Using a slotted queuing model to predict the Operational Performance of Collaborative Emergency Centres

by

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Abstract

Nova Scotia has developed a novel way to manage Emergency Department patients in small communities during overnight hours. Using a paramedic and a RN, who are in contact with a doctor over the phone, staff are able to manage the few patients who seek emergency care overnight at these Collaborative Emergency Centres (CECs). This thesis models the operational performance of the CECs using a slotted queuing model, then considers three population levels and compares the system's operational performance pre- and post-CEC implementation. It is found that a CEC's success is related to the proportion of supply to demand for primary care appointments. When there are more appointments than demand for primary care, the CEC improves primary care access by increasing physician availability during daytime hours. When there is greater demand for primary care than there are appointments available, the CEC increases wait time for primary care in all population groups modelled as the CEC requires some patients to return for additional daytime care.

List of Abbreviations and Symbols Used

ACP – Advanced Care Paramedic

CARE – Collaborative Assessment Room for Emergencies

CEC – Collaborative Emergency Centre

CTAS – Canadian Triage and Acuity Scale

ED – Emergency Department

EHS – Emergency Health Services

ePCR – Electronic Patient Care Record used by EHS

LPN – Licensed Practical Nurse

MOP – Medical Oversight Physician for a CEC

OAS – Open Access Scheduling

PCP – Primary Care Paramedic

RN – Registered Nurse

Glossary

Balking – When a patient opts to not enter a queue due to the length of the queue

Disposition – Where a patient went following their visit to the CEC

On-Call – A physician who is expected to attend the ED when a patient arrives

Reneging – When a patient chooses to leave a queue due to the remaining wait time

Acknowledgements

Chapter 1 – Introduction

Nova Scotia's rural health care practices have undergone major changes in recent years. In 2011, in response to frequent Emergency Department (ED) closures, due in part to a lack of personnel, the province realigned the staffing of emergency departments in some small towns. At night, a nurse and paramedic were on-site with a physician on-call to be consulted by telephone for all visits. During the day, the same clinic offered primary care and increased hours to 8am-8pm, 7 days a week. This had the dual goal of keeping the ED open overnight for access to care and increasing the availability of primary care appointments during daytime hours. The resulting care model, dubbed Collaborative Emergency Centres (CEC), is unique to Nova Scotia. A rapid knowledge synthesis published in 2015 found that "Zero reviews or studies were identified that assessed the effectiveness of CEC-type models as a complete concept." [1] Five years after the first CEC opened, this research seeks to assess the operational performance of the CEC program and predict how the care model will perform in larger population centres. This research does not discuss the potential impact on health care outcomes associated with CECs, however there is research underway to assess clinical outcomes.

Initial results of a program evaluation suggest that the CEC program has been well-received by care providers. [2] No evaluation of patient experience or outcomes was publicly available. Given the reported CEC cost savings associated with direct payments to physicians [3], and the ongoing pressure on health care resources, it is important to consider whether the program can be expanded into larger

communities. This research develops an analytical model to study the CECs, using data from existing CECs. It then uses the model to predict a CEC's operational performance in a larger population centre and under different ratios of appointment supply and demand.

1.1 Types of EDs in Nova Scotia

The Nova Scotia government defines four types of EDs in the province. These are Provincial, Regional, Community, and CEC. [4] The provincial EDs (Level 1) are at the two teaching hospitals, the QEII and the IWK, which are responsible for patients across Atlantic Canada. These hospitals are located in downtown Halifax. They have advanced trauma centres and specialized teams to care for the region's sickest patients. The Regional EDs (Level 2) are the major EDs of each "Zone" in the Nova Scotia Health Authority and operate 24/7/365 EDs for several communities. Examples include Dartmouth (as Halifax is Provincial), Yarmouth, and Antigonish. There are nine Regional EDs. These EDs receive ambulances, although in some cases the most acute and complex patients are sent to Halifax's QEII, either by ground or air ambulance. Community EDs (Level 3) are located in smaller communities and act to supplement the Regional EDs. Most Community EDs operate 24/7/365 [4], however some of them are only designated to operate during the day or on week days. Community EDs accept patients by ambulance, but are bypassed in certain circumstances (e.g. stroke, major trauma) in favour of Regional or Provincial EDs. Examples of Community EDs include Roseway Hospital, St. Marys Hospital, and Eastern Memorial Hospital. CECs (Level 4) operate at eight sites in Nova Scotia, all of

which are former Community EDs. The CECs operate similar to a Community ED during the daytime, but as explained in Section 1.2 they do not have a physician available on-site overnight. The Canadian Association of Emergency Physicians has stated that they do not believe CECs are true EDs, urging governments to be cautious when considering expanding the model. [5] [6] For the purpose of this research, the Nova Scotia government's definition of emergency department types is used.

1.2 An overview of the CEC Program

CECs are unique to Nova Scotia, although similar concepts are developing across North America. As a result, there is no existing literature on the care model, apart from the initial proposal. [3] The care model has gained interest from other jurisdictions seeking to change their rural emergency care delivery. Thus, this section is an operational overview of the CEC program in Nova Scotia from 2010 to the present, filling an important gap in the literature surrounding the care model. Further patient outcome studies are also necessary.

1.2.1 Introduction to the CEC Program

Nova Scotia's rural healthcare model employs a novel solution to overnight emergency care. Prior to 2011, access to many rural EDs was inconsistent, with physician shortages and other operational issues, resulting in closures up to 27 percent of the time. When physicians were available, they reportedly cancelled daytime appointments in order to recover from their night shift duties. [3] These

cancellations created gaps in primary care access; patients were forced to rely on the ED for much of their care. The vicious cycle led to frequent ED closures.

Following the Ross report on emergency healthcare [3] the province began to implement "CECs" where a nurse and paramedic would treat patients overnight with the assistance of a physician who provides advice over the phone. The Medical Oversight Physician (MOP) could work from home, or a central location such as a Regional ED, overseeing multiple CECs. Unlike an on-call physician, the MOP does not see the patient at a hospital, he or she simply provides treatment advice to the CEC team. Based on the government's outcome measures the model is considered a success, having dramatically cut the closure rate and improved availability of daytime primary care services. [2] Ross hypothesized that "the use of rural [EDs] will naturally decrease with better access to primary care." [3]

This paper explores Ross' proposed model in depth, providing an assessment of the available data on ED/CEC closures and the patients who have sought care, and analyzing findings and conclusions from four site visits by this author and a report commissioned by the Department of Health and Wellness in fall 2014. This paper focuses on the overnight care model. References to daytime practices are explicitly noted in the text.

1.2.2 A Collaborative Assessment Room for Emergencies

In 2010 physician John Ross declared there was a province-wide crisis in emergency health care. [7] Following his declaration the province hired him to produce a report titled "The Patient Journey Through Emergency Care in Nova Scotia." This report

called for the creation of a "Collaborative Assessment Room for Emergencies" (CARE) to offer emergency health services in rural towns. Ross identified 14 sites throughout the province to move to this collaborative model.

The average rural hospital was seeing 1.3 patients per night. Many nights involved no patients accessing care. [3] The average cost per patient was $2,150 for the physician alone. [*Ibid.*] This cost does not include the fixed costs of operating a hospital, such as support staff, maintenance, and medical equipment. Meanwhile some daytime clinics were experiencing six-to-seven week waits for primary care appointments. [*Ibid*.]

In Ross' report it was discovered that the vast majority of patients in rural EDs were presenting with low-acuity symptoms not requiring traditional emergency care. Acuity was assessed using the Canadian Triage and Acuity Scale (CTAS), scores of 4 or 5 mean the patient's visit is not urgent. Ross found that "during community consultations it arose that people rarely need true emergency care." [*Ibid.*]

Ross' CARE model was proposed for 14 locations throughout Nova Scotia. [4] The model involved a nurse and paramedic team working overnight (8pm-8am) with a physician available by phone. Ambulances would not deliver patients to CAREs and instead proceed directly to the nearest Regional Hospital. When a patient arrives at the CARE centre the nurse and paramedic would provide treatment within their scope of practice. If the team could not meet a patient's needs the patient would either be sent to the Regional Hospital by ambulance or asked to return the next day to see the physician.

During the daytime hours (8am to 8pm) there would be a physician available to treat walk-in patients, including those referred by the night time care team. [*Ibid*.] The CARE solution was intended to improve primary care access by ensuring the physicians are available during daytime hours. The report suggested that providing care during the daytime would mean the physician is available when he or she is most often required, patients are more likely to see their regular provider, and diseases can be better managed over the long-term. [*Ibid*.]

With a new model, the average cost per patient as measured by physician billings would drop and human resources could be redeployed to improving access to busier daytime clinics. The physician cost of a primary care visit is approximately $60 per patient, depending on the practice model. This is a significant savings compared with emergency care, assuming no physician would be needed overnight. Ross argued the CARE model, which guaranteed same-or-next-day appointments, would solve the problem of delayed access to primary care without requiring any additional physicians. [*Ibid*.]

An additional benefit of the CARE model is the proposed adoption of team-based care during the daytime. Patients would have access to an array of professionals including dieticians, physiotherapists, and nurse practitioners when visiting daytime clinics. These professionals provide different care than a physician, improving the team's ability to manage specific issues contributing to the poor healthcare outcomes experienced in rural Nova Scotia. These poor outcomes include high rates of obesity and chronic disease. [8] The team-based approach has been shown in the literature to improve patient outcomes for many diseases. [9]

The government saw the CARE model as a likely solution to two problems: first, the need to redeploy resources to where they were most needed, [10] and second, the need to maintain the community's access to 24/7/365 emergency care. [11]

The patient flow of CECs is conceptually similar to that of patients who could not get a primary care appointment and instead visited an ED. Most patients attempt to get a primary care appointment, and many of those will spend several days debating waiting another day for an appointment, going to a walk-in clinic, or seeking overnight emergency care. If the patient goes to a primary care or walk-in clinic, they leave the system. Once they arrive at overnight care they receive treatment, however some patients seeking overnight care must return the next day to see a doctor, creating inconvenience for the patient and some extra work for the healthcare providers. This is the key difference between a CEC and an ED. This flow is illustrated in Figure 1.
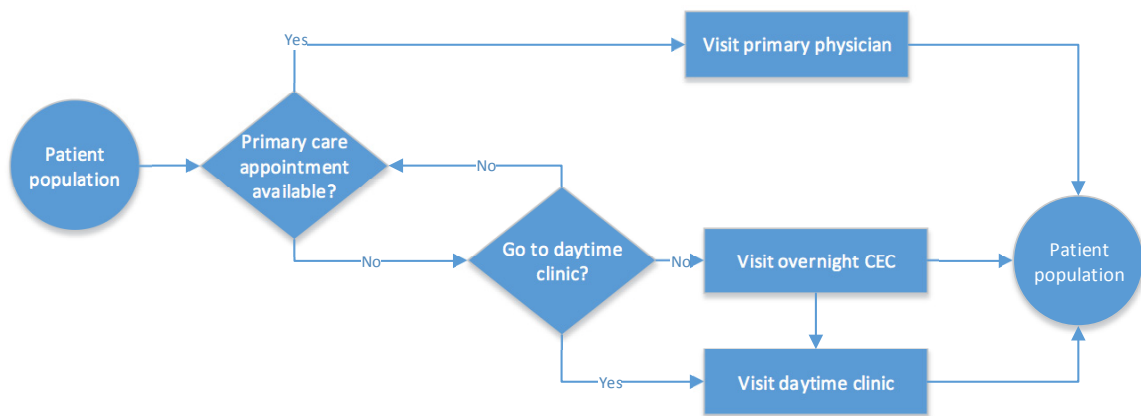
Figure 1 Conceptual CEC flow

1.3 CEC Implementation

Implementation of the CARE model began in 2011. The facilities were re-named "Collaborative Emergency Centres" prior to implementation. The first centre opened in Parrsboro in July 2011. As of Fall 2015 there are eight CECs operating in Nova Scotia.

1.3.1 Care Models

The eight CECs use one of four different care models

- Hospital-based CEC with a registered nurse (RN) and paramedic

- Hospital-based CEC with two RNs

- Ambulance-based CEC with an RN and a paramedic

- One site operates only as a daytime CEC

1.3.1.1 Hospital-based CEC with a RN and Paramedic

Five of the hospital-based CECs use a RN and paramedic model. In Parrsboro the paramedic is an Advanced Care Paramedic (ACP), in the remainder the paramedic is a Primary Care Paramedic (PCP).

ACPs are able to perform additional tasks that PCPs cannot, such as carrying medications and treating advanced airway obstructions; [12] ACPs undertake an additional year of training and more apprenticeship learning.

1.3.1.2 Hospital-based CEC with two RNs

The Springhill CEC uses two RNs to provide care. There is no paramedic at this location. As there is no paramedic, specific procedures (such as suturing) cannot be performed at this site.

1.3.1.3 Ambulance-based CEC with a RN and a Paramedic

One site, New Waterford, uses a model where the RN and paramedic work together on an ambulance. This model has been operational since late 2013. The ambulance delivers the nurse and paramedic to the patient's house. The team offers treatment at the house or transports the patient to the hospital. The daytime CEC at New Waterford operates out of the clinic at the local hospital.

1.3.2 Existing CECs

The existing CECs all operate in small communities. The largest CEC community is Springhill, with approximately 7,600 residents in the catchment area. The smallest CEC community is either Pugwash or Parrsboro, with approximately 4,000 residents. As the catchments are not formally defined it is difficult to determine which community is the smallest. As of Summer 2013, Musquodoboit Valley is operating solely as a daytime CEC, however, all paramedics responding to calls overnight can book patients a clinic appointment the following day. [13]

During the daytime, the eight sites provide diagnostic imaging and laboratory services. During the daytime the sites operate as a walk-in clinic, where appointments aren't required and patients show up on their own schedule, with a

physician present or on-call nearby. The care model, opening date, additional

services provided, availability of scheduled daytime appointments, and whether the

daytime physician's office is onsite or nearby are detailed in Table 1. The table is

compiled from interviews completed with CEC staff and personal communication

with Thomas Dobson, Coordinator of Community Paramedic Programs at EHS. At all

sites patients can access walk-in appointments 24 hours per day. At one site,

Musquodoboit Harbour, patients can call in the morning to schedule an appointment

for that day (between 9:30am and 8pm), but the CEC will still accept walk-ins at any

time.

Table 1 Comparison of CEC sites and services provided

Site	Opening date	Overnight care model	Physician office location	Daytime appointments available?
Parrsboro	July 2011	RN/ACP	Nearby	No
Springhill	March 2012	RN/RN	Onsite	No
Tatamagouche	July 2012	RN/PCP	Onsite	No
Musquodoboit Valley	Summer 2013	N/a	Onsite	Same-day only
Musquodoboit Harbour	November 2012	RN/PCP	Onsite	Same-day only
Pugwash	September 2012	RN/PCP	Onsite	No
New Waterford	September 2013	RN/PCP on ambulance	Onsite	Yes – same or next day
Annapolis Royal	September 2012	RN/PCP	Onsite	Same-day only

The daytime CEC model involves a physician who is on-call to treat walk-in patients. A nurse (RN or Nurse Practitioner) is on-site providing care and triaging patients. The nurse will also provide treatment within their scope of practice. The daytime CEC is similar to a walk-in clinic, however it includes access to services such as x-ray and a blood lab. All CEC sites include a daytime clinic at a fixed location, including the ambulance-based overnight CEC in New Waterford.

An assessment of the operational performance of these sites was conducted in 2014. It concluded that the sites are seeing an average of 6.93 patients per night (0.99 per site) and that patient arrivals have been declining since inception. [2]

1.3.2.1 General Patient Flow

The following patient flow information was determined over the course of four CEC site visits, at Tatamagouche, Parrsboro, Springhill, and Musquodoboit Harbour. Over the course of these site visits, three physicians, five paramedics, and seven nurses were interviewed. The information was corroborated in policy documents provided by EHS managers.

When a patient arrives at a CEC they must ring the doorbell. The team will go to the door together to let the patient in. This is done for staff safety. Once inside, staff triage the patient.

The patient's treatment path is different depending on their acuity level. This is detailed in Figure 2. [2]
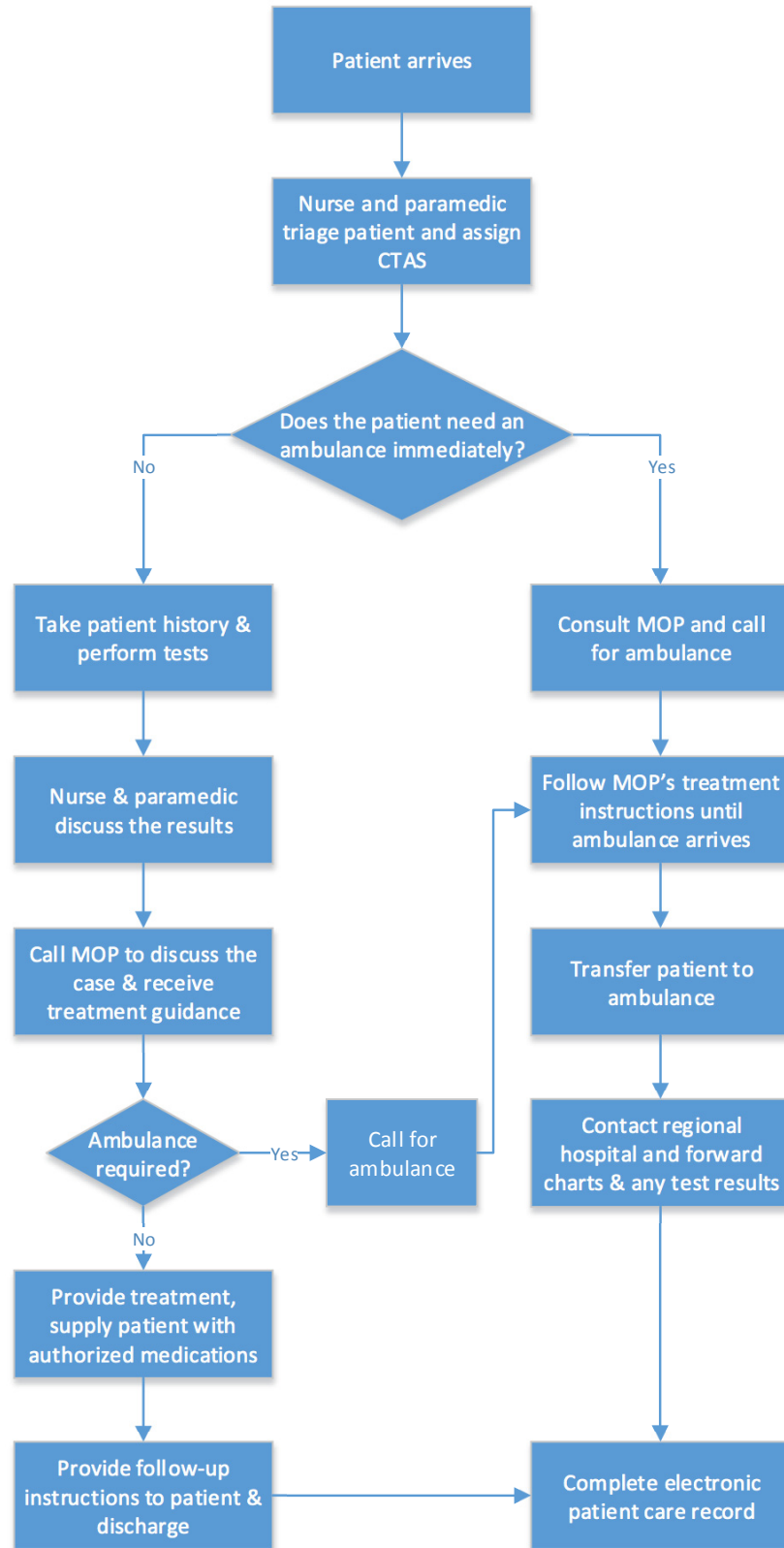
Figure 2 Patient flow through a CEC

If the patient's condition is acute, staff will consult the MOP and call an ambulance for transfer. If the patient is stable, staff will begin to collect the patient's personal information, medical history, and symptoms. The MOP will provide treatment guidance as staff wait for the ambulance to arrive. This is outlined in further detail below.

