-specified and requested appointments are scheduled accordingly. For the purpose of this project, requested appointments are assigned based on priority level on a particular day. This priority level is based on the scheduling order previously mentioned, where appointments are scheduled based on standard deviation values (Klassen & Rohleder, 1996). This means appointments are scheduled in chronological order based on demand type, with Demand #1 being scheduled first, then Demand #2 and so on.

The daily appointment slot availability is impacted by any pre-scheduled appointments. Pre-scheduled appointments include any appointments that need to be scheduled in advance or have to be scheduled on a different day due to limited availability on the day requested. Pre-scheduled appointments reduce the number of appointment slots available for any newly requested appointments on a given day and could extend the wait time for an appointment. The formula used to calculate pre-scheduled appointments is the following:

$$B_{in}^{t+1} = B_{i(n+1)}^{t} + A_{i(n+1)}^{t} \;\; \forall n < N, t < T; \; B_{iN}^{t+1} = 0 \; \forall t < T$$

In the schedule, pre-scheduled appointments are reflected based on the day they are scheduled for. For example, if appointments are scheduled two days in advance, then pre-scheduled appointments are reflected on that day's schedule and will decrease the appointment availability on that day for any newly requested appointments. Appendices P & Q illustrate how previously booked appointments are represented in the schedule. For this thesis, it was determined that appointments would not be scheduled more than 5 days in advance, as it would be well beyond the recommended timeframe of 24-72 hours after hospital discharge. This timeframe of 5 days is known as the booking horizon. If appointments cannot be scheduled within 5 days, then at the time of the request, families will be informed and diverted to another health care provider.

The scheduling process is completed for each day in the 250-day planning horizon, where daily appointment requests are scheduled based on the number of appointment slots available on a given day in the booking horizon (or diverted). To determine the number of appointment slots available on any given day of the booking horizon, the difference is taken between the number of pre-specified appointment slots available from resources and the number of pre-scheduled appointments. This calculation corresponds to the following formula:

$$A_{in}^{t} = \min\left\{ d_{it} - \sum_{k=1}^{n-1} A_{ik}^{t}, C_{t+n} - B_{in}^{t} - \sum_{j=1}^{i-1} A_{jn}^{t} \right\} \; \forall i, n, t$$

The number of appointment slots still available is part of the calculation of the number of appointment slots to be scheduled on a given day, which is found above. This is done by finding the minimum value between the number of appointments requested that have not been scheduled yet for a particular demand type and the number of pre-specified appointment slots available from resources minus the number of pre-scheduled appointments. This computation is completed each operating day and is meant to schedule any requested appointments as soon as possible. If there are more appointments requested than appointment slots available on a given day, then appointments will be scheduled in advance, up to 5 days, until all requested appointments have been scheduled. If there is no availability to schedule appointments because all the appointment slots have already been pre-scheduled on a given day, then A_{in}^{t} is zero.

To obtain the total number of appointments scheduled on a given day, the number of new appointments scheduled that day and the number of pre-scheduled appointments for that day are added together. It is worth noting that the daily number of appointments requested is represented in the daily schedules as the daily number of appointment slots requested. The corresponding formula is the following:

$$Q_t = \sum_{i=1}^{I} (B_{i1}^{t} + A_{i1}^{t}) \quad \forall t$$

Evaluation

From the daily scheduling decisions and simulated appointment durations, a number of performance measures are computed. The remainder of this section will focus on their computations. It is worth noting that certain performance measures count the number of appointment slots since the daily number of appointments requested is represented as appointment slots within the daily schedules.

Diversions

It corresponds to the number of appointment slots that could not be scheduled within 5 days from when requested. The goal is to lower the number of diversions as the objective is to provide timely follow-up appointments to families at the clinic. The formula used to calculate the daily number of diverted appointment slots is the following:

$$E_i^t = d_{it} - \sum_{n=1}^{N} A_{in}^{t} \ \forall i, t$$

As per the formula, the daily number of diverted appointment slots is calculated by taking the difference between the daily number of requested appointment slots and, of those requested appointment slots, subtracting the number of appointment slots scheduled within 5 days. This computation is completed for each day in the planning horizon and for each demand type. If appointments are diverted, it suggests that there is too much demand compared to the available resource capacity. The result of the daily number of diverted appointment slots can be found in Appendix R.

Unused Appointment Slots

It corresponds to the daily number of unused (planned) appointment slots from resources. The objective is to lower the number of appointment slots that resources have free as it is unused capacity where resources are not providing care to families. The formula used to calculate the daily number of unused appointment slots is the following:

$$U_r^t = C_{rt} - Q_t \ \forall r, t$$

As per the formula, the daily number of unused appointment slots for each resource is computed by taking the appointment slot availability of a given resource and subtracting the sum of appointment slots scheduled on a particular day. This computation is done for each day and resource. As previously mentioned, it is assumed that each resource is available for each scheduled appointment, therefore, the sum of the appointment slots scheduled on a given day is subtracted. Due to this assumption, it is expected that there may be some unused capacity. An example of the computation of the daily number of unused appointment slots for each resource can be found in Appendix R.

Number of Appointment Slots Provided Within Target

It corresponds to the total daily number of requested appointment slots that are scheduled within the target timeframe of 3 days (i.e., within 72 hours). The goal is to have a higher value for this performance metric, as the objective is to provide care within the recommended timeframe of 24-72 hours after hospital discharge. The formula used to calculate the number of appointment slots scheduled within the target timeframe of 72 hours is the following:

$$SL^t = \sum_{i=1}^{I} \sum_{n=1}^{3} A_{in}^t \ \forall t$$

This calculation includes appointment slots scheduled across all demand types and is computed for each day in the planning horizon. Appointments can be scheduled up to 5 days in advance; however, the aim is to schedule them within 3 days from when requested. Appendix S illustrates the result of this performance metric.

Number of Appointment Slots Not Provided Within Target

It corresponds to the total daily number of requested appointment slots that were scheduled beyond the target timeframe of 3 days. The goal is to have a lower value, as the objective is to provide appointments within 3 days from when requested. The formula used to calculate this performance metric is the following:

$$L_t = \sum_{i=1}^{I} \sum_{n=4}^{N} A_{in}^t \ \forall t$$

The computation of this performance metric is very similar to that of the previous one. The difference, in this case, is that the sum considers only appointment slots that were scheduled four and five days from when requested. Similar to the previous performance metric, this calculation includes appointment slots scheduled across all demand types and is computed for each day in the planning horizon. Appendix S illustrates the result of this performance metric.

Average Patient Wait Time

It corresponds to the average number of minutes families wait for their appointment from the planned appointment time on a given day. This occurs when there are delays in the schedule and appointments do not start by their scheduled time. The objective is to have short wait times for appointments. The following formula was used to calculate this performance metric:

$$\bar{W}_t = \frac{\sum_{m=1}^{M_t} W_m^t}{M_t} \quad \forall t$$

with,

$$W_m^t = \max\{W_{m-1}^t + (x_{m-1}^t - y_{m-1}^t), 0\} \quad \forall t, m = 1, \dots, M_t$$

The average number of minutes families wait for their appointment is calculated by taking the total wait time experienced by all families scheduled and dividing it by the total number of appointments scheduled on a given day. The results of this computation can be found in Appendix T. To compute the wait time (if experienced) for a specific appointment, the difference is taken between the simulated appointment duration and the planned appointment length of the previous appointment, which is added to the corresponding wait time. This computation is done for each appointment on a given day in the planning horizon. This computation determines if the previous appointment goes over the scheduled time or not. If it were to go over the scheduled time, the next scheduled appointment would experience wait time. If not, then there is resource idle time, which is further explained in the next performance metric.

The simulated durations for each scheduled appointment on a given day in the planning horizon are computed using Normal Distributions in @Risk. To simulate these values, the means (μ) and standard deviations (σ) for the durations of each demand type were used and estimated based on observational data. The specific values used were previously mentioned above, but can be found in Appendix U. To prevent negative simulated appointment durations, the Normal Distribution values were truncated at 0, meaning that appointment durations could not be less than 0 minutes long.

Resource Idle Time

It corresponds to the total number of minutes resources are not providing care to families on a given day in the planning horizon. Resources experience idle time when they finish an appointment ahead of schedule. The objective is to have a low idle time as it is unused capacity. The formula used to compute this performance metric is the following:

$$S_m^t = \max\{y_{m-1}^t - (W_{m-1}^t + x_{m-1}^t), 0\} \quad \forall t, m = 1, \dots, M_t$$

The total number of minutes resources are idle for is calculated by summing the total idle time experienced on a given day in the planning horizon. The results of this computation can be found in Appendix T. To compute the idle time (if experienced) associated with an appointment, the planned appointment length of the previous appointment is subtracted by the simulated appointment duration plus the wait time (if any) of the appointment. This computation determines if appointments finish ahead of schedule.

Overtime

It corresponds to the total number of minutes the clinic runs longer than expected on a given day. The objective is to obtain a low overtime as it is a consequence of delays in the schedule and requires resources to work longer than anticipated. The following formula is used to compute this performance metric:

$$O_t = \max\{W_{M_t}^t + (x_{M_t}^t - y_{M_t}^t), 0\} \; \forall t$$

Since wait times are rolled forward throughout the day, overtime is simply the "wait time" (if any) generated by the last appointment on a given day. This is computed by taking the difference between the simulated appointment duration and the planned appointment length of the last scheduled appointment of the day, plus the wait time associated with it. If there is no overtime experienced at the end of the day, then the value provided by the formula is simply 0. The results of this performance metric can be found in Appendix T.

Output

Based on the values obtained for the various performance metrics outlined above, the next step is to compute the various model outputs. The aim of computing the various outputs described below is to evaluate the performance of the model based on its configuration.

Service Level

This output evaluates how well the available resource capacity meets the demand for care at the clinic. The objective is to have a high service level as it illustrates that the demand is being served in a timely manner by the resource capacity available. The desired service level depends on the circumstance, where a service level of 100% may not be feasible because it would require a large amount of resource capacity to be available. The formula used to calculate the service level is the following:

$$SL = \frac{\sum_{t=1}^{T} SL^t}{\sum_{t=1}^{T} \sum_{i=1}^{I} d_{it}}$$

The service level is computed by taking the total number of appointment slots provided within 3 days from when requested and dividing it by the total number of appointment slots requested over the planning horizon. This computation is done across all demand types as well as for each individual demand type. The formula above is combined with the @Risk output function to compute the percentage of families receiving their appointments within 3 days from when requested. The result of this output demonstrates the level of demand being met based on the available resource capacity.

Average Patient Wait Time

This corresponds to the average number of minutes a family would have to wait for their scheduled appointment. This is computed by taking the total average patient wait time and dividing it by the number of days in the planning horizon. This output computes the average patient wait time experienced across the entire planning horizon. The objective is to lower this output value as it reflects delays in the schedule. The following formula, in conjunction with the @Risk output function, is used to compute the average patient wait time output:

$$\bar{W} = \frac{\sum_{t=1}^{T} \bar{W}_t}{T}$$

Average Resource Idle Time

This corresponds to the average number of minutes resources are not providing care to families. This is computed by taking the total resource idle time and dividing it by the number of days in the planning horizon. This output computes the average resource idle time experienced across the entire planning horizon. The objective is to lower this output value as it indicates that resources are not being properly utilized. The following formula, in conjunction with the @Risk output function, is used to compute the average resource idle time output:

$$\bar{S} = \frac{\sum_{t=1}^{T} \sum_{m=1}^{M_t} S_m^t}{T}$$

Average Overtime

This corresponds to the average number of minutes resources must stay longer than anticipated at the clinic to fulfill all scheduled appointments. This is computed by taking the total overtime and dividing it by the number of days in the planning horizon. Similar to the average patient wait time and average resource idle time, this output computes the average overtime experienced across the entire planning horizon. The objective is to lower this output value as it can result in additional operating costs for the clinic. The following formula, in conjunction with the @Risk output function, is used to compute the average overtime output:

$$\bar{O} = \frac{\sum_{t=1}^{T} O_t}{T}$$

Average Number of Diversions

This corresponds to the average number of appointment slots that cannot be scheduled within 5 days from when requested. The average number of appointment slots diverted is computed by taking the total number appointment slots diverted and dividing it by the number of days in the planning horizon. The objective is to lower this output value as the aim is to provide timely follow-up appointments at the clinic and not elsewhere. The following formula, in conjunction with the @Risk output function, is used to compute the average number of appointment slots diverted:

$$\bar{E} = \frac{\sum_{t=1}^{T} \sum_{i=1}^{I} E_i^t}{T}$$

Average Number of Days to Assigned Appointment

This corresponds to the average number of days from when appointment slots are requested to when they are scheduled. This is computed by taking the proportion of appointment slots scheduled 1, 2, 3, 4, or 5 days from when requested and multiplying each proportion by the corresponding number of days waited. The proportions are computed considering all operating days by taking the total number of appointment slots scheduled 1, 2, 3, 4, or 5 days from when requested and dividing it by the total number of appointment slots scheduled. The objective is to lower this output to ensure families receive their appointments in a timely manner. The following formula, in conjunction with the @Risk output function, is used to compute the average number of days waited to an assigned appointment:

$$\bar{D} = \frac{\sum_{n=1}^{N} n \times \left(\sum_{t=1}^{T} \sum_{i=1}^{I} A_{in}^t\right)}{\sum_{t=1}^{T} \sum_{i=1}^{I} (d_{it} - E_i^t)}$$

Practical Application

The next step in the model creation process was to conduct a simulation exercise to showcase the model in practice. As previously mentioned, the simulation results presented in this section are for illustrative purposes only as the demand and the resource capacity inputs are rough estimates computed from the information available.

Demand & Resource Inputs

Demand Inputs

The first step in conducting the simulation was to estimate the demand values entered into the model. Without any follow-up data, the demand inputs had to be estimated to gain a sense of what values should be entered. These values were obtained through a number of calculations and assumptions.

Estimating the demand input values began by defining the type of appointments or services associated with each demand type. This information as well as the amount of time required for each appointment is outlined in Table 9. For each demand type, Table 9 shows the planned amount of time that is reserved within the schedule to complete the appointment as well as the required number of appointment slots needed in the schedule for the appointment.

Table 9: Appointment Type Assigned to Each Demand Type

Demand Type	Appointment Type	Allocated Appointment Length (minutes)	Number of Required Appointment Slots
Demand #1	First follow-up appointment	30	1
Demand #2	Second follow-up appointment	60	2
Demand #3	Third follow-up appointment	90	3
Demand #4	Breastfeeding support appointments	120	4

As shown in Table 9, appointments scheduled under Demand #1 include first follow-up appointments that are provided within 72 hours after hospital discharge. Based on discussions with stakeholders, it was determined that the initial follow-up appointment after discharge takes approximately 30 minutes to complete. Appointments scheduled under Demand #2 are for second follow-up appointments. The first follow-up appointment is an overall assessment, but a subsequent appointment could focus on further monitoring any concerns and could take additional time; therefore, these appointments are allocated 60 minutes. Appointments scheduled under Demand #3 include third follow-up appointments where mothers and newborns may need additional support after the first two appointments. This can include mental health assessment appointments for mothers or tongue-tie release procedures for newborns. These appointments are allocated 90 minutes. Finally, appointments scheduled under Demand #4 include breastfeeding support appointments with a length of 120 minutes. Usually, the care provider will provide support, leave the mother and newborn to breastfeed and return to see how they are doing. However, it is assumed that the resource is present for the entire duration of the appointment.

After identifying the type of appointments associated with each demand type, the next step was to estimate the demand values to enter into the model. This was done by estimating the daily demand for follow-up appointments from the data obtained for this thesis. The data obtained from Quinte Health Care included the yearly average birthing volume in the Quinte Health Care region over 5 years from 2014 to 2018. This includes births delivered by both midwives and physicians. From this data, the yearly average number of births was estimated, which was computed to be 1,500 births per year. Twins were included in this estimate as only a low proportion of births (approximately 3%) were multiple births at Quinte Health Care. Thus, the 1,500 births were translated into approximately 1,500 families requiring a follow-up appointment per year.

The next step was to estimate the total yearly number of appointment requests at the clinic. Of the estimated 1,500 newborns per year, a proportion of families would have their delivery and follow-up appointment with a midwife. Based on data from 2017, approximately 16% of deliveries are done by a midwife; therefore, of the 1,500 newborns, it is estimated that 240 newborns would have a midwife (CAM, 2018). Subtracting midwifery deliveries, the yearly demand decreases to 1,260 newborns. Of the remaining 1,260 newborns, they could either complete the follow-up appointment with a physician or a nurse practitioner. However, the proportion of newborns that completed the follow-up appointment with a physician or nurse practitioner was not obtained. Additionally, based on a survey conducted by CMNRP, of the 200 women surveyed, only 1 participant completed the follow-up appointment with a nurse practitioner (Cantin & Rivard, 2017). For simplicity, it was assumed that the 1,260 newborns would most likely complete the follow-up appointment with a physician as it seems that only a small proportion of follow-up appointments are done by a nurse practitioner.

Of the estimated 1,260 newborns, a proportion would not have timely access to a physician to complete the follow-up appointment. For this simulation purpose, it was assumed that those who do not have timely access to a physician would visit the clinic, though in practice, the clinic is meant to be available to anyone. Data obtained from IC/ES was used to estimate the proportion of newborns who do not receive a timely follow-up appointment with a physician. Based on this data, approximately 34% of newborns had the follow-up appointment completed within five days after birth (IC/ES, 2020). Five days after birth was chosen as the threshold because the follow-up appointments were counted from time of birth rather than from time of discharge. From CIHI data from 2018-2019, the average hospital length of stay was 48 hours, and the recommended timeframe to complete the follow-up appointment is within 72 hours after hospital discharge (CIHI, 2020). Thus, follow-up appointments completed within 5 days were considered to account for hospital length of stay.

Based on the estimates above, it can be assumed that 66% of newborns do not complete the follow-up appointment within the recommended timeframe. To further estimate the daily demand for postpartum care at the clinic, the yearly number of newborns that would require an appointment at the clinic was computed. This was done by taking the 66% of the estimated 1,260 newborns, which results in 830 newborns. This value (830) represents the average number of newborns that would require a visit to the clinic within a year.

With an average of 830 newborns visiting the clinic on a yearly basis, the next step was to determine the total number of appointments that would be requested at the clinic over a year. Based on discussions with stakeholders, families require multiple follow-up appointments with a minimum of two follow-up appointments. Typically, low-risk births would have two to three follow-up appointments, depending on the amount of care needed. Based on this, it was assumed that every newborn visiting the clinic would require at least two follow-up appointments. Then, it was assumed that 25%, which is estimated based on observations made at the postpartum clinic, of newborns (approximately 210) would return for a third follow-up appointment. Accordingly, the clinic would receive around 1,870 appointment requests per year.

