Redesigning Panel Configurations:

A Case Study in Primary Care

by

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Dedication Page

The author would like to begin by acknowledging that this research was conducted in the ancestral and retained territory of the Mi'kmaq people.

This body of work is dedicated to those relentlessly striving to provide care for Nova Scotian citizens; medical professionals, government body employees and academics.

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Abstract

It is proposed that an integer non-linear programming formulation can establish guidelines and benchmarks for the redesign of patient panels for providers in primary care. The objective is to minimize the maximum overflow frequency. The optimization includes constraints which account for primary care daily operations. Salient to previous research, the forecasting of future patient care is obtained by analyzing historic patient behaviour.

The research uses data obtained from primary sources. The case study found that through panel redesign a reduction of overflow frequency can be achieved. The research draws correlation between overflow and the clinic performance goal of bettering patient access. An additional benefit to this research is the spreadable nature of the work.

Keywords

Panel Sizing, Overflow Frequency, Redesign, Capacity Planning

List of Abbreviations Used

AA – Advanced Access

APP – Alternative Payment Plans

CC – Continuity of Care

CFP – Collaborative Family Practice

CFPT – Collaborative Family Practice Teams

CIHI – Canadian Institute for Health Information

DHW – Department of Health and Wellness

ED – Emergency Department

EMR – Electronical Medical Records

FPM – Family Practice Medicine

FPN – Family Practice Nurse

FTE – Full Time Equivalent

IE – Industrial Engineering

MRP – Most Responsible Physician/Provider

MSI – Medical Services Insurance (Healthcare Number)

NS – Nova Scotia

NSHA – Nova Scotia Health Authority

OF – Overflow Frequency

PCP – Primary Care Provider

RN – Registered Nurse

Glossary

Attachment – The common concept of an on-going relationship between patient and provider.

Palliative Care – Relieving pain without dealing with the cause of the condition.

Postpartum – Following childbirth or the birth of the young.

Primary Care – The frequent initial contact with the healthcare system. Ideally consisting of regular relationships with medical providers. Responsible for Birth to Death patient care. Also referred to as Family Medicine.

Slots – The time window specified by a provider in the Electronic Medical Record for the average appointment.

Steady State – The state of a system or processes in which the variables defining the behaviour of the system or process are unchanging in time.

Supply Chain – The connected series of activities which are concerned with planning, coordination and controlling materials, parts, and finished foods from supplier to customer.

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I would like to thank the medical professionals in my personal life who have provided me care when I needed it most. Through their support, my positive experiences with the Nova Scotia health system had strongly motivated me to continue my graduate degree.

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Lastly, thank you to my grandmother, Annette, Je t'aime beaucoup beaucoup!

Chapter 1: Introduction

The research presents an optimization model developed through industrial engineering (IE) methodologies and is motivated by a primary care practice. The approach is prescriptive in nature. [1]. It is to be used for engagement of leadership at a family medicine (primary care) practice to help them attain some of their practice goals. We develop models to determine the number of patients that a given primary care provider (PCP) can be responsible for given their respective performance goals, while ensuring current patients of the practice continue to receive care.

The research is grounded in the procedures of a primary care practice operating in rural Nova Scotia (NS). Particular attention is given to ensure that the characteristics of the clinic are accounted for in the model. Such characteristics include multiple providers' unique schedules, appointment lengths, professional relationships and responsibilities. With appropriate consideration of these characteristics, the model outputs and research results provide well-informed support for capacity planning.

Outputs that can support capacity planning are obtained by redesigning panels, panels being a component of primary care further defined below. Redesigning panels is accomplished by a salient optimization model subject to constraints. The constraints ensure that patient care and needs are not altered by the process of panel remodeling. Further, the percentage of disruption to the clinic's care system is derived from provider preference.

For the research to be grounded in, and reflective of, daily operations of a practice, in-depth knowledge of primary care was obtained. One on one interviews with providers and administrative staff are essential. As well is approval and access to operational data. The incorporation of clinic specific knowledge into the research generates outcomes more obtainable by means of current primary care operations.

The current background of the NS health system is included for context. This research is motivated by challenges seen in rural NS practices and applies broadly across primary care. A specific challenge is the physician shortage which is being partially addressed by the restructuring of primary care delivery.

1.1 Motivation

In 2014, nine health authorities in the Province of Nova Scotia merged into a single provincial entity, the Nova Scotia Health Authority (NSHA). The impact is substantial, as they are the largest consumer of human capital in the province. [2]

A challenge identified by the NSHA is a shortage of family physicians. See Figure 1 showcasing NS as the only province with a decline in practicing physicians per population of 100,000, from 2013-2017. [3] A number of initiatives are ongoing to address this

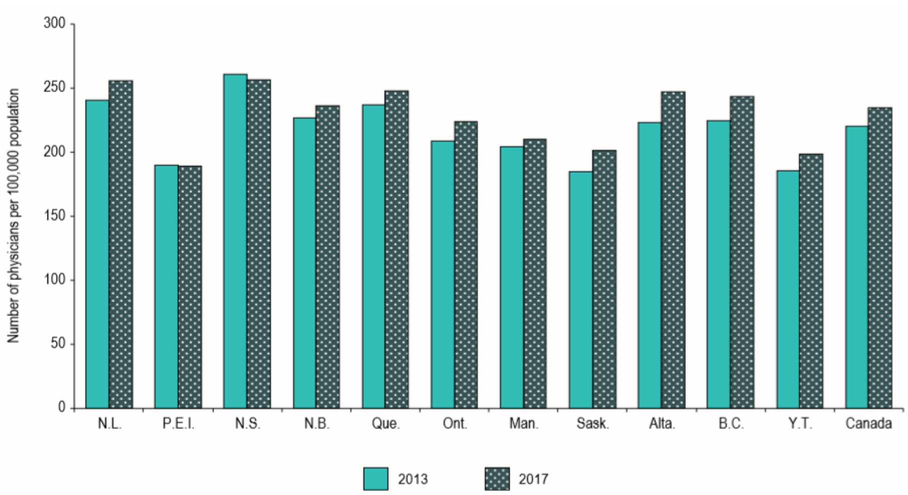


Figure 1- Number of Practicing Physicians per 100,000 population by Province, [3]

concern.

The use of Nurse Practitioners (NP) is a current initiative. This approach examines ways in which NPs alleviate doctors from providing elements of patient care. Elements of care can be categorized into acute, chronic or preventive. The objective is to increase available time for a physician to see patients, and potentially permit the physician to accept additional patients. Alternatively, NPs may adopt new patients directly. These registered nurses with advanced knowledge and education, become a valuable component to a Collaborative Family Practice (CFP) team. [4]

Collaborative Family Practice Teams (CFPTs) also referred to as Collaborative Family Practices (CFP) operate as a unit of at least two or more physicians, whom also share external responsibilities when needed. [5] Often supplementing the physicians are other health care providers, or Allied Health Professionals (AHP). No single preset or prescribed CFP team composition exists. However, many CFP teams include Nurse Practitioners who may maintain their own roster of patients. The makeup or structure of a CFP is influenced by the community and clinic needs.

CFPs typically use the same Electronic Medical Record (EMR) system. This is to ensure that appointment notes are visible to every team member. The majority of time however, a patient has their appointments with a single provider. “In the complex world of medicine, it is imperative that a single physician be identified at all times as the Most Responsible Physician(MRP).” [6] In NS, MRP is the acronym for Most Responsible Provider, as the position can be held by alternative designations. Commonly, this concept of an on-going relationship between patient and provider is known as “Attachment”.

Alberta, Newfoundland, British Columbia, and Ontario, are experimenting with the CFP model. [7] The model extends internationally as well, to jurisdictions of the United States and Australia. [*Ibid*] The wide spread of adoption can likely be attributed to the following benefits identified by the NSHA;

1. Comprehensive care – the team provides a full range of health care, from basic wellness check-ups to managing complex conditions.
2. Accessible care – the team works to offer appointments at various times that best meet the needs of patients.
3. Coordinated care – patients see the right health care provider for their needs.
4. Continuity of care – patients see the same team of providers throughout their life, building a medical history and trusting relationship over time.
5. Community-oriented care – the team works to meet the specific health needs of patients, and of the community.

[5]

Another solution to the physician shortage is the *8-1-1 Need a Family Practice Registry* which is happening in parallel to the NP recruitment. The registry was created and is maintained and evaluated by the NSHA. The percentage of residents without a PCP reflects only those patients who identify themselves. Ongoing status of the registry is reported on by the NSHA in reports titled *Finding a Primary Care Provider in Nova Scotia.* [8]. They found, among other things, that as of March of 2019 (based on the same census data of 2018) 5.6% of the population were not members of any practice. Furthermore, during the month of February 2019, 6422 people found a primary care provider, and 3,591 had added their names to the registry. [8] Cumulative registry progress is shown in Figure 2. Since first introduction to NS residents in January of 2018, to March of 2019, 75,645 patients have found a PCP. 44,830 found care through the registry, and the others through unspecified routes. NSHA reporting indicates the registry is effective at capturing the needs of patients and the progress of reducing the shortage impacts.

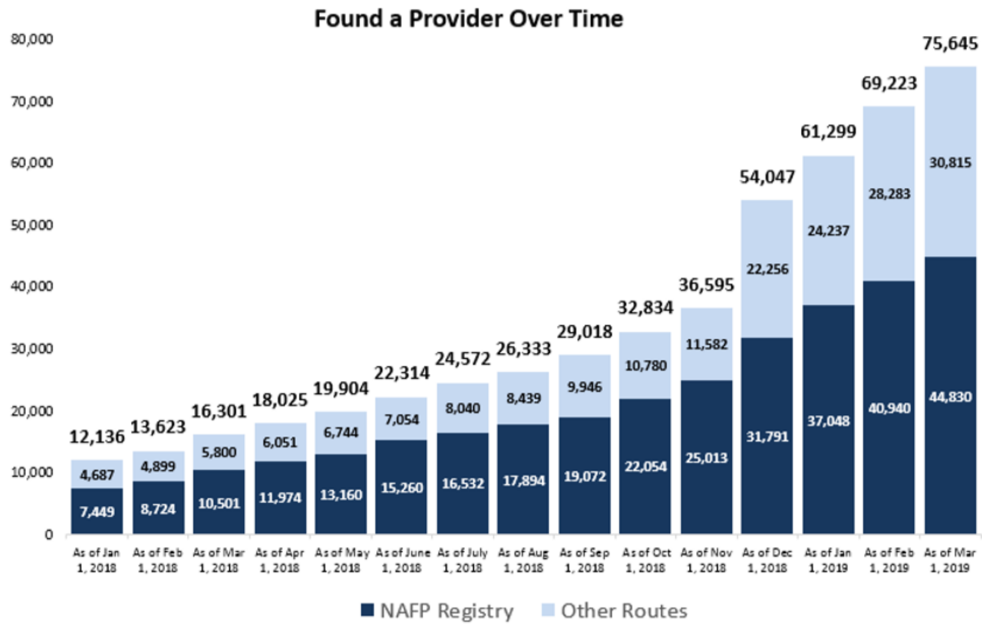


Figure 2- Total Provincial Volumes, Found a Primary Care Provider by Month, [8]

1.2 Focus of Improvement: Panel Sizing

In layman's terms, a panel can be viewed as a patient roster. As mentioned above, NPs also roster patients, however literature speaking in-depth about panel size often refers to physicians when discussing panels. Despite the terminology used in cited papers the intent of the research considers any provider whom is responsible for a panel, and utilizes the acronym MRP (most responsible provider) as the term for an rostering health professional.

A definition by Ozen and Balasubramanian defines panel size as a set of patients for whose long term, holistic care is the responsibility of the physician. [9] The College of Family Physicians of Canada states "A panel is the formalized linkage and long-term, ongoing relationship between a primary care physician to a provider and his/her patients." [10] A physician's appointment demands and obligations are determined by the size and configuration of his/her panel.

From NSHA reports, [11], we observed that there is an increasing demand for patient appointments in addition to the shortage of physicians. The concurrent increase in demand for appointments by individual patients is not captured in the statement of a MRP's panel size. For both new and established providers adopting patients from the registry, the expansion of their panel in number does not capture workload. Demand generated by patients in the panel is at risk of exceeding supply of appointments offered by a MRP.

In Canada and the USA the average physician is responsible for 2500 patients. [12] Medical doctors, and authors, Raffoul et al. [12] state that in their integrative literature review, this value (2500) appeared repeatedly but anecdotally, without basis in research. They further argued a single provider cannot sustainably offer capacity to satisfy the acute, chronic and preventative aspects of care for a panel of that size.

Cuba has a different model and is leading the world with a lower patient per doctor ratio. Differences stem from their medical education model. In Cuba medical school is free, and all doctors interested in a specialized field must first serve two years working in primary care. [13] As a result, there is a significant ongoing supply of family doctors allowing them to operate with panels a fifth of the size of Canadian panels.

To satisfy the demand of large panels in North America providers have developed solutions beyond excessive and routine overtime. One approach is to hire nurses for preventable and chronic care who work in tandem. Another approach is to operate as a "teaching clinic" allowing nursing and medical students to supplement clinic capacity. Providers have also capped their panel, meaning they do not take on any additional patients.

1.3 Impacting Factors to Panel Size

A provider's panel is shaped by the patients within it. As such, the demand for appointments is generated by the patients' needs. Over time, as this push (requests), pull (follow ups) process occurs, other factors of a clinic's operations influence how and why a panel is at its' current state. Abstractly the shortage encourages growth, however other factors such as geographical location impacts the rate of that growth. We assume many of these factors are underlying, and not motivation for deciding to adopt patients or not; many providers simply take on what they can to provide the best care to their communities.

1.3.1 Pay Model

Two methods by which physicians are paid in accordance with the Canada Health Act are Fee-for-Service and Alternative Payment Plans (APP). In 2015-16 72% of all clinical payments to Canadian physicians were made by the Fee-for-Service method. [14] In a Fee-for-Service model there exists set amount of remuneration per service. As such, income is dependant on the amount of services provided, as opposed to the number of hours of work performed. [15] The economic factor of pay impacts panel sizing, as providers under this model of pay likely, perhaps unknowingly, over saturate panels to guarantee demand.

Alternatively, the APP model is a contract used in primary care and by some rural specialists. [16] The salary method is more commonly found among physicians working in CFPs. The disassociation of income to "hands on patient" service ensures work tasks such as coordinating care through daily team huddles have a monetary incentive.

To further the operational differences of Fee-for-Service and APP, Hickson et al. [15] studied provider behaviour in practices based on reimbursement. Nine months of data was analyzed, and a P value indicated significant results, Figure 3. Their research indicates that a Fee-for-Service physician sees more patients than a salaried over the same time period. [15] Additionally, the patients with a Fee-for-Service physician will more often see their MRP. As mentioned above, APP providers are commonly found in collaborative practices; the additional team members create an alternate opportunity for care when MRPs are unavailable.