If the patient arrives with a lower acuity, staff will perform a history and basic testing (blood pressure, heart rate, etc.). Staff then call the MOP for treatment direction and authorization. One of three dispositions will then occur: 1) the patient will be discharged with instructions to monitor the situation, 2) the patient will be discharged to return in the morning to see the on-call physician in the daytime CEC, 3) the patient will be transferred to the regional hospital for further assessment and management (perhaps by ambulance, perhaps by private car). Staff may provide the patient with one or two doses of medication if the MOP instructs them to, but the patient would be booked to return for any prescriptions that might be required. Once the patient has left, staff will complete the Electronic Patient Care Record (ePCR). This is typically done by the paramedic and then reviewed by the RN.

1.3.2.2 Critical Patients' Flow

If a high-acuity patient arrives at the CEC staff will either call for an ambulance or instruct the patient to travel to the Regional Hospital. This is done in consultation with the MOP. The course of action is dependent on the patient's vital signs and other clinical factors, as well as whether they are accompanied or not. CEC staff will stabilize the patient and provide treatment on the recommendation of the MOP

while waiting for the ambulance. Once the patient is on the ambulance, staff will complete the ePCR, and send the results of any investigation and tests to the head nurse at the Regional Hospital. The MOP will phone the physician on duty at the Regional Hospital to provide additional information.

Ambulance dispatch priority is based on a number of factors including geographic coverage; the ambulance is not always dispatched immediately if a patient is in stable condition. For example, there is one ambulance scheduled on the North Shore overnight. This area includes Pugwash and Tatamagouche (approximately 2,000 km^2). Rather than using the local ambulance, another ambulance may be dispatched from Truro or Amherst if the patient's condition is such that they can wait at the CEC. No evidence was available to assess ambulance response times for emergencies at the CECs to see if they met the EHS' performance guidelines.

It is rare for patients to wait when arriving at an overnight CEC. Despite this queues do occasionally form. In this case the staff will triage patients when they arrive and provide treatment based on the patient's acuity. As high acuity patients are quickly transported by the ambulance to a Regional Hospital it is extremely unlikely that staff must treat two or more patients with significant resource needs at the same time.

1.4 Preliminary CEC Program Results

The data source consulted is the *Care Right Now* report from Stylus Consulting. [2] This publicly available report outlines patient arrivals, acuity levels, and overnight closures at the CEC sites. This is the sole extant evaluation of the CEC program, and

was commissioned by the Department of Health and Wellness. Patient care data from the electronic patient care record will be reviewed in Section 3.1.

The Nova Scotia Government continues to expand the use of CECs, citing the improved daytime care and the reduction in overnight visits as signs of success. [14] The overnight visits in the traditional model were viewed as a symptom of inadequate daytime care; by improving daytime care it was expected night-time demand would fall. [4] The CEC sites have seen a reduction in overnight ED closures and have improved availability of daytime medical care. These were the two key outcome measures declared at the program's outset.

According to the Stylus report [2], none of the CECs have seen more than five patients in a single night since the program began. On average, the CEC program sees an average of 0.99 patients per site per night, a drop of 0.32 patients per night compared to the pre-CEC average. [2] Additionally, the report found that patients have neither been arriving at the Regional Hospital in higher numbers, nor have they been overwhelming the daytime clinics. It is believed that patients are simply seeing their regular physician in a timely manner rather than delaying their care until an emergency arises. [*Ibid*.] It is also possible that rural Nova Scotia's declining population contributed to this finding. For the purposes of this finding, emergencies are events that could not have waited for a primary care appointment the next day.

Between 18-22% of patients are transferred to the Regional Hospital after care is initiated at the CEC. [2] 44-58% of patients begin their treatment in the overnight CEC and are directed to return to complete the treatment the next day, when a

physician is present. [*Ibid*.] The remaining 22-35% of patients access all necessary treatment from the overnight CEC staff.[1] [*Ibid*.]

The CEC sites have demonstrated a major improvement in terms of overnight closure. Prior to opening a CEC, some sites experienced unplanned closures up to 27% of the time due in part to a lack of staff. [3] [2] Since converting to the CEC model the worst-performing site has been closed an average of four nights per quarter (approximately 4.4%). [2] The change in closure rates for six of the eight sites is demonstrated in Figure 3, the two remaining sites were not open for at least one year at the time the data was collected. [*Ibid*.]

Hours of overnight ED closure per quarter
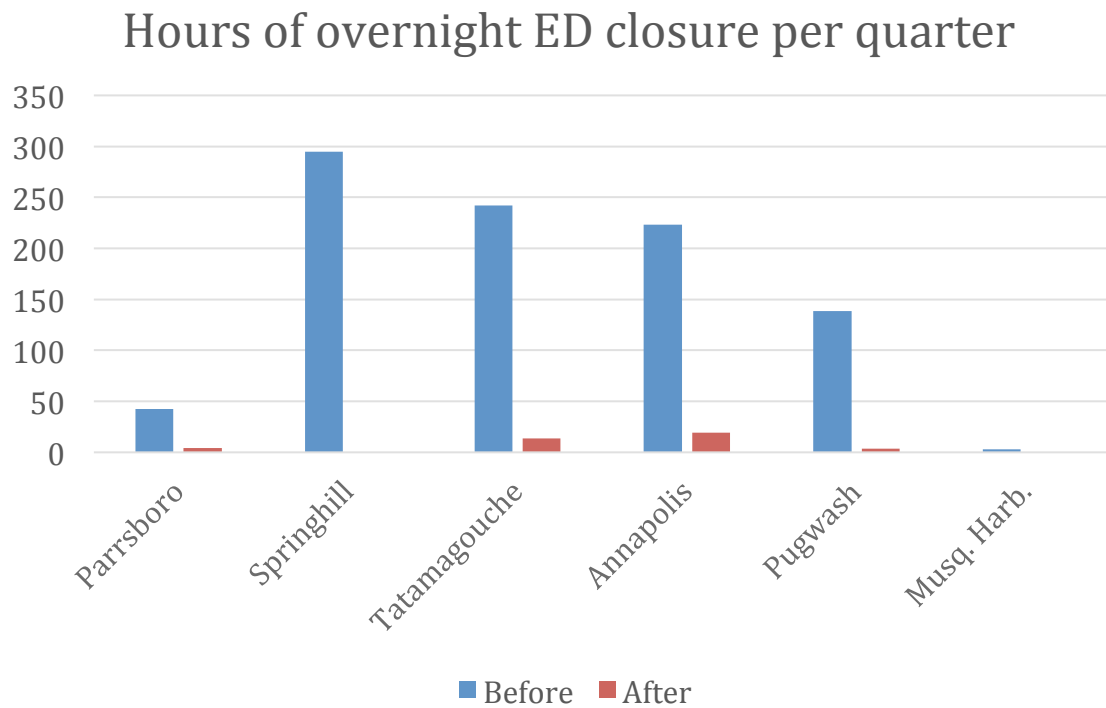
Figure 3 Hours of overnight closure per quarter [2]

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[1] Numbers do not add to 100 percent as they are drawn from multiple sites

The number of overnight patients has fallen at almost every site since the program began. Musquodoboit Harbour is the exception, with high-acuity patient arrivals rising after the CEC opened. A possible explanation for this is that patients from nearby Cole Harbour are driving to the CEC to avoid the long wait at the closer Dartmouth General Hospital, providing them with better access to care. [2] Figure 4 shows the quarterly arrivals for low-acuity (CTAS 4-5) patients for six of the eight CEC sites before and after CEC implementation. Figure 5 show the same data for high-acuity (CTAS 1-3) patients. These are the only six sites open for at least one year when Stylus completed data collection. [2]
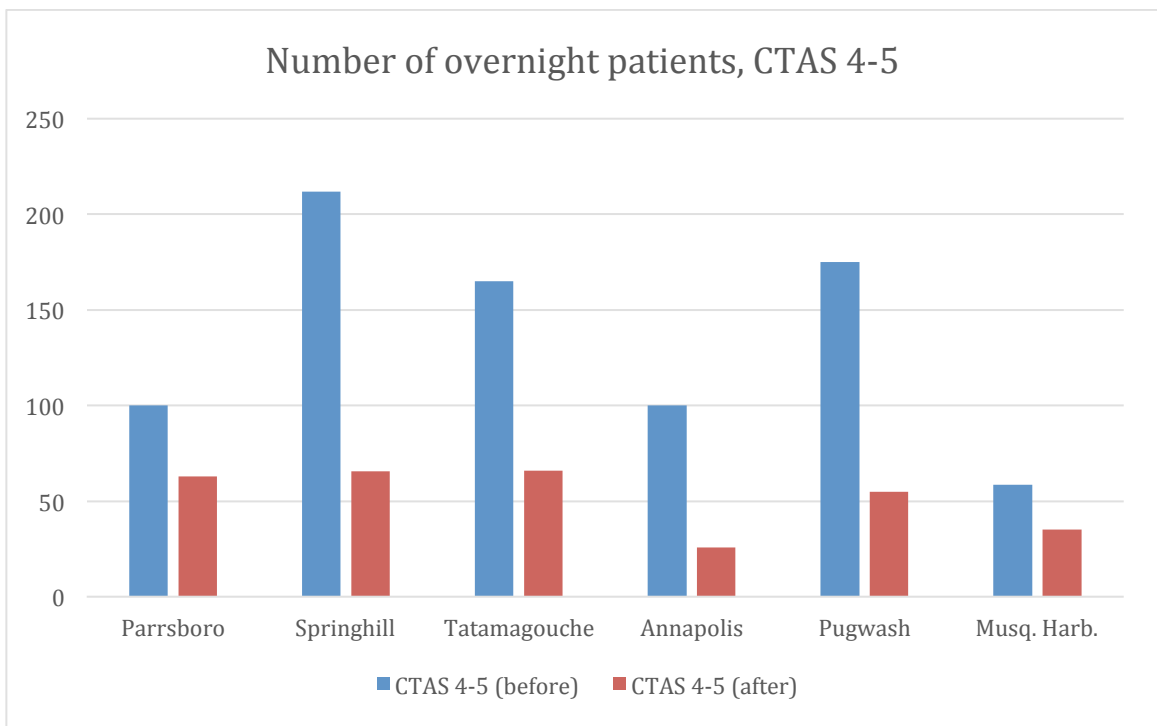
Figure 4 Average patient arrivals, CTAS 4-5, by CEC site [2]
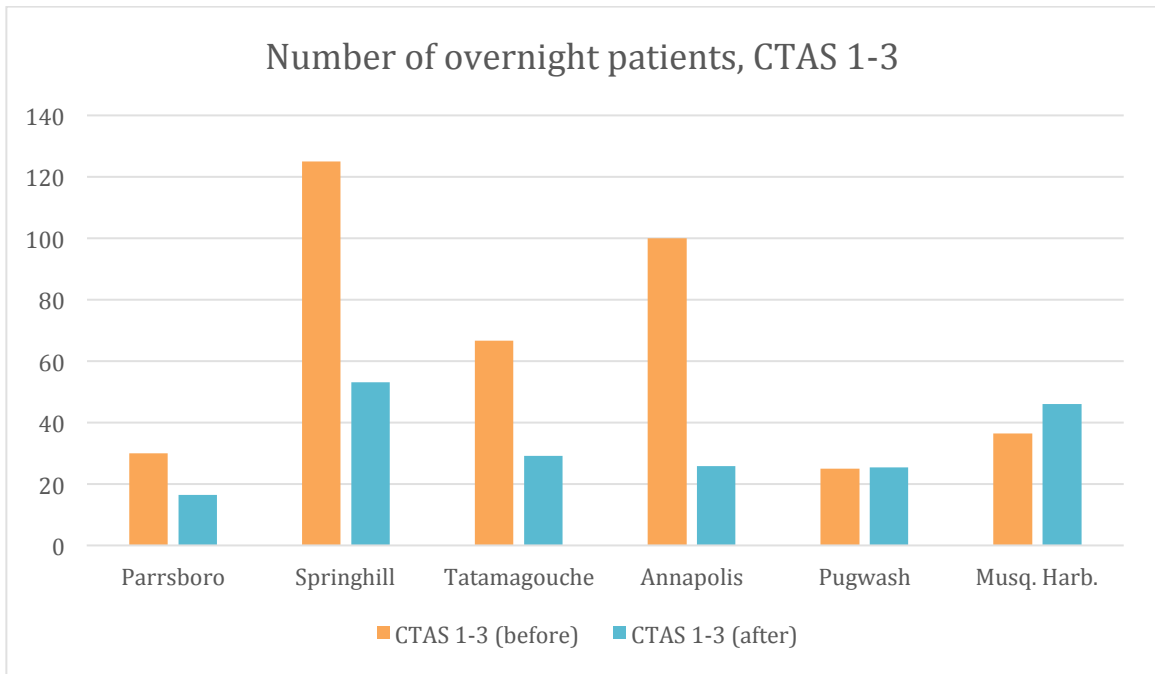
Figure 5 Average patient arrivals, CTAS 1-3, by CEC site [2]

1.5 Discussion

According to the government's report on the CEC program, the government and physician focus groups believe that the early results will lead to better quality of life for physicians, who are no longer required to be on call overnight. [2] They also anticipate that this will improve recruitment and retention of physicians. [3] [2] By improving patients' access to daytime care the system aims to provide the care patients need when it is convenient for both patient and provider. This also improves the continuity of care, as patients are seeing their primary healthcare provider for a greater proportion of their visits. When a patient is able to see the same provider for every visit they develop a stronger relationship with the provider and the provider is able to better diagnose and treat issues. This comes from a combination of the increased trust and the provider's knowledge of past treatment

attempts. This continuity of care is believed by many health professionals to lead to better management of chronic diseases. [15]

The CEC evaluation [2] suggests that the CEC program is meeting its goals of increasing primary care access, reducing unplanned closures of overnight emergency care, and reducing the physician cost of providing overnight care. Patients appear to have better availability of primary care and night time visits to the ED are down suggesting patients are less reliant on the overnight care providers than they were under the traditional ED model. As noted, this evaluation did not include patient feedback or treatment outcomes. This evaluation showed that the operational changes achieved the government's goals, with patient visits decreasing compared to the ED model. However, it is also not perfect; The 50 percent "treat and follow-up" and 20 percent "treat and transfer" rates indicate that some patient needs are not being met upon their initial visit to the hospital. This significant rate of re-work reduces the convenience for both patient and provider.

There is a research project underway to look at the patients who are sent back to primary care or sent on to the regional hospital for additional treatment. This study aims to identify the gaps between the care available and the care required by the patients to determine whether changes in the model such as additional staff training could be beneficial. By adjusting the staff training and scope of practice it may be possible to increase the proportion of "treat and release" patients who are not referred for further care. An example of this may be expanding suturing to all sites. This would further improve operational performance of CECs by reducing the re-work mentioned above. Further research could look in to the factors driving arrivals

at the CECs, patient flow through the hospitals, the appropriateness of the training offered to practitioners, and the reasons patients fail to arrive for their follow-up appointments.

There is a lack of consistency in the daytime CEC model. Only Musquodoboit Harbour allows patients to make appointments, with the others being walk-in only. In Parrsboro the physician works at a different office and must come to the hospital when a patient arrives. At the remaining sites, the physician runs his or her practice from the same site as the clinic. As the daytime CEC is staffed by an on-duty physician this does not improve continuity of care when compared with the ED, however, the CEC may still improve continuity of care by reducing appointment cancellations in primary care, increasing the probability that a patient sees his or her preferred provider. Analysis on the rate at which patients see their regular provider was not conducted for this work. The services available vary by location. The services available are detailed above in Table 1.

Services such as the laboratory and x-ray are not always available for the same hours as the physician, resulting in additional follow-up visits to offer a full suite of care. Analysis has not been done to determine the extra visits generated by lab closures or mismatched laboratory and physician hours.

The early data suggest that the program has been effective in reducing overnight closures of EDs and has increased availability of primary care. Healthcare providers believe that this will result in better long-term management of chronic diseases. The provincial government has indicated they will continue to use the model and assess

additional sites. [16] The data available paints a positive picture of the program and appears to be sufficient to begin an analysis of the program's operational performance. The data show that the CEC model is at a point where further study is both warranted and possible.

1.6 Thesis Outline

The CEC program presents several interesting questions for further research. Chiefly, the change in primary care utilization, and corresponding change in wait times for primary care present an interesting area for study. Another opportunity for research is the arrival rate at overnight care to determine a maximum suitable catchment population for the CEC model. This research seeks to address these two questions.

In Chapter 2 existing literature on EDs, family practice, and outpatient clinics are reviewed and compared with the CEC system. In Chapter 3 the background statistics on the CEC system and the analytical model are presented. Chapter 4 describes the steps taken to verify and validate the model results. Chapter 5 describes the numerical results from the model. Chapter 6 discusses the model results and their implication for the CEC program. Finally, Chapter 7 summarizes the research findings.