The final step in estimating the average number of appointment requests at the clinic per year was to consider any other appointment types not already considered. This would include breastfeeding support appointments. Breastfeeding support is regularly provided at follow-up appointments; however, sometimes additional support is provided to the mother if needed. Based on findings from the Public Health Agency of Canada, approximately 25% of women stop breastfeeding their infant prior to one month of age (2017). Based on this, it was assumed that approximately 25% of the 830 newborns would require breastfeeding support. This translates into approximately 210 breastfeeding support appointments at the clinic over a year. Thus, based on these various estimates and calculations, the clinic would receive approximately 2,080 appointment requests per year. Table 10 provides a summary of the estimations on the average yearly number of appointment requests based on appointment type.

Table 10: Yearly Demand Breakdown

Appointment Type	Estimated Yearly Number of Appointments
First follow-up appointment	830
Second follow-up appointment	830
Third follow-up appointment	210
Breastfeeding support	210
Total	**2,080**

Knowing the yearly number of appointment requests, the next step was to compute the demand inputs to be entered into the model. This first began by estimating the daily number of appointment requests. The estimated yearly number of appointment requests was divided by 250 days for each appointment type (i.e., first follow-up, second follow-up, etc.). This provided an estimate on the daily number of appointment requests per appointment type. The results can be found below in Table 11.

Table 11: Estimated Daily Number of Appointment Requests

Appointment Type	Estimated Daily Number of Appointment Requests
First follow-up appointment	3
Second follow-up appointment	3
Third follow-up appointment	1
Breastfeeding support	1
Total	**8**

The next step was to estimate the demand inputs entered into the model based on the values obtained in Table 11, which provided a base estimate. The demand inputs represent the daily number of appointment requests over a five-day period. As previously mentioned, the purpose of the simulation exercise was to evaluate the functionality of the model instead of predicting the service level for a particular situation. Rather than inputting arbitrary numbers as demand inputs, the demand inputs were informed by the calculations made earlier in Table 11 and by the data collected for this thesis. For the demand input values chosen it was assumed there would be more demand for first follow-up appointments as families may complete subsequent appointments with their primary health care provider, that there would be fluctuation in the demand throughout the week as seen at the postpartum clinic and that there would be less resource capacity available on days 2 and 4, which was also seen at the postpartum clinic. Ultimately, the demand inputs are estimates but the values chosen were selected as best as possible with the information available. A breakdown of the estimated demand inputs can be found in Table 12.

Table 12: Estimated Model Demand Inputs

Day	Demand #1	Demand #2	Demand #3	Demand #4
1	3	2	1	1
2	1	1	0	1
3	3	2	1	0

4	1	1	0	1
5	2	2	1	1
Total	**10**	**8**	**3**	**4**

The demand inputs shown in Table 12 correspond to the means used in @Risk to simulate the daily demand through a Poisson Distribution, which is simulated for each demand type for each day in the planning horizon. Based on earlier calculations for the estimated yearly number of appointment requests, appropriate estimations were made for Demand #1, #2, #3 and #4.

Resource Capacity Inputs

For establishing the resource capacity inputs, it was determined that the number of appointment slots available from resources would change over the booking horizon. This is to go along with any increases or decreases in the number of appointment requests throughout the week. Therefore, days 1, 3 and 5 were assumed to be the busiest and have the most capacity with three-full day nurses scheduled, while days 2 and 4 would be less busy and have less capacity with three-half day nurses scheduled. This is based on observational data obtained for this thesis. For example, the postpartum clinic schedules one full-day nurse once a week, two full-day nurses twice a week, and one-full day and one-half day nurse three times a week. A full breakdown of the number of 30-minute appointment slots available from each resource on each day of the booking horizon can be found in Table 13.

Table 13: Estimated Resource Capacity Inputs

Day	Resource #1	Resource #2	Resource #3
1	15	15	15
2	8	8	8
3	15	15	15
4	8	8	8
5	15	15	15
Total	**61**	**61**	**61**

With full-day resources scheduled on days 1, 3 and 5, 15 30-minute appointment slots are available on these days. This translates to 7.5 hours being available from each resource, each of these days. Each resource is scheduled for 7.5 hours rather than 8 hours to accommodate for a lunch break of 30 minutes. With half-day resources scheduled on days 2 and 4, 8 30-minute appointment slots are available. This translates into 4 hours being available from each resource, each of these days. For the purpose of the simulation, the inputted number of appointment slots available from each resource is the same across all three resources.

Model Simulation & Results

With the demand and the resource capacity input values estimated, the next step was to perform the simulation. A base case clinic configuration was evaluated based on the inputs specified earlier, with the results outlined below in the *Simulation Results* sub-section. Additionally, to observe different results achieved by the model, 26 other clinic configurations were considered with different values for the resource capacity and planned appointment lengths. The scheduling rule input, however, was left unchanged. Furthermore, the mean and standard deviation values used to simulate the appointment durations were left unchanged as they were estimated based on observational data. The results for these other configurations can be found in the *Numerical Analysis* sub-section. Therefore, a total of 27 simulations of 100 replications each were completed in @Risk, where each simulation took less than 10 minutes to produce results.

Simulation Results

This scenario is based on the demand and the resource capacity inputs estimated earlier in the *Demand Inputs* and the *Resource Capacity Inputs* sub-sections. Based on the pre-specified demand inputs, resource capacity inputs, and scheduling rule used for this clinic configuration, the outputs for this configuration can be found in Table 14.

Table 14: @Risk Output – Simulation # 1

Performance Metric	**95% Confidence Interval**
Service Level (Demand #1) [%]	99.82 +/- 0.10
Service Level (Demand #2) [%]	99.67 +/- 0.13
Service Level (Demand #3) [%]	99.18 +/- 0.26
Service Level (Demand #4) [%]	98.72 +/- 0.32
Service Level (Demand # 1 – 4) [%]	99.31 +/- 0.19
Average Patient Wait Time [minutes]	4.97 +/- 0.10
Average Resource Idle Time [minutes]	94.27 +/- 0.82
Average Overtime [minutes]	8.26 +/- 0.24
Average Number of Diversions [appointment slots]	0.00 +/- 0.00
Average Number of Days to Assigned Appointment [days]	1.36 +/- 0.02

As can be seen from Table 14, the results obtained from @Risk were quite favourable. The average service level for all demand types is quite high at 99.31% with a margin of error of 0.19%. Furthermore, the average service level for each demand type is almost 100%, meaning that families are being scheduled for their follow-up appointments within 72 hours from when it was requested. The average service level is quite high due to the large amount of capacity available. This can be further supported by the average number of appointment slot diversions, which is 0, and the average number of days waited for an assigned appointment, which is 1.36 days with a margin of error of 0.02 days. The simulation results show that the resource capacity adequately meets the number of appointment slots requested, but not very efficiently.

The remaining outputs are all quite favourable except for the average resource idle time. The average patient wait time is 4.97 minutes with a margin of error of 0.10 minutes and the average overtime is 8.26 minutes with a margin of error of 0.24 minutes. This suggests that appointments, in general, are completed by their scheduled time. However, the average resource idle time is 94.27 minutes with a margin of error of 0.82 minutes, which is quite high. This is to be expected, however, as there is a lot of resource capacity available, and the average service level is close to 100%. This may mean that there is a number of appointment slots being left unscheduled.

The large amount of average resource idle time could also be attributed to appointments finishing ahead of schedule. This could be caused by lengthier Demand #3 and Demand #4 appointments finishing much earlier than scheduled. For this clinic configuration, Demand #3 is allocated 90 minutes per appointment, while Demand #4 is allocated 120 minutes. Therefore, finishing these appointments ahead of schedule could have a significant impact on the average resource idle time experienced. To adjust the value of the average resource idle time, the planned appointment lengths would need to be adjusted, which will be further illustrated later. In this case, planned appointment lengths for Demand #3 and Demand #4 could be shortened. To further illustrate the results attained from this simulation, four box plots representing the distribution of the results can be found in Appendix V.

Numerical Analysis

The simulation results for the base case described above is quite favourable. However, is quite unrealistic. To achieve a service level close to 100%, the system requires a large amount of resource capacity, which is very costly. With this in mind, 26 other clinic configurations were simulated to observe the performance of the system under different input parameters. These additional clinic configurations were defined based on the components of the model that can be adjusted, corresponding to the key factors a manager of a postpartum nurse practitioner-led clinic would be interested in if the model were to be used in practice.

One of the inputs a manager of a clinic would have control over include the planned appointment lengths. The planned appointment lengths reserve a certain amount of time in the schedule for the appointment being scheduled. As previously mentioned, the planned appointment lengths are a multiple of one another for the different demand types. Furthermore, the shortest appointment length dictates the length of the appointment slots available from resources. For example, the shortest appointment length was 30 minutes for the base case mentioned earlier, which means that an appointment slot available from resources is 30 minutes long. In this section, we set the planned appointment length at 20 minutes, meaning Demand #1 is allocated 20 minutes, Demand #2 is allocated 40 minutes, Demand #3 is allocated 60 minutes, and Demand #4 is allocated 80 minutes. We also considered a planned appointment length of 45 minutes, meaning Demand #1 is allocated 45 minutes, Demand #2 is allocated 90 minutes, Demand #3 is allocated 135 minutes, and Demand #4 is allocated 180 minutes. Based on the planned appointment lengths, the number of appointment slots available from the different resources were adjusted accordingly.

Another input a manager would have control over is the resource capacity available. The resource capacities were adjusted by changing the number of hours resources are available to provide care and by changing the number of resources scheduled. The number of available hours were adjusted because, as previously mentioned, nurse practitioners receive minimal funding for administrative and operational support (van Soeren et al., 2009). This suggests that a nurse practitioner-led clinic may require resources to spend part of their day completing administrative and/or operational duties. Thus, adjustments were made to the number of hours full-time and part-time resources have available to see families. Additionally, the number of resources scheduled to work at the clinic on a given day was adjusted. This was done to illustrate the impact of fewer resources being scheduled on a daily basis. Due to limitations in the model, where each resource on a given day must have the same number of appointment slots available, the number of resources scheduled was adjusted by changing the number of appointment slots available by a certain percentage. Based on the number of hours resources work, the number of appointment slots available was adjusted respectively for each scenario by 25% and 50%. This means the number of appointment slots available was adjusted from 100% to 75% and 50%. Table 15 displays the levels of the different factors considered in the numerical analysis.

Table 15: Numerical Analysis – Levels of The Different Factors Being Considered

Input	Levels		
Resources workday length	7.5 hours (full-time); 4 (part-time) hours	6 hours (full-time); 4 (part-time) hours	5 hours (full-time); 3 (part-time) hours
Resources scheduled (appointment slots)	100%	75%	50%
Planned appointment lengths	20 minutes	30 minutes	45 minutes

With the different values presented in the table above, 27 different clinic configurations were defined (full factorial design). An example of the inputs entered into the model, more specifically the resource capacity inputs, for one of the configurations can be found in Table 16. The entire list of configurations, with their corresponding inputs, can be found in Appendix W.

Table 16: Configuration Example

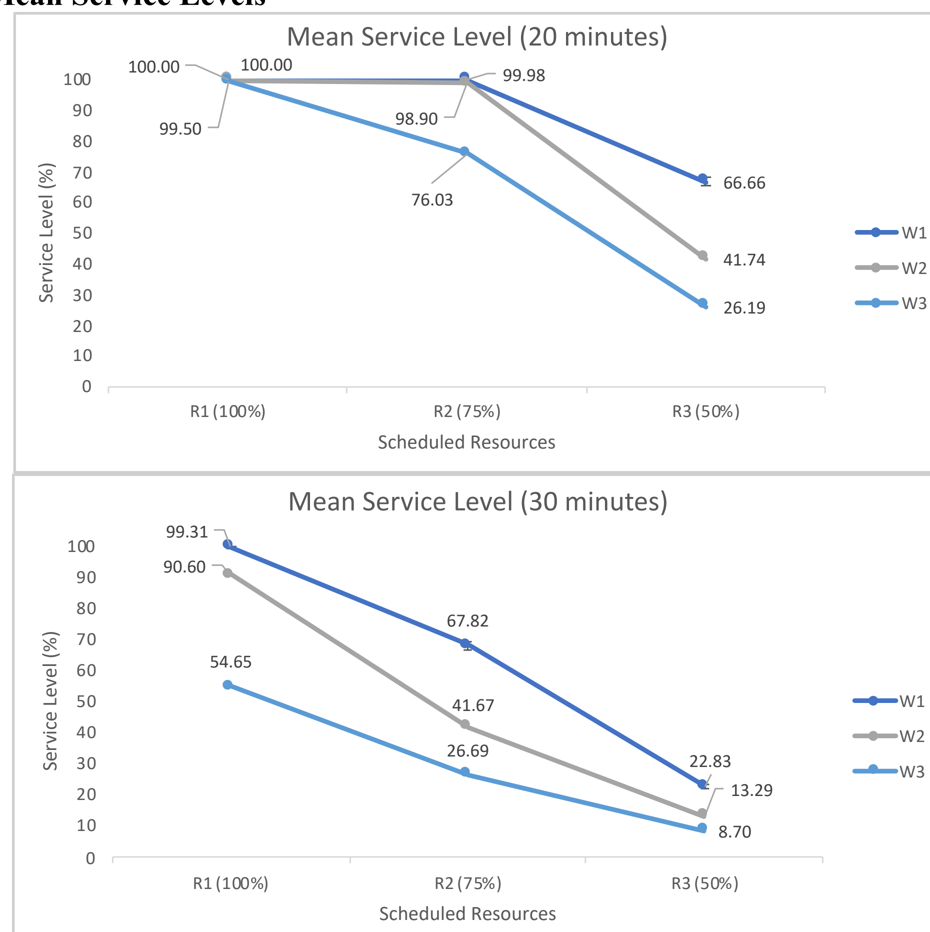
Appointment Length (20 minutes)				
Resource Workday Length (Full-time = 7.5 hours; Part-time = 4 hours)				
Resource Capacity Level (75%)				
Configuration 2		Resource #1	Resource #2	Resource #3
	Day 1	17	17	17
	Day 2	9	9	9
	Day 3	17	17	17
	Day 4	9	9	9
	Day 5	17	17	17

As previously mentioned, certain inputs of the model were left unchanged. This can be seen as a limitation of the model as some of them are typically inputs a manager could have control over. For example, the advance scheduling policy and the scheduling order were left unchanged as they are part of the model structure and would require manual adjustments. Furthermore, the mean and standard deviation values used to simulate the appointment durations were left unchanged as appointment durations are considered out of the manager's control. The same for demand rates.

The simulation results for the 27 configurations identified earlier can be found in Appendix X. To summarize and illustrate the results, Figures 3 to 6 display the mean values for the service level, average resource idle time, average overtime and average number of days families must wait for their assigned appointment, for the different factor level combinations. These performance metrics were chosen as they provide an overview of the model's performance in areas that a manager would be most interested in. Each subgraph corresponds to a specific appointment length (20, 30, and 45 minutes). They illustrate the performance obtained for the level of appointment slots available (defined as R1 for 100% available, R2 for 75% available, and R3 for 50% available) for each workday length (defined as W1 for 7.5 hours (full-time) & 4 (part-time) hours, W2 for 6 hours (full-time) & 4 (part-time) hours, and W3 for 5 hours (full-time) & 3 (part-time) hours). Furthermore, the graphs include a 95% confidence interval for each mean value but in most cases, the intervals are difficult to see as the values are very small.

Beginning with the mean service levels, which are depicted in Figure 3, it can be seen that they decrease as the resource capacity decreases. The reduced resource capacity is due to the reduced number of hours resources are available and the reduced number of resources scheduled. Both factors have a similar effect on the mean service level. Furthermore, changing the planned appointment lengths has a large impact on the resource capacity in terms of the daily number of appointment slots available. For example, configurations with a shorter appointment length of 20 minutes have higher mean service levels compared to those with a longer appointment length of 45 minutes. This outcome is due to a larger number of appointment slots being available from resources, which allow them to provide more appointments within 72 hours from when requested.

Figure 3: Mean Service Levels



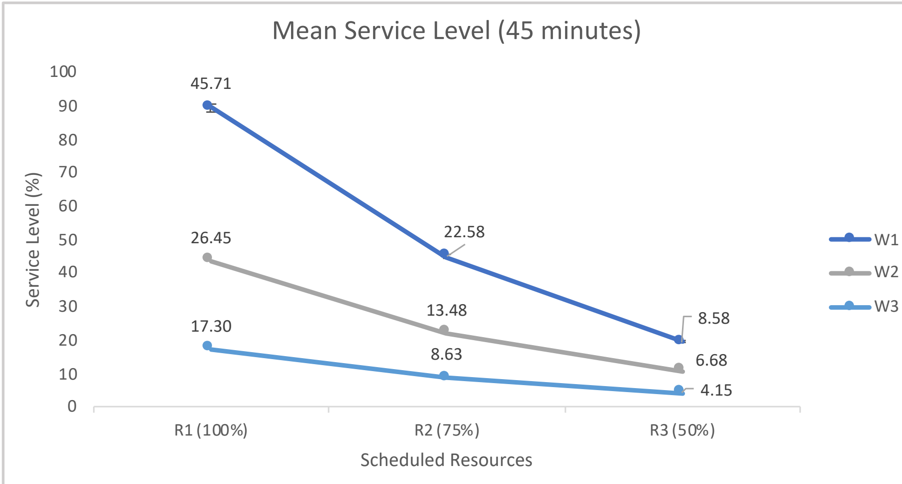


Figure 4 shows the mean average resource idle times for the different factor level combinations. From the corresponding subgraphs, it can be seen that the mean average resource idle times are greatly affected by the change in the planned appointment lengths. For example, shorter planned appointment lengths create less resource idle time compared to lengthier ones. This trend can be seen in the subgraph with a planned appointment length of 20 minutes. This could be due to the planned appointment lengths being closer aligned to the mean and standard deviation values used to simulate the "actual" appointment durations. Therefore, adjusting the planned appointment lengths to be closer aligned to the mean and standard deviation values used to simulate "actual" appointment durations can reduce resource idle time.