Practice Volume	Physician Group		*P* Value
	Fee-for-Service	Salary	
Av no. of patients enrolled/physician	43.4	55.1	<.05
Av no. of patient visits attended/physician	111.6	104.8	
% of visits attended by patient's primary physician (continuity)	86.6	78.3	<.05
Emergency room visits/enrolled patient/physician	0.12	0.22	<.01
Av no. of visits/enrolled patient/physician			
Scheduled	3.69	2.83	<.01
Completed	2.70	2.21	<.05
Sick, primary	0.95	0.98	
Sick, follow-up	0.33	0.24	
Well child	1.42	0.99	<.01

Figure 3- Influence of Mode of Payment on Clinical Practice Volumes, [15]

1.3.2 Rural verses Urban Responsibilities

An analysis of practice locations for Canadian physicians showed that 9.4% (15.7% of family physicians and 2.4% of specialists) are working in rural areas. In contrast, 21.4% of the general population in Canada lives in rural areas. [17] In comparison to urban hubs, rural communities recruit and retain less medical talent, see Figure 4. Scarce resources creates an obligation for rural providers to take on additional responsibilities such as;

hospital rounds and surgery assists, on-call night shifts, and care to local nursing homes. [18]

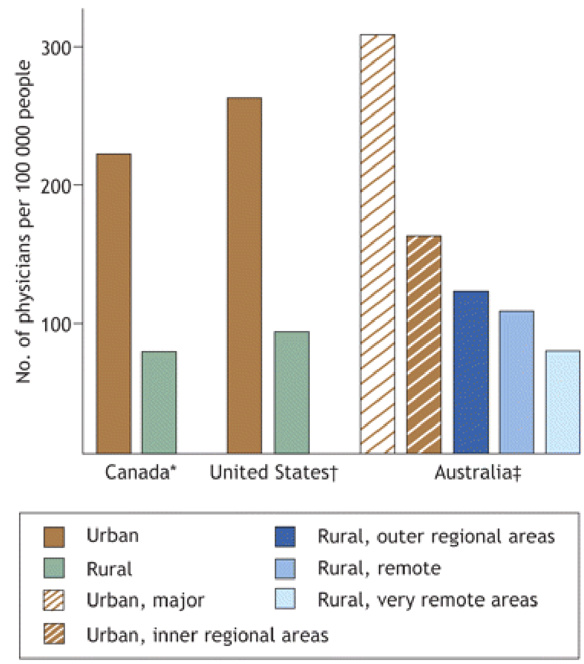


*Figure 4- Physicians and general population in rural areas of Canada, USA, and Australia, [18] * includes communities up to 10,000 people*

1.3.3 No-Shows & Cancellations

Capacity goes unused when a patient cancels an appointment or does not show up for an appointment. No-shows and cancellations create a "paradoxical situation where a physician is under-utilized while patients have long waits for getting appointments". [19] Since this situation is preferably avoided, remedies, such as reminder phone calls, can be adopted in family practices. However, with large panel sizes to manage the additional work could become strenuous for the administrative team.

The demand that can be requested of a single provider is related to the probability of a patient in the provider's panel producing demand at the start of each day. [19] Once establishing average patient daily demand probability, Green and Savin [19] analysed the probability for a patient to obtain a same-day appointment against panel size, shown in Figure 5. When the primary care team has the performance goal of offering Advanced Access, same or next day care, without cancelations or no shows the probability of achievement improves. Without cancelations or no-shows, a sustainable panel size can be around 2500 patients. [19] This is in line with the perceived national standard of 2500. However, Green et al.'s research [19] is insinuating it can only be sustainably achieved in an ideal world with no tolerance for no-shows or cancelations.

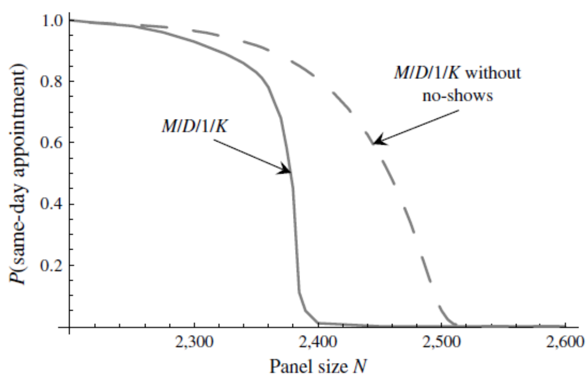


Figure 5- Probability of getting a same-day appointment as a function of the panel size, [19]

There is a correlation between no-show occurrences and patient appointment delay, see Figure 6. Shown in Figure 7 patients wait longer time frames as panel size increases. The research notes that panel sizing, access, and no-shows is a complex interaction.

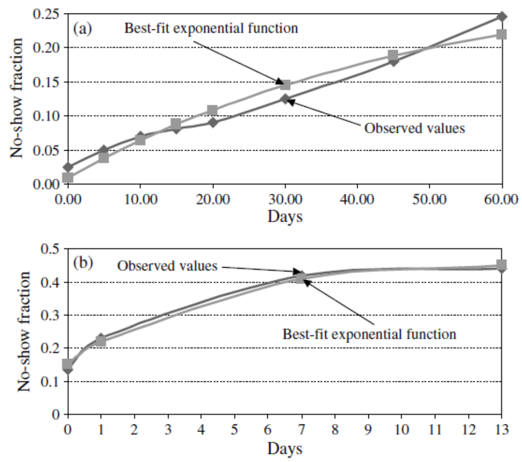


Figure 7- No-shows as a function of days waited for appointment, [19]

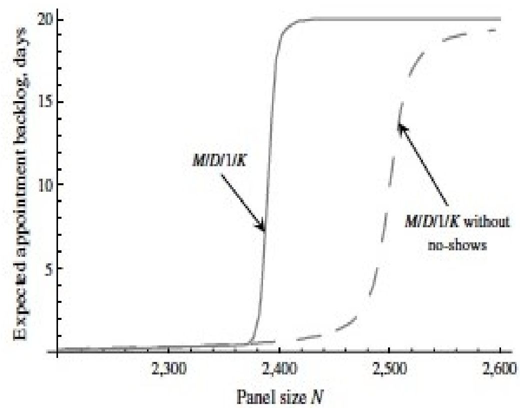


Figure 6- Panel Size impact on Expected Appointment Backlog (wait time), [19]

1.3.4 Case Mix

The number of patients in a panel does not fully characterise the patient demand. Other details such as the case mix are needed to comprehensively describe the panel. Case mix is the specification of patient demographics such as age, gender and general health condition [9] Consider the Diabetes Registries, a widely used tracker of patient aliment, a count of registered diabetic patients in the panel would be a descriptive element of the panel's case mix.

A panel's aggregate demand for access is a combination of the number of patients in a panel and their case mix. Further explored in the Literature Review, researchers often use age and gender as indicating factors for the affliction of case mix on a panel, since age often can be related to increase in volume and severity ailment. In general, the needs of

100 young adults are not equivalent to the needs of 100 patients 55+ with multiple chronic illnesses.

1.4 Research Context and Problem Statement

The content above has informed the research that panel sizing impacts operations in primary care. Large panel sizes can prevent primary care teams from obtaining performance goals, mainly patient access. Due to the current state of NS healthcare, the research has chosen to analyze panel sizing for rural communities.

Methodologies have been sought upon for improvement, including managing techniques by providers themselves. As will be elaborated on further in the Literature Review, researchers have applied IE methodologies to satisfy patient demand when it is unmatched by supply. Each panel size alteration and study are in hopes of achieving sustainability for providers, therefore enabling continuous patient care.

One of the techniques to alleviating the shortage is capacity balancing. The process of balancing is to redesign or change in attachment for patients within a CFP. The ways in which previous research obtains a redesign strategy varies. Providing primary care practices with a way to quantify patient demand and proceed accordingly is the overarching objective of this research.

Chapter 2: Literature Review

Publications cited in the literature review provided the foundation for the research. The search included the following technical keywords: optimization, capacity planning, and redesign. Citations were selected for review when the model's intentional use was within the realm of healthcare. Furthermore, papers which were validated through real-world integration were given greater consideration. In addition to the operations sector, some of the reviewed works have been published in the medical field.

Panel size was a publication keyword in all the reviewed literature. Research with close alignment to the CFP model was analyzed for research integration and data collection in team settings. Note, Collaborative Family Practices (CFPs) have several names that appear in literature including: "Inorganic Collaborative Clinics", "Holistic Health Homes", "Health Homes", "Team or Shared Practices."

2.1 Panel Size and Access

In healthcare, the definition and general concept of access depends on which party you are asking; the patient, the governing body, providers etc. There are several processes to obtain, analyze and display key indicators. Despite the metric chosen, research has shown there is a strong correlation between panel size, and the ability of a patient to obtain an appointment. [19] If a panel is exceedingly large, and therefore producing high demand, the excess demand results in delay in services. [20]

In the presence of demand uncertainty, patient panel sizes compatible with timely access to care are 5–33 percent smaller than the average. [21] Achieving access improvement can be done by establishing a foundation of correctly matched patient demand with appointment supply. [22] Disruptive, or potentially unfeasible, panel shrinking could be avoided by utilizing the CFP structure to equitably care for patients.

Balasubramanian [23] shows improvement in access can be achieved with a panel design genetic algorithm (PDGA), which is a machine learning optimization technique, see Figure 8. The data box states the mean wait time, in weeks per patient, reduces roughly 30% from 6.82 to 4.50 weeks for the current to the PDGA models respectively. The associated graph showcases that the PDGA outperforms the current panel design.

	Wait Time	Redirections
	Current Design	
Mean	6.82	531.10
Standard deviation	0.21	26.43
Upper 95% CI	6.87	538.43
Lower 95% CI	6.76	523.78
	PDGA Solution	
Mean	4.50	230.13
Standard deviation	0.18	26.77
Upper 95% CI	4.55	237.55
Lower 95% CI	4.44	222.71

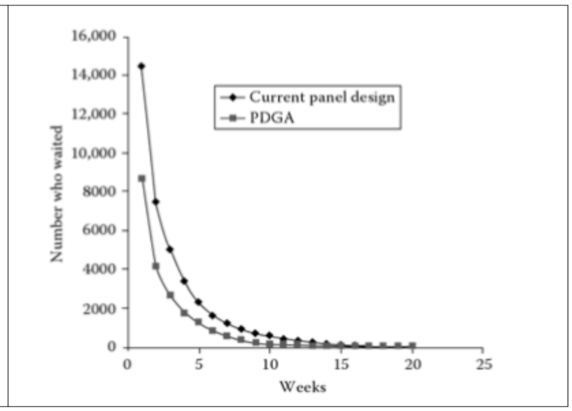


Figure 8- Comparison of current and optimized operations on appointment wait time for patients, [23]

In the data box of Figure 8 redirections represent the average weekly number of patients sent to another provider in a CFP due to the patient's primary provider being at capacity. Redirections are a concern related to Continuity of Care (CC). CC is considered a core principal of primary care as a continuing relationship between a provider and patient generates intangible value. [23] It is important when remodeling panel size to do so without undue delay to patients and without harming CC. [20]

Furthermore, CC helps the system. Studies have shown that improving CC results in a patient seeing their own provider in fewer visits, lowers the return rate, increases prescription adherence, and more services can be provided to the returning patient in the same time frame as a patient not of the providers' panel. [20] Opportunity to adopt new patients arises when reduction of dependence on the MRP from existing patients is reduced. The benefits of CC also potentially reduce patient reliance on community walk-in clinics or emergency departments. [24]

In another paper, Balasubramanian et al. [22], compares access improvement by simulating three models; Baseline, Capacity-based and Optimal, Figure 9. Baseline continues operations as they currently are within the test clinic, meaning panel sizes are not altered. Capacity-based design uses a straightforward allocation in which panels are balanced based on physician available time. "For example, if physician "A" sees patients on average 40 hours a week out of a total of 200 hours of patient available time by the whole group, A's share of the patients is 20%" [22] The optimal design uses stochastic linear programing. Each were evaluated over one year via simulation. The results indicate that on average 21.49 fewer appointments are needed in a week with the optimally created panel compared to the baseline. If offering 20 minutes appointments, 21.49 fewer appointments is equivalent to an MRP working day.

	Extra slots	Unfilled slots
Baseline design		
Mean	122.02	35.71
95% CI	(113.48, 130.55)	(33.29, 38.12)
Capacity-based design		
Mean	103.64	52.55
95% CI	(93.71, 113.56)	(49.89, 55.20)
Optimal design		
Mean	100.53	57.93
95% CI	(90.90, 110.15)	(55.13, 60.73)

Figure 9- Clinic utilization under the three design simulations, [21]

The authors recognize the importance of CC and calculate redirections as a proxy. In this study redirections are the average number of times a patient requesting care saw a physician other than their own in a week. As shown in Figure 10 redirections are monitored for current clinic demand as well as for 10% higher demand. Increase in redirections is not proportional to demand increase. A 10% higher demand results in 93%, 57% and 59% more redirections respectively, showcasing baseline operations are vulnerable to fluctuation in demand.

		Baseline		Capacity-based		Optimal	
		Wait time	Redirections	Wait time	Redirections	Wait Time	Redirections
Current demand	Mean	0.572	266.65	0.391	182.04	0.318	160.5
	95% CI	(0.570, 0.574)	(265.34, 267.96)	(0.390, 0.392)	(180.99, 183.08)	(0.316, 0.320)	(159.13, 161.87)
10% Higher demand	Mean	0.749	437.32	0.6007	285.55	0.512	254.55
	95% CI	(0.746, 0.751)	(435.05, 439.59)	(0.6001, 0.6013)	(283.7, 287.4)	(0.509, 0.0.515)	(252.02, 257.07)

Figure 10- Simulation results on wait-time and redirections with account for 10% demand increase, [21]

2.1.1 Overflow Frequency

Operations researcher, Dr. Linda Green, focuses on panel sizing and frequently utilizes overflow frequency (*OF*) calculations. She terms overflow frequency level as the fraction of days, in percentage, when demand exceeds the average number of appointment slots available. [25] The probability of demand exceeding supply could be understood as the overtime a provider must work to satisfy patients. However, if a provider is unable to do "today's work today", *OF* translates to backlog. The relations of *OF* to appointment backlog, and therefore access is visualized by Green et al. in Figure 11.

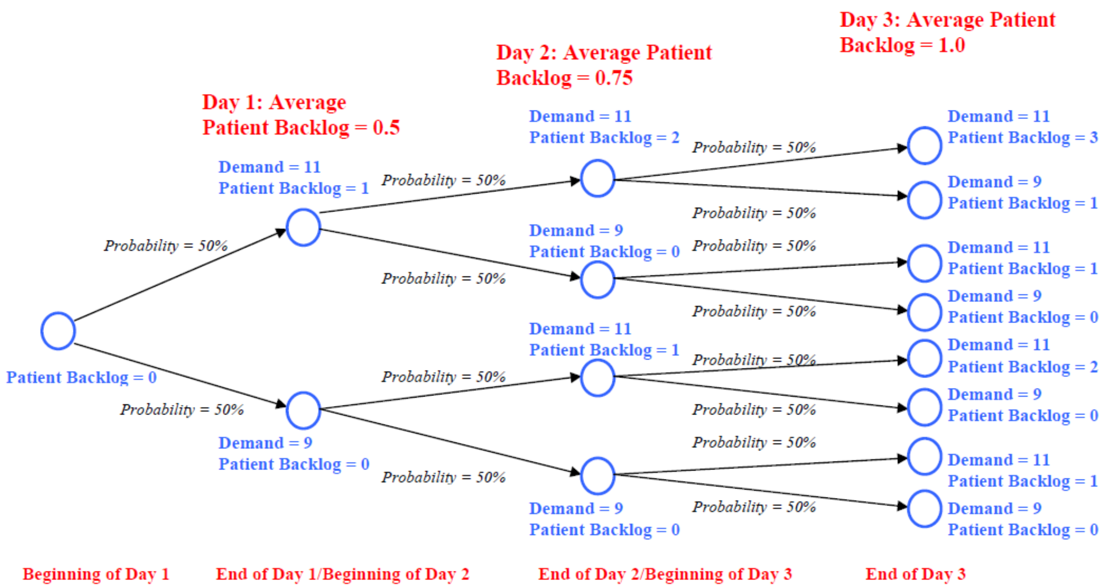


Figure 11- Illustration of growing patient backlog when average daily demand equals appointment capacity, [25]

In a Green paper with *OF* calculations, Green et al. [25] determines probability of an appointment request on any given day from any given patient, based on historical data. *OF* is then calculated with the probability of a patient's appointment request as the demand rate.