Chapter 2 – Literature Review

This chapter reviews published research relevant to CECs. The CEC care model does not exist in the literature, as it is new and unique to Nova Scotia. The three following sections compare CECs to traditional care models. These care models are EDs (Section 2.1), traditional outpatient or family practice clinics (Section 2.2), and Open Access clinics (Section 2.3). These comparisons will assist in decision making when defining the analytical model.

2.1 CECs vs EDs

As facilities providing acute medical care, CECs are faced with several of the same problems as their traditional counterpart, the ED, which provides acute care to patients without requiring appointments. The challenges include arrival rates, arrival patterns, patient acuity, human resources, and reneging. Reneging occurs when a patient tires of waiting for primary care and chooses to go to the ED or CEC instead. The two care models share similar benefits, especially during the daytime, when CECs are most comparable to EDs. For example, during the daytime patients have access to diagnostic tools such as x-ray and blood labs, and during the evening patients know they will receive some care if they show up.

2.1.1 Arrival Rates

The rate of patient arrivals at EDs is linked to access to primary care. One study found that "restructuring primary care services […] may result in decreased ED utilization rates by approximately 43% for low severity triage level cases." [17] Low

severity triage level cases are the most common arrivals at the existing CECs. This study used a hurdle negative binomial regression model to determine factors influencing arrivals. Another study used multivariate logistic regression to determine the cause of patient arrivals. The only statistically significant predictor of non-acute arrivals was access to primary care. [18] "38 percent of the patients surveyed expressed a willingness to trade an ED visit for a clinic appointment within 3 days." [*Ibid*.] This research was not followed up in a real-life situation when access to appointments was improved. There is no reason to believe that there is a different relationship to primary care availability in CECs.

As CECs have opened the arrival rate has declined; this appears to be a result of fewer cancelled primary care visits. [2] This result was predicted as part of the program proposal in 2010. [3] When patients receive timely access to primary care they no longer need to attend the ED for routine visits such as prescription refills. It appears the CEC program is successfully providing timely access to primary care. [2]

One study found that patient arrivals at the ED were highest on Sunday and lowest on Friday. [19] Day-by-day arrival data for CECs are not available but a similar pattern may exist as the primary care schedule is similar to that in areas with an ED. Further analysis of patient arrival patterns could inform staffing decisions and ensure that their regular primary care provider sees them in a timely manner. It is helpful for the system to have the greatest possible proportion of visits handled in primary care as this is the most cost-effective visit in smaller centres with few arrivals overnight. [3] A failure to adequately staff primary care then impacts the arrival rate (and staffing needs) of emergency care, which could lead to issues such

as test duplication when compared with visits to the primary care provider (i.e. reduced continuity of care).

In addition to access to primary care, studies have looked at the availability of comprehensive care paths and disease management. [20] [21] The CEC model differs from the ED in this regard; CECs were intended to increase resources available for primary care and improve disease management through better continuity of patients' care. Continuity of care refers to having the patient see the same provider or providers on a regular basis as opposed to the provider on duty when they arrive for care. Naturally, the ED does not provide continuity of care as the patient must see the provider on duty. Another study cited the convenience of the ED as a driver of inappropriate patient arrivals [22]; the CEC model aims to make daytime visits to primary care convenient to alleviate this pressure. By making the primary care visit convenient and accessible the patient will see their usual provider for most of their visits. This allows the CEC program to provide better continuity of care, thus better disease management than EDs.

The findings in the literature indicate that CEC patient arrival rates are similar to those of EDs, however CECs free primary care providers to treat patients during the daytime, improving continuity of care and disease management and deters inappropriate arrivals by removing the guarantee that a physician will see the patient at night.

2.1.2 Arrival Patterns

The patient arrival patterns for CECs and EDs cause common issues and staffing concerns. CECs and EDs face common arrival times and arrival patterns that can be modelled the same way.

The most popular period for visiting the CEC is in the evening (5-10pm), spread across the daytime CEC with a physician on duty or the overnight CEC with the MOP. Patients at the overnight CEC tend to arrive before midnight. [2] This demand pattern reflects that of a traditional ED, where non-acute patient arrivals are clustered in the morning and evening hours, when most people are not at work. [23]

The arrival patterns of walk-in patients at EDs has been modelled in the literature. One study used a power spectral density analysis to find that walk-ins have a 7-day seasonality. [24] This means that the arrivals vary by day of week but the patterns repeat each week. The study used a structured time series model to create arrival forecasts from 1 to 7 days ahead. Another study used Artificial Neural Networks (ANN) to predict low acuity patient arrivals. [25] The same study compared the performance of the ANN to nonlinear least squared regression and multiple linear regression to confirm that ANN provided a more accurate prediction of arrival patterns.

2.1.3 Patient Acuity

Patients arriving overnight at CECs differ from ED patients because they typically have a low acuity (CTAS 4-5). [2] Patients requiring an ambulance are transported directly to the Regional Hospital at night. [4] It is extremely rare for a very high

acuity patient (CTAS 1-2) to arrive on his or her own accord at a CEC. Patients with CTAS 3 appear to be more common, though a precise breakdown is not available. CEC sites see approximately one CTAS 1-3 patient every three or four nights (25-30 per quarter). These patients are transferred by ambulance to the Regional Hospital. [2] According to Ross, during the daytime high-acuity patients will occasionally arrive. [4] Complete data detailing these arrivals was not available. Studies examining EDs focus on larger centres, where high acuity (CTAS 1-3) patients form a greater proportion of the patient population. [23] Thus, existing models that are based on patient acuity are not applicable to CEC communities.

2.1.4 Staff Qualification

The specialized care model at the CEC requires different staff training than at an ED. The CEC model involves a dual-trained emergency nurse who conducts registration and triage. In the traditional ED the patient will see a registration clerk, then a triage nurse, then eventually begin treatment. This model has been cited as needlessly delaying low-acuity patients by requiring two steps in the process before moving patients to the appropriate stream, rather than doing a quick assessment to determine the appropriate stream before registering and fully triaging the patient. [26] The daytime CEC uses the traditional ED registration and triage process.

There may be an opportunity to offer a dual-trained registration clerk and rapid triage at the CEC sites during the daytime. Reducing delays in receiving care, especially for follow-up patients, could be achieved by providing more information to the daytime physician to forewarn him or her of potential follow-up patients.

Notifying the team in charge of follow-up of their daily caseload has been successfully piloted in Burnaby, BC and improved the efficiency of the ED by reducing delays in the triage step. This pilot used Lean principles to achieve its outcomes. [*Ibid*.] The CEC staff do not provide daytime staff with a summary of patients referred to primary care, thus the daytime care providers must start the case from scratch.

The lessons learned for low acuity patients at larger EDs could be used to make better staffing and training decisions at CECs. By notifying daytime staff of potential referrals CECs could improve the patient's experience and reduce time spent with care providers.

2.1.5 Reneging

Reneging is a behaviour where patients leave the queue after losing patience. This is contrasted with "balking," where a patient chooses not to enter a queue due to the wait. [27] The low overnight usage of CECs, approximately one patient every other night, [2] suggests that reneging is not an issue. However, if the model is deployed to larger centres there is a greater risk of reneging. Reneging is a common problem in traditional EDs. Patients will leave the emergency queue when delays are too high for them. [28] [29] [30] No model to replicate this behaviour was found in the literature.

2.1.6 Conclusion

CECs and EDs share many challenges, and the solutions to these challenges are often similar. Arrival modelling can allow hospital managers to improve resource

scheduling. Lean methodologies, such as the process changes described above, can be used to improve triage and treatment efficiency for low-acuity patients. Improvements to primary care services can reduce the overall patient demand in the ED or CEC. Many of the challenges found in the CECs can be investigated using techniques proven to work in ED settings.

2.2 CECs vs Outpatient/Family Clinics

The daytime CEC also shares traits with a traditional outpatient or family clinic. The traditional family clinic involves a physician who sees non-urgent patients who have pre-scheduled appointments. These patients typically have a pre-existing relationship with the physician. The family physician needs to plan for walk-ins, or refuse them; the daytime CEC physician must accept walk-ins. In smaller communities the physician on call must fit daytime CEC patients in during their usual practice, similar to a family physician planning for walk-ins, though the patients' acuity could be higher at the CEC, as no traditional, fully-staffed ED exists. Finally, the family practice model has a risk of no-shows; except in Musquodoboit Harbour and Musquodoboit Valley, the CEC does not schedule patients and does not face this risk, however CECs experience a failure of some patients to return for follow up. This section compares these differences and the way they are modelled, specifically looking at walk-in patients, wait times, and the risk of no-shows.

2.2.1 Planning for walk-in patients

Both daytime CECs and family practice clinics see walk-in patients. Seven of the eight existing daytime CECs are run in conjunction with the physician's regular

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practice hours. [2] These physicians accept CEC patients during the daytime and fit them within their existing patient schedule. This can be compared to the traditional practice where some physicians will make room for walk-in patients (or same day appointments) even if there are no slots in the appointment book.

To see these patients without undue delay, physicians can leverage efficient scheduling tools. In one study a simulation model was used to evaluate nine scheduling policies. [31] The aim was to decrease the overall patient waiting time and length of stay. The simulation found that starting the clinic on time and allowing patients to be scheduled at any time during the clinic would minimize wait times. The authors did not specify the arrival and service time distributions used. In the study the "diary" patients can be compared to the walk-in patients in a traditional outpatient clinic. The diary patients are patients slotted in to an appointment by the physician, rather than through the regular appointment booking process. The diary patients do not appear in the daily schedule.

Another study examined the problem of multi-period scheduling. [32] A scheduling period could be a part of a day (morning or afternoon, e.g.), an entire day, or any other contiguous grouping of appointments without a major break in service. The study found a combination of scheduling low-variance patients at the beginning (LVBEG) of the period and spreading urgent appointment slots throughout the day is the best method to minimize waiting times while maintaining high resource utilization. Low-variance patients are those believed by the scheduling clerk to have a predictable service time, such as a routine check-up or prescription refill. This

paper suggested using an exponential distribution for inter-arrival times and a lognormal distribution for service times in healthcare settings. [*Ibid*.]

2.2.2 Wait times

Daytime CECs and family clinics both involve patients who must wait to see the provider. Patients value the quality of the time with the physician more than they value low wait times. [33] This suggests that patients are tolerant of some delays in their appointment. Therefore a provider accepting some unplanned walk-in patients may not result in higher no-show rates in the clinic. There are proven techniques to accommodate walk-ins without causing patients to balk due to long wait times.

One paper compared nine appointment scheduling rules and concluded that scheduling multiple patients at the beginning of an appointment block was detrimental to average waiting time. [34] The paper found that scheduling them throughout the day was more effective in terms of reducing the wait for service. The paper used a simulation model to analyse the scheduling heuristics for varying values of the number of patients, risk of no-shows, and the service time distribution.

Another comparison of scheduling rules used a simulation to evaluate four registration strategies for clinics with a mix of walk-ins and scheduled patients. The clinics studied experienced an average walk-in rate of 72 percent. The four strategies are to begin the clinic with a block of scheduled patients and end with walk-ins, begin with a block of scheduled patients and then alternate walk-ins and schedule patients, to alternate from the beginning, and to adjust the planned service time based on appointment type. The combination of alternating the appointment

type (scheduled vs walk-in) and varying the service time had the lowest time in system and the lowest waiting time. [35]

These scheduling insights can be used to improve the wait times when a physician is assigned the daytime CEC shift.

2.2.3 Wait time for walk-in patients

As daytime CECs and family clinics both feature walk-in patients, it is instructive to examine the walk-in patients specifically. One paper suggests that walk-in patients may be more tolerant of a wait than scheduled patients. [36] In the CEC setting the walk-ins may take precedence over scheduled patients depending on their acuity. This likely requires extra planning by the scheduler to reduce the risk of scheduled patients leaving the clinic without being seen. One paper found that walk-ins and no-shows do not tend to occur at the same rate or the same time, which means the schedule must plan for both separately; they do not cancel each other out. [37]

Another paper says walk-in patients experience hourly seasonality; that is walk-in arrival rates are highly dependent on the time of day. [38] Another study found that walk-ins peaked toward the end of the clinic period (1-6pm). [19] The inter-arrival rate of walk-in patients can be modelled using a Poisson distribution. [38] [39] Another study uses the exponential distribution to model inter-arrival times of patients at a family clinic. [40] These have been dismissed as not being sufficiently robust when walk-ins, emergencies, and no-shows are taken into account. [36]

One paper found that leaving room for walk-in patients near the beginning of the schedule period minimizes the impact of the walk-ins on overall wait time, however

more walk-in patients will be served if the bulk of the walk-in slots are available toward the end of the schedule period. [41] This suggests that the bulk of walk-in slots should be left to the times of day when their use is highest. This may be highly dependent on the clinic's patient peculiarities.

A version of the traditional clinic model where walk-ins take precedence over scheduled patients was not found in the literature. The information on scheduling walk-in patients within the regular clinic hours can be instructive to schedulers in the CEC system.

2.2.4 Risk of no-shows

Unlike daytime CECs, traditional family clinics face a risk of patients not showing up for an appointment. Schedulers must account for the potential of "no-shows." There are several ways to account for the risk of no-shows when managing a practice that could be instructive for CEC planning.

One study found that ten percent of patients do not attend their appointment. [42] In the clinic observed in the paper, a failure to account for no-shows leads to a one percent increase in doctor idle time. [*Ibid*.] Another paper found the no-show rate to fall between 12-42% [43], with higher numbers being linked to longer appointment lead times. [44] [43] No show rates have also been shown to fall between 5-55%. [45] Several scheduling models describe no-shows and appointment slots for urgent patients as buffers, which allow the overall schedule to remain on track when the slots are not filled. [34] [32] As seen previously, the number of no-shows and walk-

in slots are not related [37], however, both must be taken into account and both can assist in managing the overall wait time.

One study recommended scheduling low variance patients at the beginning of the clinic in combination with an overloading strategy to mitigate against the risk of no-show patients. [46] A related study found that even if the scheduler erred in determining the patients' appointment length this method would result in a lower overall wait time for the patients. The study found that even for the scenario with the highest scheduler uncertainty this method would perform eight percent better than the next-best method studied. [47]

The rate at which patients fail to return to the CEC for follow-up is not documented in the existing literature, but is referred to in one report. [2] In the current daytime CEC format the provider does not know to expect a patient returning after overnight care. These insights may be better applied when CECs are large enough to begin scheduling arrivals, as in Musquodoboit Harbour.

2.2.5 Conclusion

The literature presents methods for planning the primary care physician's workload in an outpatient environment. The models typically rely on simulation experiments to test scheduling heuristics. Most of the studies reviewed model the inter-arrival time with as a Poisson process with an exponential distribution. Service times have typically been modelled with the lognormal distribution. If the physician is seeing CEC patients during the course of their family practice the no-show rate may help in finding appointment slots for CEC patients. The methods discussed in this section

can be used to model the daytime aspects of CEC care in smaller centres where the physician manages the CEC patients alongside a regularly scheduled practice as well as the larger CEC in Musquodoboit Harbour where the patients are scheduled using an Open Access approach, discussed in Section 2.3.

2.3 CECs vs Open Access Clinics

The daytime CEC in Musquodoboit Harbour is similar to an Open Access primary care clinic. An Open Access clinic aims to schedule all patients on the day they call, with limited appointments being booked for future dates. At the Musquodoboit Harbour CEC patients can call any time after 9:30am to receive a same-day appointment slot. Open Access scheduling aims to reduce the rate of low-acuity patients attending the ED by decreasing the time to get a primary care appointment. [48] In Section 2.1 it was shown that patients will tolerate up to three days' wait before abandoning the primary care path. This section examines Open Access' impact on no-show rates, appointment lead time, demand modelling, and finding a suitable blend of appointment slots (fixed vs. open) for a clinic.

2.3.1 No-show rates

Daytime CECs and Open Access clinics are similar in that few patients have an appointment scheduled in advance. In Section 2.2 we saw that no-show rates are positively correlated with appointment lead time. [43] By accepting same-day appointments, only the Musquodoboit Harbour CEC likely experiences a low no-show rate. Open Access clinics leave 65-75% of appointments for same day patients,

with the remainder being held for follow-up appointments scheduled no more than two days in advance. [48] This mix may be varied depending on the clinic's needs.

The Open Access model may not apply directly to the other daytime CECs. The other seven locations are handled as part of the physician's regular practice. Physicians may leave slots open for CEC patients or find other ways to ensure CEC patients are seen in a timely manner. This was discussed previously, in Section 2.2.

A model developed for an individual patient's no-show probability is $f(x) = 1 - 0.5 \cdot e^{-0.017 \cdot x}$ where x is the appointment lead time in days. [48] Another study found an average drop in no-shows across 25 clinics of five percent; upon implementation of Open Access scheduling the average no-show rate fell from 16 percent to 11 percent. [49]

A key performance metric in Open Access is the time to find an appointment. One study assumed that 50 percent of patients who failed to receive a same day appointment would make another attempt within five days. [48] Another found that the third available appointment was on average 4 days away, an improvement from 36 days prior to implementation of Open Access. [49]

Based on these findings, it may be instructive for physicians in CEC communities to adopt Open Access care to decrease appointment lead time.

2.3.2 Patient satisfaction

It has been shown that Open Access clinics improve patient satisfaction compared with traditional practice scheduling. [49] This matches the experience in the CEC model, where patients were happy with the improved access to care. [2] Despite the

improvements in patient satisfaction and primary care access it is not clear why widespread adoption of Open Access has not happened.

2.3.3 Modelling demand

The efficiency of an Open Access clinic is affected by the fluctuations of daily demand. As patients are not scheduled far in advance there may be days where the clinic cannot meet the demand, and days where the clinic is operating far below capacity. One study uses a trivariate Poisson distribution to model daily demand. [50] Events such as flu season lead to high correlation in daily demand, though much of the year sees low correlation in daily demand. [*Ibid*.] In order to maximize provider utilization another study uses a hybrid model where some slots can be booked several days in advance and others are held open until the day of the clinic. This was found to increase utilization by 1.0%. [50] The authors concluded that this was insufficient to warrant the complexity of a hybrid system, except where the demand for fixed and open appointments is highly correlated.

2.3.4 Ratio of fixed and open appointments

To maximize provider utilization, clinics must find an appropriate ratio of fixed (scheduled) to Open Access appointments. A mean-variance model has been developed to determine the proportion of fixed and open appointment slots appropriate for a given clinic. [51] Another study used discrete event simulation to test several proportions of Open Access. Using a 2^4 experimental design the authors found that clinics should start with few Open Access appointments and eventually

move to having a large proportion (75 percent) of patients on Open Access with the remaining patients offered a 30-day schedule horizon. [52]

When the expected demand for Open Access appointments is much higher than provider capacity, all appointment slots should be held open; otherwise the ratio of provider capacity to demand for Open Access can be used to find the optimal ratio of Open Access appointments. [53] The same study finds that the number of Open Access slots is affected by the ratio of no-shows for fixed appointments and Open Access appointments.