Another observation made from Figure 4 is that longer planned appointment lengths can have a greater effect on decreasing the resource idle time when decreasing the number of resources scheduled. For example, the mean average resource idle times in the subgraph with a planned appointment length of 20 minutes is minimally affected by the decrease in the number of resources scheduled (R1, R2, and R3). However, it is greatly affected with longer planned appointment lengths, such as 30 and 45 minutes, where it decreases as fewer resources are scheduled. Additionally, between all three subgraphs, it can be seen that the resource idle time decreases as the workday length decreases (W1, W2, and W3). This trend is also impacted by the planned appointment lengths, where larger decreases in the average resource idle time are experienced with longer planned appointment lengths. For example, the subgraph with a planned appointment length of 45 minutes shows a larger change in the average resource idle time as the workday length decreases.

Figure 4: Mean Average Idle Times

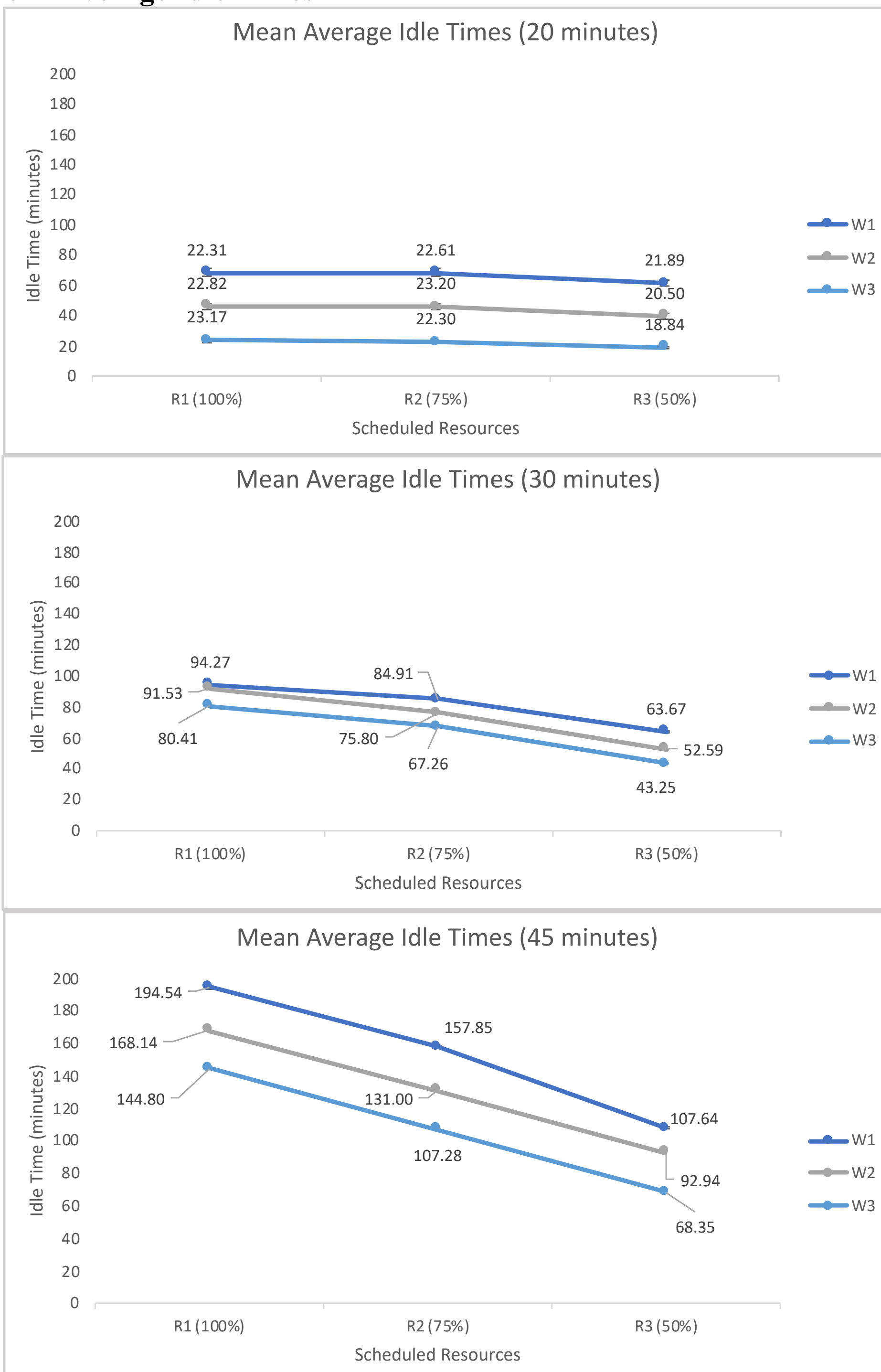
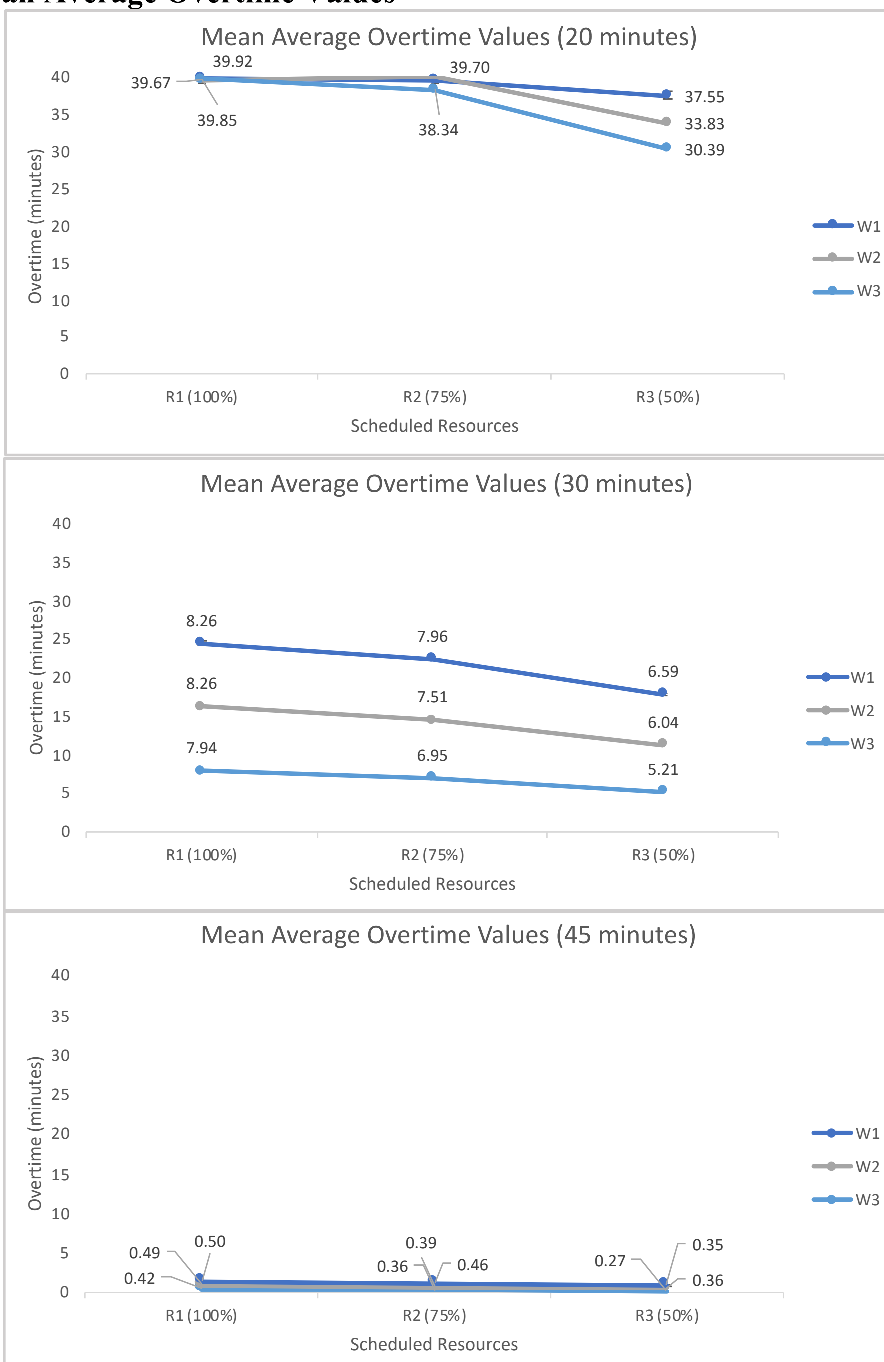


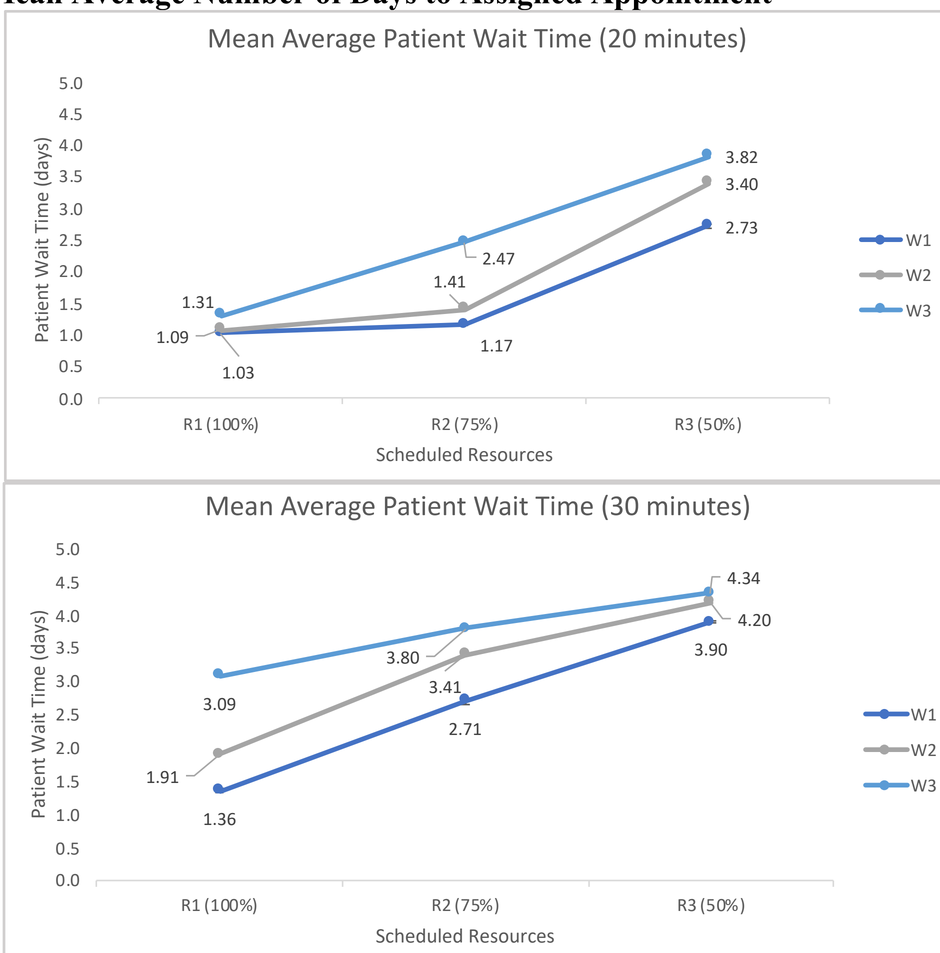
Figure 5 summarizes the mean average overtime. Though the mean overtime values are fairly similar within each subgraph, there seems to be a small decrease with less resource capacity being available. This is impacted by decreasing both the number of hours resources work and the number of resources scheduled. This result could be due to lengthier appointments being diverted elsewhere as there is less capacity available to fulfill these appointments and based on the scheduling order, would be the first to be diverted. Additionally, it can be seen that a large amount of overtime is experienced, on average, with shorter planned appointment lengths while less is experienced with longer planned appointment lengths. This is due to the mean and standard deviation values used to simulate the "actual" appointment durations. More overtime would be expected with shorter planned appointment lengths, while less would be expected with longer planned appointment lengths. This can be seen by comparing the subgraph with a planned appointment length of 20 minutes with that with a planned appointment length of 45 minutes.

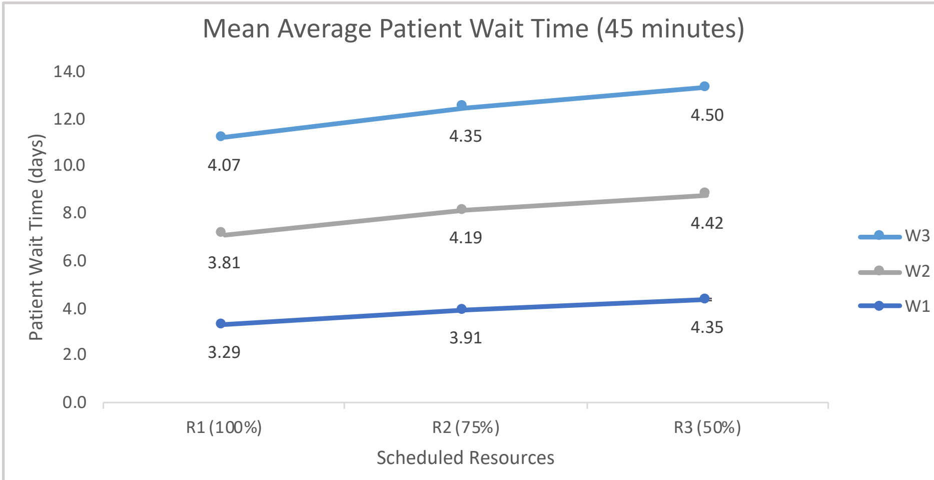
Figure 5: Mean Average Overtime Values



The last performance metric to be analyzed is the average number of days families must wait for their assigned appointment. The mean values for this performance metric can be found in Figure 6. It can be seen that the mean average number of days waited increases as the resource capacity decreases. This would be expected as there is less capacity available to meet the demand. This is impacted by decreasing both the number of hours resources work in a day and the number of resources scheduled. Additionally, the mean average number of days waited for an assigned appointment is impacted by the planned appointment length. Longer planned appointment lengths result in longer wait times, while shorter planned appointment lengths result in shorter wait times. This would be a result of the amount of capacity available, where less resource capacity is available with longer planned appointment lengths, which results in fewer appointment slots being available. Similar trends are experienced with the mean service level as both performance metrics are similarly affected by the resource capacity available.

Figure 6: Mean Average Number of Days to Assigned Appointment





The findings from these results provide some insight on the decisions a manager can make related to the resource capacity available at their clinic. If a manager is looking to reduce costs, they could staff fewer resources or reduce the number of hours they work. This decision would reduce salary expenses and the amount of resource idle time experienced. Furthermore, specialized resources are required for a postpartum nurse practitioner-led clinic to operate, such as lactation specialists. These candidates may be more difficult to hire because their qualifications are less common, resulting in a smaller pool being available. Thus, the clinic may not be able to staff as many resources. However, the drawback of reducing resource capacity is that it would increase how long families must wait for an appointment. Moreover, it would decrease the service level, where fewer families would be receiving their appointment within 72 hours. Another drawback is that resources would have a smaller patient roster with shorter workday lengths. This could be problematic where it may be more difficult to retain nurse practitioners as they are mandated by the government to see a certain number of patients within a year. Therefore, reducing the resource capacity could be financially beneficial but would be at the expense of the care provided to families.

If the clinic is looking to prioritize the care provided to families by offering timely appointments, then a manager could increase the resource capacity and time given to families during the appointment. Increasing the resource capacity would be costlier and could be achieved by hiring additional resources or increasing their workday lengths. With more resource capacity available, families can quickly receive an appointment and have timelier access. In addition, the clinic could also increase the planned appointment lengths, where families have more time with a resource at their appointment. This would also have the benefit of decreasing the overtime. However, without the appropriate availability, it could increase how long families must wait, in days, for an assigned appointment because it would require more time from resources. Therefore, a longer planned appointment length is beneficial to patients but the drawback is that it would increase resource idle time, where resources are being underutilized and can also increase how long families must wait for an assigned appointment.

As a manager of a clinic, the service level would be the primary output one would be concerned with. To better understand the significance of the interactions between the planned appointment length, the number of hours resources work, and the number of resources scheduled, on the service level, a three-way ANOVA was conducted. From this statistical analysis, it was found that each interaction was significant as they all had a $p-value$ less than 0.05. This suggests that there is a statistically significant association between the service level and these three factors. Furthermore, a Bonferroni Pairwise Comparison was done and identified 14 statistically different groupings.

Unfortunately, the results above are not reliable. This is due to the data not being normally distributed and containing unequal variances, which are the two main conditions required by an ANOVA test. For this reason, a two-sample t-test was conducted where required for the service level analysis. Referring to the subgraph of a planned appointment length of 20 minutes in Figure 3, the mean values of W1-R1 (100%), W2-R1 (100%), W3-R1 (99.50%), W1-R2 (99.98%), and W2-R2 (98.90%) look very similar. Since these five mean values do not look significant, ten two-sample t-tests were completed to identify if any two means are statistically significant. From these t-tests, it was found that the following combinations were not statistically significant as they had a $p-value$ greater than 0.05: W1-R1 & W2-R1, W1-R1 & W1-R2, & W2-R1 & W1-R2. This suggests that the differences between the means for these combinations are not significant.

From a systems point of view, a manager would be concerned with the average resource idle time and the average overtime. For the average resource idle time, a three-way ANOVA test was conducted. The three-way ANOVA test was valid for this performance metric as it met the required conditions (i.e., normality and equal variances). From this statistical analysis, it was found that each interaction was significant as they all had a $p-value$ less than 0.05. This suggests that there is a statistically significant association between the average resource idle time and the three factors (i.e., planned appointment length, number of hours resources work, and the number of resources scheduled).

Since the results of the three-way ANOVA are valid for the average resource idle time, the results of the Bonferroni Pairwise Comparison can be used to identify groups that are statistically different. In total, the Bonferroni Pairwise Comparison identified 17 statistically different groupings. The Bonferroni Pairwise Comparison was used to analyze certain mean average resource idle times that seemed to be similar in the graphs depicted in Figure 4. For example, the subgraph of a planned appointment length of 30 minutes had similar values for W1-R1 (94.27) and W2-R1 (91.53). From the Bonferroni Pairwise Comparison, these two mean values are statistically different because they are in separate groupings. Additionally, the subgraph for the planned appointment length of 20 minutes shows an increase in the average resource idle time for mean values W1-R2 (22.61) and W2-R2 (23.20). From the Bonferroni Pairwise Comparison, these two mean values are in the same group; therefore, it cannot be concluded that they are statistically different. The results of the Bonferroni Pairwise Comparison can be found in Appendix Y.