Calculating the overflow frequency

If the daily patient demand is modeled as a binomial random variable with parameters N (panel size) and p (demand rate), the probability that the number of patients will exceed the number of available slots C (overflow frequency) can be calculated as:

$$\textbf{Overflow frequency} = 1-(1-p)^N - \sum_{k=1}^{C} \frac{(N-k+1)(N-k+2)\times\ldots\times N}{1\times 2\times\ldots\times k} p^k (1-p)^{N-k}$$

where k is the index of summation.

This expression can also be re-written as

$$\textbf{Overflow frequency} = 1-(1-p)^N - \frac{N}{1} p(1-p)^{N-1} - \frac{N(N-1)}{1\times 2} p^2 (1-p)^{N-2}$$
$$- \frac{N(N-1)(N-2)}{1\times 2\times 3} p^3 (1-p)^{N-3} - \ldots - \frac{N(N-1)(N-2)\ldots(N-C+1)}{1\times 2\times 3\times\ldots\times C} p^C (1-p)^{N-C}$$

Figure 12- OF Mathematical Model [25]

Patient requests are assumed independently of each other. The assumption of independence means that demand is a binomial random variable. Depending on physician capacity, the probability of overflow is calculated using the Cumulative Distribution Function of the binomial distribution. [25] As *OF* is a tractable non-linear objective function it can be chosen as a variable objective to minimize. [9] As shown in Table 1, smaller panel sizes are coordinated to a reduction in *OF*.

Table 1- Panel Sizes by Parameter Values, [25]

	General and Family Practice	
	Daily Appointment Slots = 24	Daily Appointment Slots = 20
Overflow frequency = 5%	2321 (73%)	1879 (70%)
Overflow frequency= 10%	2515 (79%)	2053 (77%)
Overflow frequency = 20%	2765 (86%)	2279 (85%)

2.2 Estimating Demand by Patient Classification

Green et al. [25] assumes a homogeneous population by selecting a single appointment probability for every patient in the physician's panel. A panel showcasing high demand variability is an indicator that case mix is influencing access. [22]. Classifying patients can reduce the variable portion of demand. Common classifications include; age, health status, geographical location, and pattern of historical appointments. [23] Said by Balasubramanian and Ozen, "when working with panel size, research is not about finding the best classification but rather showing the impact of patient classes on measurable access." [9]

Murray MD, Davies MD and Boushon RN [20], investigated panel size based on the annual number of appointments requested by each patient (assuming a homogeneous population). As shown in Figure 13 when offering 20 appointments per a day (approximately 20 minute long appointments) if each patient sees a doctor once in a year a sustainable panel size is 4200 patients. However, if each patient comes in 6 times per a year, the suggested panel size is reduced to 700.

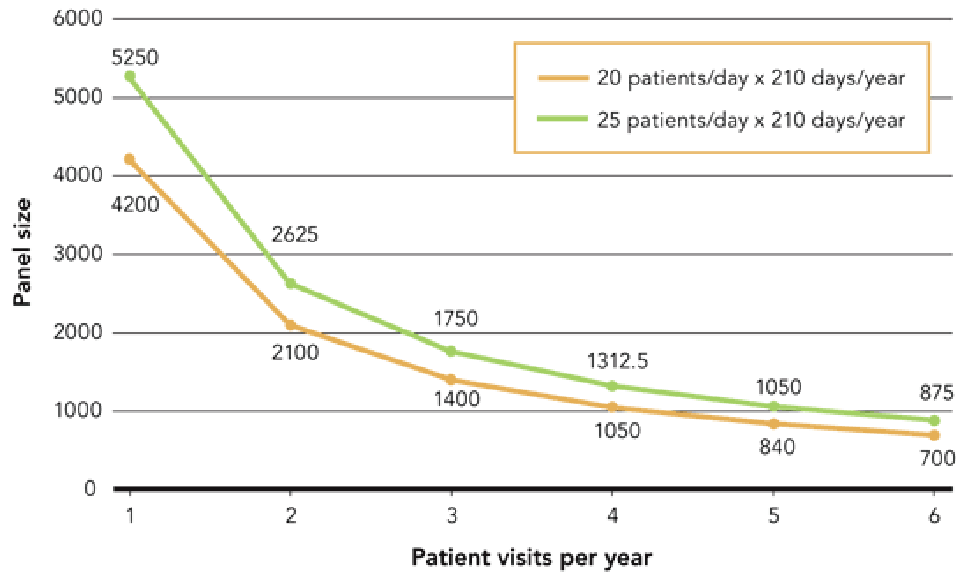


Figure 13- Panel Sizing by Patient visits per year, [20]

2.2.1 Age and Gender

Balasubramanian et al. [23] noted the correlation between age and gender to appointment request. As an example, women 55-60 are twice as likely to request an appointment then men 25-30. [23] Research findings from Balasubramanian et al. [23], are shown in Figure 14. The bar graphs represent the appointment frequency of 708 men and 986 women in their respective age classes. It should be noted the clinic participating in this study had in total of 40 providers, and 20,230 patients. On any given week 4.8% of men 48-53 will request an appointment, and 8.4 percent of women 73-78. Approximately 39 male and 83 female patients are forecasted to be seen in a given week. The appointment motivation, or severity is not captured.

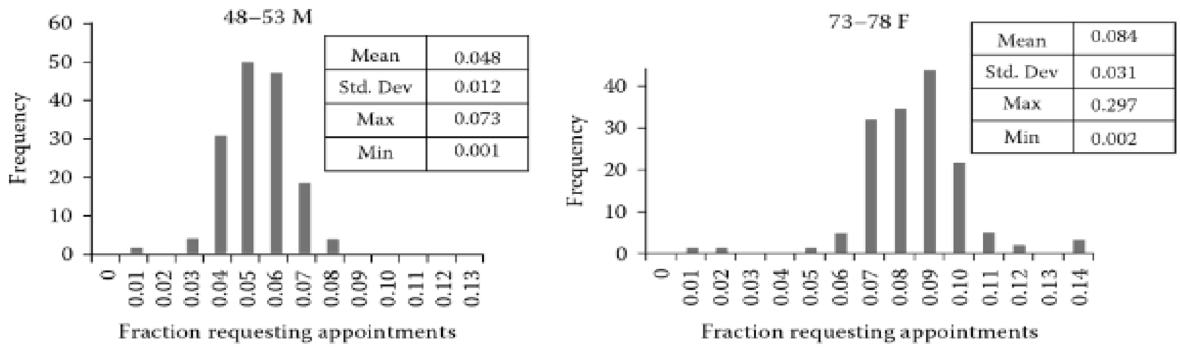


Figure 14- Comparison of age/gender categories to appointment frequency, [23]

2.2.2 Disease Burden

In Ozen et al., [9] the number of chronic conditions a patient is diagnosed with is used as the predictor of care needs (visits) in the following year. These conditions are termed as comorbidities or multimorbidity. As the number of comorbidities increases as does the annual care needs, Figure 15. The change in standard deviation suggests multimorbid patients represent greater demand variability than those who have less than three chronic illnesses. From a CART analysis (classification and regression trees) the health statuses found to be most demanding on the system was coronary artery disease, hypertension, and depression. [9] Their research concludes that having a holistic lens to remodeling panels is superior to focusing on a single identifier; since primary care itself is holistic and not disease specific. [9]

# of comorbidities	# of patients	Avg. visits/ pat/year	Std. dev.
0	6,524	1.72	2.88
1	6,980	2.74	4.56
2	5,819	3.82	6.25
3	4,179	5.16	8.56
4	2,370	6.82	9.95
5	989	7.67	10.72
6	346	9.62	13.14
7	84	11.17	13.39

Figure 15- Historic visits per year based on patient comorbidities, [9]

2.2.3 Patient External Events

Rossi et al. [26] state that deterministic models equating panel size to visits per patients per year is not satisfactory. Neither are the more advanced queueing modes that consider probability of delay with the inherent random nature of demand. Rossi et al. [26] argues this is because both models consider only office-based visits, "primary care was conceived with the intent of delivering holistic, comprehensive, and coordinated care … an important concern is keeping track of and proactively managing encounters that happen to the physician's patients in the broader health system." [26] As CC (care coordination) is vital to primary care, the model proposed by Rossi et al. [26] correlates workload generated for a MRP by mapping external health events of the patient. Historical information detailing a patient's care journey through the entire health system, over a two-year period, is analyzed and each patient is assigned a weight. The weight is based on The Medical Expenditure Panel Survey and represents how many Americans a single patient is representative of. In Figure 16, this female, 69, has a weight of 3,603. [26]

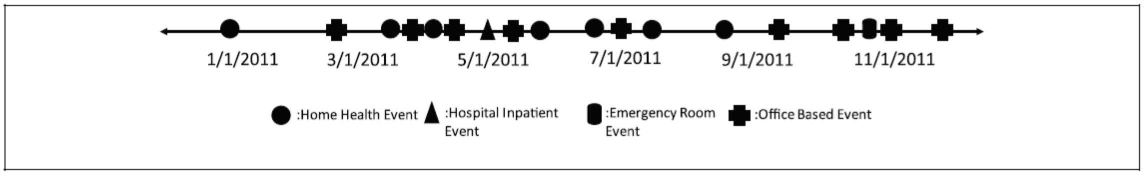


Figure 16- Event timeline of a 69 year old female in the Medical Expenditure Panel Survey 2011, [26]

Rossi et al. [26] aggregates the individual timelines of all panel patients in a summary chart, Figure 17, and combines unique timelines to determine the high-level demand of an entire panel. In Figure 18 the results showcase the impact on overflow frequency for two different sized panels. Results showed while offering the same number of appointments in a workday, MRPs supplying four in-office days a week resulted in half the overflow frequency than offering three and a half in-office workdays.

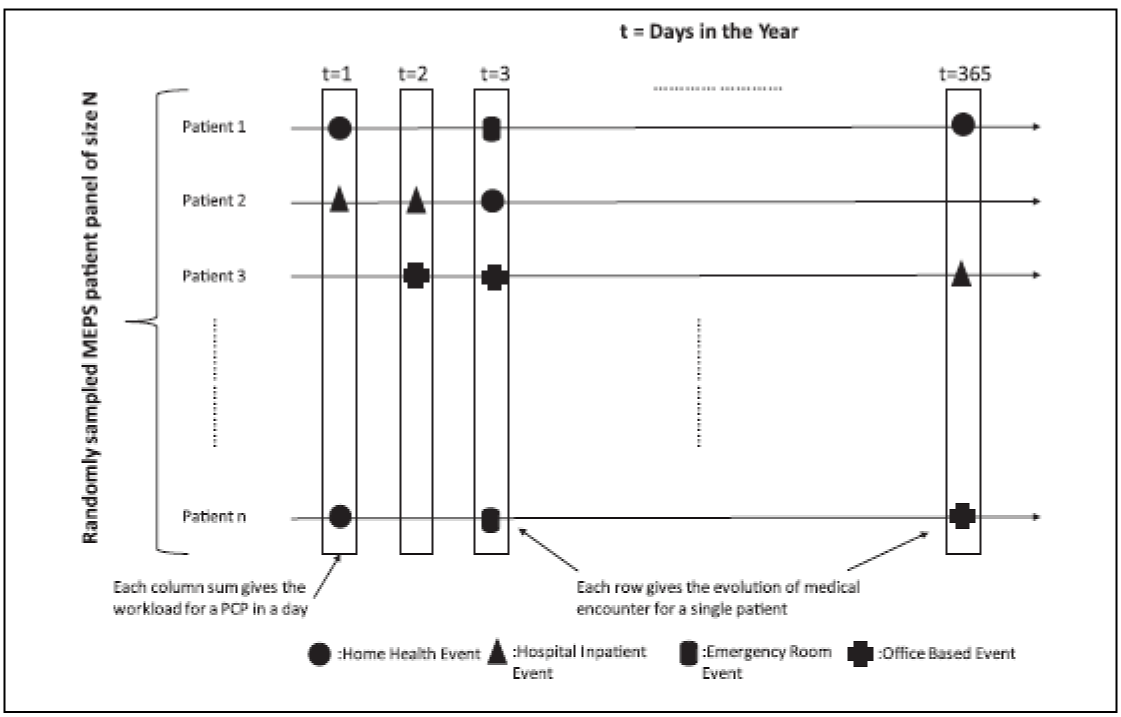


Figure 17- A visual illustration of patent event aggregation,

	Office Visits/Day	Office Visits/Week (C)	PCP Office Visits Overflow: O^N Panel Size = 1,500	Panel Size = 2,000
4 days per workweek for office visits	20	80	0.250	0.788
	22	88	0.096	0.519
	24	96	0.038	0.365
3.5 days per workweek for office visits	20	70	0.577	0.923
	22	77	0.365	0.885
	24	84	0.154	0.654

PCP, primary care physician.
[a]Overflow for a panel of size N = (# of weeks in the year that the PCP office visit demand exceeds the available capacity C)/52.

Figure 18- Overflow values for parameters

Rossi et al. [26], concludes that if historical information is to be used to predict demand, it must be holistic, including every medical event experienced by the patient both in and outside clinic. Similarly, the capacity of the provider must also consider all the externalities they are engaged in.

The acknowledgement of external MRP activities is shared in literature by health care professionals, Murray MD, Davies MD and Boushon RN [20]. Authors suggest that remodeling be approached by determining the whole panel of a clinic and dividing the panel amount by the available Full Time Equivalents (FTE). To determine proper FTE, one must subtract nonclinical duties, such as hospital rounds, nursing homes, procedures, and administrative meetings. [20] At a high-level, a 1.0 FTE physician, who only spends .5 FTE conducting in-office visits should not be given the workload of a 1.0 FTE provider.

2.3 Redesign Models

2.3.1 Conceptual

Three conceptual models for panel redesign were identified and are reviewed in this subsection. Each of them considers multiple provider environments which is of interest to the research. First, Balasubramanian et al. [22] showcases how panel age brackets may be unbalanced. See Figure 19, Provider C is seeing a greater number of patients 50-80 (indicated by arrow thickness), presumed to have higher care needs. As a result, C is overburdened, and A has available capacity.

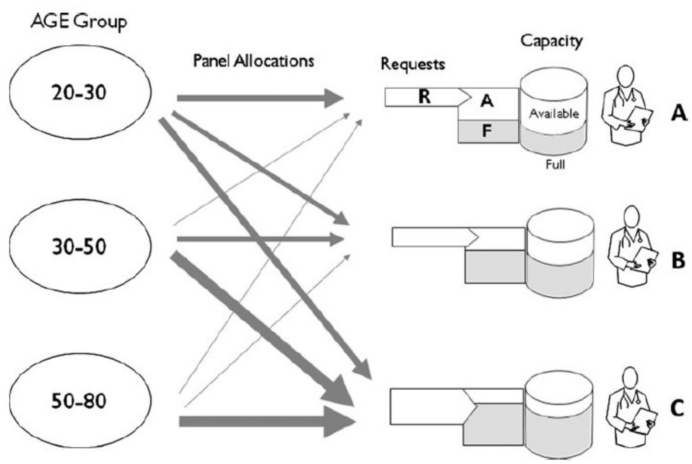


Figure 19- Redesign Conceptual Model 1, [22]

Second, a broader model by Balasubramanian proposes redesigning MRP panels in *the Handbook of Healthcare Delivery Systems.* In this depiction, Figure 20, x_{ij} is the variable representing patients moved of category *i* to panel *j.* [23] In turn, during any given week *t*, the demand d_{jt} can be determined. [23] The categories, *i,* could be any of the above discussed (age, disease…), so long as the classification relates to demand anticipation.