2.3.5 Team Approach

Another way to mitigate the impacts of daily demand fluctuation is to use a team approach. Some clinics have adopted provider teams, which include nurse practitioners and doctors' assistants, to increase the total number of available appointments. [54] [49] Other clinics use teams of physicians (2-4) who will share the caseload to balance access against continuity of care. [51]

2.3.6 Conclusion

The Open Access model gets patients into the clinic sooner than a traditional fixed scheduling system. [49] This is aligned with a CEC program goal of improving access to primary care. The CEC model can benefit from the demand forecasting methods outlined in this section. Primary care access can be improved by moving more patients into an Open Access model. The overnight CEC will remain available for acute care and those who could not see their primary care provider in a timely manner.

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2.4 Literature Review Conclusion

The CEC model combines elements from EDs, traditional primary care practices, and newer Open Access practice models. The methods used to model these three practice types, predict patient demand, and schedule patient visits can be applied to various aspects of the CEC program. The unique nature of the CEC program means that no single model exists to study the behaviours occurring within the program.

Chapter 3 – Model Background

This section outlines the data collected as part of this research. The data have been analysed to compare sites and inform the model. The two sites reviewed are located in the towns of Springhill and Parrsboro. These towns were chosen because Parrsboro was the first CEC to open and because at the time of data collection Springhill and Parrsboro were in the same District Health Authority, facilitating access to the necessary data. The towns are located in Cumberland County, near the town of Amherst, NS, as identified in Figure 6. The primary industries in the area are tourism, fishing, mining, and forestry. Detailed National Household Survey data is only available for Cumberland County as a whole. The average resident of Cumberland County is 48.9 years old, and the population has been declining for several decades. Nearly half (46.9%) of adults have a post-secondary certificate, diploma, or degree.

The county has a high prevalence of chronic disease, and low levels of physical activity. Only 21 percent of the region's population is considered to be physically active, and three out of four deaths are related to chronic diseases. [55] These factors could increase residents' reliance on the healthcare system. Nova Scotia has some of the highest rates of chronic disease of any Canadian province. Out of the top 10 causes of death in Nova Scotia, eight exceed the national average occurrence rate. Nova Scotia has Canada's highest rates of arthritis, asthma, and high blood pressure. [8]
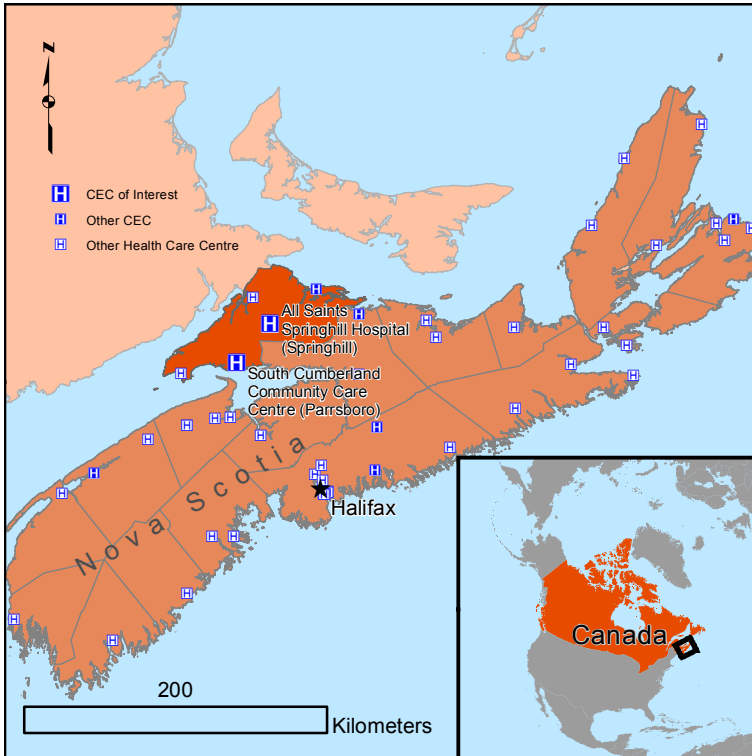
Figure 6 Map of Nova Scotia's health care centres

3.1 Patient Data

One major source of data for this research is the Department of Health and Wellness' billings database. This database contains details of all physician billings and shadow billings in Nova Scotia. Shadow Billings refer to the documentation a salaried physician must provide to show that he or she is seeing the agreed upon caseload. This data allows researchers to see how often patients are accessing various services, such as office visits and emergency services, at all healthcare facilities in Nova Scotia. For this project, a data extract was prepared to show where residents of the Springhill and Parrsboro CECs went for care, and how many patients accessed primary care services in Springhill and Parrsboro in the 2012-2013 (April 1, 2012-March 31, 2013) fiscal year. The data did not include

information that would identify patients or providers. The data were aggregated for the whole year, and divided only by service type and location type (e.g. office visit or emergency visit). To gather the data, a list of postal codes corresponding to the catchment areas was provided to the Department of Health and Wellness, billing data for patients whose health card information matched one of the postal codes was returned.

According to this data, 2,762 patients were seen at primary care clinics in Parrsboro and 5,137 in Springhill. In Parrsboro the patients accounted for 7,478 primary care visits, compared with 12,139 in Springhill. Based on a work year with 260 weekdays, six holidays, and eight weeks of vacation, personal leave, and training, there are 214 clinic days, or 34.9 patients per day in Parrsboro and 56.7 patients per day in Springhill. If we assume just four weeks of vacation, personal leave, and training, there are 32.0 patients per day in Parrsboro and 51.9 in Springhill. In Springhill this would be the equivalent of one less hour of physician time needed per day to meet demand with the increased time off. The population of the Parrsboro hospital catchment is 4,113, and 7,736 for the Springhill hospital. This results in 8.49 visits per thousand people per day in Parrsboro and 7.33 visits per thousand people per day in Springhill. These numbers are comparable to typical daily primary care appointment rates cited in the literature of approximately eight per thousand people. [56] Population figures were obtained by filtering the provincial health card database by postal code. This information is summarized in Table 2 below.

3.1.1 Patient Characteristics

The EHS electronic patient care record (ePCR) database contains information on every patient treated by the EHS system in Nova Scotia. This includes all visits to the overnight CECs since their inception. The database contains all patient information, including name, age, gender, medical history, Canadian Triages and Acuity Scale (CTAS), prescription drug use, reason for visit, and more. The data do not include visits to a family doctor or regular hospital visits such as trips to the ED. The ePCR data for Springhill and Parrsboro were obtained to complete several research studies on the CEC program, and provided by analysts at EHS.

Table 2 Primary care visits and population according to DHW billings database

	Primary Care visits	Population	Visits per 1,000 patients per day
Springhill	5,132	4,113	7.33
Parrsboro	2,762	7,736	8.49

The data for this study were collected from April 1, 2012 to March 31, 2013. The data includes 813 patients: 557 patients in Springhill and 256 in Parrsboro. 79 Springhill patients and nine Parrsboro patients were excluded as they did not have both CTAS and disposition (where the patient went after receiving treatment) on their file, or they were entered into the dataset during the daytime (arrival time between 8am and 8pm). A further five patients at Springhill and three at Parrsboro were excluded as they were marked "left without being seen." This is believed to be patients who did not want treatment without a physician present, CEC staff were

asked to not log these patients in the ePCR after the first few months of operation.

The ePCR data does not include demographic information such as age or gender.

The in-scope data includes 475 patients at Springhill and 242 in Parrsboro.

3.1.2 Arrivals Per Night

There is an average of 0.68 arrivals per night at Parrsboro and 1.30 arrivals per

night at Springhill. The majority of patients arrive at the very beginning or end of

the shift. 66.2% of arrivals occur before midnight and 14.2% happen after 6am. The

arrival rates by hour, as well as the cumulative arrival rate, are shown in Figure 7.

The figure includes the 95 percent confidence interval for the proportion of patients

arriving during each hour of operation. The arrivals are further broken down by the

number of arrivals per night in Table 3. The number of patients per night ranges

from zero to six. Parrsboro has no patients on 178 (49 percent) nights and

Springhill has no patients on 108 (30 percent) nights.

Table 3 Nights with N arrivals

Arrivals per night	Instances at Parrsboro	Instances at Springhill
N=0	178 (48.8%)	108 (29.6%)
N=1	128 (35.1%)	112 (30.7%)
N=2	43 (11.8%)	74 (20.3%)
N=3	10 (2.7%)	42 (11.5%)
N=4	3 (0.8%)	19 (5.2%)
N=5	3 (0.8%)	9 (2.5%)
N=6	0 (0.0%)	1 (0.3%)
Total	365 (100%)	365 (100%)
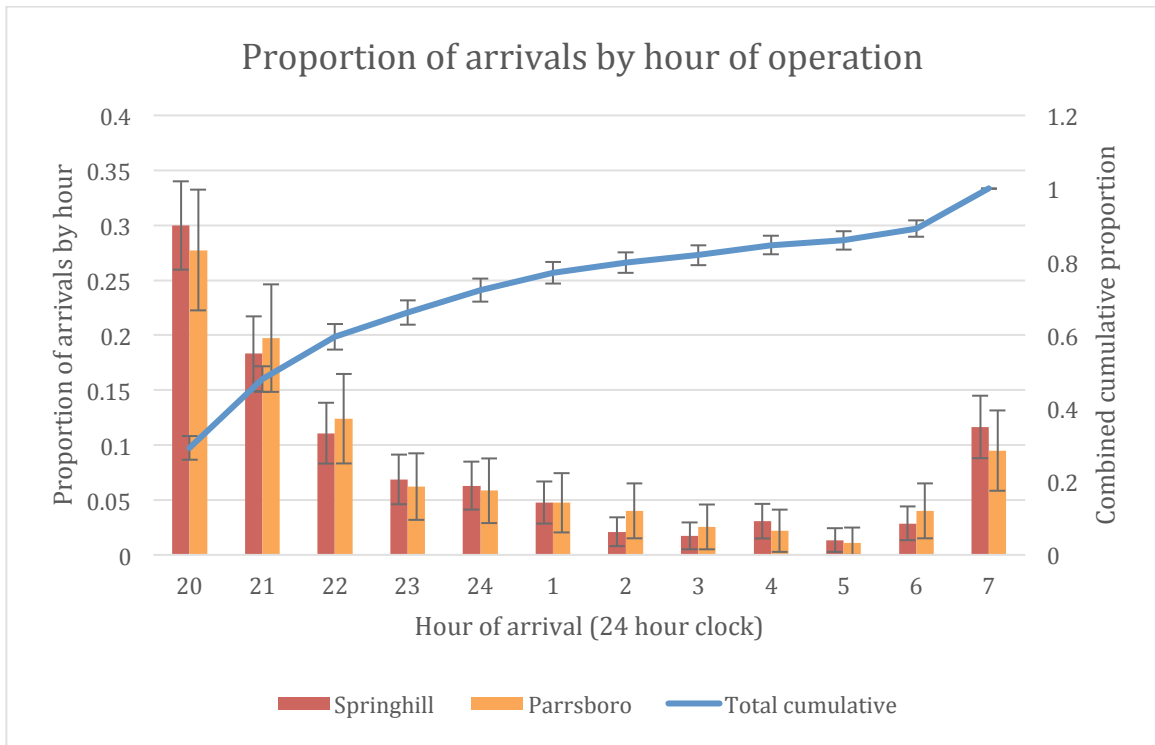
Figure 7 Hourly arrival rates at CECs

3.1.3 Canadian Triage and Acuity Scale

Each patient arriving at a CEC is assessed using CTAS, which determines treatment priority. The result is logged in the EHS ePCR. In analyzing the data it was determined using a chi-square test for proportions that the proportion of patients assigned each CTAS cannot be considered the same across both sites (p<0.000001). As shown in Figure 8 patients in Parrsboro skew lower in acuity (higher CTAS). The figure includes error bars to show the 95% confidence interval for each proportion. Table 4 breaks the CTAS down by site in greater detail, including the size of the confidence interval.

Table 4 Proportion of patients by CTAS

CTAS	Springhill	Parrsboro
1	0.21±0.51%	0.0±0.2%
2	3.1±1.7%	3.6±2.5%
3	49.0±4.6%	21.5±5.3%
4	40.2±4.5%	31.6±6.0%
5	7.5±2.4%	43.3±6.4%
Total	100%	100%
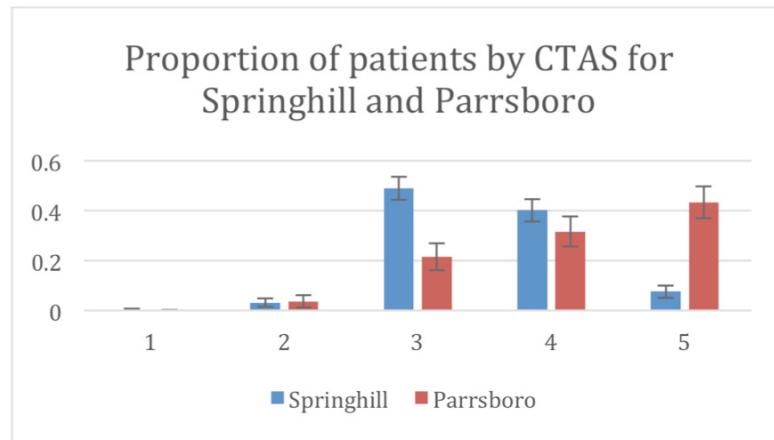
Figure 8 Proportion of patients by CTAS for Springhill and Parrsboro

3.1.4 Discharge Proportions

After a patient has been assessed they may be transferred to the Regional Hospital (1), treated and released with follow-up (2), treated and discharged home (3). Using a chi-square test it was found that there is no statistically significant difference in

the discharge proportions between each site (p=0.49). These data show that despite

the difference in CTAS distribution at the two sites, the disposition rates appear to

be the same. Figure 9 shows the proportion of patients by discharge stream and site.

After aggregating the data from the two sites, it was found that 14.9±2.6% of

patients are transferred to a regional hospital, 56.2±3.7% return the next day for
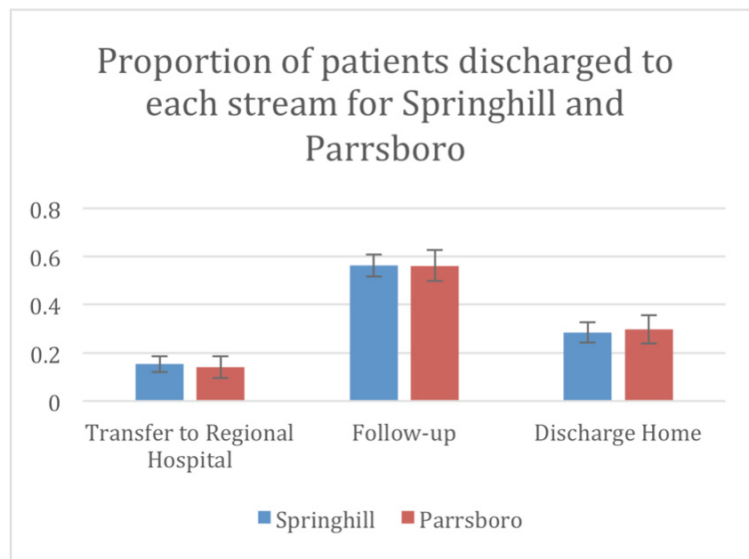
Figure 9 Proportion of patients discharged to each stream for Springhill and Parrsboro

follow-up, and 28.9±3.4% are sent home. This is shown in Figure 10.

3.2 Reneging

An important characteristic of the model is patient reneging. While waiting for a

primary care appointment, patients may decide to instead visit a CEC. The best

research on reneging we found asked ED patients how long they had been

experiencing an issue, and grouped them as 1 day or less, 1-7 days, and more than
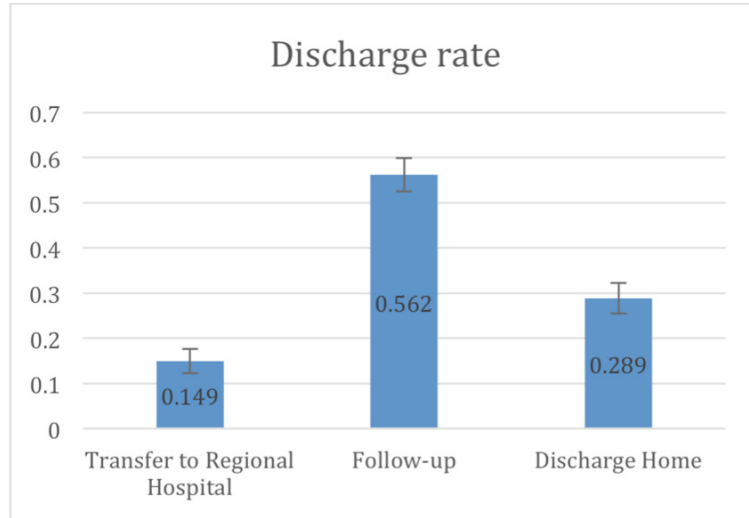
Figure 10 Discharge proportion with confidence intervals

seven days. Table 1 shows these data, adapted from the authors' scale for

emergencies to approximate the CTAS used in this analysis.

Table 5 Proportion of patients who reneged after *r* days. Adapted from [12]

Duration	P_r
< 1 day	16%
1-7 days	33%
> 7 days	51%

These data allow us to compute the chance a patient will renege after a given

number of days. To determine this, the following equation was used:

$$p_r = \frac{P_r}{1 - \sum_{y=0}^{r-1} P_y}$$

where p_r is the probability the patient reneges on day r and P_r is the proportion of

patients who have reneged after r days (from Table 5). $1 - \sum_{y=0}^{r-1} P_{i,y}$ removes

patients from the population in order to calculate the probability that remaining patients renege. For example:

$$p_0 = \frac{0.16}{1-0} = 0.16$$

$$p_1 = \frac{0.055}{1-0.16} = 0.065$$

$$p_2 = \frac{0.055}{1-0.77} = 0.070$$

etc.

Through the above method it is found that the chance of reneging is highest on day 0 (16 percent), then drops, before slowly climbing back, from 6.5 percent on day 1 to 7.0 percent on day 6. This method is an adaption of the probability that a patient leaves a hospital after n days. [57] The renege rates are shown in Table 6.