The next performance metric is the average overtime. From the three-way ANOVA test, it was found that each interaction was significant as they all had a $p-value$ less than 0.05. However, the results are not valid because the ANOVA conditions are not met. Due to this, a two-way ANOVA test was completed for both planned appointment lengths of 20 minutes and 30 minutes as the mean values obtained from both were closely related. The two-way ANOVA test was valid because the required conditions were met. From the two tests, each interaction was significant as they all had a $p - value$ less than 0.05. For the planned appointment length of 20 minutes, 5 groupings were identified in the Bonferroni Pairwise Comparison. From the subgraph in Figure 5, the mean values between all three workday lengths for R1 are quite similar (39.92, 39.67, and 39.85). From the Bonferroni Pairwise Comparison, W2-R1 and W3-R1 are in the same grouping; therefore, it cannot be concluded that they are statistically different. Furthermore, the mean values between all three workday lengths for R2 are also quite similar (39.70, 40.04, and 38.34). From the Bonferroni Pairwise Comparison, W1-R2 and W2-R2 are in the same grouping; therefore, it cannot be concluded that they are statistically different. For the planned appointment length of 30 minutes, 7 groupings were identified in the Bonferroni Pairwise Comparison. From the subgraph in Figure 5, the mean values between all three workday lengths for R1 are quite alike (8.26, 8.26, and 7.94). From the Bonferroni Pairwise Comparison, all three mean values are in the same grouping; therefore, it cannot be concluded if they are statistically different.

The mean average overtime values for the planned appointment length of 45 minutes did not satisfy the required conditions for the two-way ANOVA. Since each mean value from the subgraph in Figure 5 are quite similar, a total of 36 two-sample t-tests were completed for each combination. This was completed to identify if any two mean values are statistically significant. From the tests, 11 combinations were not statistically significant as they had a $p - value$ greater than 0.05. These combinations include: W1-R1 & W1-R2, W1-R1 & W2-R1, W1-R2 & W2-R1, W1-R2 & W3-R1, W1-R3 & W2-R2, W1-R3 & W3-R2, W2-R2 & W2-R3, W2-R2 & W3-R1, W2-R2 & W3-R2, and W2-R3 & W3-R2. This suggests that the differences between the means for these combinations are not significant.

From a patient's point of view, a manager would be concerned with the average number of days families must wait for an assigned appointment. The three-way ANOVA revealed that each interaction was significant as they each had a $p - value$ less than 0.05. However, the results are not valid because the ANOVA test does not meet the required conditions. Due to this, a number of two-sample t-tests were conducted to identify if there are any differences in the means. From Figure 6, the subgraph of a planned appointment length of 20 minutes shows similar mean values for W1-R1 (1.03), W2-R1 (1.09), and W3-R1 (1.31). Three two-sample t-tests were completed between all three mean values and found that each combination was statistically significant with a $p - value$ less than 0.05. Furthermore, the subgraph of a planned appointment length of 30 minutes shows similar means values for W2-R3 (4.20), and W3-R3 (4.34). A two-sample t-test was completed for these two means and concluded that they are statistically significant with a $p - value$ less than 0.05. This suggests that there is a difference in the means.

Overall, this numerical analysis showcases what adjustments managers can make to the model and their resulting impact. It can be seen that the decisions a manager can make for their clinic can have various impacts on the clinic's performance. What a manager decides is based on what needs to be prioritized and what he/she aims to achieve. For instance, if a manager is looking to maximize the overall resource utilization then he/she is looking to reduce the resource idle time experienced. This can be done by shortening the planned appointment lengths. The effect, however, would be more overtime and less time given to families for their appointment. Additionally, this section statistically analyzes the significance of different interactions and mean values found in the different subgraphs outlined in Figure 3 to 6. Depending on the result, either a three-way ANOVA, two-way ANOVA or two-sample t-test was completed. These statistical tests provide insight on the significance of different mean values showcased in these subgraphs. Therefore, this section outlines and analyzes the resulting impact of different operational decisions managers can make. This can help assist future managers of a postpartum nurse practitioner-led clinic for scheduling resources at their clinic.

Discussion

The analytical model developed in this thesis provides a general design methodology for postpartum nurse practitioner-led clinics. For a predefined clinic configuration, it computes the associated service level, along with other outputs, through a Monte Carlo simulation. The predefined factors for a clinic configuration include the data and design inputs. The data inputs include the demand, represented as Poisson means, used to simulate the daily demand over 250 operating days, as well as the information used to simulate appointment durations. The design inputs include the resource capacity available over time and the defined appointment slot lengths, which are used to specify the number of appointment slots available from resources each operating day. Additionally, the other two design inputs are appointment priorities and the scheduling rule, which are used to determine the scheduling order of appointments. Based on these inputs, various outputs are simulated to evaluate the clinic's performance. The aim of this thesis was to create a capacity planning tool that can be adaptable to different communities; therefore, the predefined operational factors entered into the model can be manually adjusted to reflect different clinic configurations. Either pre-specified results are achieved based on the desired inputs or they can be achieved through trial-and-error by adjusting the values of the inputs.

The purpose of designing and implementing this model was to illustrate the feasibility of operating a postpartum nurse practitioner-led clinic. The model could help support the development of such clinics as it provides daily schedules and achieves outputs based on the entered data and design inputs. The daily schedules are evaluated through various outputs, which could provide an indication on the clinic's performance. For example, the average resource idle time and average overtime could illustrate how well resources are being utilized. Furthermore, from the patient's point of view, the average wait time could provide an indication of the service offering capable by the clinic. Finally, the service level, the average number of appointment slots diverted, and the average number of days waited for an assigned appointment slot, could provide support in assessing the clinic's capability in offering timely follow-up appointments.

The findings from this thesis could help support the development of postpartum nurse practitioner-led clinics. For example, the analytical model created could be utilized as a capacity planning tool. More details about its benefit and the benefits of postpartum clinics, will be further discussed in the following *Benefits* sub-section. However, there are some limitations associated with the model due to the nature of its design, which will be further discussed in the *Limitations* sub-section. Nevertheless, the findings of this thesis and the model designed as part of it, provide a lot of support in the development of postpartum nurse practitioner-led clinics. The preliminary research required for the development of these clinics was completed in this thesis, but it could be further expanded on in future research, which is further discussed in the *Future Research* sub-section.

Benefits

The development of postpartum nurse practitioner-led clinics in the community could yield many benefits. For one, the clinics could increase access to postpartum care for those who have difficulty attaining a follow-up appointment within 72 hours after hospital discharge. As illustrated in this thesis, attaining a follow-up appointment within 72 hours after hospital discharge could be difficult for some families. As previously mentioned, data from IC/ES suggests that approximately 66% of newborns do not receive a timely follow-up appointment with their physician (IC/ES, 2020). This could be due to families not having timely access to a physician or due to them not having a physician at all. Furthermore, based on the data obtained, it was observed that families of lower socioeconomic status were more likely to not complete the follow-up appointment after hospital discharge. With increased access to postpartum care, it would be possible that more families could receive timely follow-up appointments, which could improve the overall health of mothers and newborns in the community.

At the moment, if families cannot get timely access to their health care provider or do not have access to one, they will most likely resort to visiting emergency departments for care (Cargill et al., 2007). This could result in additional health care spending for the health care system because families would be using more expensive resources. If families had timely access to postpartum care, however, then they would be less likely to visit the emergency department. Therefore, increasing access to postpartum care could help divert families from emergency departments, which could be more cost effective and thus help contain health care costs.

In addition to decreasing emergency department visits, the postpartum nurse practitioner-led clinic model could be more cost effective compared to physicians. For example, in 2018, the gross payment in Ontario for a physician in family medicine was $309,000, while the gross payment for a nurse practitioner in a community-health setting was $103,000 (CIHI, 2019; Little, 2018). Furthermore, the nurse pracititoner-led model could be more cost effective following a salaried reimbursment model rather than a fee-for-service model. A study conducted in rural Alberta compared the cost of reimbursing a nurse practitoner between both models (Hunter et al., 2016). The study found that the fee-for-service model cost approximately $903.44 a day to reimburse a nurse practitioner, with the exclusion of chronic disease and rural service fees (Hunter et al., 2016). For the salary model, it was found that the daily cost of a nurse practitioner was $801.89 a day, which was $101.55 a day less compared to the fee-for-service model (Hunter et al., 2016). Though this study was conducted in Alberta, where the costs could differ from those in Ontario, it does suggest that a salary model for a nurse practitioner could be more cost effective compared to a fee-for-service model.

Another benefit to postpartum nurse practitioner-led clinics is that there would be emphasis on educating families about newborn care. As it is, families are meant to be educated prior to hospital discharge about life at home with their newborn; however, due to shortened postnatal lengths of stay, nurses in the hospital have less time to educate families. With less time available from nurses in the hospital, families may have less time to asks questions and feel prepared. This could result in them feeling overwhelmed and stressed. Therefore, there is greater emphasis to provide this information at the follow-up appointment. The follow-up appointment would be a good opportunity to educate families because families may feel more settled a few days after hospital discharge and be able to better retain the information provided to them. Thus, nurse practitioners at the postpartum clinic could take the time to educate families at the follow-up appointment, which could help families feel more prepared and confident about life at home with their newborn.

With nurse practitioners at postpartum nurse practitioner-led clinics emphasising education about newborn care to families at the follow-up appointment, they may also be able to better inform families about maternal newborn services available in the community. Since this type of clinic would be community based, they would be interconnected with other community services and be aware of the services available. Nurse practitioners could then promote these services by informing families about them during the follow-up appointment. This could result in more families accessing community services, which could help them while caring for their newborn.

As outlined, postpartum nurse practitioner-led clinics can have many benefits that could benefit families and the health care system. The clinic could allow more families to complete the follow-up appointment in a timelier manner compared to other care models. As seen in this thesis, many families do not seem to complete the follow-up appointment within 72 hours after hospital discharge. Therefore, postpartum nurse practitioner-led clinics could yield many benefits and could enrich the community where it is being implemented in.

Limitations

There are a number of benefits to postpartum nurse practitioner-led clinics, but the model developed to help support the implementation of them has some limitations. These limitations are related to the design of the model and what its capable of. Furthermore, as mentioned earlier, the data used to illustrate the model's performance has some limitations as well. Therefore, it is important to acknowledge these limitations so they can potentially be addressed in the future.

Firstly, it was difficult to obtain data on when newborns complete the follow-up appointment with their physician after hospital discharge. Over various months and meetings, many options were explored to try to obtain this data. Working with Quinte Health Care, it was found that neither the BORN database nor their hospitals internal databases collected this information. Since Quinte Health Care did not collect this data, other options were explored. A colleague connected us with a contact at The Ottawa Hospital who could possibly help us collect the data needed for this thesis. Multiple meetings were held to determine whether The Ottawa Hospital collected newborn follow-up data as they have various maternal-newborn units (i.e., Low Risk Pregnancy Unit, Maternal Fetal Medicine and a Neonatal Follow-up Clinic). Unfortunately, the hospital does not track when families complete the follow-up appointment after hospital discharge. However, exploring these various options led us to IC/ES, who thankfully could provide data on newborn follow-up appointments, specifically when newborns complete their first follow-up appointment with a physician.

Through the data collection process for this thesis, it was quite challenging to gather data on when follow-up appointments were completed after hospital discharge. This is because the data is not tracked in the health care system, resulting in it not being accessible for this thesis. To overcome this challenge, an estimate on when newborns complete the follow-up appointment after hospital discharge was obtained based on fee-codes entered into OHIP. The data obtained from IC/ES was the best estimate available to understand in practice when newborns complete the follow-up appointment after hospital discharge with their physician. The data collected could, however, be improved if the health care system began to start collecting and tracking follow-up appointment data. Doing this could help improve health care services in the future, as it would provide insight on the timeframe of when newborns actually receive follow-up appointments.

Due to follow-up appointment data being difficult to obtain, many of the values entered into the model to illustrate its application had to be estimated. The estimated inputs include the demand inputs used to simulate the daily demand, the resource capacity inputs, the planned appointment lengths, and the mean and the standard deviation values used to simulate the "actual" appointment durations. The drawback of using estimated values is that the results do not reflect reality. The output values obtained from the model, however, could provide a general indication of how the clinic would perform based on the inputs entered. To overcome this challenge, the input values entered into the model would need to be based on more accurate data.

Another limitation related to the model design is that manual adjustments are required to make changes to the model structure. For example, the model was designed under the assumption that the clinic would operate 5 days a week; therefore, the inputs entered are based on a 5-day cycle. To change the number of days in the cycle, manual adjustments are required. The number of days in the cycle is important because the associated input values drive the simulation and affect the schedule creation. Therefore, if the model is to be adjusted based on a 7–day cycle, where the clinic is open every day, long and tedious manual adjustments would be required.

Another shortcoming of the model is its scheduling capability. For one, there is a finite limit to the number of appointments that can be scheduled on a given day. No more than 50 appointments can be scheduled on a given day because any additional appointments would not be reflected in the average wait time, average resource idle time, and average overtime outputs. This is due to a limit on the number of appointments that can have their durations simulated, which is 50 appointments a day. Additionally, there is a limit on the number of days appointments can be scheduled for, which cannot exceed 250 operating days. To overcome these limitations, manual adjustments would be required. Furthermore, there are limitations to how resources are scheduled in the daily schedule. As previously mentioned, it was assumed that resources would be available for the entire duration of the scheduled appointment. Finally, closures of the clinic are not automatically reflected in the resulting schedules and need to be manually incorporated. Therefore, deviating from the current design or implementing additional features in the model could pose some challenges.

The final limitation to the implementation of the model is the cost of the program, @Risk, used to code and run the simulations. For this thesis, a student version of the program was utilized; however, regularly the @Risk software costs roughly between 2,000 to $3,000 USD, depending on the type of license. This could pose as a large challenge to many clinics, as they are typically small businesses with very limited budgets due to them being publicly funded. To utilize such a capacity planning tool, clinics would have to attain the budget for it. In addition, there could be a technological gap to using the program, where the clinic would need the appropriate computer/software to run the program. For example, @Risk can only run on a Microsoft Windows operating system. Finally, the last barrier is the potential learning curve to the program. Though it is used within Microsoft Excel, there are features of @Risk that need to be learned to conduct simulations. Therefore, there are some barriers that would need to be overcome to utilize this model in practice. Alternative solutions will be further discussed in the following *Future Research* sub-section.

Future Research

Though it has some limitations, the current model could be utilized as a capacity planning tool that could be quite beneficial to clinics. Future research could address the limitations outlined above and explore how to improve certain attributes of the model, which could make it more effective and easier to use. Furthermore, future research would be needed to better understand how to execute the implementation of postpartum nurse practitioner-led clinics in communities. This thesis explored the feasibility of these clinics and what would be required to operate them; however, additional research would be required to understand how to implement them in practice.

To use the model in practice, more precise data would be required. This could be achieved by using internal data from the health care organization using the model. Ideally, the health care organization would track the data that is required to be entered into the model. This data should include the daily demand, daily resource availability, appointment slot lengths, and appointment durations. Having this information would omit the need to estimate data values, which was done for this project as certain data variables were simply not available. If data cannot be obtained, however, the model would still be a useful planning tool for implementing clinics in the community because it would allow decision makers to evaluate the performance of the clinic based on defined inputs.

Changes could also be made to improve the scheduling order in the model. For example, at the moment, appointments are chronologically scheduled based on their demand type. In practice, however, this may not be the case where different demand types are scheduled throughout the week and within the day using different scheduling rules. Furthermore, with the current scheduling order, it is possible that the number of appointment slots scheduled is more or less than what is available from resources that day. For example, if the last appointment of the day requires 4 appointment slots, but 13 out of 15 appointment slots are already booked, then the last appointment is scheduled with 2 appointment slots left. This could lead to additional overtime for the clinic because the number of required appointment slots is not fully represented in the schedule for the appointment requested. This could be overcome through manual adjustments by scheduling appointments that fit the last few remaining slots available of the day. Therefore, changes could be made by expanding the model to incorporate more flexible appointment scheduling rules. This could have the benefit of minimizing patient wait times, resource idle time, and clinic overtime.

To expand the model and implement the features mentioned above, the model would most likely need to be re-created in a different software (e.g., a general-purpose programming language such as Java). Developing the model in a different software would minimize the limitations that are currently experienced in Microsoft Excel. It would allow, for example, for more sophisticated scheduling rules. Though, similarly to @Risk, there could be technological barriers for the user utilizing the software. Nevertheless, re-creating the model in a different software program could overcome many of the limitations outlined earlier in the *Limitations* sub-section.

In addition, future research could also look into better understanding the costs associated with a postpartum nurse practitioner-led clinic. For one, future research could investigate the cost of operating the clinic. This would include salary costs, equipment costs, rental costs and any other costs associated with running this type of clinic. Unfortunately, this information was not obtained for this thesis because it is not publicly available. It would most likely need to be obtained through discussions with other nurse practitioner-led clinics or through paid data. Furthermore, future research could also investigate the costs related to the clinic's performance. These costs would include resource idle time, patient wait time, clinic overtime, and patient diversions. Obtaining estimates for these performance metrics would allow for a cost analysis to be completed. This would be insightful for a manager of a clinic because it would facilitate the comparison of different clinic configurations (i.e., scheduling fewer/more resources, scheduling shorter/longer workdays or changing planned appointment lengths). Without proper cost value estimates, arbitrary numbers would need to be used, which would not be very accurate. Therefore, future research could investigate the different costs associated with a postpartum nurse practitioner-led clinic, which could help managers in their planning decisions.

Finally, the model was developed as a high-level tool to determine what a postpartum nurse practitioner-led clinic would be capable of; however, future research would be needed to understand the steps required to successfully implement these clinics in the community. This thesis studied nurse practitioner-led clinics but did not explore the cost, the details regarding the funding needed to operate them, the potential limitations faced while in operation, and other considerations. Thus, additional research would be required to further understand the practical implementation and operation of these clinics in the community, although, some information in the early chapters of this thesis could be certainly useful.

Conclusion

The model created for this thesis determines the expected service level achieved by a clinic configuration based on the entered inputs (i.e., daily appointment requests, daily resource availability, appointment lengths, etc.). This thesis focused on how postpartum nurse practitioner-led clinics would work and what is entailed to operate them. The model created could help support the development of these clinics; however, future research could help improve the model for practical use as there are some limitations to it. Nevertheless, there is a clear need for this model of care in the community since it could significantly improve access to postpartum care for families. This type of clinic would provide a wide range of health benefits to families in the community by providing timely postpartum care. This thesis illustrates that postpartum nurse practitioner-led clinics could add a lot of value to the community and to the health care system as a whole. Thus, in conjunction with the model developed, postpartum nurse practitioner-led clinics should be considered to be implemented in our health care system.