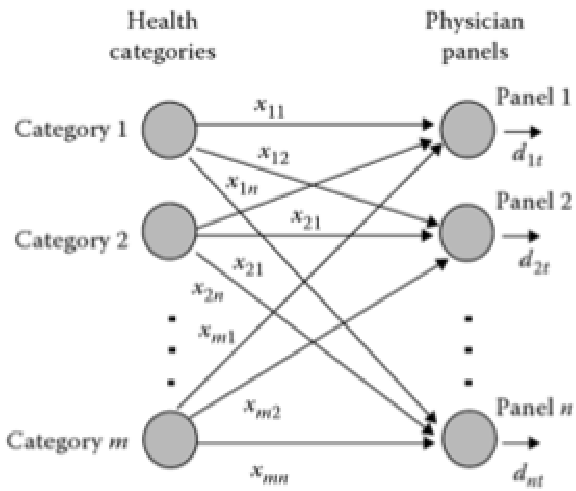


Figure 20- Conceptual Model 2, [23]

Lastly, the Ozen et al. [9] model, is the visual representation of the authors panel redesign formulation (PRF). This integer non-linear program has the objective of minimizing the maximum overflow experienced by a physician, Figure 21. "Choosing overflow frequency allows us to derive properties that eventually allow near optimal solutions to be reached using simple heuristics…minimax is chosen over summation because even if the sum over all physicians is a minimum, some physicians may have higher frequencies in relation to others". [9] Additionally, of interest to the research, the conceptual model showcases that the physician capacity is considered.

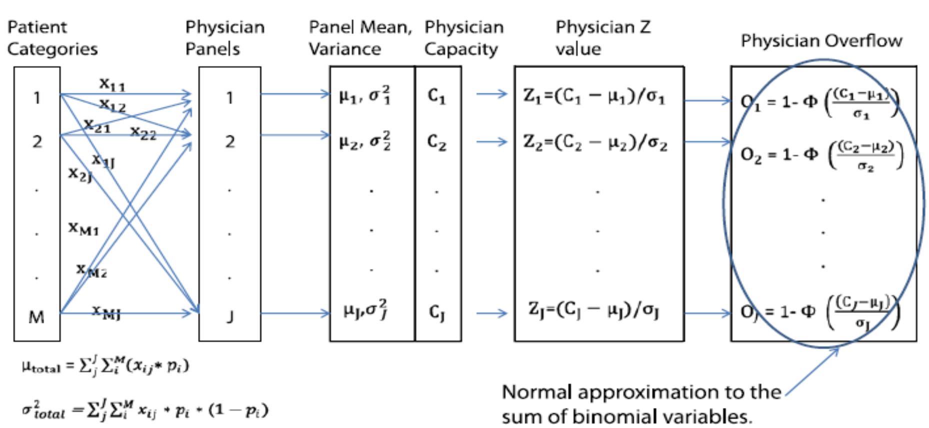


Figure 21- Conceptual Model 3, [9]

2.3.2 Collaborative Care Approaches

The standard of 2500 patients per panel size does not quantify the impact of changing patient demographics from the customer side, and therefore does not acknowledge the need for alterative methods on the server side. [21] A study by Green et al. [21] ran a probabilistic model of demand. In this study demand was either Advanced, accommodating 75% request same day, or Moderate, accommodating 50% requested same day. Broken down by sub-category of appointment slots offered in a day, the sizes of a panel such that all patient needs are accommodated is determined, Figure 22. For a physician to have a steady state panel in which 75% of the patient could confidently receive same or next day appointments (while offering 20 appointment slots per a day) a MRP can manage, at most, 1853 patients.

Comparison Of Primary Care Practices' Patient Panel Sizes, By Daily Appointment Capacity

	Appointment slots per day		
Appointment capacity	**20**	**24**	**28**
Matching expected demand	2,419	2,902	3,386
Advanced access	1,853	2,315	2,781
Moderate access	2,149	2,624	3,228

Figure 22- Comparison of Primary Care Practices' Patient Sizes, by Daily Appt Capacity, [22]

Green et al. [21] continued the study to see the impact of patient pooling, or collaborative offerings of care. Three different physician pooling options were added to the model. This was to determine the impact of diverting demand. Pool 2 and 3 indicate the number of alternate available physicians who could accept the diversions. The diversions were for those who needed immediate attention (same day care), the frequency of which taken from results of a National Ambulatory Medical Care Survey. [21]

The results are a physician working solo with zero diversion could sustain 1853, 2315, or 2781 patients, offering 20, 24, or 28 appointments a day, respectively. On the other end of the spectrum, a physician working in a Pool 3 (with two other physicians) allowing up to 40% diversion could manage panel sizes of 3783, 4582, and 5384, again respective to appointment offerings per a day.

Green et al. [21] use the model to forecast physician needs. Using a single physician model, providing advanced care, 112,743 physicians would be needed to meet the regional populations needs. [21] Population needs were for the United States, considering various epidemiology studies. However, using a “Pool 3” approach, with 20% diversion only 77,150 servers are needed in the system. The authors bring to light an important limitation of their analysis. As it is based on an aggregate national estimate, it was found less valuable then using data related to the actual population being served.

There is further literature on team-based care and how these models impact health care delivery. A paper with the specific focus of team delegation, took an approach of straightforward mathematics but strong social interaction. Alschuler et al., [27] four MD authors, first categorized acute, preventative, and chronic activities which happen in the clinic of study. Next, teams worked together to identify each of their skill sets. Various team members indicated their perceived capacity to take on each element of care. The sensitivity of these estimates of capacity was investigated using two additional models with adjusted values. The percentages of identified care needs were matched to the percentages of capacity specified by each provider.

Alschuler et al., cites the Duke University Department of Community and Family Medicine to estimate the time needed to meet preventive, chronic and acute care needs and used this to forecast demand generated by the panel. [27] Duke devised an estimate of hours needed to sustain good health per each care element, per patient, per year; 0.71, 0.99, 0.36 for preventive, chronic, and acute respectively. Shown in Figure 23, by assuming working hours of a single physician, 983 patients were the suggested panel of a single physician to achieve holistic and through care. [27] In contrast, the delegation models, shown below, indicated with AHPs the panel of a physician could be up to 1,947 (model 1). Models 2 and 3 were adjusted for modesty.

Type of Care	Nondelegated Model (Panel = 983)		Delegated Model 1 (Panel = 1,947)		Delegated Model 2 (Panel = 1,523)		Delegated Model 3 (Panel = 1,387)	
	Time Delegated %	Hours per Patient/Year	Time Delegated %	Hours per Patient/Year	Time Delegated %	Hours per Patient/Year	Time Delegated %	Hours per Patient/Year
Preventive	0	0.71	77	0.16	60	0.28	50	0.35
Chronic	0	0.99	47	0.53	30	0.70	25	0.75
Acute	0	0.36	0	0.36	0	0.36	0	0.36
Total	–	2.06	–	1.04	–	1.33	–	1.46

Figure 23- Estimated Panel Sizes under Different Models of Physician Task Delegation to Nonphysician Members, [26]

The feasibility of remodeling is questioned by all authors mentioned in the literature review. Ozen et al. [9] noted opportunities do arise for redesign change to be actionable. A physician may leave forcing a reassignment, or a new physician may join. Teaching clinics with high turnover rates provide constant opportunity for panel redesign. [9]

Human behaviour and bonds with providers dictate people's dislike to reconfiguration. One paper did quantify the impact to patients. They found, at most 5-8% of the patients (250 out of 4300) will be impacted by their redesign, and as low as 2% while still seeing improvement in overflow frequency. [9]

Chapter 3: Methodology

The reviewed literature has established that remodeling a panel is a method by which a clinic can better obtain their performance goals, particularly as related to improving patient access. The structure of this section follows the recommendation of Savin, [28], to establish a proper panel size, proceed through the following steps,

1. Define the current panel size
2. Estimate daily rate of appointment requests
3. Establish the target number of daily appointment slots
4. Set the target overflow frequency
5. Compute appropriate panel size based on the overflow frequency trade offs

[28]

Each variable used in the model is further explained in Chapter 4: Data Collection; regarding the variable's numeric value used for the case study, and the specifics on how it was determined. The Table 2 is a summary chart of the variables to be further defined below.

$$Objective\ function = Minimize\ (Maximum\ f(OF_x))$$

$$f(OF_x) = 1 - (1-\rho_x)^{P_x} - \sum_{k=0}^{s_x} \frac{(P_x - k + 1)(P_x - k + 2) \times \ldots \times P_x}{1 \times 2 \times \ldots \times k} \rho_x{}^k (1-\rho_x)^{P_x - k}$$

Where,

$$\rho_x = \frac{\sum_{\theta}^{z} P_{x,\beta} \times \beta'}{P_x \times T_x}$$

Subject to,

$$P_{x,\beta} \geq 50$$

$$P_{x,\beta} = integer$$

$$\sum_{x=1}^{n} \sum_{\beta=\theta}^{z} P_{x,\beta} = \sum_{x=1}^{n} \sum_{\beta=\theta}^{z} Pcurr_{x,\beta}$$

Table 2- Notation Table

Notation	Definition	Notation Subscript	Definition
t	The 18-month time frame for which panel size data is relevant		
x	The MRP a panel is associated to		
T	Available working days during time t to satisfy the care needs of a panel, *utilized for current state and forecasted calculations*	T_x	Specific to MRP
		T_y	Specific to AHP
		T'_x	Working days available to satisfy a panel associated to x, when an AHP has a structured relationship to provide care to said panel
β	The classification bin	β'	The average value in the class bin range
P	The size of a panel	P_{curr}	Current patient size the whole clinic cares for
		$P_{curr,x}$	The current panel size a specific MRP cares for
		P_{β}	The panel size specific to class, β
		$P_{x,\beta}$	The panel size specific to, MRP and class β
		P_x	The remodelled panel size for MRP
ρ	The daily demand rate	ρ_x	Daily demand rate of a specific MRP panel
A	The demand; appointments produced by patients	A_t	Historic demand determined from historic data
		A_x	Specific demand produced by an MRP panel
s	Average (over a week) number of slots in an EMR	s_x	Specific to MRP
c	Cycle time	c_x	Specific to MRP
OF	Overflow Frequency, percentage	OF_x	Specific to MPR
α	Percentage of class β patients moved	α_{β}	Specific to class β

3.1 Time Frame *(t)*

Legal responsibility is a reason why clinics may have more patient portfolios on file (physically or electronically) than those regularly requesting appointments. Several papers have citied the length of 18 months as an appropriate "cut off" for collecting panel size related data. [25], [20], [12]. Specifically, they define panel size to include any patient who had an appointment in the previous 18 months. In this research all data was collected over an 18-month period and $t=18$. Data collected during t depicts the operations occurring during a specific 18 months. This data is used to determine the variables below.

3.2 Current Panel Size (*Pcurr*)

The panel is the numeric total of patients for which the respective clinic provides ongoing and onsite medical care (*Pcurr*). For instance, external nursing home residents, seen regularly by the clinic's physicians, are still excluded from the *Pcurr*. Clerical staff or providers may have an approximation of *Pcurr*; however, it is likely *Pcurr* will need to be calculated from supporting data (section, 4.2.4, page 49). To do so, the EMR is efficient and effective for obtaining either the exact panel value or the necessary supporting data.

$Pcurr_x$ *where x=rostering providers 1,2,3…n,* is the variable representing an individual MRPs' respective panel, and,

$$Pcurr = \sum_{x=1}^{n} Pcurr_x$$

3.3 Establishing Demand

The daily patient demand is modelled as a binomial variable with parameters*,* $Pcurr_x$, and ρ, demand rate. The demand rate is estimated by the recommendations of Green et. al. [25]. The approximation is determined from the values of historic visits, current panel size ($Pcurr_x$), and available working days.

3.3.1 Demand Rate *(ρ)*

The demand rate *(ρ)* is the anticipated arrival rate of appointment requests from any given patient, on any given day. Research by Green et. al [25] uses overflow frequency as the focus of optimization and specifies a method for calculating the daily demand rate of a panel *(ρ).* It requires that a measurement of all requests and follow up visits. [25]. As such detailed data was not available for the research, the estimation based on historically satisfied appointments, Figure 24, can only be utilized to determine the historic average of *OF*.

Calculating the daily demand rate for a panel of current size N_{cur}

1. Choose an observation period (for example, 18 months) and calculate the number of working days T within this period.
2. Count the number of patient visits, A, over those T days.
3. The daily demand rate for appointments (per day per patient) is

$p = \frac{A}{N_{cur} \times T}$, where N_{cur} is the current panel size.

Figure 24- Calculating the daily demand rate, [25]

3.3.1.1 Determining Working Days (T)

The number of available clinic days in the observation period, *t,* is denoted by *T* and is computed by subtracting days when the clinic is closed from the total number of days in *t*. A full list of closure considerations can be found in section 4.2.2. page 47.

$$T = Calendar\ Days\ in\ t - Closure\ Dates$$

Working days, T_x are the days in t where the respective provider x offers appointments. Rossi et. al [26] emphasizes the holistic nature of primary care, acknowledging primary care responsibilities often extend beyond onsite care. The research also excludes routine external responsibilities to calculate the number of working days. Hospital rotations, and nursing home rounds are an example of routine care completed outside the clinic. However, care that can not be forecasted, such as surgical assists, are not accounted for.

$$T_x = Calendar\ Days\ in\ t - Closure\ Dates - Routine\ External\ Responsibilites\ _x$$

Often in a CFP, AHPs who do not roster patients provide care to *Pcurr* patients. If AHPs have provided care to *Pcurr* patients during *t* the calculation of working days must incorporate this additional capacity. Let T_y be the days where an AHP provides care, where

$$T_y = Calendar\ Days\ in\ t - Closure\ Dates - Unavailable\ days_y$$

$$where\ y\ indexes\ AHP\ 1,2,3\ ....$$

If a single AHP's supply is provided to multiple MRPs, the "Unavailable days" parameter is used to reflect this.