Table 6 Rate at which patients renege to the CEC after r days' wait

Day (r)	0	1	2	3	4	5	6	> 7
Proportion who reneged (P_r)	16%	5.6%	5.6%	5.6%	5.6%	5.6%	5.6%	51%
Renege rate (p_r)	16%	6.5%	7.0%	7.5%	8.1%	8.9%	9.7%	100%

3.3 Description of Model

3.3.1 Model Definition

The method used to analyse the CEC is a slotted queuing model. The slotted queuing model has slots representing one day of operation from 8:00am until 7:59am the

following day. The model accounts for both the daytime clinics and the nighttime CEC. A slotted queueing model aggregates periods of time and considers arrivals and services as batches during this time period. An example day could see 12 patients arrive at primary care with 10 being served, meaning that two patients overflow from the first aggregate time period and contribute to the arrivals in the second time period. For further details on slotted queueing models see Vanberkel [58].

3.3.2 Patient Flow Dynamics
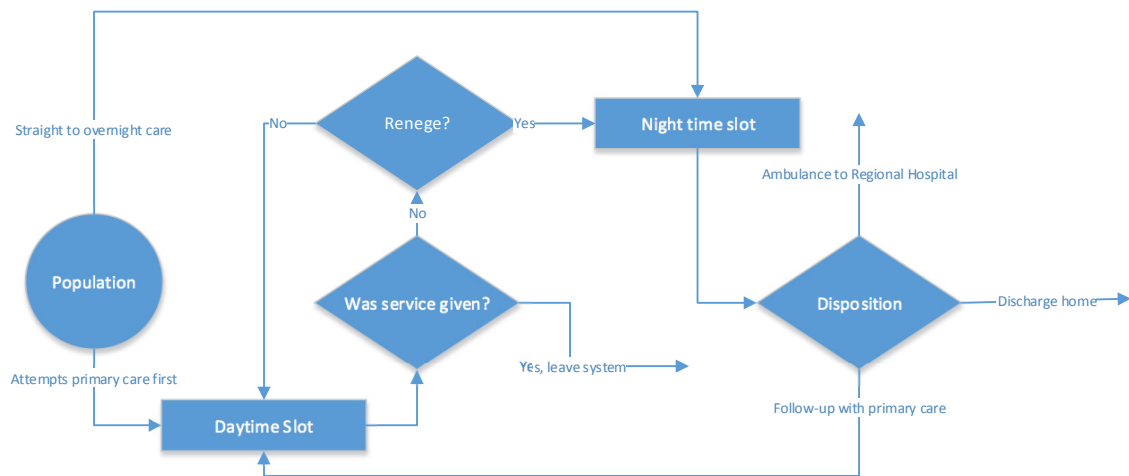
Figure 11 Patient flow through the model

A single day is divided into two slots, one representing daytime CEC and one representing nighttime CEC. Patients arriving to the daytime slot will be served if there is sufficient capacity. Patients who are served leave the system. Patients who are not served from the daytime slot will either try again the next day or renege to the nighttime slot. Patients arriving to the nighttime slot will have either reneged or represent new demand. Patients served at the nighttime slot will either be

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discharged to the Regional Hospital, home, or to the daytime slot the next day. The former two means that they leave the system and the latter means they return to the next day's daytime slot. This is illustrated in Figure 11.

Patient arrivals at the daytime slot, denoted by $A_t^{P,i}$, where t is the present day, i is the patient's CTAS, and P represents primary care. The daytime slot has a daily capacity to see S_t^P patients on day t independent of the patient's CTAS.

Those patients who are not seen on the day they requested an appointment are denoted by $L_{t,r,i}$, where r indexes the number of days that have passed since requesting an appointment. These patients will have priority for appointments over new appointment requests for the next daytime slot, however they renege and go the nighttime slot with probability p_r. We denote these reneging patients by $A_{t,r}^{E,i}$. All other nighttime slot arrivals are denoted by $A_t^{E,i}$. It follows that the aggregate arrival rate to the nighttime slot is $A_t^{C,i} = \sum_{r=0}^{\infty} A_{t,r}^{E,i} + A_t^{E,i}$. The nighttime slot has a capacity to see S_t^E patients per night.

After service in the nighttime slot, patients are discharged to the Regional Hospital with probability p'_1, patients are sent back to the daytime slot with probability p'_2, and patients are discharged home with probability p'_3. The number of patients discharged in each manner is,

- $D_{1,t} = p'_1 A_t^{C,i}$

- $D_{2,t} = p'_2 A_t^{C,i}$

- $D_{3,t} = p'_3 A_t^{C,i}$

Patients sent back to the daytime slots ($D_{2,t}$) receive first priority for appointments. This implies that daytime clinics keep appointments open for these patients or simply squeeze them in, as observed in practice.

That completes the feedback loop demonstrating how workload from the daytime slots overflow to the nighttime slots and vice versa.

The state of the queue is completely described by $L_{t,r,i}$. $L_{t,r,i}$ is computed daily, increased by arrivals (A_t^P), and decreased by patients served by primary care (S_t^P) and patient reneging ($A_{t,r}^{E,i}$). The number of patients that have been waiting for service from the daytime slot follows from

$$L_{t+1,r+1,i} = \left\{ L_{t,r,i} - A_{t,r}^{E,i} - \left\{ S_t^P - D_{2,t} - \sum_{j=r}^{\infty} L_{t,j,i} - A_{t,j}^{E,i} \right\}^+ \right\}^+$$

where $L_{t,0,i} = A_t^P$ and $x^+ = \max\{0, x\}$.

For ease of understanding, in the following description of the formula we ignore the CTAS index i. Consider that the number of patients waiting 3 days (or any value r+1 days) tomorrow is the number of patients waiting 2 days (or r days) today ($L_{t,r,i}$) minus those that reneged to the nighttime CEC ($A_{t,r}^E$) minus those that received an appointment today ($\{S_t^P - D_{2,t} - \sum_{j=r}^{\infty} L_{t,j,i} - A_{t,j}^{E,i}\}^+$). This final term requires more explanation. To determine how many of these patients received an appointment today we must consider how many daytime clinic appointments were available today (S_t^P) and how many of these appointments were consumed by patients of higher priority. Patients of higher priority include those referred from the nighttime

slot ($D_{2,t}$) and those who have waited more days ($\sum_{j=r}^{\infty} L_{t,j,i} - A_{t,j}^{E,i}$). It follows that

$S_t^P - D_{2,t} - \sum_{j=r}^{\infty} L_{t,j,i} - A_{t,j}^{E,i}$ of these patients received an appointment today. Note

that $L_{t+1,r+1,i}$ is the number of patients waiting $r + 1$ days after all of the daytime

clinic appointments have been consumed, i.e. at the end of the clinic day. This

formulation is analogous to Lindley's Recursion. [58].

In order to simplify the model formulation, from this point on the index for CTAS (i)

is ignored. Furthermore, S_t^P is treated as a constant for all periods t and weekends

are ignored. We assume that a physician sees four patients per hour during the

daytime clinics and that clinic hours are not cancelled. These assumptions are

reasonable because much of the literature reviewed above uses a rule-of-thumb of

four patient visits per hour of operation, and because the number of clinics

cancelled due to provider illness and other unpredictable factors appears to be

negligible. Furthermore, the model considers planned system capacity rather than

hour-by-hour observations of clinics, the number of physicians available and the

hours worked to see those patients is outside of the model scope.

3.3.3 Modelling the Random Processes

The two arrival processes, A_t^P and A_t^E, are assumed to be Poisson-distributed with

mean λ_P and λ_E as described in section 3.1 Patient Data. The Poisson distribution

has been shown to effectively model non-scheduled arrivals in healthcare settings.

[59]

Reneging ($\boldsymbol{A_{t,r}^{E,i}}$) is modelled using a binomial distribution. The probability that $A_{t,r}^E$

patients waiting r days renege is equal to

$$P(A_{t,r}^E = A_{t,r}^E) = \frac{L_{t,r}!}{\left(L_{t,r} - A_{t,r}^E\right)! \, A_{t,r}^E!} p_r^{A_{t,r}^E} (1 - p_r)^{L_{t,r} - A_{t,r}^E}$$

This assumes that patients renege independently and with equal probability P_r given the number of days they have waited for an appointment. The assumption is what would be expected from a waiting list where patients do not interact, as in this case. For example the decision by any patient to renege and go to a CEC does not influence any other patient's decision. The number of patients being sent back to the daytime clinics $(D_{2,t})$ is also modelled using a binomial distribution.

In a typical Canadian hospital, the arrival rate at the ED (A_t^C) is 4% of the arrival rate at primary care (A_t^P) [23]. In Parrsboro, 0.68 patients arrive at the CEC each night, compared with 34.9 primary care appointments. The overnight arrivals represent 2% of daytime arrivals, which is similar to the rate at typical hospitals. We assume non-reneging arrivals (λ_E) to be half of the total overnight arrivals.

3.3.3.1 Scenarios

The model is calculated using two scenarios. In the first scenario, the model assumes a traditional ED is in operation. In the second, the ED is replaced with a CEC, while appointment demand remains constant. When the traditional ED scenario is run, patients do not go from the nighttime slot to the daytime slot to receive additional care, any routine follow-ups would be captured in the calculation of appointment demand (λ_P), while in the CEC scenario approximately 55 percent of patients return the next day for additional follow-up care. This reflects the fact that in the

traditional scenario physicians are present at night. The differences in operational

performance between the two scenarios is studied.

3.3.3.2 Cancellations

In the traditional ED scenario, physicians reduced the availability of daytime

appointments to recover from overnight care hours. In the model this is managed by

reducing the supply of daytime appointments by four, representing one hour of

cancelled care. When the CEC is open, the supply of appointments is the full value of

S_t^P.

Justification for this factor is found in the literature. After the CECs were opened,

"[p]hysician office hours have also been extended during the day, (now also

including evenings and weekends) helped significantly by local doctors no longer

having to be on-call at night and therefore not needing to adjust their next day

schedule." [2] Prior to the CEC opening, "[i]f a doctor was on call overnight, they

generally didn't book appointments for at least part of the following day so they

could catch up on sleep." [*Ibid*.]

3.4 Simulation

To analyze our model, we use a simulation programmed in Microsoft Excel. For each

day t we generate a random variate for each of our random variables described

above ($D_{2,t}, A_t^P, \lambda_E, A_{t,r}^E$). A random variate is a specific outcome of a random

variable, that is, the result of one trial of a random distribution.

To generate a random variate for the Binomial Distribution $(D_{2,t}, A_{t,r}^E)$, consider

parameter p which is the probability of an event occurring, and parameter N which

is the the number of trials. To generate a random variate we determine a random

number, $x=U[0,1]$. If $x<p$ we set $Y_1=1$, otherwise $Y_1=0$. This is repeated N times. X, the

sum of these Y_i, $i=1, 2, ..., N$ is the number of successful trials and the value returned.

Finally, we denote this process as follows: [60]

$$bin(N, p) = X = \sum_{i=1}^{N} Y_i$$

Note that this can be facilitated in Excel with the Binomial Inverse function. For

example, the probability that $D_{2,t}$ patients are sent back to the daytime clinic is

equal to

$$P(\mathbf{D_{2,t}} = D_{2,t}) = bin(A_t^C, 0.5514)$$

To generate a random variate for the Poisson distribution we first define the

average of the distribution, λ. Next, let

(1) $a = e^{-\lambda}, b = 1, i = 0.$

(2) $U_{i+1} \sim U(0,1), b = bU_{i+1}$

(3) If $b < a$ then $X=i$. Otherwise, $i = i + 1$, and the process is repeated at (2).

(4) $X = i$ if and only if $\sum_{j=1}^{i} Y_j \leq 1 < \sum_{j=1}^{i+1} Y_j$, $Y_j = -\frac{1}{\lambda}$, and the Y_j's are

    independent. [60]

This process of generating random variates for the Poisson distribution is

computationally intensive for large values of λ. In order to implement this we will

use Excel to generate an indexed list of possible values and use the *vlookup* function to pick values from the list, much like an empirical distribution.

3.5 Model Performance Metrics

The chosen model performance metrics are calculated in the following manner.

3.5.1 Calculation of Model Performance Metrics

Eight primary performance metrics were calculated for the model. These are:

- the proportion of patients who did not get an appointment on the first day they asked

- daytime provider utilization rate

- physician cost per overnight patient

- number of follow-up appointments required

- average overnight arrivals

- daytime appointments offered

- average days waiting before reneging to overnight care, and

- the number of out-of-community ambulance trips needed.

3.5.1.1 Proportion of patients who did not get an appointment on the first day they asked

The proportion of patients who did not get an appointment on the first day they asked is found by taking the average of $L_{t,0}$ for all t. These patients may renege to the CEC on the day they requested an appointment, or attempt to be served the next day (or thereafter). This can be shown as:

$$E\left(L_{t,0}\right) = \frac{\sum_{i=1}^{M} L_{i,0}}{M}$$

Where M is the model run time in days.

3.5.1.2 Daytime provider utilization rate

The daytime provider utilization rate is found by taking the average number of appointments filled during the daytime care hours divided by the average number of appointments offered during the daytime. The number of appointments filled is the minimum of the sum of patients returning from the previous night's CEC, all patients waiting for care, and that day's arrivals at primary care, or the total supply of primary care appointments. This can be formulated as follows:

$$\rho_P = \frac{\sum_{t=1}^{M}[\{S_t^P, D_{2,t} + A_t^P + \sum_{j=r}^{\infty} L_{t,j} - A_{t,j}^E\}^-]}{\sum_{t=1}^{M} S_t^P}$$

3.5.1.3 Physician cost per overnight patient

In the non-CEC scenario the physician cost per overnight patient is found by taking the average cost of overnight care, ($1,438 per day for the physician) and dividing by the average number of overnight arrivals. "The average cost to taxpayers for having doctors on overnight emergency call for small hospitals is $350,000 to $700,000 per year per site." [3] This corresponds to some facilities receiving eight hours of physician care per night and others receiving 14 hours of physician care, as well as the fact that many small sites see regular closures. As the CEC sites see 12 hours of overnight CEC operation, a flat rate of $1,800 ($150 per hour for 12 hours) is used as the cost when no CEC is present, based on Ross' cost estimate. [*Ibid.*] This

corresponds to $657,000 per year assuming there are no cancellations. This nightly

cost is divided by the number of arrivals to determine the cost per patient, as shown

below.

$$Physician\ cost\ per\ overnight\ patient\ (ED) = \frac{\$1,800 * M}{\sum_{t=1}^{M} A_t^E}$$

For the CEC scenario, there is a flat fee of $150 per night for the MOP, as well as a fee

of $60 per patient referred back to primary care, for the cost of the patient's primary

care appointment. The MOP is paid for each site covered, and covers more than one

site per night. However, this model looks at each site independently, so the $150

figure will be used. The sum of these two costs is divided by the total number of

patients, as shown below:

$$Physician\ cost\ per\ overnight\ patient\ (CEC) = \frac{\$150 * M + \sum_{t=1}^{M} D_{2,t} * \$60}{\sum_{t=1}^{M} A_t^E}$$

The difference between fixed building operating costs and support staff costs for the

CEC and ED care models are assumed to be negligible, [3], therefore they are

ignored.

3.5.1.4 Number of follow-up appointments required

The number of follow-up appointments required is zero in the pre-CEC scenario. In

the post-CEC scenario it is the average number of patients referred back to primary

care following a CEC visit.

$$E\left(D_{2,t}\right) = \sum_{t=1}^{M} \frac{D_{2,t}}{M}$$

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3.5.1.5 Average days waiting before reneging to overnight care

The average days waiting before reneging to overnight care is found by computing the sum over all days (t) of the patients who arrived after waiting r days, multiplied by r, and then dividing this result by the total number of patients who arrived.

$$E\left(A_{t,r}^{E}\right) = \frac{\sum_{i=1}^{M} \sum_{j=0}^{7} (A_{i,j}^{E} * j)}{\sum_{i=1}^{M} \sum_{j=0}^{7} (A_{i,j}^{E})}$$

3.5.1.6 Number of out-of-community ambulance trips needed

It is assumed that in the pre-CEC scenario there are no out-of-community ambulance trips required. Ambulance trip data for pre-and-post CEC implementation was not available. In the post-CEC scenario this is found by taking the average number of people who were sent to the regional hospital by ambulance each night, as shown below:

$$E\left(D_{1,t}\right) = \frac{\sum_{i=1}^{M} D_{1,i}}{M}$$

3.5.1.7 Average daytime appointment requests

The average daytime appointment requests is calculated to verify the distribution of patient arrivals is working correctly during the daytime. With a long model run this metric should match the average arrival rate specified above. This metric is calculated as follows:

$$E(A_{t}^{P}) = \frac{\sum_{i=1}^{M} A_{i}^{P}}{M}$$

3.5.2 Model Populations

The model will be run for three different population sizes with three different levels of primary care appointment availability. The populations will be 4,000 patients (a small town similar to Parrsboro), 10,000 patients (moderate-sized town, approximately 25 percent larger than Springhill), and 20,000 patients (large rural town). For each town the model will be run assuming 100 primary care appointments per 95 requests (some oversupply), 99 appointments per 100 requests (supply matched with demand), and 100 appointments per 110 requests (demand exceeds supply).

Chapter 4 – Verification and Validation

Verification and validation are terms to describe the process of ensuring the model correctly represents the system being studied. Verification is the process of ensuring the computer model accurately executes the model's logic. Validation is a way of showing the model is credible, by discussing results with the client (decision-maker receiving the model results), checking the results against measured data, the model is consistent with existing model theory, and the results are consistent with the modeler's intuition. [60]

4.1 Model Verification

Verification is the process of ensuring that the model, as defined, is set up properly in the computer system. [*Ibid.*] To verify the model logic, the following tests were performed:

> ➤ Set all renege rates to 0
> ➤ Set $D_{2,t}$ to 0
> ➤ Set service rate to 0 and renege rate to 0
> ➤ Manual calculation of sample $L_{t,r}$ values

The first test, setting renege rates to 0, confirms that the index for days waiting is increased each day, i.e. patients are moving properly from $L_{1,0}$ to $L_{2,1}$. The second test, setting p_2' to 0, confirms that all patients who are treated in the CEC leave the system after their overnight visit, which helps to confirm that the model logic is properly assigning the patients who are waiting for daytime care to the available appointments. The third test, setting the service rate and renege rate to 0, is also

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done to confirm that the patient indexes for waiting are being increased. Finally, the fourth test confirms that the model is properly calculating the increase in days waiting. Through these verification tests, and other ad-hoc checks, it was determined that the mathematical model was operating correctly in Excel.