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Appendices

Appendix A: Nurse Practitioner-Led Clinic Implementation Roadmap

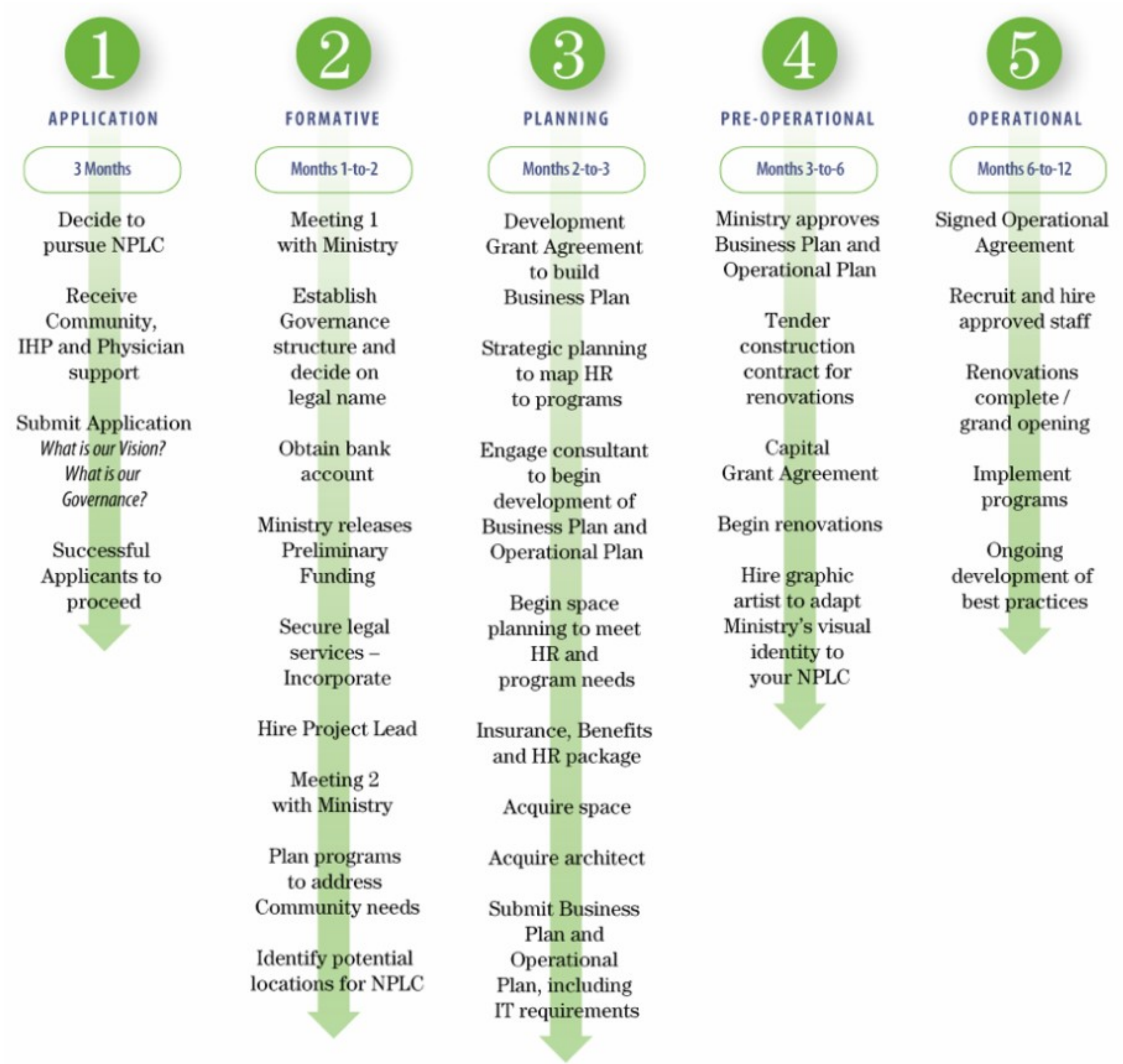


Figure from: Ministry of Health and Long-Term Care, *Guide to Completing a Nurse Practitioner-Led Clinic Wave 3 Application Form: A Guide Sheet* (Number 2), April 2010, Appendix 1, p. 14. https://collections.ola.org/mon/24005/301596.pdf

Appendix B: Literature Review Search

Database	• Pubmed • Google Scholar • University of Ottawa Library Database • Nursing and Allied Health Databases
Search	• Newborn AND early discharge AND follow-up • Nurse led newborn clinic • Follow-up appointments AND (newborns) • Infant follow-up appointment postdelivery • Postpartum health clinic • ((postpartum) AND follow-up) AND health clinic • (postpartum health clinic) AND follow-up • (community postpartum health clinic) AND follow-up • Nurse practitioner-led clinics • Nurse practitioner-led clinics AND follow-up • (postpartum) AND nurse practitioner-led clinics • newborn AND (nurse practitioner-led clinics) • (early discharge) AND nurse practitioner-led clinics • (community-based care model) AND postpartum • (nurse practitioner-led clinics) AND model • (nurse practitioner-led clinics) AND model* • (nurse practitioner-led clinics) AND modelling • (nurs* clinic model) AND newborn • (nurs* clinic schedule) AND newborn • (nurs* practitioner-led clinic) AND newborn AND follow-up • (nurs* clinic) AND (newborn OR infant OR postpartum) AND follow-up • (nurs* clinic) AND (newborn OR infant OR postpartum) AND follow-up AND (transition* care)

Appendix C: Article Categories

Category	Number of Articles	Articles
Nurse-led clinic performance	6	1. (Heale et al., 2016) 2. (Lieu et al., 2000) 3. (Murfet et al., 2014) 4. (Shiu et al., 2012) 5. (Heale et al., 2018) 6. (Sofer, 2018)
Postnatal length of stay	5	1. (Gupta et al., 2006) 2. (Chen et al., 2018) 3. (Harron et al., 2017) 4. (Bowers & Cheyne, 2015) 5. (Beake et al., 2005)
Follow-up appointments	4	1. (Britton, 1998) 2. (Galbraith et al., 2003) 3. (Feinberg et al., 2004) 4. (Milambo et al., 2018)
Patient satisfaction	2	1. (Heale & Pilon, 2012) 2. (Randall et al., 2017)
History of nurse-led clinics in Ontario	2	1. (*NP-led clinics Ontario leads the way*, 2011) 2. (Heale, 2012)
Postpartum clinic	1	1. (Hardy et al., 2018)
Patient characteristics	1	1. (Nowik et al., 2016)
Leadership within nurse-led clinics	1	1. (Gousy & Green, 2015)

Appendix D: Number of Articles per Country of Origin

Country	Number of Articles
Canada	9
United States	3
Canada/United States	1
United Kingdom	4
Australia	2
South Africa	1
India	1
Hong Kong	1

Appendix E: Article Country of Origin by Reference

Article Reference	**Country**
(Britton, 1998)	Canada and United States
(Galbraith et al., 2003)	United States
(Gupta et al., 2006)	India
(Feinberg et al., 2004)	United States
(Milambo et al., 2018)	South Africa
(Heale et al., 2016)	Canada
(Lieu et al., 2000)	United States
(Heale & Pilon, 2012)	Canada
(Gousy & Green, 2015)	United Kingdom
(Hardy et al., 2018)	Canada
(Nowik et al., 2016)	Canada
(Randall et al., 2017)	Australia
(Murfet et al., 2014)	Australia
(Chen et al., 2018)	Canada
(Harron et al., 2017)	United Kingdom
(*NP-led clinics Ontario leads the way*, 2011)	Canada
(Shiu et al., 2012)	Hong Kong
(Heale et al., 2018)	Canada
(Sofer, 2018)	Canada
(Heale, 2012)	Canada
(Bowers & Cheyne, 2015)	United Kingdom
(Beake et al., 2005)	United Kingdom

Appendix F: Phototherapy Curve

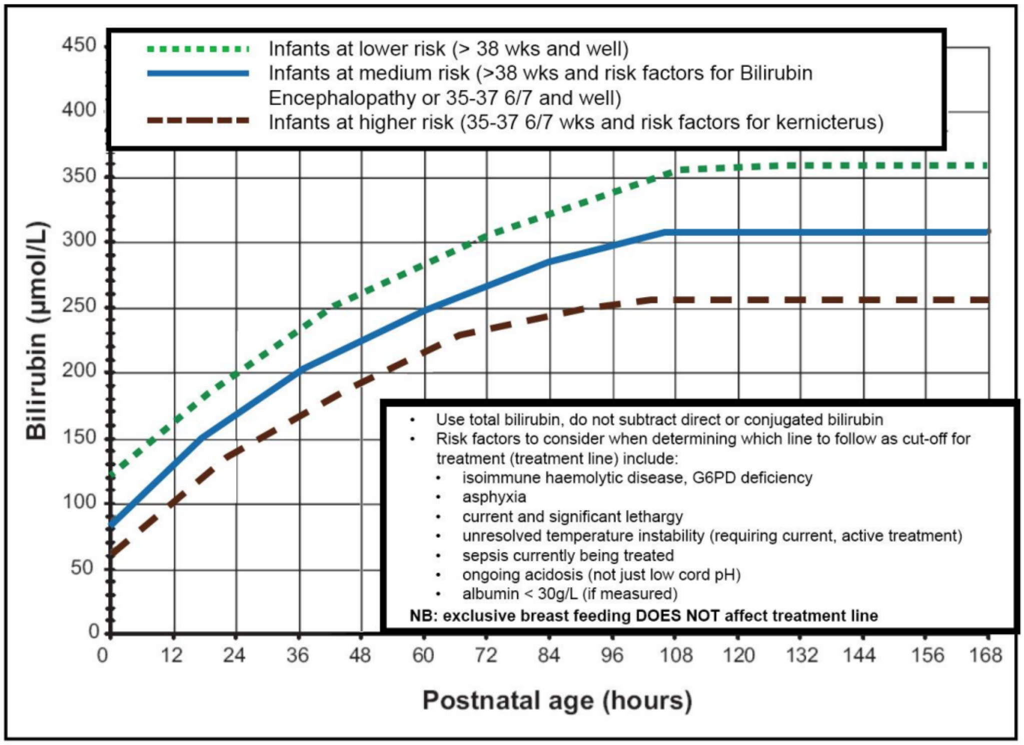


Figure from: Ministry of Health and Long-Term Care, *Clinic Pathway Handbook for Hyperbilirubinemia in Term and Late Pre-Term Infants (>=35 weeks)*, December 2017, Related Figures, p.15. http://www.health.gov.on.ca/en/pro/programs/ecfa/docs/qbp_jaundice.pdf

Appendix G: Risk Zones on Hour Specific Nomogram

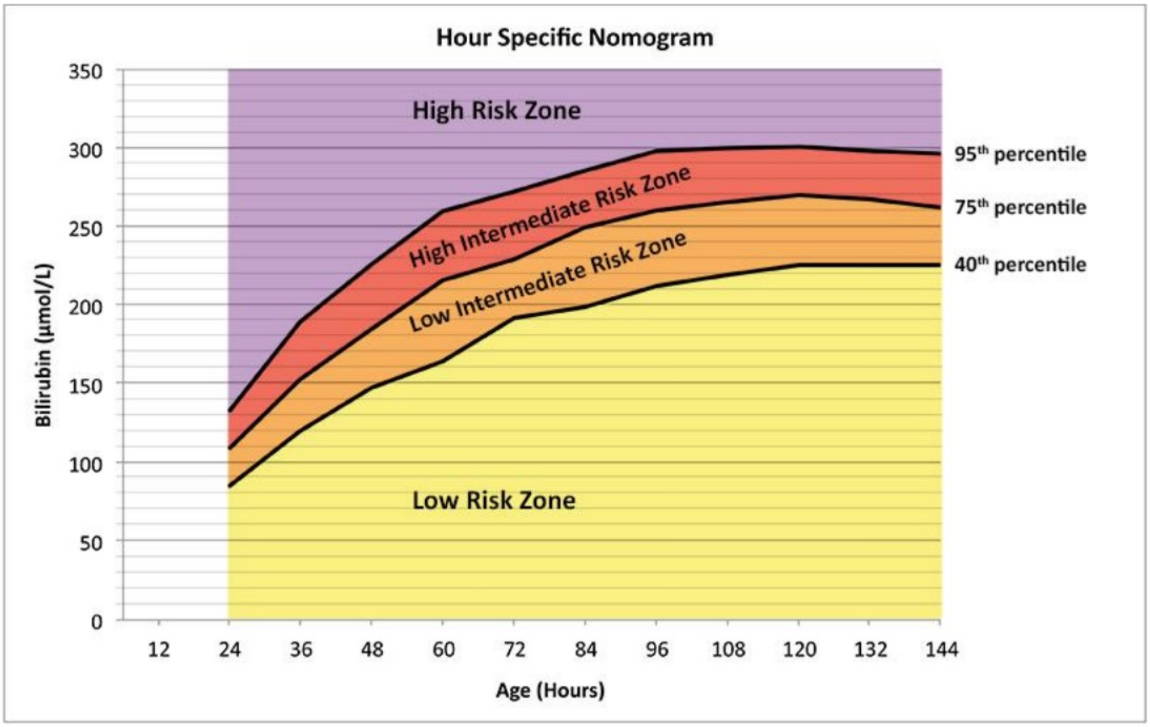


Figure from: Ministry of Health and Long-Term Care, *Clinic Pathway Handbook for Hyperbilirubinemia in Term and Late Pre-Term Infants (>=35 weeks)*, December 2017, Related Figures, p.17. http://www.health.gov.on.ca/en/pro/programs/ecfa/docs/qbp_jaundice.pdf

Appendix H: Follow-Up Algorithm

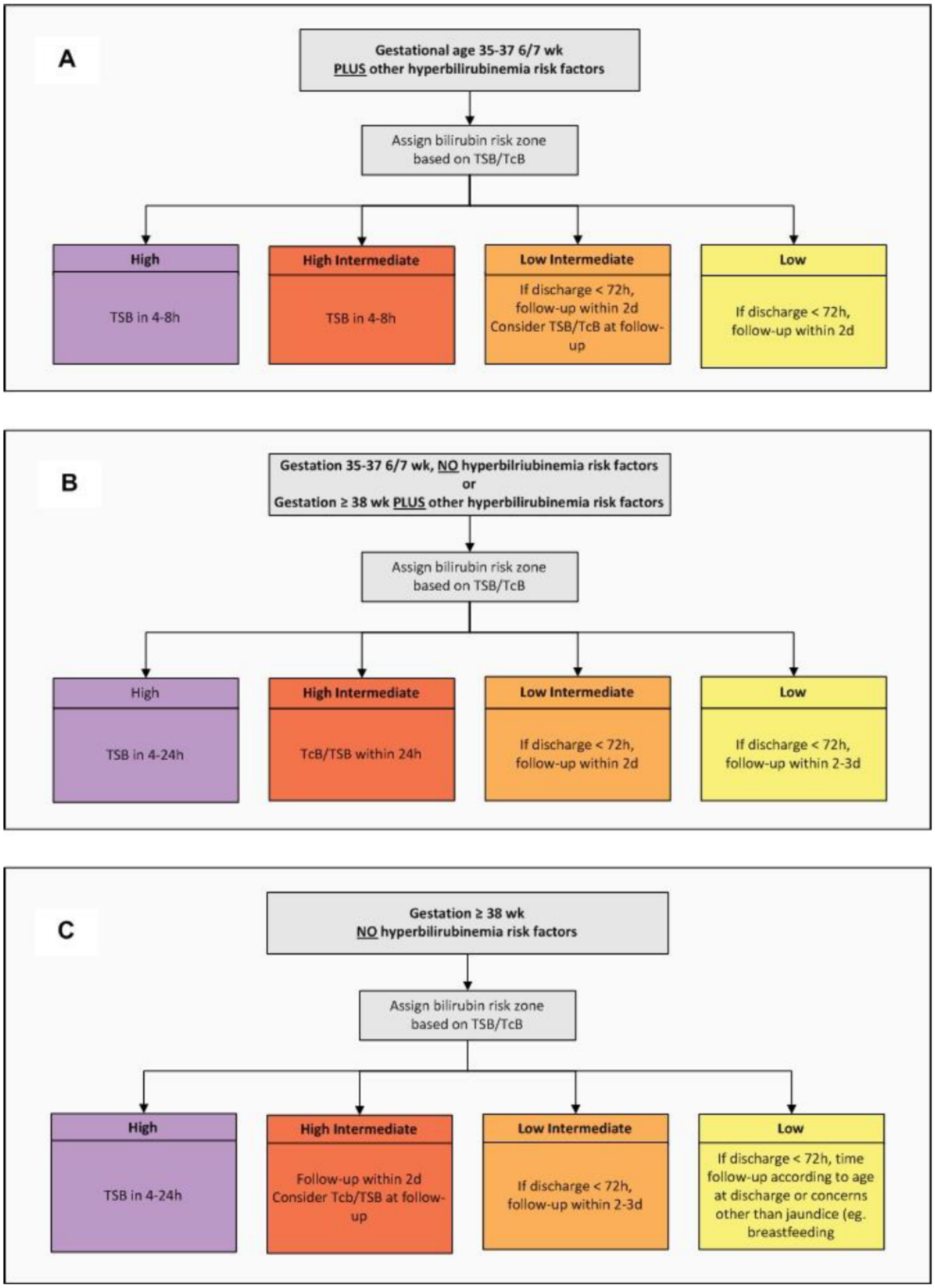
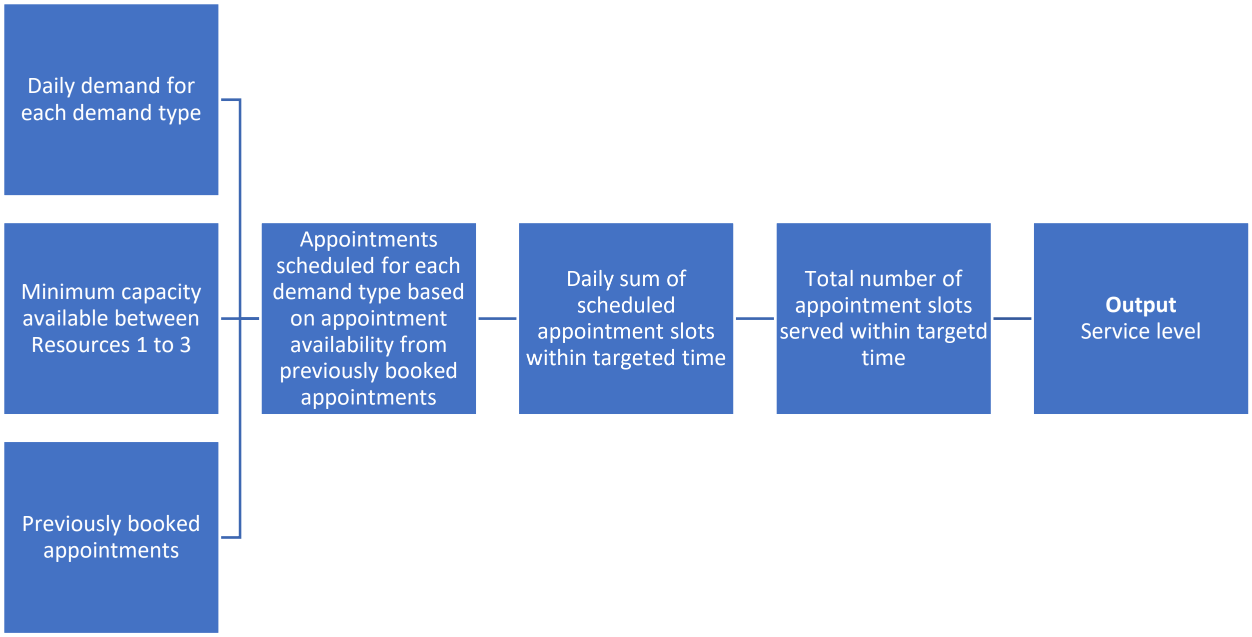
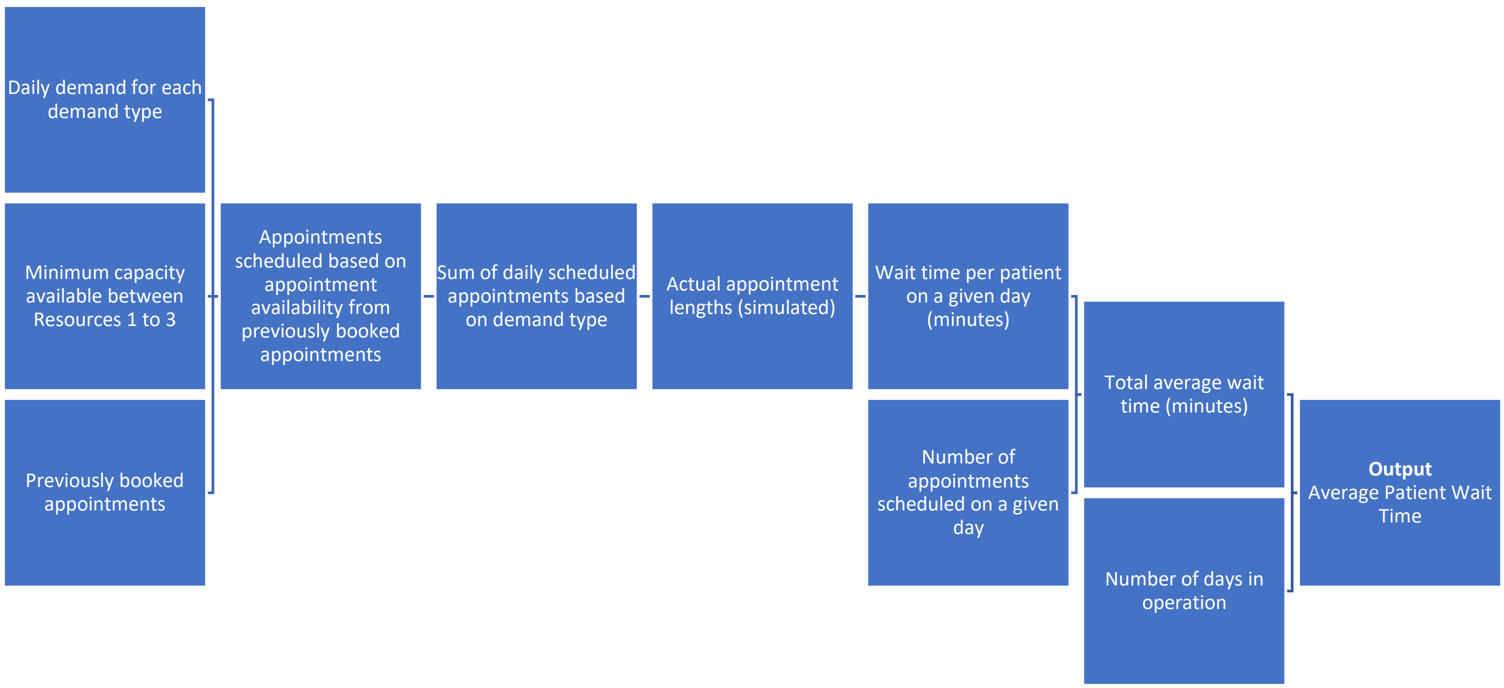