In the instance of AHPs in structured working relationships with an MRP, the total working days available in t to provide care to $Pcurr_x$ is then,

$$T'_x = T_x + T_y$$

3.3.1.2 Historic Appointment Requests (A_t)

The number of visits that occurred over t is denoted by (A_t). This denotes the demand that was fulfilled and recorded. Please note that it does not encompass:

- If the appointment went over schedule allocated time
- Associated provider effort towards paperwork (workers comp, referrals, scripts)
- Cross communication or care during appointment (such as a doctor and nurse both engaged in a single appointment)
- Does not capture multiple people in an appointment (example: mother and child)
- Does not count appointments that were "squeezed in" but not recorded in EMR
- Does not count every request for an appointment that went unsatisfied
- Does not count appointments obtained but not satisfied (no-shows)

Let A_x be the number of patient appointments generated by an MRP x's panel, and let $Pcurr_x$ be the panel size for MRP x. In summary, the daily demand rate for MRP x is,

$$\rho_x = \frac{A_x}{Pcurr_x \times T'_x}$$

3.4 Establishing Supply, Target Number of Daily Appointments *(s)*

The supply of daily appointments *(s),* commonly referred to as appointment slots, is the metric used to represent supply. A specific provider's appointment slot supply is denoted by s_x . To obtain s_x we divide the working hours in a day by the average appointment length or cycle time which we denote by c_x (section 4.2.3, page 48). Cycle time is the total time from beginning to end of a process before beginning a next task. Each provider should have a standard appointment length in the EMR system; however, common cycle times are 10 minutes for physicians and 30 minutes for NPs. We assume that the cycle time accommodates for travel time, paperwork and other appointment related duties that are not patient interaction.

3.5 Set Target Overflow Frequency *(OF)*

Savin et. al, [28] and Green et. al [25], showed that the daily patient demand can be modeled as a binomial random variable if you assume patient requests are generated independently. The daily demand rate *(ρ)* in their research is considered a constant, as it represents a long-term average, see Figure 25. In the research, we assume the same independence.

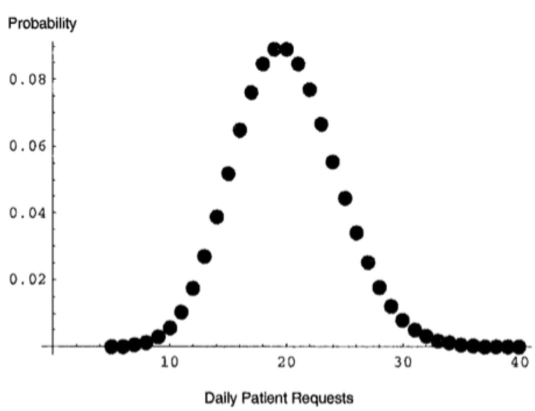


Figure 25- Daily demand distribution under binomial model

The probability that the number of patients requests in a given day will exceed the number of appointment slots offered in a given day is *OF*. [25] The *OF* for a primary provider who sets the target number of daily appointment slots, to be s_x and manages panel size $Pcurr_x$ with the daily patient visit rate of ρ_x is calculated by, [28]

$$(OF_x) = 1 - (1-\rho_x)^{P_x} - \sum_{k=1}^{s_x} \frac{(P_x - k + 1)(P_x - k + 2) \times \ldots \times P_x}{1 \times 2 \times \ldots \times k} \rho_x{}^k (1-\rho_x)^{P_x - k}$$

Overflow frequency can be interpreted for real world impact by converting the percentages to anticipated overtime working days in a month, Table 3. [25]

Table 3-Understanding Overflow Percentages

Understanding Overflow Percentage	
Percent	Translation
49.40%	Overtime work more than twice a week to meet demand
20%	Once a week on average
10%	Modest amount; Once in two weeks
5%	Once a Month

3.6 Compute Appropriate Panel Size (P_x)

3.6.1 Conceptual Modeling

The model, programmed in Excel, was developed after numerous visits to clinics throughout Nova Scotia. The application of the model is based on a specific clinic's challenge. This clinic had a physician vacancy and clinic members questioned, "upon a new physician entering the clinic, is it best to let the new provider build their panel individually, or do we share our current load, and adopt new patients simultaneously."

To redistribute existing patients, we need to understand and classify the demand of existing patients. The model divides panels by a classification proxy to case mix. In Figure 26 each

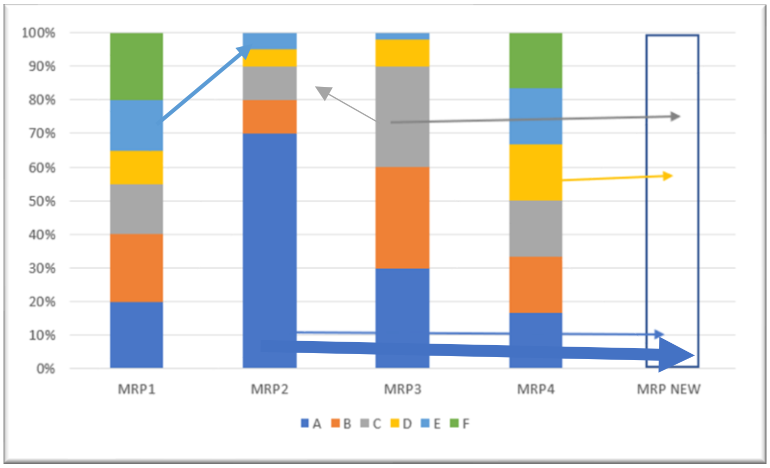


Figure 26- Conceptual Model, where A,B,... represent classification categories. (for illustrative purposes only)

provider's panel is depicted by percentage of patients from each classification category. Patients are then selected to move from one MRP panel to another, such that the overflow frequency is optimized. For clarification, the model does not select specific patients to move, just the class of a patient to be moved. The intention of this model is to configure panels that are more equitable than the current panels. In doing so, it is anticipated there will be benefits for the providers by reducing overtime potential and patients by reducing potential backlog (lessen wait-time).

3.6.2 Classifying Patients by Historic Behaviour

Having considered the various classification methods to reflect a panel's case mix, discussed in the literature review, the research proceeds with historical utilization. Patients will be classified by their appointment frequency. A primary reason for this choice is the associated anonymity. No names, addresses, or date of births is needed to analyze frequency of use in the system.

Furthermore, upon discussion with medical stakeholders, it was concluded that appointment frequency indirectly captures some demographics such as, age and disease mix, as these patient may have care needs that require frequent visits with their provider. Providers also felt this would be a better way of capturing the specific clinic's demand opposed to national averages or other aggregate statistics. Furthermore, providers felt that age was not capturing trends in primary care. Rises in mental health awareness and diagnosis has an outcome of more frequent use of the primary care system by those under the age of 55. [29] [30]

To reflect this in the model, we now use β to index the different appointment frequency bins, $A, B, C, \dots, Z$. The number of patients of each type in provider *x's* panel is denoted by $P_{x,\beta}$ and the total panel for the clinic is

$$P = \sum_{x=1,}^{n} \sum_{\beta=\theta}^{z} P_{x,\beta}$$

The total number of patients in individual MRP panel is,

$$P_x = \sum_{\beta=\theta}^{z} P_{x,\beta}$$

The bin ranges and the research reasoning to their structure is discussed in Chapter 4.3, as the ranges are specific to the research clinic. An outlier range is specified to capture rare high frequency patients, as a single individual of such nature consumes substantial supply in the system. The reality of these patients is they are often highly vulnerable, or palliative. As primary care is a vast scope of birth to death, there are short term health cases to be considered. Palliative patients, intrapartum, and postpartum patients will have high utilization of the system in short period of time. The research will not reallocate any of these potentially vulnerable outlier patients.

3.6.2.1 Normality

The research assumes the population in the catchment of the clinic is distributed normally. If panel sizes are sufficiently large (>800–1,000 patients), the total demand is the sum of as many Bernoulli random variables, and is likely to be well approximated by a normal distribution. [9] As patients progress through the system (aging) there is potential they will generate more demand. In the context of the research, be classed into a higher bin. With the normality assumption as patients progress others will exit the system, due to death or relocation.

3.6.3 Forecasting Demand by Historic Behaviour

To account for the multiple classes of patients, the demand equations must also be updated. The anticipated appointment needs from redesigned panels are determined by the multiplication of the number of patients in each remodeled MRP's panel bins $P_{x,\beta}$ by the average number of forecasted visits for that bin, which we denote with β', in which the patients reside.

$$\rho_x = \frac{\sum_{\theta}^{z} P_{x,\beta} \times \beta'}{P_x \times T_x}$$

The rational of grouping patients into bins of frequency is to offer a range of potential demand that a patient categorized in a respective bin could produce. Similar to how Balasubramanian et al. [22] modeled for a 10% higher demand. Classifying patients in this manner allows the reassignment of patients to be more specific.

3.6.4 Mathematic Modeling

The results of remodeling panels will be expressed as the new panel sizes and case mix configurations. The new values are remodeled such that the objective function is maximized, and all constraints are satisfied. The chosen objective is minimizing the maximum overtime frequency, as modeled with a binomial distribution.

$$Objective\ function = Minimize\ (Maximum\ f(OF_x))$$

$$f(OF_x) = 1 - (1 - \rho_x)^{P_x} - \sum_{k=0}^{S_x} \frac{(P_x - k + 1)(P_x - k + 2) \times \ldots \times P_x}{1 \times 2 \times \ldots \times k} \rho_x{}^k (1 - \rho_x)^{P_x - k}$$

OF is used as our objective instead of backlog (how far out appointments are being booked on any given day for any given provider). The latter was not available but relates to *OF* as described by Green et. al [25] , shown in Figure 11, page 17.

A secondary objective is patient waiting time (W_t) is tracked, but not optimized. This is to further detail the impact of patient reassignments on patient access. Patient waiting time is computed using Little's Law [31]:

$$W_q = \frac{L_q}{\lambda} = \frac{\lambda}{\mu(\mu - \lambda)}$$

3.6.4.1 Constraints

One: Minimum Panel Size

It is undesirable for physicians to have an extremely small panel, as enough demand must be generated such that providers have stable incomes. The research constraint states that each provider panel must have at least 50 patients from each classification β.

$$P_{x,\beta} \geq 50$$

Two: Whole Number

The resulting new panels must be whole numbers. In addition to the fact you can not have "half a person" the legal responsibility of adoption is covered under this constraint. Each patient will have an MRP and cannot be divided among providers.

$$P_{x,\beta} = integer$$

Three: Attachment; Classification Consistency

This constraint specifies that each patient in the clinic needs to be assigned to a rostering provider, it additionally constraints the classification bins. A patient who is currently in bin β, must remain in the respective β in either the new or current provider panel.

$$\sum_{x=1}^{n} \sum_{\beta=\theta}^{z} P_{x,\beta} = \sum_{x=1}^{n} \sum_{\beta=\theta}^{z} Pcurr_{x,\beta}$$

3.6.4.2 Feasibility

The last constraint handles feasibility of the model. It also ensures the element of Continuity of Care (CC) is upheld. In the below equation, α indicates the movable percentage of a provider's existing panel. The specified percentage can be derived many ways; from the providers anecdotally, through patient surveys, or by inquisition of the front-end staff.

$$Pcurr_{x,\beta} - \alpha Pcurr_{x,\beta} \leq P_{x,\beta} \leq Pcurr_{x,\beta} + \alpha Pcurr_{x,\beta}$$

The model was built in Microsoft Excel. Excel Solver was utilized for optimization. The solver utilized the Generalized Reduced Gradient (GRG) method. Furthermore the constraint precision was set to 0.0001. Each model iteration took approximately 5 minutes to solve, however upwards of 20 minutes when substantial additional supply was considered.

Chapter 4: Research Approach

Various data is necessary for current state analysis and redesign modeling. For the research, data was obtained from the EMR (Electronic Medical Record), as well as from discussions with providers. The EMR system houses the majority of data needed.

4.1 Data Collection

Table 4 describes the data elements needed in the model, the method for obtaining them, as well as notes for effective data collection. Additionally, terminology stated may vary based on geographical location, primary care delivery model, or provider experiences. Included are alternate names perceived through primary data collection.

Table 4- Data Elements of Supply and Demand

Data Element	**Method of Obtaining**	**Notes**
(1) 18-month time frame t	Discussion among stakeholders	Choose a time frame with a fair representation of holidays. During this time there must not have been several radical changes in the clinic (new hires, remodeling, closures...) If conducting across many clinics, uphold the same time frame to adhere to consistency and seasonality.
(2) Out of Clinic Time (Vacation/Holiday)	Ask; Administrative Staff Supporting Documents	The administration staff should know an approximation each provider spends in a year (1.5 for 18 months) on vacation. For NSHA employees' holidays and vacation time are contractually specified.

(3) Out of Clinic Time (Routine External Responsibilities) *Used to calculate* T_x	Ask; Administrative Staff responsible for appointment booking, as well as providers	In rural areas this includes nursing home and hospital rounds. Be diligent with notes as providers individual obligations can easily become confusing.
Data Element	**Method of Obtaining**	**Notes**
(4) Provider Cycle Time (Appointment Length) c_x	Electronic Medical Record	Provider cycle time is the mode appointment length offered by a provider. Note whether or not this value includes paperwork and travel time. The value is specified in blocks of the EMR but should be confirmed with provider.
(5) Clinic Operating Hours *Used to calculate* s_x	Ask; Administrative Team Lead Supporting Documents	This value should be clearly stated on webpage/contact information for the clinic. If offered frequency of "overtime" include as a note, not as extended hours.
(6) Patient Appointment Unavailability (Breaks) *Used to calculate* s_x	Ask; Providers Electronic Medical Record	Lunch breaks, Community Obligations, blocked out paperwork time, Team Meetings…. Count any non-patient face to face time.
From EMR Historic Appointment Log over 18-month time frame		
(7) Appointment Date and Time *Used to calculate* A_t	Electronic Medical Record	Format is often extracted as DD-MM-YY, 00:00. If not, the consolidation excel sheet will have to be altered to extract month properly.

		Ensure that out of clinic visits (nursing home patients) are not included. They should be in a separate EMR, but if not there is often a "tag" associated with that patient i.e. John Snow-Beyond the Wall Nursing Home, to easily remove these patients from bulk data.
Data Element	**Method of Obtaining**	**Notes**
(8) Appointment Physician *Used to calculate Cross Coverage*	Electronic Medical Record	The physician who the patient saw for that appointment. The names of providers are often short formed. Note any renditions of the name. i.e. Snow, JSnow, Dr.Snow
(9) Patient Physician (Most Responsible Provider) *Used to calculate* A_x	Ask; Administrative Staff & Provider Electronic Medical Record	If the patient frequently visits the clinic but is "unattached" the answer may come from Administrative or Clinical staff. Ensure in both this data and that above, providers no longer in the clinic are not included. Associate the patient to the most often seen provider, via Asking.
Patient Information		
(10) A Unique Patient Identifier	Electronic Medical Record	To query appointment frequency a unique patient identifier is needed. This is common in EMRs.
(10) Patient Sex	Electronic Medical Record	The information is not necessary but can be used for supportive showcasing of demographics

Data Element	Method of Obtaining	Notes
(11) Patient Birth Year	Electronic Medical Record	The information is not necessary but can be used for supportive showcasing of demographics. The EMR will likely give the full birthday as DD-MM-YY. Alter data so just year is stated, in format YYYY
(12) Patient Active Status	Electronic Medical Record	Not all EMRs will have this information to showcase. The 18 months is to exclude those who have moved or passed away, but if one of those occurrences happened in the time frame, the status will be set to "Active-False", and they can be removed from the panel.

4.1.1 Data Collection Time Frame *(t)*

The time frame chosen was July 1st, 2017 to December 31st, 2018. This time frame accounted for seasonal factors, such as flu season. By the time of Excel model completion, the historical data was approximately 5 months lagging.

4.1.2 Working Days *(T)*

The variable *T* represents the working days in the specified time frame *t.* Days the clinic will be closed, such as holidays, are removed. Additionally, consider vacation time, which may vary based on salaried or fee for service providers. Example considerations are shown in Table 5 .