4.2 Model Validation

Model validation is used to ensure a simulation model accurately represents the underlying system. Validating the model helps to ensure credibility of the results insofar as they relate to the objectives of the study. [60] One test of validity is whether the client, or recipient of the information from the model, believes them to be correct. [*Ibid.*] Other tests can be used to ensure the model's results are consistent with modelling theory (e.g. patient arrivals are a Poisson process), or the model's results are consistent with other similar models. Another test is to see whether the model results are consistent with the modeller's intuition. [*Ibid.*] In the case of this model, the metrics validated are those that provide insight into the difference in operational performance between a CEC and an ED.

To validate the model against the behaviour in Parrsboro, the number of overnight arrivals to the CEC was compared to the observations from Stylus. Then, the model was run as a CEC assuming the same ratio of appointments to demand. In the ED version, the model found 1.479±0.049 (from here to end, ± denotes the size of the 95% confidence interval) arrivals per night, compared with 1.44 in the historical data. With the CEC operating, there were 0.635±0.021 arrivals per night, compared with 0.68 in the historical data. It is felt that the slight under-estimation of overnight

arrivals is consistent with the finding that the arrival rate declined as the CEC

program progressed. [2] The historical data for CECs covered two years of

operation. Based on this information, it is felt that the model provides a valid

approximation of the overnight arrivals emergency care in both the CEC and ED

scenario.

The same procedure was used to validate the model against the second town where

historical data were also available, Springhill. In Springhill, running the model as an

ED resulted in 3.62±0.14 overnight arrivals, compared with 3.75 in the historical

data. With the CEC operating, the model found 1.33±0.04 arrivals, compared with

1.34 in the historical data. As Springhill is a larger community, the proportion of ED

arrivals to primary care appointments was increased by 1.5% during the model

calibration, and the number of appointments to cancel was set to 8.

The remainder of this research uses a town similar to Parrsboro as a baseline, and

population extrapolations are based on this unique case. Research on other towns

will require re-setting the model parameters to suit the town in question.

Chapter 5 – Numerical Results

5.1 Warm-up Period

The warm-up period was found using Welch's graphical procedure. Welch's graphical procedure was performed on each model performance metric to determine which performance metric took the longest time to warm up. The model was run for 2500 days, with ten replications, to perform Welch's procedure.

Welch's graphical procedure is used to determine when the model output reaches a steady state, meaning the outputs are independent of the initial conditions. The method uses a moving window to analyse the variability of the model's results. The procedure uses a moving average ("window") which is performed for varying window sizes, w, to determine the smoothness of the model results. The procedure allows the user to visualize the period at which the model is in steady state. The procedure averages across model replications and time. Each moving average, $\bar{Y}_i(w)$, is centered around a day (i), and includes the values from all model replications. [60]

The equation for Welch's graphical procedure is shown below

$$\bar{Y}_i(w) = [\frac{\sum_{s=-w}^{w} \bar{Y}_{i+s}}{2w+1}, if\ i = w+1, \dots, m-w, \frac{\sum_{s=-(i-1)}^{i-1} \bar{Y}_{i+s}}{2i-1}, if\ i = 1, \dots, w]$$

The user then determines the point at which $\bar{Y}_i(w)$ and $\bar{Y}_{i+1}(w)$ have converged. This can be done graphically. The point at which they converged is considered the steady state (l). The user should select the smallest number (w) where the values converge.

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The window size (w) should be no greater than the m/4, where m is the length of one replication of the model. Once *l* has been determined, the model should be run for at least 10 times longer than *l* for final analysis. [60]

Based on this method, it was determined that a warm-up period of 500 days is sufficient for all metrics. The patient arrivals in Figure 12 appear to smooth out after 150 days, 500 days was chosen as the warmup as computation time is not an issue for this model.
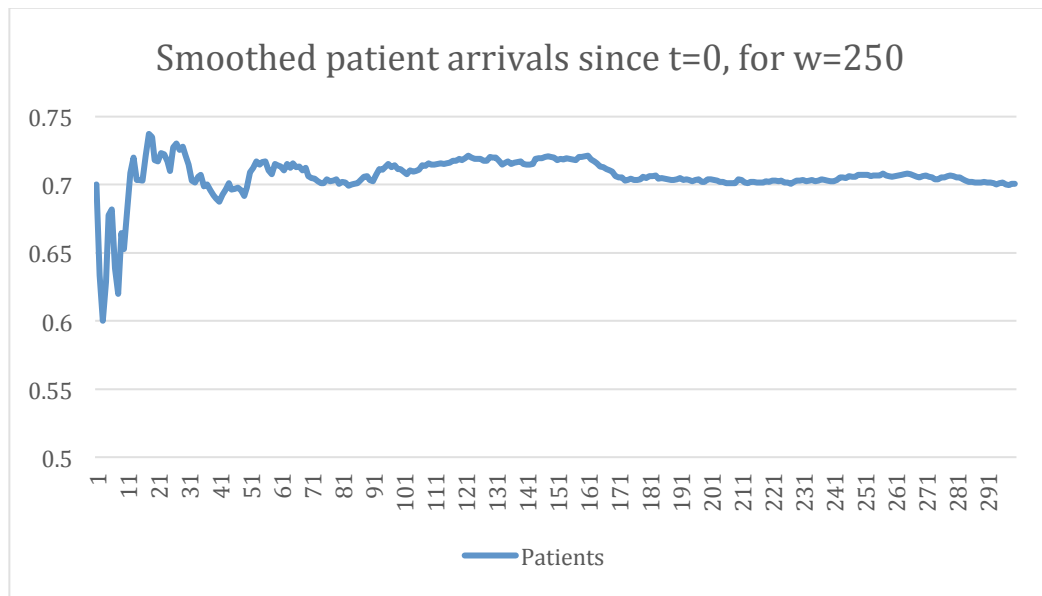
Figure 12 Smoothed patient arrivals since t=0, for w=250

The model was run for 5000 days following the conclusion of the warm-up period. This is 10 times the warm-up period, as recommended in the literature. [60] [61] All numeric results are calculated from the end of the warm-up period to the end of the model run.

As simulations are inherently random it is necessary to compute several iterations to reduce the variability of the result. The number of model replications required

was found by performing 10 (n) replications of the model and then calculating the number of replications required to keep the confidence interval within certain bounds. The following calculations assume five percent of the average as an acceptable bound for the confidence interval. To determine the minimum number of runs to achieve the desired half-width, first the t-statistic was calculated for nine (n-1) degrees of freedom and a two-tailed 95 percent confidence level. The t-statistic was multiplied by the standard deviation (s) and divided by the bound on the confidence interval (E), and the result was squared. The next-highest integer is the lowest acceptable number of model iterations. Details on this method can be found in [61]. This calculation was performed on each model metric to find the highest number of runs. The calculation is expressed by the following equation:

$$n \geq \left(\frac{t_{\alpha/2,n-1} S}{E} \right)^2$$

For the proportion of patients who received an appointment on the first day they asked, a different formula was used. The formula to determine a $100 \times (1-\alpha)\%$ confidence interval for a proportion comes from [61]:

$$\hat{p} \pm z_{\alpha/2} \sqrt{\frac{\hat{p}(1-\hat{p})}{n}}$$

$\hat{p}$ is the estimate for p. The number of iterations required to estimate $\hat{p}$ within the chosen precision is n, as shown below:

$$n = \left(\frac{z_{\alpha/2}}{E} \right) \hat{p}(1-\hat{p})$$

This equation is also from [61]. If there is no pilot run for the model, a $\hat{p}$ of 0.5 is assumed.

Using these methods, the metric requiring the most iterations was the number of days waiting before receiving a daytime appointment, requiring 10 model runs. Because computation time was not a concern, each case was run 50 times.

5.2 Model Automation

The model is automated using a macro described in Appendix A. The macro allows the user to specify the following input parameters on the "Distributions" worksheet:

- Population

- Appointments per 1,000 patients

- Fraction of patients who do not attempt to get a primary care appointment

- Ratio of appointment requests to supply of appointments

- Whether there is a CEC or ED

- Number of model iterations to perform, and

- Warm up period.

Once the user has configured the "Distributions" worksheet, the model can be initiated from the "Numerical Results" worksheet. The user will simply click "Calculate Model" and the model will run for the desired number of iterations. This functionality is illustrated in Figure 13.
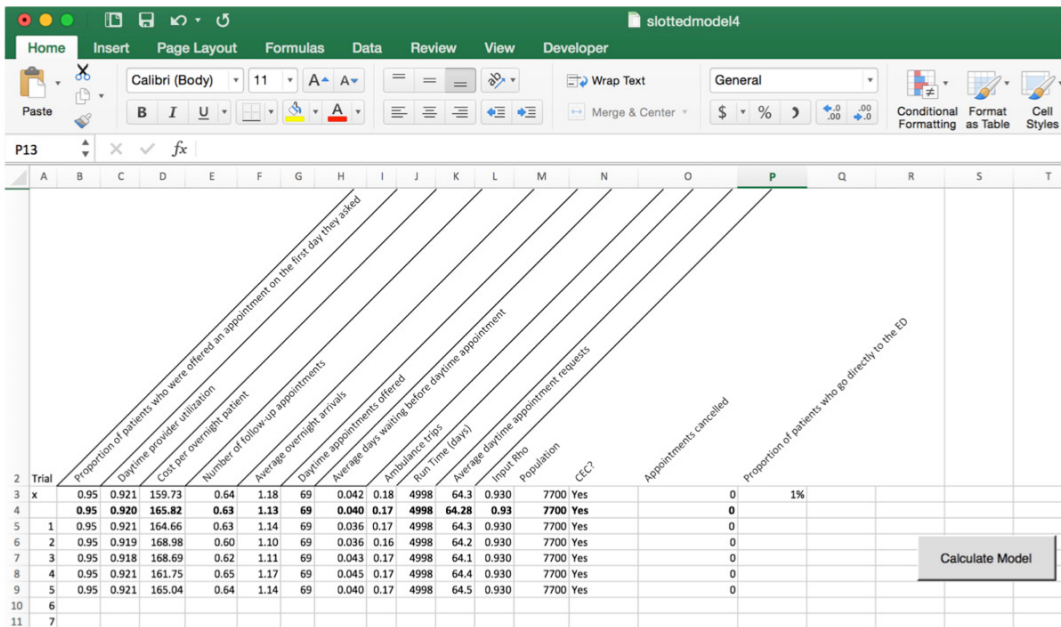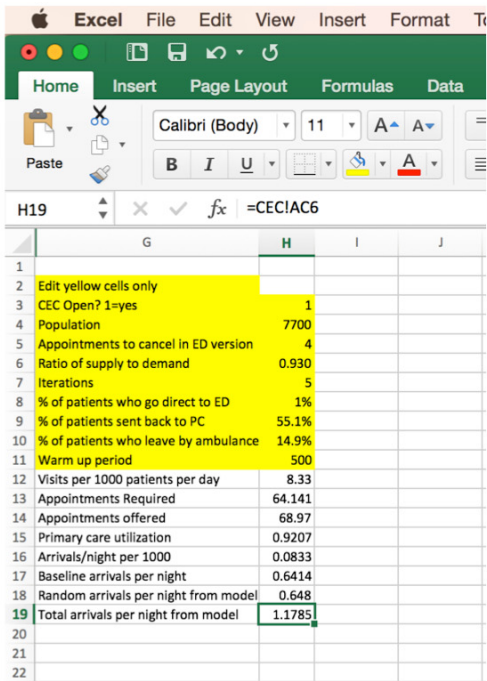
Figure 13 Screenshots of macro automation functionality

5.3 Summary of Numerical Results

In this section we review the numerical results for the 11 scenarios (two baselines and nine population expansions) and the eight metrics. The summary results for each metric and scenario is in Table 7 and each subsection discusses specific noteworthy metrics for the baseline scenario and each ED type. Within each subsection the ratio of primary care appointments requested to primary care appointments offered is explored. For simplicity this ratio is expressed as a fraction e.g. 90 appointments requested per 100 offered is referred to as the "90/100 scenario."

5.3.1 Baseline Scenarios

In the baseline scenario, with 4,100 residents, we see that 79.2% of patients can get an appointment on the first day they ask, compared with 94.6% when the CEC opens. In the slightly larger Baseline 2 scenario, with 7,700 residents, we see that 74.2% of patients receive care on the first day they ask, increasing to 96.3% when the CEC opens. This is illustrated in Figure 14. Big improvements are seen in cost, where the physician cost per patient drops from $1,218 in the baseline to $270 when the CEC opens, a drop of 77.8%, shown in Figure 15.

Table 7 Summary of numerical results

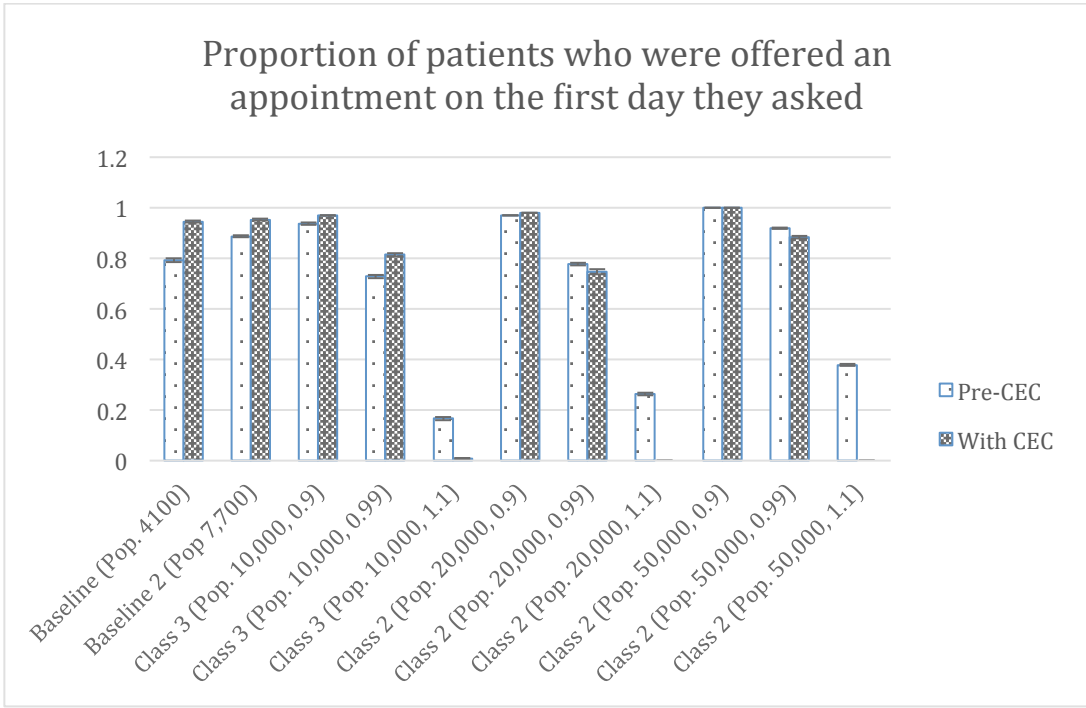| Site (Population & proportion of appointments requests to appointments offered)	Scenario	Proportion of patients who were offered an appointment on the first day they asked	Daytime provider utilization	Physician cost per overnight patient	Number of follow-up appointments	Average overnight arrivals	Daytime appointments offered	Average days waiting before daytime appointment	Net ambulance trips
Baseline (4,100, 0.95)	ED	79.2%	95.2%	$1,218	0	1.48	34	0.169	0
	CEC	94.6%	88.4%	$270	0.35	0.64	38	0.046	0.10
Baseline 2 (7,700, 0.95)	ED	74.1%	98.2%	$497	0	3.62	62	0.208	0
	CEC	96.3%	91.0%	$145	0.73	1.33	70	0.030	0.198
Class 3 (10,000, 0.90)	ED	93.7%	94.6%	$1,067	0	1.67	86	0.053	0
	CEC	97.0%	91.8%	$155	0.68	1.23	90	0.025	0.18
Class 3 (10,000, 0.99)	ED	72.8%	98.9%	$403	0	4.45	80	0.219	0
	CEC	81.4%	97.3%	$78	1.83	3.31	84	0.152	0.49
Class 3 (10,000, 1.1)	ED	16.6%	100.0%	$149	0	12.12	72	0.671	0
	CEC	0.7%	100.0%	$41	9.94	18.04	76	1.911	2.69
Class 2 (20,000, 0.9)	ED	97.0%	95.1%	$743	0	2.42	173	0.024	0
	CEC	98.0%	93.8%	$102	1.19	2.16	177	0.016	0.32
Class 2 (20,000, 0.99)	ED	77.7%	99.4%	$237	0	7.58	161	0.180	0
	CEC	74.7%	99.3%	$51	4.64	8.42	165	0.203	1.263
Class 2 (20,000, 1.10)	ED	26.3%	100.0%	$84	0	21.34	147	0.557	0
	CEC	0.0%	100.0%	$37	21.1	38.44	151	2.211	5.73
Class 2 (50,000, .90)	ED	100.0%	94.6%	$404	0	4.45	439	0.004	0
	CEC	100.0%	94.3%	$67	2.43	4.42	443	0.003	0.66
Class 2 (50,000, .99)	ED	91.9%	99.1%	$187	0	9.62	413	0.068	0
	CEC	88.4%	99.2%	$46	6.57	11.92	417	0.095	1.78
Class 2 (50,000, 1.10)	ED	37.8%	100.0%	$40	0	45.51	375	0.475	0
	CEC	0.0%	100.0%	$48	51.0	66.99	379	1.967	13.83

Figure 14 Proportion of patients who were offered an appointment on the first day they asked
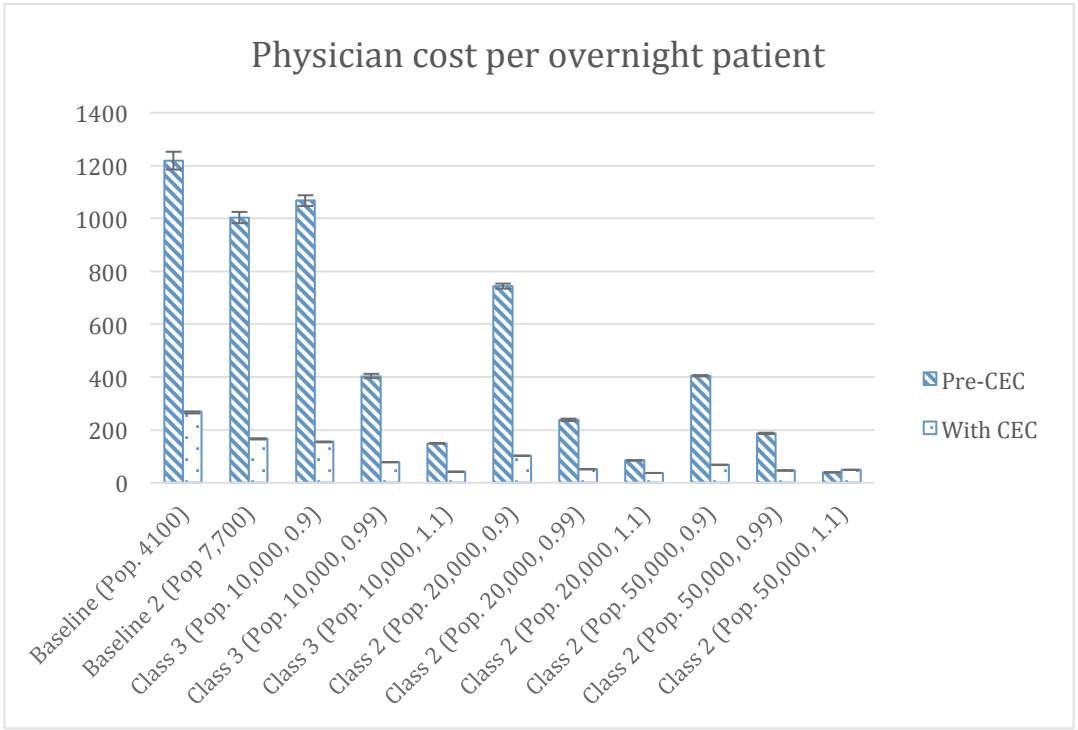

Figure 15 Physician cost per overnight patient

5.3.2 Results for Class 3 Emergency Rooms

As discussed in Section 1.1, Class 3 Emergency Departments serve communities near a Regional ED, and a small population (fewer than 10,000 residents in all cases). In the model, the Class 3 community is at the upper end of that range, with 10,000 residents. In the 90/100 scenario, 93.7% of patients can get an appointment on the first day they ask, which increases to 97.0% when the CEC opens. In the 110/100 scenario, only 16.6% of patients will get appointments on the first day they ask, dropping to 0.3% when the CEC opens.