Figure from: Ministry of Health and Long-Term Care, *Clinic Pathway Handbook for Hyperbilirubinemia in Term and Late Pre-Term Infants (>=35 weeks)*, December 2017, Related Figures, p.18. http://www.health.gov.on.ca/en/pro/programs/ecfa/docs/qbp_jaundice.pdf

Appendix I: Pathway to Service Level Output



Appendix J: Pathway to Average Patient Wait Time Output



Appendix K: Pathway to Average Idle Time Output

Appendix L: Pathway to Average Overtime Output

Appendix M: Demand Inputs

Simulation Parameters (Forecasted Demand)				
	Demand #1	Demand #2	Demand #3	Demand #4
t1	3	2	1	1
t2	1	1	0	1
t3	3	2	1	0
t4	1	1	0	1
t5	2	2	1	1

Appendix N: Simulated Daily Demand

Day (t)	Demand #1	Demand #2	Demand #3	Demand #4	Sum
-1	4	2	3	0	9
-2	0	2	0	4	6
-3	3	6	3	0	12
-4	1	0	0	0	1
-5	1	0	0	4	5
-6	1	6	0	4	11
-7	1	6	0	0	7
-8	2	2	0	0	4
-9	3	0	0	0	3
-10	3	4	3	0	10
-11	2	2	6	4	14
-12	2	0	0	4	6
-13	3	2	6	0	11
-14	0	6	0	0	6
-15	4	0	3	8	15
-16	2	4	3	0	9
-17	0	0	0	4	4
-18	3	2	6	0	11
-19	0	2	0	0	2
-20	1	0	0	4	5
-21	3	2	3	0	8
-22	0	4	0	4	8
-23	1	6	0	0	7
-24	0	8	0	0	8
-25	4	2	0	4	10
-26	6	8	3	8	25
-27	0	2	0	4	6
-28	3	6	0	0	9
-29	1	0	0	4	5
-30	2	8	3	0	13
1	3	4	0	4	11
2	0	0	0	0	0
3	4	2	6	0	12

Appendix O: Resource Capacity Input

	Resource #1	Resource #2	Resource #3
Day 1	15	15	15
Day 2	8	8	8
Day 3	15	15	15
Day 4	8	8	8
Day 5	15	15	15

Appendix P: Appointment Schedule Legend

Legend	Description
	Previously Booked Appointment Slots for Demand #1
	Previously Booked Appointment Slots for Demand #2
	Previously Booked Appointment Slots for Demand #3
	Previously Booked Appointment Slots for Demand #4
	Summary of Previously Booked Appointment Slots
	Demand #1
	Demand #2
	Demand #3
	Demand #4
	Capacity of Resource

Appendix Q: Daily Schedule

Target Days	Resource #1					Resource #2					Resource #3		
Day (t)	Capacity Utilization (Ct1)	Capacity Utilization (Ct2)	Capacity Utilization (Ct3)	Capacity Utilization (Ct4)	Capacity Utilization (Ct5)	Capacity Utilization (Ct1)	Capacity Utilization (Ct2)	Capacity Utilization (Ct3)	Capacity Utilization (Ct4)	Capacity Utilization (Ct5)	Capacity Utilization (Ct1)	Capacity Utilization (Ct2)	Capacity Utilization (Ct3)
-1	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	4	0	0	0	0	4	0	0
	2	0	0	0	0	2	0	0	0	0	2	0	0
	3	0	0	0	0	3	0	0	0	0	3	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0
	15	8	15	8	15	15	8	15	8	15	15	8	15
-2	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	2	0	0	0	0	2	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	4	0	0	0	0	4	0	0
	8	15	8	15	15	8	15	8	15	15	8	15	8
-3	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	3	0	0	0	0	3	0	0
	6	0	0	0	0	6	0	0	0	0	6	0	0
	3	0	0	0	0	3	0	0	0	0	3	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0
	15	8	15	15	8	15	8	15	15	8	15	8	15
-4	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0
	1	0	0	0	0	1	0	0	0	0	1	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0
	8	15	15	8	15	8	15	15	8	15	8	15	15

Appendix R: Daily Number of Diversions & Daily Number of Unscheduled Appointment Slots

	Diversions					Resource Idle Time			
Day	Demand #1	Demand #2	Demand #3	Demand #4	Total	Resource #1	Resource #2	Resource #3	Total
-1	0	0	0	0	0	6	6	6	18
-2	0	0	0	0	0	2	2	2	6
-3	0	0	0	0	0	3	3	3	9
-4	0	0	0	0	0	7	7	7	21
-5	0	0	0	0	0	10	10	10	30
-6	0	0	0	0	0	4	4	4	12
-7	0	0	0	0	0	1	1	1	3
-8	0	0	0	0	0	11	11	11	33
-9	0	0	0	0	0	5	5	5	15
-10	0	0	0	0	0	5	5	5	15
-11	0	0	0	0	0	1	1	1	3
-12	0	0	0	0	0	2	2	2	6
-13	0	0	0	0	0	4	4	4	12
-14	0	0	0	0	0	2	2	2	6
-15	0	0	0	0	0	0	0	0	0
-16	0	0	0	0	0	6	6	6	18
-17	0	0	0	0	0	4	4	4	12
-18	0	0	0	0	0	4	4	4	12
-19	0	0	0	0	0	6	6	6	18
-20	0	0	0	0	0	10	10	10	30
-21	0	0	0	0	0	7	7	7	21
-22	0	0	0	0	0	0	0	0	0
-23	0	0	0	0	0	8	8	8	24
-24	0	0	0	0	0	0	0	0	0
-25	0	0	0	0	0	5	5	5	15
-26	0	0	0	0	0	0	0	0	0
-27	0	0	0	0	0	0	0	0	0
-28	0	0	0	0	0	0	0	0	0
-29	0	0	0	0	0	1	1	1	3
-30	0	0	0	0	0	2	2	2	6

Appendix S: Daily Number of Appointment Slots Provided within Target & Beyond Target

	Number of Appointments Served within Target (3 days)					Number of Appointments Not Served within Target (3 days)				
Day	Demand 1	Demand 2	Demand 3	Demand 4	Demand 1 to 4	Demand 1	Demand 2	Demand 3	Demand 4	Demand 1 to 4
-1	4	2	3	0	9	0	0	0	0	0
-2	0	2	0	4	6	0	0	0	0	0
-3	3	6	3	0	12	0	0	0	0	0
-4	1	0	0	0	1	0	0	0	0	0
-5	1	0	0	4	5	0	0	0	0	0
-6	1	6	0	4	11	0	0	0	0	0
-7	1	6	0	0	7	0	0	0	0	0
-8	2	2	0	0	4	0	0	0	0	0
-9	3	0	0	0	3	0	0	0	0	0
-10	3	4	3	0	10	0	0	0	0	0
-11	2	2	6	4	14	0	0	0	0	0
-12	2	0	0	4	6	0	0	0	0	0
-13	3	2	6	0	11	0	0	0	0	0
-14	0	6	0	0	6	0	0	0	0	0
-15	4	0	3	8	15	0	0	0	0	0
-16	2	4	3	0	9	0	0	0	0	0
-17	0	0	0	4	4	0	0	0	0	0
-18	3	2	6	0	11	0	0	0	0	0
-19	0	2	0	0	2	0	0	0	0	0
-20	1	0	0	4	5	0	0	0	0	0
-21	3	2	3	0	8	0	0	0	0	0
-22	0	4	0	4	8	0	0	0	0	0
-23	1	6	0	0	7	0	0	0	0	0
-24	0	8	0	0	8	0	0	0	0	0
-25	4	2	0	4	10	0	0	0	0	0
-26	6	8	3	8	25	0	0	0	0	0
-27	0	2	0	4	6	0	0	0	0	0
-28	3	6	0	0	9	0	0	0	0	0
-29	1	0	0	4	5	0	0	0	0	0
-30	2	8	3	0	13	0	0	0	0	0
1	3	4	0	4	11	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0
3	4	2	6	0	12	0	0	0	0	0
4	2	0	0	4	6	0	0	0	0	0
5	2	4	3	8	17	0	0	0	0	0
6	2	6	6	4	18	0	0	0	0	0
7	0	2	0	0	2	0	0	0	0	0
8	6	6	3	0	15	0	0	0	0	0
9	0	2	0	4	6	0	0	0	0	0
10	4	6	6	4	20	0	0	0	0	0
11	3	0	9	4	16	0	0	0	0	0
12	0	0	0	12	12	0	0	0	0	0
13	9	0	3	0	12	0	0	0	0	0
14	1	0	0	0	1	0	0	0	0	0
15	2	4	9	4	19	0	0	0	0	0
16	3	6	0	4	13	0	0	0	0	0
17	1	2	0	4	7	0	0	0	0	0

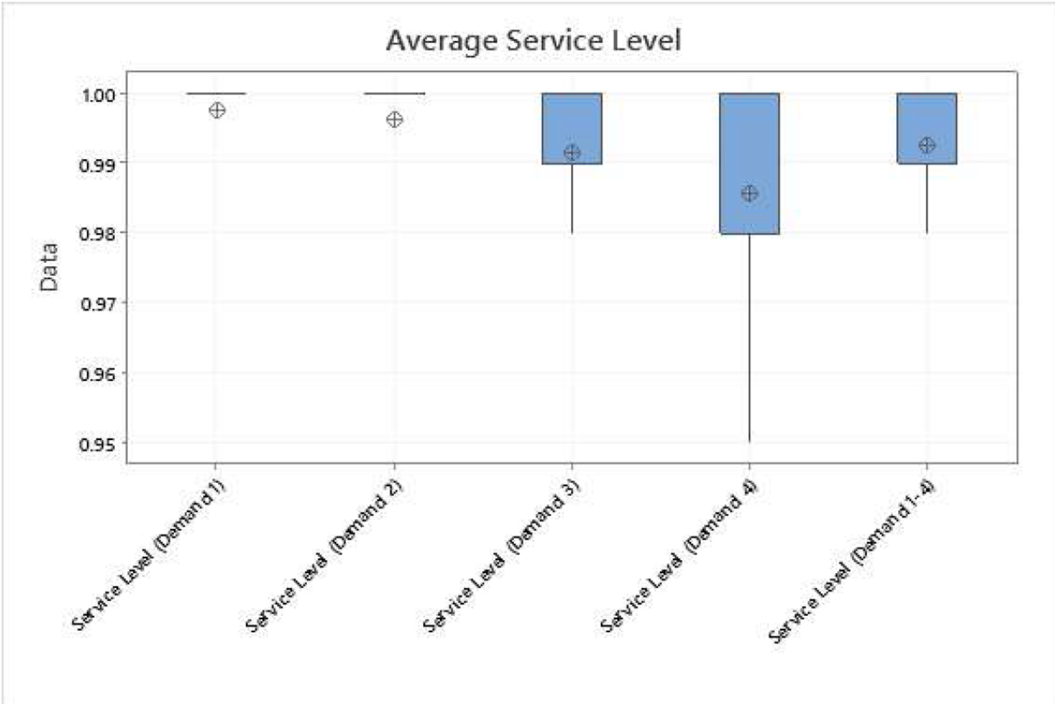
Appendix T: Average Patient Wait Time, Daily Resource Idle Time, Daily Overtime & Number of Appointment Slots Scheduled Within 1 to 5 Days

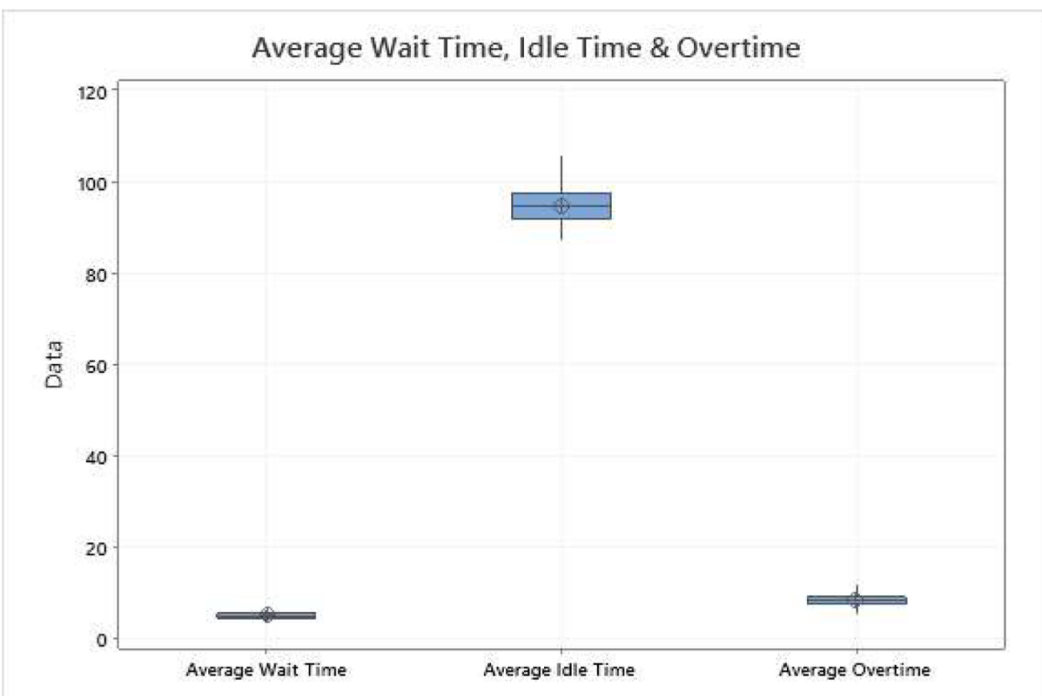
Day	Average Wait Time (minutes)	Total Idle Time (minutes)	Total Overtime (minutes)	Number of Appointments Scheduled Within 1 to 5 Days				
				1 Day	2 Days	3 Days	4 Days	5 Days
-1	0	-72	0	10	0	0	0	0
-2	8	-48	24	8	11	0	0	0
-3	2	-163	9	4	6	0	0	0
-4	0	-94	0	2	3	0	0	0
-5	0	-292	0	12	3	0	0	0
-6	4	-113	24	12	5	0	0	0
-7	0	-69	0	3	5	0	0	0
-8	0	-244	0	9	0	0	0	0
-9	0	-143	0	7	0	0	0	0
-10	4	-132	0	15	4	0	0	0
-11	42	0	51	3	0	0	0	0
-12	0	-103	0	6	0	0	0	0
-13	5	-152	39	15	3	0	0	0
-14	3	-93	8	4	0	0	0	0
-15	9	-34	11	13	0	0	0	0
-16	1	-129	0	13	0	0	0	0
-17	0	-30	0	4	0	0	0	0
-18	15	0	16	2	0	0	0	0
-19	10	-2	20	3	0	0	0	0
-20	2	-134	0	15	3	0	0	0
-21	6	-167	0	15	1	0	0	0
-22	0	-106	0	6	0	0	0	0
-23	22	0	15	7	0	0	0	0
-24	2	-161	0	8	2	0	0	0
-25	0	-104	0	13	1	0	0	0
-26	28	-19	19	14	8	0	0	0
-27	9	-52	17	0	7	0	0	0
-28	1	-156	0	7	0	0	0	0
-29	3	-21	0	8	7	0	0	0
-30	4	-154	13	8	5	0	0	0
1	0	-72	0	4	0	0	0	0
2	0	-84	0	8	4	0	0	0
3	8	-145	13	11	2	0	0	0
4	0	-45	0	5	0	0	0	0
5	0	-198	0	15	6	0	0	0
6	22	-44	77	9	2	0	0	0
7	2	-86	0	5	0	0	0	0
8	1	-134	0	9	0	0	0	0
9	5	-37	0	6	0	0	0	0
10	14	-68	5	12	0	0	0	0
11	1	-184	0	15	8	0	0	0
12	2	-11	4	0	4	0	0	0
13	1	-130	0	5	0	0	0	0
14	17	0	17	4	0	0	0	0
15	1	-141	0	15	7	0	0	0