Table 5- Accounting for dispersion of clinic days in 18 Months

Type of Day	Total Count	Remainder of Onsite Working Days
Common in Primary Care		
Total Days in 18 Months	(549) via, https://www.timeanddate.com/date/duration.html?y1=2017&m1=7&d1=1.	T= 276 days
Weekends	- (158) Calculated via same link as above	
Holidays	- (20) via same link as above, or administrative knowledge	
Unopen Days	- (78) Two half days a week results in a loss of 78 days in t	
Vacation	- (14) Via NSHA contracts, or provider knowledge (3.5 weeks @ 4days a week)	
Sick Days/ Snow Days	- (3) based on historic events. Clinic loses power from snow at least twice a year	
Out of Clinic Responsibilities		
Rotations	- (65) (65) and (91) respectively, Hand count	
On Calls	- (18) Once a Month	T_1 = 189 days T_2 = 189 days T_3 = 163 days

Changes in unavailable time, mainly vacation time and sick days can fluctuate. The research keeps the numbers consistent for remodeling and ignores such variability.

4.1.3 Availability of Appointment Slots in a Day *(s_x)*

The available appointments (s_x) are determined according to the following steps:

1. Observe, or inquire to working hours in a day.
    a. A working week will be dependant on objective and purpose of the operation. Example, a rural oncology centre could be open one day in a week, and an urgent primary care centre could be open seven days a week.
    b. Operating hours of each open day should be recorded separately, as they may vary.

   c. It should also be noted this must be done on a provider by provider bases. In Nova Scotia, NSHA employees have different weekly hour requirements than self-employed physicians.
2. Removed the “unavailable to patient” time across the week from the respective days. Include considerations from Table 4 – (6)
3. The cycle time, c_x, is divided from the remaining time of each day, for each respective provider.
4. The previous values are summed for each provider and divided among the working days in a week for the respective provider. The resulting value is s_x, slots per a day.

4.1.4 Panel Size (*Pcurr*, $Pcurr_x$)

The current panel size had to be derived from data elements (see Table 4): (7) Appointment Date and Time, (9) Patient Physician and (10) Unique patient identifier. MSI numbers were converted into unidentifiable unique identifiers. Pivot Tables in Excel cross-reference Unique Identifier with Appointment Data and Time, computing the instances when a patient came into for care. To compute the panel size, repetitive Unique Identifiers are removed. Filtering the pivot table by Patient Physician, or MRP results in $Pcurr_x$. To determine cross coverage, additional filtering of Appointment Physician, Table 4-(8) is used.

4.2 Classification (β)

The range values for frequency bins are the result of blended data collection. Initially bins were developed anecdotally with the clinic team lead. The clinic lead expressed how they felt their patients accessed care over 18 months. After historic data consolidation the ranges were later adjusted to capture outliers, see Table 6.

The wide ranges in class F are to capture all outliers. These outliers must be included in as they consume a substantial number of appointments. The reality of these patients is they are often highly vulnerable, or palliative. As primary care is a vast scope of birth to death, there are short term health cases to be considered. Indicated by grey, vulnerable patients are not eligible in the redesign to be assigned a new MRP.

Table 6- Patient Historic Use Classification Bins

Class	Appointment Range for 18 Months	Average
A	0-2	1
B	3-5	4
C	6-8	7
D	9-13	11
E	14-18	16
F-i	19-25	19
F-ii	26-41	26
F-iii	41-64	42

Chapter 5: Case Study

5.1 Current State

We have applied the research to a clinic in rural NS, establishing a research partnership between the clinic and Dalhousie. Through the results section, this CFP medical clinic will be referred to as “the clinic”. Results regarding the current state are derived from analysis of the data extracted over *t*. Data extracted from *t* is the historic operations having occurred during July 1st 2017 to Dec 31st 2018. Current state analysis follows the methodology specified by Savin et al. [28] in the Methodology.

During *t* the clinic had satisfied 39,595 (A_t) appointments, this is shown chronologically in Figure 27. The likely cause of peak demand in November is the beginnings of flu season. The clinic’s team members have cared for 10,293 patients during *t*, who had generated the 39,595 appointments. During *t* the clinic team members consisted of; four physicians, two nurse practitioners, three AHPs (various classifications of nurse) and a team of up to seven of administrative staff.

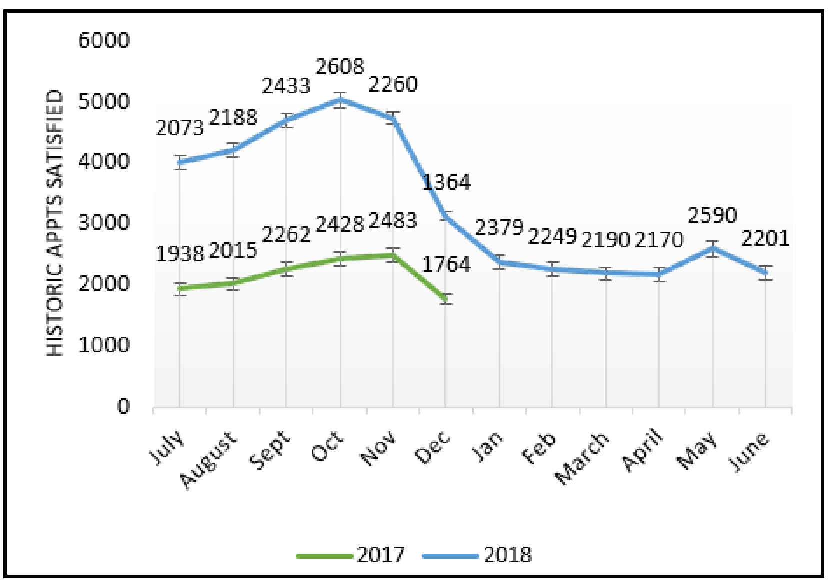


Figure 27- Historic Appointments by Month

The research adjusted current state values in accordance with clinic qualitative research. Interviews and observations concluded that the NP panels would not be eligible for a redesign. By end of *t,* the NPs had established less than 36 months cumulatively in the clinic. Based on comments by Ozen et. al [9] this novel status would make redesign more feasible, however the data was too vulnerable to external factors. An example of such factors being, for the majority, NPs adopted patients off the 811 list. A portion of their appointments, greater than that of an established MRP, were considered "first time visits". It is common that patients off that 811 list have not received primary care for several years. For some patients, chronic illnesses must be managed first, which then requires more frequent follow ups as new medications are being adjusted. The then forecasted NP panel demand was overinflated. Further confirming unusable data, at time of research extraction administration staff confirmed NP panels of 323, and 646. Comparatively, the research analysis indicated 291, 601 patients respectively. As their current and ongoing growth could not be quantified in panel remodeling, their panel size contributions were excluded.

One of the four physicians had left the clinic near the end of *t.* The MRP had taken the entirety of their panel and associated AHP with them. The contributions of this provider to the overall clinic have been removed. Resulting in the eligible and appropriate panel size to be remodeled as $Pcurr$ = 6964. The historic appointments generated by the remaining MRP panels (regardless of which provider patients saw for care) is A_t= 24,468.

Table 7- Current State Clinic Metrics Obtained by Historical Data

The Panel is Associated to MRP *(x)*	Panel Size ($Pcurr_x$)	Historic Appts $Pcurr_x$ generated (A_x)	Available Days utilized to satisfy A_x (T'_x)	Historic Daily Arrival Rate (ρ_x)
1	2900	9835	325	0.01
2	2524	8159	325	0.01
3	1540	6474	299	0.01

Table 8 showcases cross coverage historically between team members. The research considers team members to be those still present at end of *t*.

Table 8- Historic Cross Coverage by Current Team Members

The Panel is Associated to MRP *(x)*	Appointments by $Pcurr_x$ satisfied by Other Physicians	Appointments by $Pcurr_x$ satisfied by NPs	Appointments by $Pcurr_x$ satisfied by AHPs
1	210	421	1769
2	308	181	874
3	52	124	1222

In Table 7, working days T'_x is the sum of MRP and AHP available days in *t* for face to face patient care. AHP supply is incorporated so that the historic ratio of supply and demand is not over inflated. The sharing of AHP aid in the clinic is complex; booking procedures (supply) was determined from interviewing administrative staff. One AHP provides care to MRP panels 1 and 2, whereas MRP panel 3 receives 50% of the aid of a second AHP. The other 50% portion of the second AHP care is given to the NPs. The research could not fully incorporate the nature of the appointments that AHPs help with, however in general it consists of well-woman appointments, vitals, and chronic illness management.

Sole MRP supply is detailed in Table 9. Available patient appointment days is lessened by the unavailable days considered in section 4.1.2. Provider 3 cares for an additional nursing home, removing every Friday availability, hence the lower value. The research does not capture when unavailable days coincide (holiday and clinic rotation). Slots per a day is the result of dividing available minutes in a day by cycle time. The daily appointments slots are an average over the week.

Table 9-Physican Available Time, including External Responsibilities

The Panel is Associated to MRP *(x)*	Available days for in-clinic patient care, (T_x)	Cycle time *(c_x)*	Average daily appt slots *(s_x)*
1	189	10	29
2	189	10	35
3	163	15	23

The research has determined the current panel size and historic appointments (Table 7) as well as supply (Table 9). In the methodology structure by Savin et. al [28] the fourth step is to *"Set the target overflow frequency"*. Establishing the current *OF* would provide a benchmark from which to set a target. However, since available historic data does not encapsulate unsatisfied requests for demand (additional walk-ins, phone calls, electronic booking etc..) the *OF* based on historic data only showcases what was satisfied against supply, effectively reducing *OF* to zero.

This is shown by the calculation of *OF* when incorporating AHP supply. The values are respectfully 0.28%, 0.00%, and 3.34%, Table 10, indicating nearly negligible *OF*. The *OF* percentages greater than zero are likely attributed to inaccurate estimation of historic T'_x, The interviews and qualitative study in the clinic did not reflect operations associated with low *OF* values. The clinic team members feel overburdened and express concern for patient access. This was also seen by observation of the clinic waiting room. As the clinic providers opt to see patients during regular work hours and do paperwork on off hours, over time is manifesting as paperwork, opposed to patient appointments. Removing the AHP supply is a better approximation of what a single panel is producing in demand, Table 10.

Table 10-Overflow Frequency by Historic Data

The Panel is Associated to MRP *(x)*	*OF* %, ***with the AHP***	*OF*%, ***Without AHP***
1	0.28	99.97

2	0.00	88.27
3	3.34	99.74

Literature cited in the introduction and literature review speak to the significance of case mix on panel sizing, and the ability to use such classifications as methods to forecast demand. Outlined in the methodology the research divides patients by their historic use of the system into bins, then uses the projected average visits of that bin to forecast demand. Figure 28 is a visual representation of current MRP panels in terms of frequency bin β.

For each provider, patients of type A are the largest majority of their panels. It appears that type B patients are a similar portion for all providers. Further detail however indicates 855, 761, and 525 type B patients respectfully. In terms of appointments 3420, 3044, 2100. At 10 minute per an appointments, between provider 1 and 3, that is a difference of approximately 27.5 working days.

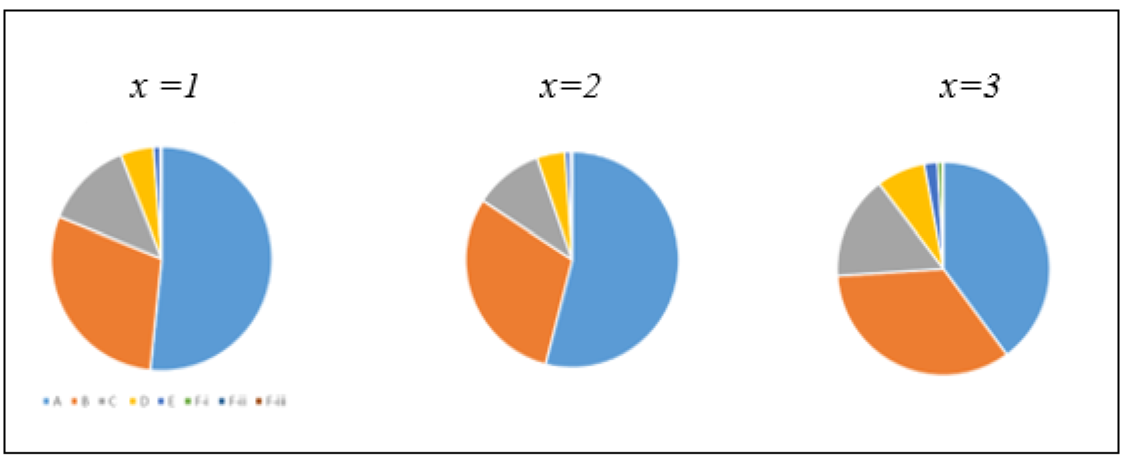


Figure 28- MRP panels by proportion of Class Bins

Figure 29 is a representation of the percentage of the clinic total each provider is caring for from each class bin. Apparent to the research, MRP-3 has the largest portion of high utilization F patients. However, MRP-1 has the largest portion of A,B,C, and D patients.

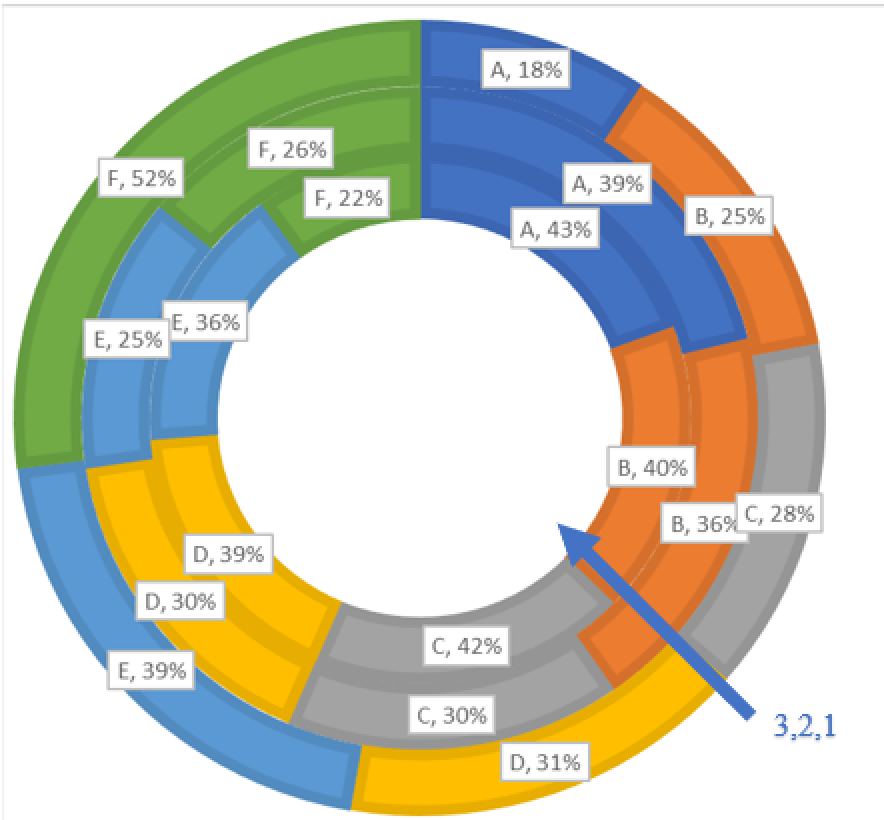


Figure 29- Percentages of clinic total each provider cares for from each bin class

5.2 Remodel Results

Computing the appropriate panel size requires model runs to obtain the local *OF* optimum. The value of T_x is changed with each redesign model to analyze the impact on OF. Ozen et. al [9] noted that panel redesign is most feasible when clinic operations are altered such that supply is increased. Noting this, we test four scenarios for remodeling with varied supply parameters.