For the 90/100 scenario, 94.6% of daytime appointment times are filled prior to opening a CEC. When the CEC opens this drops to 91.8%, partly as a result of fewer appointments being cancelled, as shown in Figure 16. In the 99/100 98.9% of appointments are filled, falling to 97.3% once the CEC opens. In the 110/100 scenario 100% of appointments are filled, and the CEC opening does not change this result.

In the 90/100 and 99/100 scenarios, the ED sees 1.67 and 4.45 patients per night respectively. When the CEC opens the team sees 1.23 and 3.31 patients per night respectively. In the 110/100 scenario 12.12 patients arrive at the ED on average, rising to 18.04 when the CEC opens. These scenarios result in 0.68, 1.83, and 9.94 patients being referred to primary care for follow-up.

In all three scenarios the CEC reduces the physician cost per patient. For the 90/100 scenario the cost goes from $1,067 to $155 when the CEC opens. In the 99/100

scenario it falls from \$403 to \$78. Finally, in the 110/100 scenario it falls from \$149

to \$41 (Figure 15).

These results show that the CEC remains cost effective in the largest Class 3 ED

communities. However, the findings from the case where there are more

appointment requests than appointments available show that the CEC care model

reduces access in towns where there is a shortage of primary care appointments,
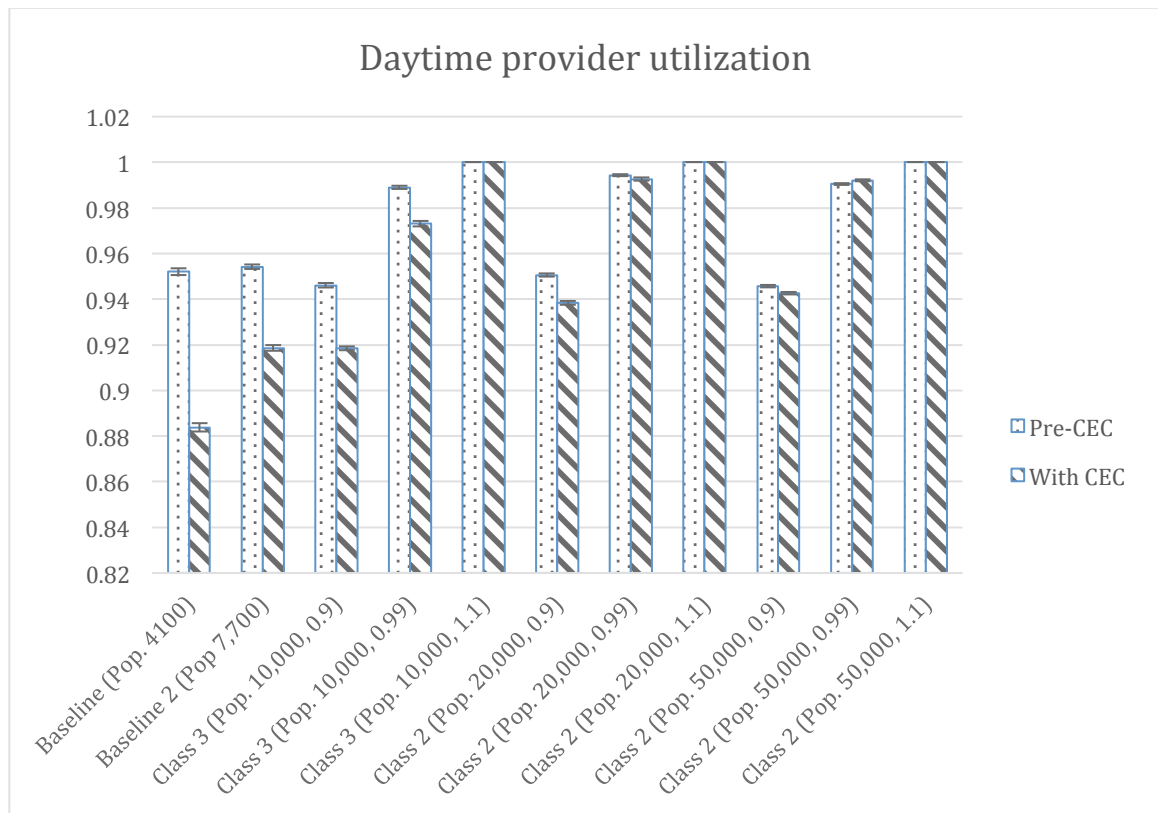
even if the population is relatively small.

Figure 16 Daytime provider utilization

5.3.3 Results for Class 2 Communities

As the Class 2 EDs fall in to a broad range of communities, from smaller centres like

Yarmouth (Population ca. 8,000) up to large communities like Sydney/Cape Breton

Regional Municipality (Population ca. 110,000) it was decided to run the model with 20,000 residents and 50,000 residents to determine an upper limit for community size for a CEC. These results are broken down within this section.

5.3.3.1 Results for Class 2 Community with 20,000 residents

With 20,000 people and the 90/100 scenario, the CEC increases the proportion of patients seen on the first day from 97.0% to 98.0%. The proportion of daytime appointments times that were filled dropped from 95.1% to 93.8%. (Figure 14) This resulted in a drop in overnight arrivals from 2.42 to 2.16 patients. When the CEC opened 1.19 patients were referred back to daytime care each night. The CEC reduced the physician cost of overnight care from $743.21 to $102.35 in this scenario.

In this community the CEC model showed modest operational performance advantages compared with EDs in the 99/100 scenario. The proportion of patients who were seen on the first day fell from 77.7% to 74.7% when the CEC opened, however the proportion of primary care appointments filled fell slightly, from 99.4% to 99.3%. The number of overnight arrivals increased from 7.58 to 8.42, and 4.64 patients were referred back to primary care when the CEC opened. The physician cost per patient did decline, from $238 to $51, when the CEC opened. (Figure 15)

The advantages of the CEC were not found when there was a shortage of primary care appointments. In the 110/100 scenario, 26.3% patients were seen on the first day they asked for an appointment when the ED was open, but none were seen on

the first day they asked once the CEC opened. In both cases 100% of available daytime appointments were filled. When the ED was open, the physician saw 21.34 patients per night. The CEC saw 38.44 patients per night. The estimated capacity of the CEC is below 24 patients per shift, as discovered in Section 1.5. Furthermore, 21.18 are sent back to primary care for follow-up, which would require 2/3 of a physician's daytime appointment capacity to treat. Despite this, the physician cost per patient still goes down, from $85 to $37. The model does not consider whether a second physician would be required in order to handle the patient volume.

The findings from the 20,000 person community show that the CEC remains beneficial when there is an excess of primary care capacity, but that it is detrimental to care when there is a shortage of primary care appointments.

5.3.3.2 Results for Class 2 Community with 50,000 residents

The final community considered has a population of 50,000 residents in the CEC's catchment area. Modelled as a traditional ED, in the 90/100 scenario we see that 100% of patients are offered an appointment on the first day they asked, regardless of the type of overnight care. With the ED open, 94.6% of primary care appointments are filled, falling slightly to 94.3% when the CEC opens. (Figure 16) For the patients going directly to emergency care without requesting an appointment first, there are 4.45±0.03 arrivals per night at the ED, and 4.42±0.03 arrivals when the CEC opens, showing no advantage to the CEC model. The CEC would refer 2.43 patients back to primary care on average. The cost per patient drops from $404 to $66 when the CEC opens. (Figure 15)

In the 99/100 scenario, 91.9% of patients receive a primary care appointment on the first day they ask when the ED is operating, compared with 88.4% when the CEC opens (Figure 14). The proportion of daytime appointments filled is the same, 99.1% with the ED and 99.2% with the CEC. There is a slight increase in overnight arrivals, from 9.62 to 11.92 when the CEC opens, and 6.57 patients are sent back to primary care on the average night. However, there is still a drop in physician cost, from $180 to $46 per patient when the CEC opens.

When the demand for primary care exceeds supply, (110/100 scenario) the CEC performs poorly compared with the ED. First, the proportion of patients who receive an appointment on the first day they ask falls from 37.8% to zero. 100% of daytime appointments are filled in both the ED and CEC case. The number of patients arriving overnight goes from 45.51 to 66.99 when the CEC opens, and 51.08 are sent back to primary care from the CEC. Furthermore, opening the CEC causes the physician cost per patient to increase, from $40 to $48. In this scenario it appears the CEC is detrimental to primary care access.

Chapter 6 – Discussion

Three important considerations need to be made with respect to the model. First, we discuss the numerical results, then the limitations of the model, and finally provide suggestions for future research topics.

6.1 Discussion of Numerical Results

The numerical results of the model show that the CEC's predicted (and real-world) benefits do occur in the model, namely the average cost per patient is reduced, the primary care capacity is increased, and the overnight arrivals decrease. This results in faster access to primary care, which according to the background research leads to lower healthcare costs. These results assume there is no increase in adverse treatment outcomes when an ED becomes a CEC.

The CEC program is prone to diminishing returns. As the catchment population grows the proportional cost savings and primary care access improvements decrease. At the same time, a greater proportion of a physician's day will be spent treating patients who attended the CEC the previous night. This finding suggests that other metrics may need to be considered when assessing the suitability of a CEC in a given community.

These results show that the CEC program meets its stated objectives even in large communities, as long as the demand for primary care does not exceed the supply. The numeric results (Table 7 on page 70), show that the potential success of a CEC is based on a combination of primary care appointment availability and catchment

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population. As the catchment population grows, the number of overnight arrivals grows, however larger catchments are more tolerant to the loss of one provider for a portion of the day, meaning the utilization advantage of a CEC diminishes with population growth. The model does not increase the number of appointments cancelled based on overnight arrivals, but this parameter can be set prior to the model run to better reflect the behaviour in a community. In the 50,000 person town, the cancelled daytime appointments represent one percent of supply, compared with 12 percent in the baseline and five percent in the 10,000 person town. In all cases, the results show a stronger dependence on primary care utilization than on overall population size. The results show that with large catchments, as long as there are more appointments offered than requested, the CEC has adequate supply to serve the overnight arrivals, and the cost per patient remains lower than in a traditional ED.

Once primary care appointment demand exceeds supply the advantage of the CEC diminishes rapidly. In the small town example, with fewer than 10,000 patients, 10 patients per day are sent back to primary care, and 6 more patients arrive for overnight care than had no CEC been installed. With 20,000 patients, there are 21 additional patients sent back to primary care and 17 additional arrivals at the overnight emergency care. This represents more than half of a typical physician's daily case load.

The number of follow-up appointments is small in all but the large and very large town with over 100 percent utilization scenarios. With fewer than 10,000 patients, approximately 7.75 patients are referred for follow-up; this represents less than two

hours' work for the physician. In the scenario with 20,000 patients and 110 appointments requested for every 100 offered more than 20 patients return per day, which represents 2/3 of a typical doctor's daytime patient visits. At this level of patient returns it may be more effective to have a doctor on-site overnight treating the patients as they arrive.

Except in scenarios where daytime demand exceeds capacity, patients tend to experience very little wait for primary care appointments, with most patients seen on the day they requested an appointment or the next day. This metric improves slightly after the implementation of a CEC. This is reflected again in the "average days waiting before a daytime appointment," which tends to be less than one day, meaning the majority of patients are seen on the first day, whether in the primary care clinic or overnight CEC.

6.1.1 Effect of Daytime Demand on CEC Arrivals

The results also show that the leading indicator of overnight arrivals is the proportion of appointment supply to demand in daytime care. As the CEC helps to improve this ratio, the CEC is seen to be effective, while further primary care investments should be expected to reduce the need for overnight care, except when the care needed is urgent (e.g. car crash, heart attack, stroke, etc.).

Except where demand for daytime appointments exceeds the supply, the CEC model has a positive impact on access to care. The model shows that the CEC worsens overall operational performance of the system when the demand for primary care

exceeds the supply, as more than half of patients need to go back to primary care the next day to complete their treatment. This is further illustrated in Figure 17.

Number of patients referred back to daytime care
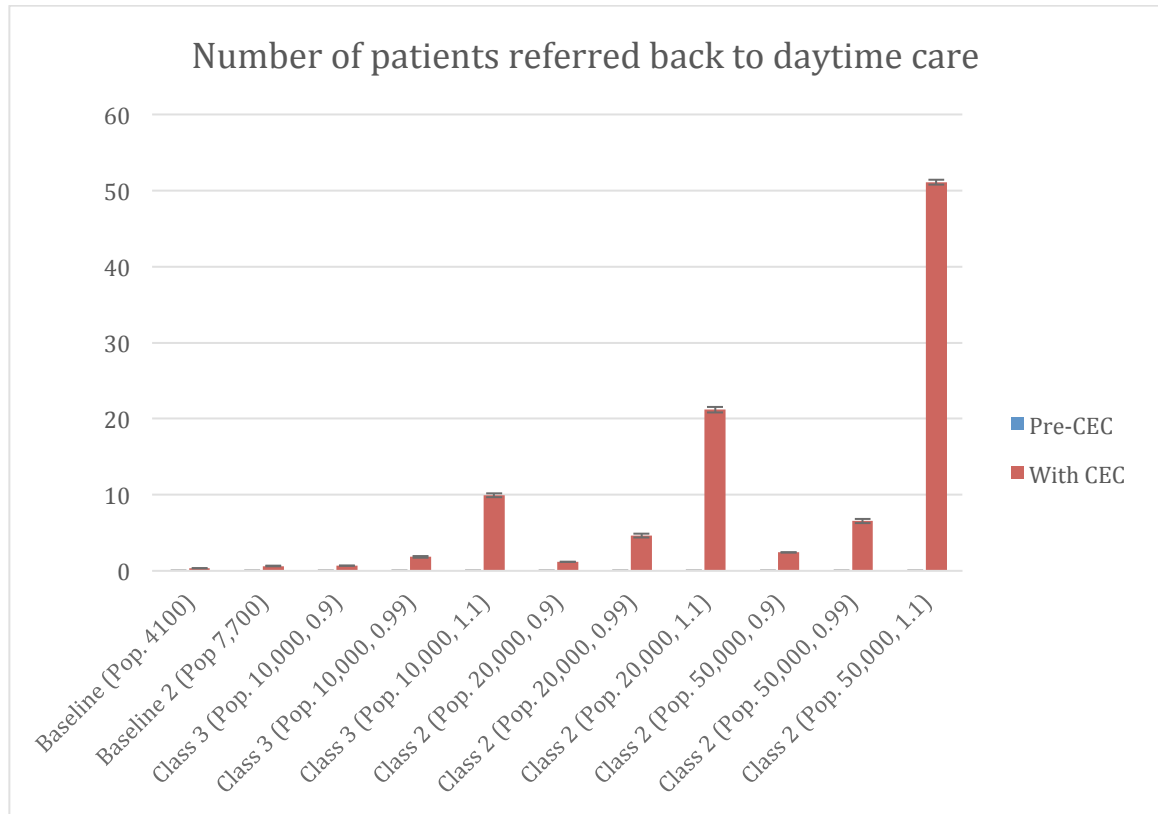
Figure 17 Number of patients referred back to daytime care

6.1.2 Access to primary care

As hypothesized, the CEC is shown to improve access to primary care in all catchments studied, however this result only occurs if there is a surplus of primary care capacity. One way the model measures access to primary care is the number of days waiting before a daytime appointment. As seen above, the number of days waiting before a primary care appointment is offered drops when the CEC opens, unless there is already a shortage of appointments. This is illustrated in Figure 18.

Viewed another way, the proportion of patients who receive an appointment on the first day they ask increases in many communities where a CEC is opened. This is true for communities with fewer than 20,000 residents and an excess of primary care appointments. With 20,000 residents and 99 appointment requests for every 100 appointments the traditional ED provides better access to primary care. With 50,000 residents the CEC appears to worsen access, according to this metric, which is shown in Figure 14.