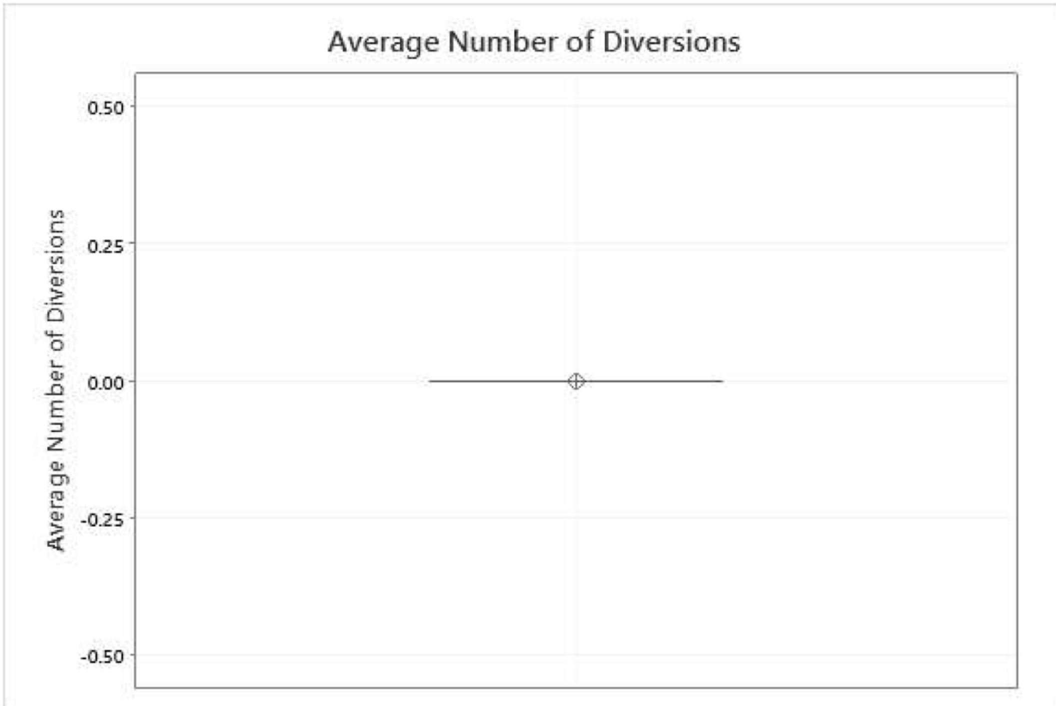
Appendix U: Mean and Standard Deviation for Normal Distribution

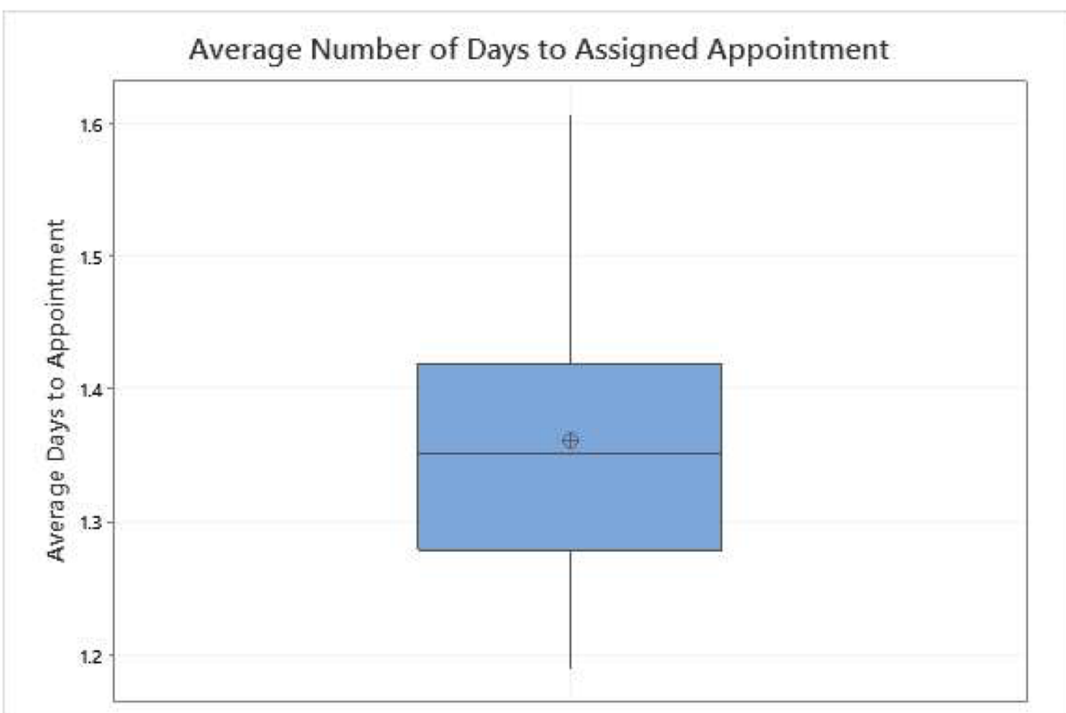
Variable	Minutes	Description
μ_1	20	Mean - Appointment Lengths - Demand #1
σ_1	13	Standard Deviation - Appointment Lengths - Demand #1
μ_2	40	Mean - Appointment Lengths - Demand #2
σ_2	26	Standard Deviation - Appointment Lengths - Demand #2
μ_3	60	Mean - Appointment Lengths - Demand #3
σ_3	40	Standard Deviation - Appointment Lengths - Demand #3
μ_4	79	Mean - Appointment Lengths - Demand #4
σ_4	52	Standard Deviation - Appointment Lengths - Demand #4

Appendix V: Box Plots – Simulation #1






Average Number of Diversions
Average Number of Diversions
0.50
0.25
0.00
-0.25
-0.50


Average Number of Days to Assigned Appointment
Average Days to Appointment
1.6
1.5
1.4
1.3
1.2

Appendix W: Numerical Analysis – Inputs

Appointment Length (20 minutes)				
Resource Workday Length (Full-time = 7.5 hours; part-time = 4 hours)				
Configuration 1 (100% resource capacity)		Resource #1	Resource #2	Resource #3
	Day 1	23	23	23
	Day 2	12	12	12
	Day 3	23	23	23
	Day 4	12	12	12
	Day 5	23	23	23
Resource Workday Length (Full-time = 7.5 hours; part-time = 4 hours)				
Configuration 2 (75% resource capacity)		Resource #1	Resource #2	Resource #3
	Day 1	17	17	17
	Day 2	9	9	9
	Day 3	17	17	17
	Day 4	9	9	9
	Day 5	17	17	17
Resource Workday Length (Full-time = 7.5 hours; part-time = 4 hours)				
Configuration 3 (50% resource capacity)		Resource #1	Resource #2	Resource #3
	Day 1	11	11	11
	Day 2	6	6	6
	Day 3	11	11	11
	Day 4	6	6	6
	Day 5	11	11	11
Resource Workday Length (Full-time = 6 hours; part-time = 4 hours)				
Configuration 4 (100% resource capacity)		Resource #1	Resource #2	Resource #3
	Day 1	18	18	18
	Day 2	12	12	12
	Day 3	18	18	18
	Day 4	12	12	12
	Day 5	18	18	18
Resource Workday Length (Full-time = 6 hours; part-time = 4 hours)				
Configuration 5 (75% resource capacity)		Resource #1	Resource #2	Resource #3
	Day 1	14	14	14
	Day 2	9	9	9
	Day 3	14	14	14
	Day 4	9	9	9
	Day 5	14	14	14
Resource Workday Length (Full-time = 6 hours; part-time = 4 hours)				
Configuration 6 (50% resource capacity)		Resource #1	Resource #2	Resource #3
	Day 1	9	9	9
	Day 2	6	6	6
	Day 3	9	9	9
	Day 4	6	6	6

	Day 5	9	9	9
Resource Workday Length (Full-time = 5 hours; part-time = 3 hours)				
Configuration 7 (100% resource capacity)		Resource #1	Resource #2	Resource #3
	Day 1	15	15	15
	Day 2	9	9	9
	Day 3	15	15	15
	Day 4	9	9	9
	Day 5	15	15	15
Resource Workday Length (Full-time = 5 hours; part-time = 3 hours)				
Configuration 8 (75% resource capacity)		Resource #1	Resource #2	Resource #3
	Day 1	11	11	11
	Day 2	7	7	7
	Day 3	11	11	11
	Day 4	7	7	7
	Day 5	11	11	11
Resource Workday Length (Full-time = 5 hours; part-time = 3 hours)				
Configuration 9 (50% resource capacity)		Resource #1	Resource #2	Resource #3
	Day 1	8	8	8
	Day 2	5	5	5
	Day 3	8	8	8
	Day 4	5	5	5
	Day 5	8	8	8
Appointment Length (30 minutes)				
Resource Workday Length (Full-time = 7.5 hours; part-time = 4 hours)				
Configuration 10 (100% resource capacity)		Resource #1	Resource #2	Resource #3
	Day 1	15	15	15
	Day 2	8	8	8
	Day 3	15	15	15
	Day 4	8	8	8
	Day 5	15	15	15
Resource Workday Length (Full-time = 7.5 hours; part-time = 4 hours)				
Configuration 11 (75% resource capacity)		Resource #1	Resource #2	Resource #3
	Day 1	11	11	11
	Day 2	6	6	6
	Day 3	11	11	11
	Day 4	6	6	6
	Day 5	11	11	11
Resource Workday Length (Full-time = 7.5 hours; part-time = 4 hours)				
Configuration 12 (50% resource capacity)		Resource #1	Resource #2	Resource #3
	Day 1	8	8	8
	Day 2	4	4	4
	Day 3	8	8	8
	Day 4	4	4	4
	Day 5	8	8	8
Resource Workday Length (Full-time = 6 hours; part-time = 4 hours)				

		Resource #1	Resource #2	Resource #3
Configuration 13 (100% resource capacity)	Day 1	12	12	12
	Day 2	8	8	8
	Day 3	12	12	12
	Day 4	8	8	8
	Day 5	12	12	12
Resource Workday Length (Full-time = 6 hours; part-time = 4 hours)				
		Resource #1	Resource #2	Resource #3
Configuration 14 (75% resource capacity)	Day 1	9	9	9
	Day 2	6	6	6
	Day 3	9	9	9
	Day 4	6	6	6
	Day 5	9	9	9
Resource Workday Length (Full-time = 6 hours; part-time = 4 hours)				
		Resource #1	Resource #2	Resource #3
Configuration 15 (50% resource capacity)	Day 1	6	6	6
	Day 2	4	4	4
	Day 3	6	6	6
	Day 4	4	4	4
	Day 5	6	6	6
Resource Workday Length (Full-time = 5 hours; part-time = 3 hours)				
		Resource #1	Resource #2	Resource #3
Configuration 16 (100% resource capacity)	Day 1	10	10	10
	Day 2	6	6	6
	Day 3	10	10	10
	Day 4	6	6	6
	Day 5	10	10	10
Resource Workday Length (Full-time = 5 hours; part-time = 3 hours)				
		Resource #1	Resource #2	Resource #3
Configuration 17 (75% resource capacity)	Day 1	8	8	8
	Day 2	5	5	5
	Day 3	8	8	8
	Day 4	5	5	5
	Day 5	8	8	8
Resource Workday Length (Full-time = 5 hours; part-time = 3 hours)				
		Resource #1	Resource #2	Resource #3
Configuration 18 (50% resource capacity)	Day 1	5	5	5
	Day 2	3	3	3
	Day 3	5	5	5
	Day 4	3	3	3
	Day 5	5	5	5
Appointment Length (45 minutes)				
Resource Workday Length (Full-time = 7.5 hours; part-time = 4 hours)				
		Resource #1	Resource #2	Resource #3
	Day 1	10	10	10

Configuration 19 (100% resource capacity)	Day 2	5	5	5
	Day 3	10	10	10
	Day 4	5	5	5
	Day 5	10	10	10
Resource Workday Length (Full-time = 7.5 hours; part-time = 4 hours)				
Configuration 20 (75% resource capacity)		Resource #1	Resource #2	Resource #3
	Day 1	8	8	8
	Day 2	4	4	4
	Day 3	8	8	8
	Day 4	4	4	4
	Day 5	8	8	8
Resource Workday Length (Full-time = 7.5 hours; part-time = 4 hours)				
Configuration 21 (50% resource capacity)		Resource #1	Resource #2	Resource #3
	Day 1	5	5	5
	Day 2	3	3	3
	Day 3	5	5	5
	Day 4	3	3	3
	Day 5	5	5	5
Resource Workday Length (Full-time = 6 hours; part-time = 4 hours)				
Configuration 22 (100% resource capacity)		Resource #1	Resource #2	Resource #3
	Day 1	8	8	8
	Day 2	5	5	5
	Day 3	8	8	8
	Day 4	5	5	5
	Day 5	8	8	8
Resource Workday Length (Full-time = 6 hours; part-time = 4 hours)				
Configuration 23 (75% resource capacity)		Resource #1	Resource #2	Resource #3
	Day 1	6	6	6
	Day 2	4	4	4
	Day 3	6	6	6
	Day 4	4	4	4
	Day 5	6	6	6
Resource Workday Length (Full-time = 6 hours; part-time = 4 hours)				
Configuration 24 (50% resource capacity)		Resource #1	Resource #2	Resource #3
	Day 1	4	4	4
	Day 2	3	3	3
	Day 3	4	4	4
	Day 4	3	3	3
	Day 5	4	4	4
Resource Workday Length (Full-time = 5 hours; part-time = 3 hours)				
Configuration 25 (100% resource capacity)		Resource #1	Resource #2	Resource #3
	Day 1	7	7	7
	Day 2	4	4	4
	Day 3	7	7	7
	Day 4	4	4	4

	Day 5	7	7	7
Resource Workday Length (Full-time = 5 hours; part-time = 3 hours)				
Configuration 26 (75% resource capacity)		Resource #1	Resource #2	Resource #3
	Day 1	5	5	5
	Day 2	3	3	3
	Day 3	5	5	5
	Day 4	3	3	3
	Day 5	5	5	5
Resource Workday Length (Full-time = 5 hours; part-time = 3 hours)				
Configuration 27 (50% resource capacity)		Resource #1	Resource #2	Resource #3
	Day 1	3	3	3
	Day 2	2	2	2
	Day 3	3	3	3
	Day 4	2	2	2
	Day 5	3	3	3

Appendix X: Numerical Analysis – Results

Configuration	Performance Metric	95% Confidence Interval
Configuration 1	Service Level (Demand #1) [%]	100 +/- 0.00
	Service Level (Demand #2) [%]	100 +/- 0.00
	Service Level (Demand #3) [%]	100 +/- 0.00
	Service Level (Demand #4) [%]	100 +/- 0.00
	Service Level (Demand # 1 – 4) [%]	100 +/- 0.00
	Average Patient Wait Time [minutes]	21.26 +/- 0.28
	Average Resource Idle Time [minutes]	22.31 +/- 0.37
	Average Overtime [minutes]	39.92 +/- 0.64
	Average Number of Diversions [appointment slots]	0.00 +/- 0.00
	Average Number of Days to Assigned Appointment [days]	1.03 +/- 0.00
Configuration 2	Service Level (Demand #1) [%]	100 +/- 0.00
	Service Level (Demand #2) [%]	99.99 +/- 0.00
	Service Level (Demand #3) [%]	99.99 +/- 0.00
	Service Level (Demand #4) [%]	99.95 +/- 0.04
	Service Level (Demand # 1 – 4) [%]	99.98 +/- 0.01
	Average Patient Wait Time [minutes]	21.52 +/- 0.27
	Average Resource Idle Time [minutes]	22.61 +/- 0.36
	Average Overtime [minutes]	39.70 +/- 0.63
	Average Number of Diversions [appointment slots]	0.00 +/- 0.00
	Average Number of Days to Assigned Appointment [days]	1.17 +/- 0.01
Configuration 3	Service Level (Demand #1) [%]	77.25 +/- 1.27
	Service Level (Demand #2) [%]	70.57 +/- 1.35
	Service Level (Demand #3) [%]	62.14 +/- 1.59
	Service Level (Demand #4) [%]	58.65 +/- 1.50
	Service Level (Demand # 1 – 4) [%]	66.66 +/- 1.32
	Average Patient Wait Time [minutes]	21.30 +/- 0.25
	Average Resource Idle Time [minutes]	21.89 +/- 0.33
	Average Overtime [minutes]	37.55 +/- 0.46
	Average Number of Diversions [appointment slots]	0.39 +/- 0.03
	Average Number of Days to Assigned Appointment [days]	2.73 +/- 0.04
Configuration 4	Service Level (Demand #1) [%]	100 +/- 0.00
	Service Level (Demand #2) [%]	100 +/- 0.00
	Service Level (Demand #3) [%]	100 +/- 0.00
	Service Level (Demand #4) [%]	100 +/- 0.00
	Service Level (Demand # 1 – 4) [%]	100 +/- 0.00
	Average Patient Wait Time [minutes]	21.30 +/- 0.25
	Average Resource Idle Time [minutes]	22. 82 +/- 0.30