Table 11 - Design of Experiments

Model	Scenario	Supply of Appointments	Details
0	No Remodel		For comparison, *OF* forecasted values with no remodel at all
1	Current Clinic Structure	s_1=5481	Supply is identical to T_x over the historic time frame *t*
		s_2=6615	
		s_3=3749	
2	Addition of AHP	**s_1=10,099**	The total supply of a clinic AHP, 4624 appts, is added to the supply of MRP-1
		s_2=6615	
		s_3=3749	
3	No External Responsibilities	**s_1=8004**	Supply is identical in terms of slots per a day. but T is used for all providers (276 days)
		s_2=9660	
		s_3=6348	
4	Addition of a New Physician	s_1=5481	Supply is identical to T_x over the historic time frame *t.* An additional provider is added with the same daily capacity as MRP-1, but no external responsibilities (276 working days)
		s_2=6615	
		s_3=3749	
		s_{new}=8004	

Each value of α found below, relating to disruption of a panel, was found with an iterative method, opposed to provider input.

5.2.1 No Panel Redesign

If no redesign occurs at all over the next 18 months the patients in β bins stay the same. However, the overflow percentage has changed slightly from the current state, Table 10 as the demand is being forecasted.

- Overflow Frequency average: 99.04%

Where x is the MRP for which the panel is associated with, respectively the *OF* value is;

- *X=99.95%*
- *X=84.33%*
- *X=99.71%*

- Wait time: *Values from Little's Law to track wait time is unavailable. The system was out of steady state, demand consistently was greater than supply.*
- Disruption, α: *No patients moved*

For easier visual analysis the distribution of remodeled panels is converted to bar graphs.

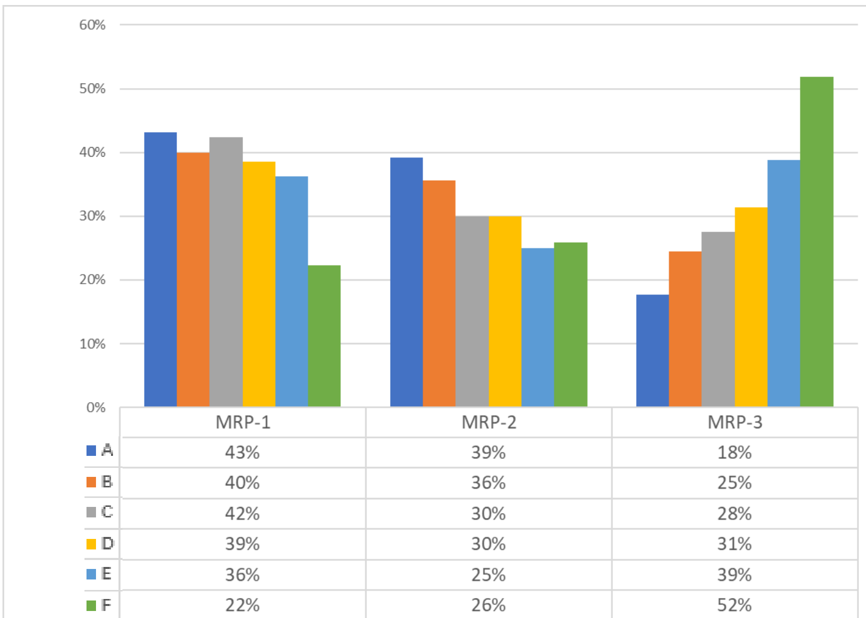


Figure 30- MRP panels by Class, No Remodel

5.2.2 Panel Remodel 1, Existing Supply

The initial redesign attempts to achieve the clinic performance goals and satisfy the panel demand using the current MRP staff.

- Overflow Frequency average: 99.04%

  Where x is the MRP for which the panel is associated to, respectively the *OF* value is;

  - *X=99.05%*

- *X=99.04%*
- *X=99.04%*

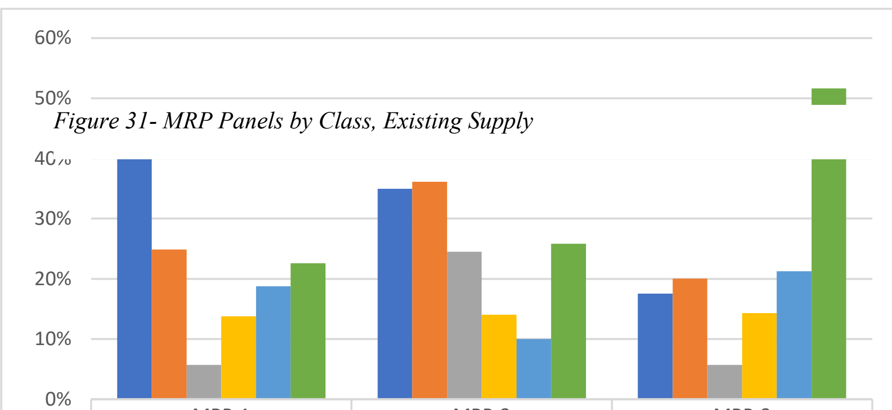
- Wait time: *Values from Little's Law to track wait time is unavailable. The system was out of steady state, demand consistently was greater than supply.*
- Disruption α: 33.35%

5.2.3 Panel Remodel 2, Addition of Supply, AHP

As a second application of the model the resign considered supply of an AHP. The AHP available supply is reflective of a current team member. The key difference from current operations to the redesign is that the AHP's availability is given only to MRP-1. This model iteration shows a valuable reduction in both OF and α percent of disruption.

- Overflow Frequency average: 91.18%

Where *x* is the MRP for which the panel is associated to, respectively the OF value



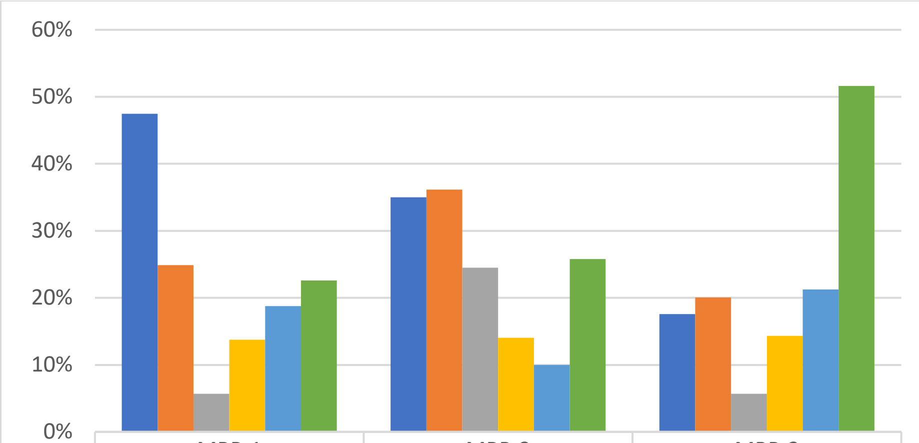
	MRP-1	MRP-2	MRP-3
A	47%	35%	18%
B	25%	36%	20%
C	6%	25%	6%
D	14%	14%	14%
E	19%	10%	21%
F	23%	26%	52%

Figure 31- MRP Panels by Class, Existing Supply

is;

- *X=91.19%*
- *X=91.24%*
- *X=91.09%*

- Wait time: *Values from Little's Law to track wait time is unavailable. The system was out of steady state, demand consistently was greater than supply.*
- Disruption α: 16.65%



	MRP-1	MRP-2	MRP-3
A	47%	35%	18%
B	25%	36%	20%
C	6%	25%	6%
D	14%	14%	14%
E	19%	10%	21%
F	23%	26%	52%

Figure 32-*MRP Panels by Class, AHP aid to a single MRP*

5.2.4 Panel Remodel 3, Addition of Supply, No External Responsibility

The third remodel determines the impact of external responsibilities on the performance goals of the clinic. The AHP supply is not incorporated. If each MRP is given the opportunity to add unavailable days due to external medical responsibilities back into in-office working days, the results are shown below.

- Overflow Frequency average: 48.53%

  Where *x* is the MRP for which the panel is associated to, respectively the *OF* value is;
  - *X=48.41%*
  - *X=48.53%*
  - *X=48.65%*
- Wait time: *Values from Little's Law to track wait time is unavailable. The system was out of steady state, demand consistently was greater than supply.*

To showcase why wait time is still not able to be calculated, Table 12 showcases the anticipated additional supply against demand. The demand being shown is the forecasted average demand (if every patient came in for care at the average amount in the bin). Even with the large addition of supply, the providers can not handle the demands of their panels without AHPs.

Table 12-Forecasted Supply and Demand for MRPs, Model 3

The Panel is Associated to MRP *(x)*	Demand/ of Appointments
1	8004/7882.2
2	9634/9513
3	6387/6251.4

- Disruption α: 33.36%

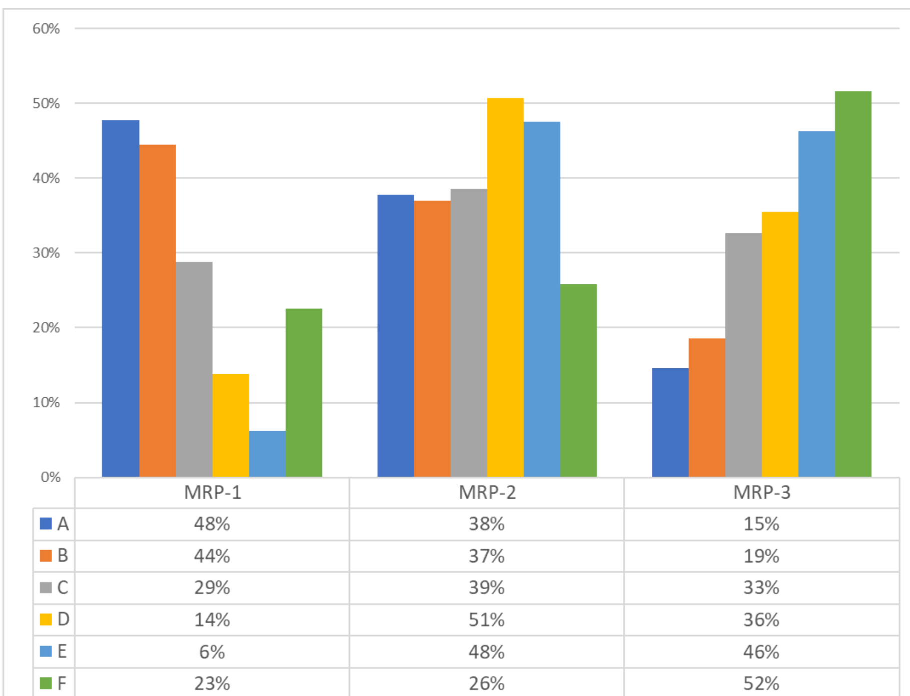


Figure 33-MRP Panels by Class, No External Responsibilities

5.2.5 Panel Redesign 4, Addition of Supply, New Provider

The final remodel optimizes the *OF* if given the opportunity to remodel due to a new provider being added to the clinic. This new provider does not impact the external responsibilities for the research, and their available days has no removal dates for that purpose. In practice, a new physician would take on external responsibilities, altering nursing home rounds for MRPs from every third week, to once a month. A new provider's capacity and working conditions could not be anticipated. For simplicity the new MRP is given the same conditions (daily appointment slots) as MRP-1.

Overflow Frequency average: 46.38%

Where *x* is the MRP for which the panel is associated to, respectively the *OF* value is;

- *X=29.17%*
- *X=47.46%*
- *X=47.34%*
- *X=61.55%*

- Wait time: *Values from Little's Law to track wait time is unavailable. The system was out of steady state, demand consistently was greater than supply.*

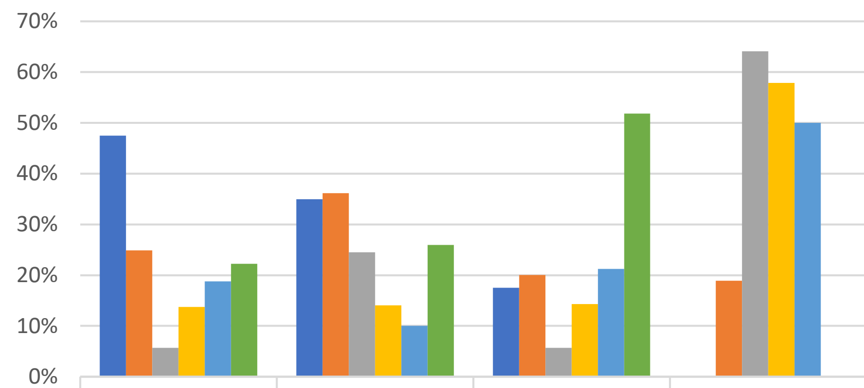
Table 13 showcases the anticipated additional supply against demand. The ratio is very close to 1, average 1.006275, however as it is not less than one, steady state is not achieved for Little Law's calculations to be valid.

Table 13-Forecasted Supply and Demand for MRPs, Model 4

The Panel is Associated to MRP*(x)*	Demand/ Supply of Appointments
1	5475.2/5059
2	6662/6608

3	3800/3744.4
New	8504/7888

- Disruption α: 33.36%



	MRP-1	MRP-2	MRP-3	New
A	47%	35%	18%	0%
B	25%	36%	20%	19%
C	6%	25%	6%	64%
D	14%	14%	14%	58%
E	19%	10%	21%	50%
F	22%	26%	52%	0%

Figure 34-*MRP Panels by Class, New Provider*

The disruption of remodels in terms of patient numbers being moved is shown in Table 14. Across all models MRP-1 is assuming more type A patients. Considering the final model, a new provider would assume the majority of type C patients. The research notes that in terms of real-world integration, that a type C patient represents the consumption of eight appointments in 18 months. If it is more feasible to do so, moving eight A type patients instead of one C would achieve the same result.

Table 14: Changes in Panel Size, All Models

		Redesign				
		Current	Model 1	Model 2	Model 3	Model 4
MRP 1	A	1498	▲ 1502	▲ 1585	▲ 1658	▲ 1650
	B	855	▼ 830	▲ 990	▲ 952	▼ 533
	C	372	▼ 318	▲ 401	▼ 253	▼ 50
	D	140	▼ 54	▲ 155	▼ 50	▼ 50
	E	29	▲ 35	▬ 29	▼ 5	▼ 15
	F	6	▬ 6	▬ 6	▬ 6	▬ 6
P-1		2900	▼ 2745	▲ 3166	▲ 2924	▼ 2304
MRP 2	A	1364	▼ 1355	▼ 1351	▼ 1312	▼ 1216
	B	761	▲ 772	▲ 775	▲ 792	▲ 774
	C	263	▲ 312	▲ 266	▲ 338	▼ 215
	D	109	▲ 207	▲ 133	▲ 184	▼ 51
	E	20	▲ 40	▲ 27	▲ 38	▼ 8
	F	7	▬ 7	▬ 7	▬ 7	▬ 7
P-2		2524	▲ 2693	▲ 2559	▲ 2671	▼ 2271
MRP 3	A	614	▲ 619	▼ 540	▼ 506	▼ 610
	B	525	▲ 539	▼ 376	▼ 397	▼ 429
	C	242	▲ 247	▼ 210	▲ 286	▼ 50
	D	114	▼ 102	▼ 75	▲ 129	▼ 52
	E	31	▼ 5	▼ 24	▲ 37	▼ 17
	F	14	▬ 14	▬ 14	▬ 14	▬ 14
P-3		1540	▼ 1526	▼ 1239	▼ 1369	▼ 1172
New MRP						0
						405
						562
						210
						40
						0
P-New						1217
P		6964	6964	6964	6964	6964

Chapter 6: Discussion

Prior to following the method of minimax by Ozen et al. [9], the research was attempting remodeled panels by minimizing the average *OF*. Upon review of these values within real world context, we determined that unequitable *OF* would not be of value to the performance goals of a collaborative clinic. Obtaining new optimal *OF* was done by minimizing the maximum value for all providers resulted in more equitable operations, then the current state, see Figure 35.