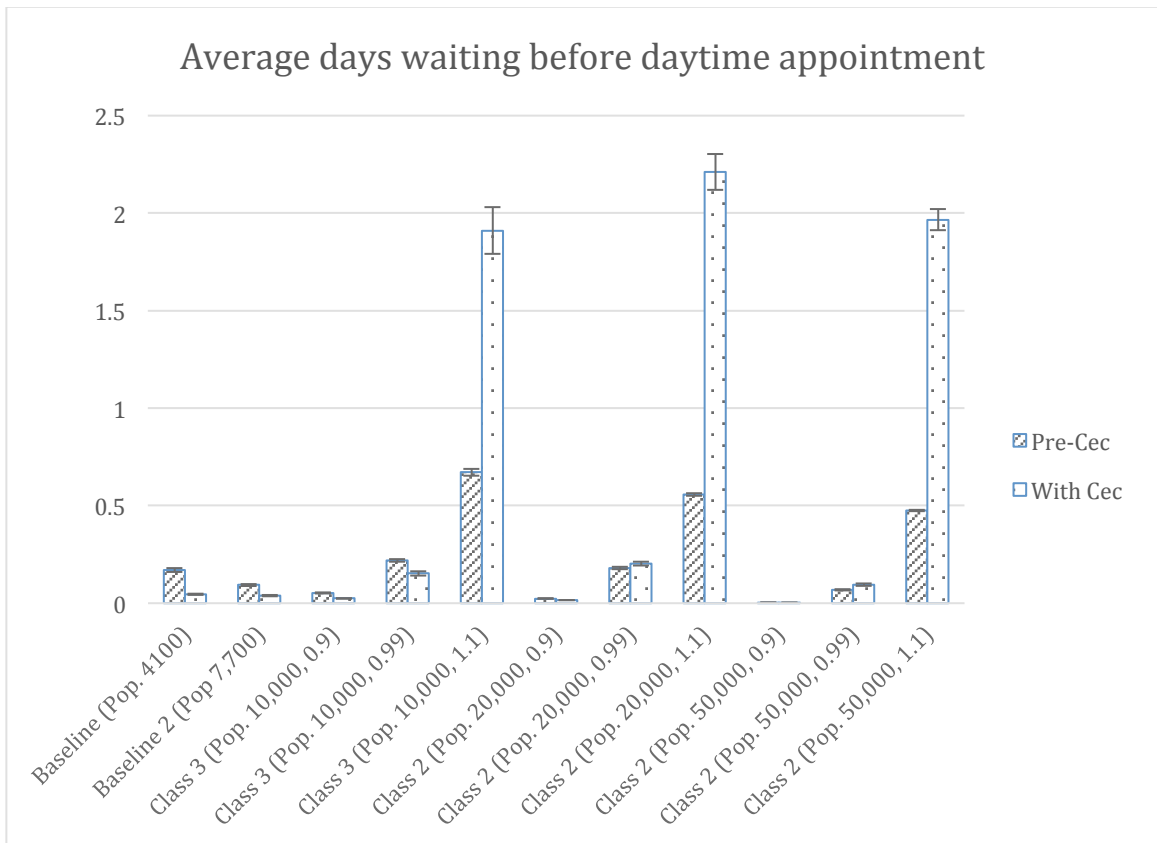**Figure 18 Average days waiting for a daytime appointment**

6.1.3 Predictive Power in Larger Catchments

The operational performance of the CEC in larger centres proved more efficient than might have been expected. The number of patients who reneged remained low even

as the population increased, remaining well below the estimated CEC capacity

except in situations where primary care was overwhelmed. The ability of

paramedics and nurses to handle emergency situations with no direct physician

oversight could be a beneficial insight for larger hospitals, where tepid changes have

been made to offer team-based care. From an operational efficiency standpoint,

these results suggest that a team approach for patients with CTAS 3-5 could free up

physician time to focus on more critical patients and increasing ED throughput. This

sort of approach has already been studied in the literature, as shown in Section 2.1,

and these results suggest the model is worthy of further study.

6.2 Model Limitations

The model has a number of limitations which may reduce its utility in measuring

certain aspects of CEC care. These model limitations, which are discussed below, do

not affect the model's ability to make comparative assessments of EDs and CECs in a

particular community when configured with appropriate input parameters.

6.2.1 Model Calibration

The model is calibrated using a population subgroup distinct to rural Nova Scotia.

Different demographics may result in different rates at which patients seek care.

Care should be taken when extrapolating model results to a new community to

ensure the service rates are appropriate for the community's demographics. A

future enhancement of the model could be to break service rates down by

demographics, allowing users to enter local characteristics at a more granular level,

testing the impacts of growth in one population subgroup over another.

6.2.2 Model Efficiency

The model is overly efficient with regard to primary care appointments. The three primary causes of this efficiency are provider pooling, ignoring patient/physician preferences, and the first-come, first-served nature of the queue. In reality, not all providers are available to see all patients, as the primary care providers operate independent clinics within the community. This means that the wait time for one provider could be long, while another may have appointments available on the same day. In addition, patients tend to have a preferred physician (their family doctor), and seeing this physician helps improve continuity of care. These two issues are correlated. The third issue is specific to queuing model design, as it ignores the acuity of a patient's condition. By treating all patients as first-come, first-served the model overestimates the system's ability to handle non-urgent patients and underestimates the system's ability to handle urgent patients. These factors explain why the model shows very little waiting time in most situations.

6.2.3 Local Data

A lack of Canadian data, as well as a lack of rural data, could impact the model's predictive capability. With universal health coverage it is likely that Canadians seek healthcare at different rates than Americans, who must pay for care themselves (or through an insurer). It is possible that American patients use the ED at higher (or lower) rates than Canadian for primary care purposes, though no definitive conclusions were found in the literature. In addition, data tends to come from large

urban research hospitals, where the characteristics and needs of the patients differ from their rural counterparts.

6.2.4 Cost Calculation

The cost calculation used in the model is likely unreliable for larger catchment sizes. In the existing CECs, the overnight physician is paid approximately $150 per site to be available by phone. Given that they are paid approximately $1,800 per night at a busier rural ED it seems unlikely that the physicians would agree to work at a busy CEC site for the same $150 fee. The model does not consider if additional providers are needed to satisfy demand; additional providers would increase the physician cost per patient if they are not operating at full capacity when the second provider is added. In the current CEC sites physicians receive on average two calls per three nights per site, almost always occurring before midnight. If the CEC program expands to larger centres it is likely that physicians will need to take calls throughout the night, and at a higher frequency, likely resulting in higher fees to be negotiated. As a result, the cost metric should be used with caution in larger sites.

6.2.5 Appointments to cancel

In all model scenarios more daytime appointments are offered after CEC implementation than before. This parameter occurs by design, as the same number of appointments are planned regardless of the presence of a CEC, with four being cancelled each day in towns with no CEC. It is likely that this contributes to the over-efficiency of the model in larger centres, and a method to determine the number of appointments to cancel would be beneficial.

6.2.6 Summary of Limitations

Despite the limitations described above, the model and methods are correct in this application. As shown in Section 4.2 *Model Validation*, the model correctly replicates the changes in patient arrivals in Parrsboro, thus can be used to estimate physician cost and improvements in primary care access. The model can also be used to extrapolate from the Parrsboro scenario, which was the stated goal of the research in Section 1.6 *Thesis Outline*.

In addition, many of these limitations can be overcome by an end user. The automation of the model allows any user to perform analysis on the CEC program by inserting the parameters relevant to their primary care setting. This allows an administrator to quickly check whether a CEC may be warranted in their area before performing an in-depth assessment of the program's merits.

6.3 Future Research

The young CEC program provides many excellent opportunities for research. This research assessed one aspect of the CEC care, modelling the operational performance of a CEC compared with an ED. This section outlines some additional research questions identified over the course of this research.

6.3.1 Renege rates

One opportunity for future CEC research could be detailed data capture on patients' renege rates. This result could be used to more accurately predict patient behaviour when a CEC is opened in a new jurisdiction, improving the predictive capability of

this model. Renege rates to the CEC specific to rural areas would be a unique contribution to the extant research.

6.3.2 Primary care capacity

Another opportunity to enhance the model is to determine the capacity for primary care appointments in the target community. This would allow the model to respond more accurately to patient behaviour.

6.3.3 CEC Service Hours

The CEC hours are another area that may affect operations. In the EHS data, 80 percent of patients arrived between 8pm and 1am, with 60 percent before 11pm, and 40 percent before 10pm. This indicates that extending the physician coverage by one or two hours could reduce or eliminate CEC visits. Further research into the reasons patients arrive just arrive the physician leaves is recommended.

6.3.4 Provider Training and Skill Set

Research is currently underway to assess the suitability of nurse and paramedic training at the existing CECs. If the research concludes that different training or policies will change the ratio of patients returning to primary care this model can be easily updated by an administrator to assess the relative impact this would have on the operational performance of the system.

6.3.5 Unplanned return to primary care

Companion research to this model is already underway to determine the rate at which patients make an unplanned return to primary care after attending the CEC.

This research will help determine the policies and skillset needed to operate a CEC, and could positively or negatively impact the service rates outlined above. The model can easily be adapted to capture these patients who return to primary care, as well as modified to change the proportion of patients who make a planned return to primary care the following day. By varying the rate at which patients return to primary care (planned or unplanned) this model could be used to perform research into the impact of additional training for overnight staff on service rates and primary care access.

Chapter 7 – Conclusion

The CEC care model is a novel idea from Nova Scotia. Our review of the literature did not come across a method to model the system. This thesis presents an overview of the patient journey through this care model, a comparison of this care model to extant care models, and presents an analytical approach to determining the suitability of the CEC care model in a community.

This research used a slotted queuing model to assess the operational performance of the CEC program in three different population centres, with 10,000, 20,000, and 50,000 residents. Using the results from two of the eight existing CEC sites, the model was used to predict the operational performance changes which occur following CEC implementation.

Results of the model show that when there is an excess of primary care capacity, the CEC shows operational performance advantages to the ED in communities up to 11 times larger than the existing CEC sites (50,000 residents vs 4,500). The model shows that there is a cost saving to the CEC program in all but one scenario, where there are 50,000 residents and a shortage of primary care appointments. The model results also suggest that primary care access is a key determinant of demand for overnight care; when there is a surplus of primary care appointments the CEC improves primary care access, but when there is a shortage of primary care appointments the CEC detrimental to primary care access for all population sizes measured. The literature shows that patients with good primary care access, as measured by wait time for a primary care appointment, are far less likely to seek

overnight care than patients who face long waits for primary care. The slotted queuing model shows that overnight visits decrease when a CEC opens, as a result of increased access to primary care, except in scenarios where there is a shortage of primary care appointments.

This research shows that the slotted queuing model is a suitable way to study the effects of the CEC program. The resulting model can be easily modified by an end user to assess the potential operational performance of a CEC in their community. This thesis presented a way for end users to assess the suitability of a CEC in their community. The model was developed in Microsoft Excel to ensure widespread access to the model.

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Appendix A – Macro Description

The VBA macro developed to automate the model uses the following code. The code first initializes the sheet to ensure the user's inputs are up-to-date. Then, the code selects any previous values that were calculated, and deletes them. Finally, the code enters a loop, calculating the model, selecting the values, and copying them to the next open row on the sheet, then calculating the model again. This happens the number of times specified by the user. Finally, the macro selects the newly calculated values for the user.

```vba
'
' CalculateModel3 Macro
'

'
Dim iterations As Integer
Dim i As Long
Dim trueLength As Long
Dim desiredLength As Long
Dim row As Long
Dim endRow As Long
Dim warmup As Long
Dim population As Long
Dim cecOpen As Integer
Dim appointmentsToCancel As Integer
Dim appointmentsRatio As Single

' Ensures the sheet is up to date
    Calculate

' Prompts for initial conditions
    population = Range("Distributions!H4").Value
    cecOpen = Range("Distributions!H3").Value
    appointmentsToCancel = Range("Distributions!H5").Value
    appointmentsRatio = Range("Distributions!H6").Value
    warmup = Range("Distributions!H11").Value
    iterations = Range("Distributions!H7").Value
    desiredLength = Range("Distributions!H12").Value
    Range("Distributions!H11").Value = InputBox(prompt:="What is
the desired model warmup?", Title:="Initial Conditions",
```

```vba
Default:=warmup)
    Range("Distributions!H12").Value = InputBox(prompt:="What is
the post-warmup run length?", Title:="Initial Conditions",
Default:=desiredLength)
    Range("Distributions!H7").Value = InputBox(prompt:="How many
iterations should we perform?", Title:="Initial Conditions",
Default:=iterations)
    Range("Distributions!H4").Value = InputBox(prompt:="What is
the catchment population?", Title:="Initial Conditions",
Default:=population)
    Range("Distributions!H3").Value = InputBox(prompt:="Put 1 for
CEC, 0 for ED?", Title:="Initial Conditions", Default:=cecOpen)
    Range("Distributions!H5").Value = InputBox(prompt:="How many
appointments are canceled when the ED is open?", Title:="Initial
Conditions", Default:=appointmentsToCancel)
    Range("Distributions!H6").Value = InputBox(prompt:="What is
the ratio of appointments requested to appointments offered?",
Title:="Initial Conditions", Default:=appointmentsRatio)

'Improves model speed
    Application.ScreenUpdating = False

' Ensures the sheet is up to date
    Calculate

' Ensures the model run length is correct
    population = Range("Distributions!H4").Value
    cecOpen = Range("Distributions!H3").Value
    appointmentsToCancel = Range("Distributions!H5").Value
    appointmentsRatio = Range("Distributions!H6").Value
    warmup = Range("Distributions!H11").Value
    iterations = Range("Distributions!H7").Value
    desiredLength = Range("Distributions!H12").Value

    Worksheets("CEC").Activate
    Range("K8").End(xlDown).Select
    trueLength = ActiveCell.row - warmup - 7

    endRow = desiredLength + warmup + 7

    If trueLength < desiredLength Then

        ' loop through formula insertions
        ' this idea is started in extendLength sub but not
implemented. Use slow method below.

        Range("A9:AX9").Select
        Selection.AutoFill Destination:=Range(Cells(9, 1),
Cells(endRow, 50))
```

```vba
    ElseIf trueLength > desiredLength Then
        Range(Cells(desiredLength + warmup + 8, 1), _
Cells(desiredLength + warmup + 8, 52)).Select
        Range(Selection, Selection.End(xlDown)).Select
        Selection.ClearContents
    End If

' This section ensures formulas are up-to-date
    Call updateFormulas(warmup, desiredLength, "H", "H1", "sum", _
"CEC")
    Call updateFormulas(warmup, desiredLength, "K", "K1", "sum", _
"CEC")
    Call updateFormulas(warmup, desiredLength, "L", "L1", "sum", _
"CEC")
    Call updateFormulas(warmup, desiredLength, "L", "L1", "sum", _
"CEC")
    Call updateFormulas(warmup, desiredLength, "M", "M1", "sum", _
"CEC")
    Call updateFormulas(warmup, desiredLength, "N", "N1", "sum", _
"CEC")
    Call updateFormulas(warmup, desiredLength, "O", "O1", "sum", _
"CEC")
    Call updateFormulas(warmup, desiredLength, "P", "P1", "sum", _
"CEC")
    Call updateFormulas(warmup, desiredLength, "Q", "Q1", "sum", _
"CEC")
    Call updateFormulas(warmup, desiredLength, "R", "R1", "sum", _
"CEC")
    Call updateFormulas(warmup, desiredLength, "S", "S2", "sum", _
"CEC")
    Call updateFormulas(warmup, desiredLength, "T", "T2", "sum", _
"CEC")
    Call updateFormulas(warmup, desiredLength, "U", "U2", "sum", _
"CEC")
    Call updateFormulas(warmup, desiredLength, "V", "V2", "sum", _
"CEC")
    Call updateFormulas(warmup, desiredLength, "W", "W2", "sum", _
"CEC")
    Call updateFormulas(warmup, desiredLength, "X", "X2", "sum", _
"CEC")
    Call updateFormulas(warmup, desiredLength, "Y", "Y2", "sum", _
"CEC")
    Call updateFormulas(warmup, desiredLength, "Z", "Z2", "sum", _
"CEC")
    Call updateFormulas(warmup, desiredLength, "D", "D5", _
"average", "CEC")
    Call updateFormulas(warmup, desiredLength, "E", "E5", _
"average", "CEC")
    Call updateFormulas(warmup, desiredLength, "AA", "AA6", _
"average", "CEC")
```

```vbnet
    Call updateFormulas(warmup, desiredLength, "AB", "AB6",
"average", "CEC")
    Call updateFormulas(warmup, desiredLength, "AC", "AC6",
"average", "CEC")
    Call updateFormulas(warmup, desiredLength, "AE", "AE6",
"average", "CEC")
    Call updateFormulas(warmup, desiredLength, "AF", "AF6",
"average", "CEC")
    Call updateFormulas(warmup, desiredLength, "AP", "AP5",
"sum", "CEC")
    Call updateFormulas(warmup, desiredLength, "AQ", "AQ5",
"sum", "CEC")
    Call updateFormulas(warmup, desiredLength, "AR", "AR5",
"sum", "CEC")
    Call updateFormulas(warmup, desiredLength, "AS", "AS5",
"sum", "CEC")
    Call updateFormulas(warmup, desiredLength, "AT", "AT5",
"sum", "CEC")
    Call updateFormulas(warmup, desiredLength, "AU", "AU5",
"sum", "CEC")
    Call updateFormulas(warmup, desiredLength, "AV", "AV5",
"sum", "CEC")
    Call updateFormulas(warmup, desiredLength, "AW", "AW5",
"sum", "CEC")
' The histogram is a special case
    Worksheets("Graphs").Range("B3").Formula =
"=countif(CEC!$AC$" & 8 + warmup & ":$AC$" & endRow & ",
Graphs!A3)"
    Range("B3").Select
    Selection.AutoFill Destination:=Range("B3:B73")

' formulas are up to date
' now we go back to the results page and run the model
    Worksheets("Numerical Results").Activate
    Range("B5:O5").Select
    Range(Selection, Selection.End(xlDown)).Select
    Selection.ClearContents

    For i = 1 To iterations

        Calculate
        row = 4 + i

            Range(Cells(row, 2), Cells(row, 15)).Value =
Range("B3:O3").Value

    Next i

' We need to update the charts
'     Worksheets("Graphs").Activate
```

```vba
' The patients waiting
'    ActiveSheet.ChartObjects("Chart1").Activate
'    ActiveChart.SeriesCollection(1).SetSourceData
Source:=Range("CEC!K8:K" & endRow)

    Worksheets("Numerical Results").Activate
    Range("B5:05").Select
    Range(Selection, Selection.End(xlDown)).Select

    Application.ScreenUpdating = True
    MsgBox "All done."
End Sub

Sub updateFormulas(warmup As Long, runLength As Long,
targetColumn As String, targetCell As String, formulaType As
String, targetSheet As String)
'
' updateFormulas Macro
'


'
    Worksheets("" & targetSheet & "").Range("" & targetCell &
"").Formula = "=" & formulaType & "(" & targetColumn & warmup + 8
& ":" & targetColumn & warmup + runLength + 8 & ")"
End Sub

Sub extendLength(endRow As Long)
        ' loop through formula insertions
        For i = 9 To endRow
'            Range("D" & i &"").Formula = "=MIN(E" & i &",H" & i
"+SUM(K" & i & ":R " & i & ")+AE" & i & ")"
'            Range("E" & i &"").Formula =

        Next i
End Sub
```