	Average Overtime [minutes]	39.67 +/- 0.54
	Average Number of Diversions [appointment slots]	0.00 +/- 0.00
	Average Number of Days to Assigned Appointment [days]	1.09 +/- 0.01
Configuration 5	Service Level (Demand #1) [%]	99.66 +/- 0.18
	Service Level (Demand #2) [%]	99.41 +/- 0.22
	Service Level (Demand #3) [%]	98.69 +/- 0.43
	Service Level (Demand #4) [%]	98.04 +/- 0.46
	Service Level (Demand # 1 – 4) [%]	98.90 +/- 0.30
	Average Patient Wait Time [minutes]	21.62 +/- 0.27
	Average Resource Idle Time [minutes]	23.20 +/- 0.34
	Average Overtime [minutes]	40.04 +/- 0.61
	Average Number of Diversions [appointment slots]	0.00 +/- 0.00
	Average Number of Days to Assigned Appointment [days]	1.41 +/- 0.02
Configuration 6	Service Level (Demand #1) [%]	52.84 +/- 1.36
	Service Level (Demand #2) [%]	44.91 +/- 1.13
	Service Level (Demand #3) [%]	37.45 +/- 1.16
	Service Level (Demand #4) [%]	34.01 +/- 1.01
	Service Level (Demand # 1 – 4) [%]	41.74 +/- 1.04
	Average Patient Wait Time [minutes]	19.96 +/- 0.23
	Average Resource Idle Time [minutes]	20.50 +/- 0.29
	Average Overtime [minutes]	33.83 +/- 0.46
	Average Number of Diversions [appointment slots]	1.21 +/- 0.05
	Average Number of Days to Assigned Appointment [days]	3.40 +/- 0.03
Configuration 7	Service Level (Demand #1) [%]	99.87 +/- 0.09
	Service Level (Demand #2) [%]	99.73 +/- 0.13
	Service Level (Demand #3) [%]	99.44 +/- 0.22
	Service Level (Demand #4) [%]	99.08 +/- 0.26
	Service Level (Demand # 1 – 4) [%]	99.50 +/- 0.17
	Average Patient Wait Time [minutes]	21.64 +/- 0.23
	Average Resource Idle Time [minutes]	23.17 +/- 0.35
	Average Overtime [minutes]	39.85 +/- 0.52
	Average Number of Diversions [appointment slots]	0.00 +/- 0.00
	Average Number of Days to Assigned Appointment [days]	1.31 +/- 0.01
Configuration 8	Service Level (Demand #1) [%]	85.09 +/- 1.27
	Service Level (Demand #2) [%]	79.83 +/- 1.32
	Service Level (Demand #3) [%]	72.43 +/- 1.55
	Service Level (Demand #4) [%]	68.52 +/- 1.45
	Service Level (Demand # 1 – 4) [%]	76.03 +/- 1.32
	Average Patient Wait Time [minutes]	21.60 +/- 0.30
	Average Resource Idle Time [minutes]	22.30 +/- 0.33
	Average Overtime [minutes]	38.34 +/- 0.57

	Average Number of Diversions [appointment slots]	0.18 +/- 0.02
	Average Number of Days to Assigned Appointment [days]	2.47 +/- 0.04
Configuration 9	Service Level (Demand #1) [%]	34.73 +/- 1.02
	Service Level (Demand #2) [%]	28.63 +/- 0.87
	Service Level (Demand #3) [%]	22.44 +/- 0.94
	Service Level (Demand #4) [%]	20.59 +/- 0.69
	Service Level (Demand # 1 – 4) [%]	26.19 +/- 0.72
	Average Patient Wait Time [minutes]	18.42 +/- 0.23
	Average Resource Idle Time [minutes]	18.84 +/- 0.27
	Average Overtime [minutes]	30.39 +/- 0.43
	Average Number of Diversions [appointment slots]	2.27 +/- 0.06
	Average Number of Days to Assigned Appointment [days]	3.82 +/- 0.02
Configuration 10	Service Level (Demand #1) [%]	99.82 +/- 0.10
	Service Level (Demand #2) [%]	99.67 +/- 0.13
	Service Level (Demand #3) [%]	99.18 +/- 0.26
	Service Level (Demand #4) [%]	98.72 +/- 0.32
	Service Level (Demand # 1 – 4) [%]	99.31 +/- 0.19
	Average Patient Wait Time [minutes]	4. 97 +/- 0.10
	Average Resource Idle Time [minutes]	94.27 +/- 0.82
	Average Overtime [minutes]	8.26 +/- 0.24
	Average Number of Diversions [appointment slots]	0.00 +/- 0.00
	Average Number of Days to Assigned Appointment [days]	1.36 +/- 0.02
Configuration 11	Service Level (Demand #1) [%]	78.28 +/- 1.24
	Service Level (Demand #2) [%]	71.41 +/- 1.38
	Service Level (Demand #3) [%]	63.39 +/- 1.54
	Service Level (Demand #4) [%]	60.17 +/- 1.50
	Service Level (Demand # 1 – 4) [%]	67.82 +/- 1.35
	Average Patient Wait Time [minutes]	5.04 +/- 0.10
	Average Resource Idle Time [minutes]	84.91 +/- 0.61
	Average Overtime [minutes]	7.96 +/- 0.22
	Average Number of Diversions [appointment slots]	0.35 +/- 0.03
	Average Number of Days to Assigned Appointment [days]	2.71 +/- 0.04
Configuration 12	Service Level (Demand #1) [%]	31.18 +/- 0.85
	Service Level (Demand #2) [%]	24.83 +/- 0.71
	Service Level (Demand #3) [%]	19.41 +/- 0.83
	Service Level (Demand #4) [%]	17.46 +/- 0.59
	Service Level (Demand # 1 – 4) [%]	22.83 +/- 0.59
	Average Patient Wait Time [minutes]	4.51 +/- 0.11
	Average Resource Idle Time [minutes]	63.67 +/- 0.41
	Average Overtime [minutes]	6.59 +/- 0.23
	Average Number of Diversions [appointment slots]	2.71 +/- 0.07

	Average Number of Days to Assigned Appointment [days]	3.90 +/- 0.02
Configuration 13	Service Level (Demand #1) [%]	94.95 +/- 0.79
	Service Level (Demand #2) [%]	92.96 +/- 0.95
	Service Level (Demand #3) [%]	89.46 +/- 1.22
	Service Level (Demand #4) [%]	86.26 +/- 1.32
	Service Level (Demand # 1 – 4) [%]	90.60 +/- 1.05
	Average Patient Wait Time [minutes]	5.04 +/- 0.10
	Average Resource Idle Time [minutes]	91.53 +/- 0.79
	Average Overtime [minutes]	8.26 +/- 0.24
	Average Number of Diversions [appointment slots]	0.03 +/- 0.01
	Average Number of Days to Assigned Appointment [days]	1.91 +/- 0.04
Configuration 14	Service Level (Demand #1) [%]	52.87 +/- 1.41
	Service Level (Demand #2) [%]	45.11 +/- 1.32
	Service Level (Demand #3) [%]	37.80 +/- 1.46
	Service Level (Demand #4) [%]	33.54 +/- 1.14
	Service Level (Demand # 1 – 4) [%]	41.67 +/- 1.22
	Average Patient Wait Time [minutes]	4.84 +/- 0.10
	Average Resource Idle Time [minutes]	75.80 +/- 0.64
	Average Overtime [minutes]	7.51 +/- 0.21
	Average Number of Diversions [appointment slots]	1.23 +/- 0.06
	Average Number of Days to Assigned Appointment [days]	3.41 +/- 0.03
Configuration 15	Service Level (Demand #1) [%]	19.42 +/- 0.50
	Service Level (Demand #2) [%]	14.78 +/- 0.48
	Service Level (Demand #3) [%]	11.15 +/- 0.49
	Service Level (Demand #4) [%]	9.19 +/- 0.38
	Service Level (Demand # 1 – 4) [%]	13.29 +/- 0.30
	Average Patient Wait Time [minutes]	4.19 +/- 0.11
	Average Resource Idle Time [minutes]	52.59 +/- 0.41
	Average Overtime [minutes]	6.04 +/- 0.18
	Average Number of Diversions [appointment slots]	4.12 +/- 0.07
	Average Number of Days to Assigned Appointment [days]	4.20 +/- 0.01
Configuration 16	Service Level (Demand #1) [%]	65.79 +/- 1.23
	Service Level (Demand #2) [%]	58.90 +/- 1.39
	Service Level (Demand #3) [%]	49.57 +/- 1.56
	Service Level (Demand #4) [%]	46.28 +/- 1.35
	Service Level (Demand # 1 – 4) [%]	54.65 +/- 1.29
	Average Patient Wait Time [minutes]	5.00 +/- 0.11
	Average Resource Idle Time [minutes]	80.41 +/- 0.63
	Average Overtime [minutes]	7.94 +/- 0.21
	Average Number of Diversions [appointment slots]	0.73 +/- 0.04

	Average Number of Days to Assigned Appointment [days]	3.09 +/- 0.03
Configuration 17	Service Level (Demand #1) [%]	35.46 +/- 0.94
	Service Level (Demand #2) [%]	29.14 +/- 0.88
	Service Level (Demand #3) [%]	22.80 +/- 0.85
	Service Level (Demand #4) [%]	20.93 +/- 0.64
	Service Level (Demand # 1 – 4) [%]	26.69 +/- 0.68
	Average Patient Wait Time [minutes]	4.64 +/- 0.12
	Average Resource Idle Time [minutes]	67.26 +/- 0.50
	Average Overtime [minutes]	6.95 +/- 0.21
	Average Number of Diversions [appointment slots]	2.25 +/- 0.06
	Average Number of Days to Assigned Appointment [days]	3.80 +/- 0.02
Configuration 18	Service Level (Demand #1) [%]	13.85 +/- 0.45
	Service Level (Demand #2) [%]	10.18 +/- 0.29
	Service Level (Demand #3) [%]	7.31 +/- 0.39
	Service Level (Demand #4) [%]	4.80 +/- 0.29
	Service Level (Demand # 1 – 4) [%]	8.70 +/- 0.21
	Average Patient Wait Time [minutes]	3.92 +/- 0.10
	Average Resource Idle Time [minutes]	43.25 +/- 0.35
	Average Overtime [minutes]	5.21 +/- 0.16
	Average Number of Diversions [appointment slots]	5.23 +/- 0.07
	Average Number of Days to Assigned Appointment [days]	4.34 +/- 0.01
Configuration 19	Service Level (Demand #1) [%]	57.10 +/- 1.37
	Service Level (Demand #2) [%]	49.94 +/- 1.39
	Service Level (Demand #3) [%]	40.75 +/- 1.42
	Service Level (Demand #4) [%]	37.20 +/- 1.23
	Service Level (Demand # 1 – 4) [%]	45.71 +/- 1.24
	Average Patient Wait Time [minutes]	0.33 +/- 0.02
	Average Resource Idle Time [minutes]	194.54 +/- 0.8
	Average Overtime [minutes]	0.50 +/- 0.05
	Average Number of Diversions [appointment slots]	1.08 +/- 0.06
	Average Number of Days to Assigned Appointment [days]	3.29 +/- 0.03
Configuration 20	Service Level (Demand #1) [%]	30.65 +/- 0.85
	Service Level (Demand #2) [%]	24.67 +/- 0.71
	Service Level (Demand #3) [%]	19.52 +/- 0.7
	Service Level (Demand #4) [%]	17.08 +/- 0.64
	Service Level (Demand # 1 – 4) [%]	22.58 +/- 0.57
	Average Patient Wait Time [minutes]	0.32 +/- 0.03
	Average Resource Idle Time [minutes]	157.85 +/- 0.68
	Average Overtime [minutes]	0.46 +/- 0.05
	Average Number of Diversions [appointment slots]	2.67 +/- 0.06

	Average Number of Days to Assigned Appointment [days]	3.91 +/- 0.02
Configuration 21	Service Level (Demand #1) [%]	13.41 +/- 0.42
	Service Level (Demand #2) [%]	9.73 +/- 0.33
	Service Level (Demand #3) [%]	7.06 +/- 0.36
	Service Level (Demand #4) [%]	5.22 +/- 0.28
	Service Level (Demand # 1 – 4) [%]	8.58 +/- 0.18
	Average Patient Wait Time [minutes]	0.28 +/- 0.03
	Average Resource Idle Time [minutes]	107.64 +/- 0.58
	Average Overtime [minutes]	0.35 +/- 0.04
	Average Number of Diversions [appointment slots]	5.24 +/- 0.07
	Average Number of Days to Assigned Appointment [days]	4.35 +/- 0.01
Configuration 22	Service Level (Demand #1) [%]	35.59 +/- 1.05
	Service Level (Demand #2) [%]	29.03 +/- 0.88
	Service Level (Demand #3) [%]	22.70 +/- 0.87
	Service Level (Demand #4) [%]	20.22 +/- 0.71
	Service Level (Demand # 1 – 4) [%]	26.45 +/- 0.73
	Average Patient Wait Time [minutes]	0.33 +/- 0.02
	Average Resource Idle Time [minutes]	168.14 +/- 0.64
	Average Overtime [minutes]	0.49 +/- 0.05
	Average Number of Diversions [appointment slots]	2.30 +/- 0.06
	Average Number of Days to Assigned Appointment [days]	3.81 +/- 0.02
Configuration 23	Service Level (Demand #1) [%]	19.83 +/- 0.65
	Service Level (Demand #2) [%]	14.66 +/- 0.52
	Service Level (Demand #3) [%]	11.37 +/- 0.53
	Service Level (Demand #4) [%]	9.51 +/- 0.41
	Service Level (Demand # 1 – 4) [%]	13.48 +/- 0.35
	Average Patient Wait Time [minutes]	0.30 +/- 0.02
	Average Resource Idle Time [minutes]	131.00 +/- 0.50
	Average Overtime [minutes]	0.39 +/- 0.04
	Average Number of Diversions [appointment slots]	4.06 +/- 0.07
	Average Number of Days to Assigned Appointment [days]	4.19 +/- 0.01
Configuration 24	Service Level (Demand #1) [%]	11.15 +/- 0.33
	Service Level (Demand #2) [%]	7.95 +/- 0.25
	Service Level (Demand #3) [%]	5.26 +/- 0.33
	Service Level (Demand #4) [%]	3.35 +/- 0.22
	Service Level (Demand # 1 – 4) [%]	6.68 +/- 0.12
	Average Patient Wait Time [minutes]	0.28 +/- 0.03
	Average Resource Idle Time [minutes]	92.94 +/- 0.48
	Average Overtime [minutes]	0.36 +/- 0.04
	Average Number of Diversions [appointment slots]	5.93 +/- 0.07

	Average Number of Days to Assigned Appointment [days]	4.42 +/- 0.01
Configuration 25	Service Level (Demand #1) [%]	24.44 +/- 0.66
	Service Level (Demand #2) [%]	18.72 +/- 0.54
	Service Level (Demand #3) [%]	14.77 +/- 0.59
	Service Level (Demand #4) [%]	12.86 +/- 0.46
	Service Level (Demand # 1 – 4) [%]	17.30 +/- 0.41
	Average Patient Wait Time [minutes]	0.31 +/- 0.02
	Average Resource Idle Time [minutes]	144.8 +/- 0.50
	Average Overtime [minutes]	0.42 +/- 0.04
	Average Number of Diversions [appointment slots]	3.39 +/- 0.07
	Average Number of Days to Assigned Appointment [days]	4.07 +/- 0.02
Configuration 26	Service Level (Demand #1) [%]	13.42 +/- 0.42
	Service Level (Demand #2) [%]	9.90 +/- 0.32
	Service Level (Demand #3) [%]	7.37 +/- 0.36
	Service Level (Demand #4) [%]	5.08 +/- 0.32
	Service Level (Demand # 1 – 4) [%]	8.63 +/- 0.19
	Average Patient Wait Time [minutes]	0.27 +/- 0.03
	Average Resource Idle Time [minutes]	107.28 +/- 0.5
	Average Overtime [minutes]	0.36 +/- 0.04
	Average Number of Diversions [appointment slots]	5.21 +/- 0.07
	Average Number of Days to Assigned Appointment [days]	4.35 +/- 0.01
Configuration 27	Service Level (Demand #1) [%]	8.22 +/- 0.24
	Service Level (Demand #2) [%]	5.46 +/- 0.20
	Service Level (Demand #3) [%]	2.79 +/- 0.23
	Service Level (Demand #4) [%]	1.09 +/- 0.14
	Service Level (Demand # 1 – 4) [%]	4.15 +/- 0.06
	Average Patient Wait Time [minutes]	0.24 +/- 0.02
	Average Resource Idle Time [minutes]	68.35 +/- 0.39
	Average Overtime [minutes]	0.27 +/- 0.03
	Average Number of Diversions [appointment slots]	7.10 +/- 0.06
	Average Number of Days to Assigned Appointment [days]	4.50 +/- 0.01

Appendix Y: Numerical Analysis – Bonferroni Pairwise Comparison

Duration*Workday*Resources	N	Mean	Grouping
A3 W1 R1	100	195.147	A
A3 W2 R1	100	168.518	B
A3 W1 R2	100	158.591	C
A3 W2 R2	100	130.726	D
A3 W1 R3	100	107.513	E
A3 W3 R2	100	107.002	E
A2 W1 R1	100	94.700	F
A3 W3 R1	100	93.614	F
A3 W2 R3	100	93.614	F
A2 W2 R1	100	91.241	G
A2 W1 R2	100	84.681	H
A2 W3 R1	100	80.712	I
A2 W2 R2	100	75.834	J
A3 W3 R3	100	68.713	K
A2 W3 R2	100	66.824	L
A2 W1 R3	100	62.787	M
A2 W2 R3	100	52.940	N
A2 W3 R3	100	43.451	O
A1 W3 R1	100	23.325	P
A1 W2 R2	100	23.207	P
A1 W1 R2	100	22.907	P
A1 W1 R1	100	22.606	P
A1 W3 R2	100	22.573	P
A1 W2 R1	100	22.544	P
A1 W1 R3	100	22.042	P
A1 W2 R3	100	20.521	Q
A1 W3 R3	100	18.487	