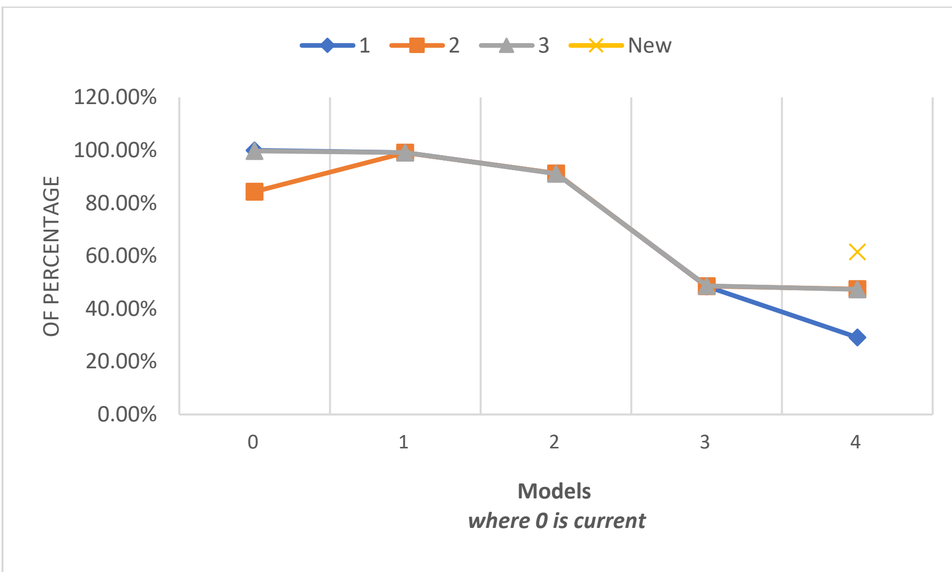


Figure 35: OF Across MRPs and Models

The initial model of no redesign results in 99.04% *OF* on average. This translates to MRPs needing overtime each day to satisfy the anticipated demand of the panel. In practice, the demand would be supplemented by the AHPs, reducing *OF* to a manageable percentage, but as the research saw from clinic investigation, the backlog would still be increasing. As shown in Table 8, section 5.1, the two present AHPs historically have provided 1769, 874, 1222 appointments respectively to the MRP panels. In Table 15, by respectively adding the historic AHP appointments to remodel 3, the forecasted *P* demand can be partially satisfied. It is an assumption, and therefore a limitation of the research that regardless of remodel iterations, the needs of the patients can still be satisfied with the AHP's expertise.

Table 15: Supply and Demand of Model 3 with AHP

The Panel is Associated to MRP *(x)*	Demand/ Supply of Appointments in Remodel 3 without AHP	Demand/Supply of Appointments in Remodel 3 With AHP
1	7882.2/8004	7882.2/9773
2	9513/9634	9513/10387
3	6251.4/6387	6251.4/7609

As an average, the panel size of MRPs in the clinic prior to remodel is 2321 (calculated from Table 7). This is roughly 200 less than the North American average. [12] Anecdotal estimates for the panels sizes in NS for salaries professionals are approximately, 1,350 for physicians, and 800 for Nurse Practitioners. Seen in Figure 36, there are only three instances in the remodeling where this value is achievable by MRPs.

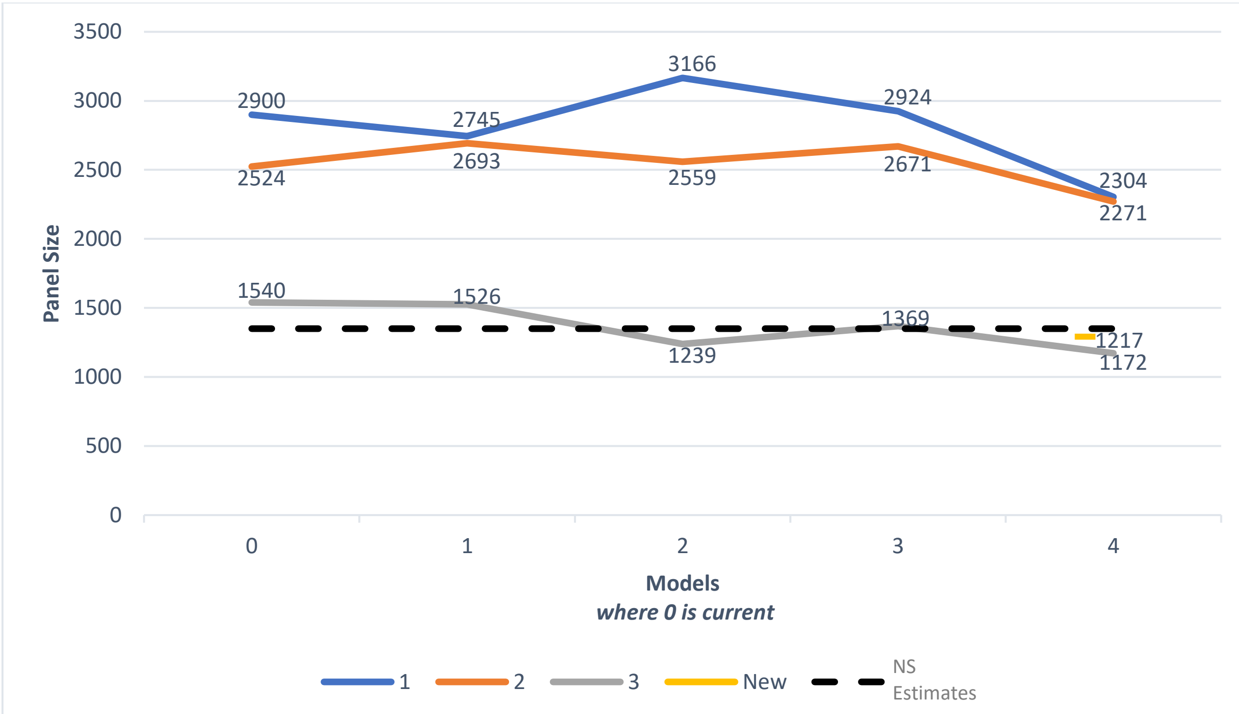


Figure 36: MRP Panels All Models

6.1 Limitations

The research indicates limitations of the work. These limitations are inspired by the understanding of primary care operations attained from emersion into the clinic.

During initial interviewing, providers voiced a concern that their days have become repetitive, in a way that is negative to the sustainability of their work life. The research cannot anticipate what changes remodeling has on a physician's variable day, meaning the appointment reasonings they care for. Ideally, a provider's day would result in a mixture of ages, disease burdens, and medical concerns. However, the research has no method of quantifying this.

The cycle times for providers are an average which has limitations. If the patient voices the motivation behind requesting an appointment, the administrative staff, when possible, will schedule the appointment into the EMR for an anticipated time that appointment type will take. Additionally, there is a subgroup of patients who always receive longer cycle times. Consider high utilization patients, like patient Es. They will request 16-18 appointments in 18 months, however, if they are seeing the physician for twice the research specified cycle time, in actuality the demand is 32-36. This was noted when comparing the clinic AHP's supply in the current state against their cross coverage. Their assumed cycle time was 15 minutes yielding 4624 appointments in 18 months, which is incorporated as supply into remodel 2. In contrast the appointments that they did satisfy, determined as a sum of cross coverage for MRP-1 and 2 (Table 8), is 2593 appointments. Compared to what was historically achieved, approximately 2000 more appointments were assumed in the research. The research assumed the majority of historical appointments satisfied by this AHP were scheduled as 15 minutes, in actuality, they would likely have been 30.

Lastly, the remodeling does not account for the real-world impact on physician remuneration. Introduced in the first chapter, Fee-For-Service providers relay on patient demand for income. The impact on physician pay due to change in demand for service is not captured in the research.

6.1.1 Impacts of High Utilization Patients (E&F)

High utilization patients are likely to benefit most from continuity of care. It is presumed the nature of their illness has developed a strong on-going relationship with the physician. Upon discussion with the lead physician, it would seem the F patients are highly vulnerable palliative patients. Hence why they were not eligible for redesign. Changing these patients could have had a large impact on panel, as a single F-iii patient would see the doctor 40-

60 times in 18 months. The likely best solution here would be for those patients to receive more appropriate alternative care; home care or a nursing home.

Lastly, the research specified ranges of demand to incorporate results for if every patient came in at the maximum of a bin. The research does not have probabilities of this situation happening, nor a real-world scenario that would result in such an influx of demand. Regardless, understanding the vulnerability of the models to demand increase is valuable.

Table 16- Impact of Maximum Value in Bin Range on OF

		Redesign				
		Forecast	*Model 1*	*Model 2*	*Model 3*	*Model 4*
MRP-1	*OF* at Avg	99.95%	99.05%	91.19%	48.41%	27.17%
	OF at Max	100.00%	100.00%	56.09%	96.48%	95.22%
	Avg Demand	9663	8339	10658	8004	5059
	Max Demand	12779	11220	14055	11030	7475
MRP-2	*OF* at Avg	84.33%	99.04%	91.24%	48.53%	47.46%
	OF at Max	99.86%	100.00%	99.95%	94.91%	96.95%
	Avg Demand	7924	9700	8364	9634	6662
	Max Demand	10629	12692	11135	12579	9044
MRP-3	*OF* at Avg	99.71%	99.04%	91.09%	48.65%	47.34%
	OF at Max	100.00%	99.99%	99.72%	86.80%	93.09%
	Avg Demand	6438	5986	5003	6387	3800
	Max Demand	8211	7707	6429	8010	5129
MRP-New	*OF* at Avg					61.55%
	OF at Max					88.77%
	Avg Demand					8504
	Max Demand					9971

Chapter 7: Conclusion

The results of the remodels show that forecasted overflow frequency is altered by redesigning MRP panels. By understanding how OF is manifesting in the clinic, research can convert these results into potential of providing better access to patients. Partial but substantial daily demand from panels can be meet in all model considerations, including the current operations, with the use of AHPs. However, to sustainably meet the demands of patients and provider better access to patients, adding additional supply to the clinic is necessary. The addition of supply can reduce *OF* by approximately half. This occurs in remodel 3, removing external responsibilities, and 4, the addition of a new provider. The research has produced 4 remodels of potential when given the opportunity to introduce supply. The results of this research can act as guidelines for decision makers who must allocate new supply in NS.

Considering the context of the NS doctor shortage, the research was not able to relate any remodeling model can alleviate the shortage. The best results included adding a new provider, which is not always feasible. The third model shows the same reduction in *OF* can be achieved by removing the external responsibilities. However, without the clinic providers caring for the patients in the community, there is still a gap needed for a new physician.

There is no direct impact on the NS shortage, however there is an indirect benefit. It has been voiced by primary care providers, that understanding a person's capacity and balancing supply optimally, is valuable for recruitment. Health care providers that do not appear “burnt out” and who exemplify a positive work life balance, are appealing to young graduates.

The research results can not be instantaneously achieved. Except remodel 2, each satisfies constraints and achieves minimal *OF* with 33.35% disruption. Continuity of care, and the bonds that patients develop with providers is valuable. The discussion of changing providers would be a conversation between patient and provider.

Upon sharing results with the lead physician, they noted that the division of their panel by use is helpful. Although they may not be able to move patients, being aware of the number or patients producing ranges of demand is valuable. Knowing the patient behaviour, the lead physician believes he is more likely to identify patterns of patients. With the additional knowledge he can then attempt to better manage high utilization patients and potentially move them to lower frequency bins. This can be achieved by means of, suggesting community health programs, connecting them to online resources, and encouraging self-management.

7.1 Future Work

Firstly, it would be valuable to the research to repeat the study with all demand requests of the system, not just historically satisfied demand. This would allow the research to determine historic OF properly, opposed to setting an approximation by removing AHP supply. This data can be obtained by observation, and time studies of the clinic telephone lines. As this is invasive to the administrative team, brainstorming of other methods to obtain this data is also an element of approaching this future work. Additionally, tracking a small diverse subject of patients, and/or repeating the study in 18 months time, the patients should be compared to their forecasted appointments in the research.

Of the different methods specified in the literature review for patient classification, as an extension of the research, disease burden and external historic events could be used for patient classification in the future. [9], [26] To overcome challenges of recruiting new talent, partnering with specialists in the bigger cities, via tele-health, can add the potentially necessary supply. Patients of a disease class, or those who frequently need the care of external specialists can be reallocated appropriately to the care of allied health professionals, who are external to the clinic. Determining the impact on access by remodels of this nature will help stakeholders determine the best practices for building CFPs. As an example, clinics with high billing for general pain, could add a physiotherapist to the team. This would increase available appointments for MRPs, and arguably the patient is receiving care better aligned to their needs. The same concept could be applied to mental illness, and social workers in a CFP.

Further, using disease burden against the Clinical Practice Guidelines can forecast the needs of a patients based on what experienced professionals have determined is the necessary amount from proper care for respective diseases. However, the interaction of multiple chronic illnesses is not within the expertise of IEs, and it is suggested this research is approached from a partnership with a field of medical study.

This research presents complex issues by methods and interpretations of applied science. Continuing to be welcoming to research is important for management to proceed in this area of problem solving. The holistic nature of primary care requires a holistic approach to problem solving. Various areas of academic study can have a role in understanding the challenges and barriers of primary care. It is recommended that management in primary care take further action to understanding patient needs. Engagement of patient advisors is a suggested method to approaching this. It would appear that high utilization patients are of greatest concern to the system. Public education with regards to the purpose and differences between emergency and primary care could help reduce demand to the system. Education should also be provided to clinic patients with regards to the roles and scopes of practice of the different providers in Primary Care (NP, MD, FPN etc). Finally, management should consider a more holistic model of funding care. Funding self management programs, and better access to a healthily lifestyle, will reduce the demand primary care.

7.2 Final Comments

The initial interaction with stakeholders indicated that wait time was of greatest concern, and work-life balance of providers was a close secondary. Several researchers, showcased in the literature review, using various methodologies that redesign among primary care team members resulted in positive improvements for patient access. Utilizing overflow frequency as a proxy to access, the research was able to show remodeling panels has an impact on patient access in addition to the equity of operations, and work balance.

Time spent capturing primary data from the CFP has motivated the research to model in accordance with the diversity of individual patient needs. This is why historic utilization was used in forecasting, opposed to assumptions drawn from demographics like age and gender.

As of Fall 2019 the clinic in partnership with the research had acquired a new rostering provider. The team members had expressed that with the new provider availability, patients who produce overflow demand for current MRPs will organically gravitate to the new. The results produced from the research will be used as guidelines for the clinic. During team meetings, the progress of the organic panel remodelling with be sequentially monitored.

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