Introduction

In Britain during the 1930s, war appeared imminent. To prepare for it, Britain's military assembled interdisciplinary teams of military personnel, scientists, physiologists, physicists and mathematicians, to understand and improve operations such as the use of radar [Cunningham 1984] [Lindsey 1995]. The teams' success led to the establishment of many operational research groups, so named because of their research on military operations. Common to these efforts was developing an understanding of those operations from multiple perspectives, including those of the individuals planning the operations as well as those performing those operations, use of analysis to optimize performance, and dissemination of results so they were used where appropriate.

Decades later in the spring of 2016, there is a need for a major healthcare delivery improvements in Quebec. Though the passage of Quebec's Bill 10 opened the door to potential improvements, it did not guarantee those improvements would be achieved, or describe how to implement them. These circumstances suggest the need for the use of interdisciplinary operational research groups, like those used since before World War II, to fully understand healthcare delivery in Quebec, apply carefully analyzed approaches to improve it, and disseminate the results so they are used throughout the province.

This paper presents a perspective, based on the operational research approach used by the British, for improving healthcare delivery in Quebec. The paper discusses systemic challenges facing healthcare delivery in Quebec, Bill 10, the operational research approach, the role of analytics, information systems and organizational redesign for improving healthcare delivery, and the need for disseminating results of this work so they are used throughout Quebec. And while it contains a mix of old and new ideas, the primary contribution of this paper is that it presents how these ideas might together improve healthcare delivery in Quebec.

Systemic Challenges

Quebec's healthcare delivery systems face numerous challenges including:

- The variability and lack of total predictability in the need for healthcare and the resulting delays in healthcare delivery.

  To understand the effect of variability on healthcare delivery, picture a clinic which operates 24/7 with one physician, where one patient arrives exactly every ten minutes, and the physician takes exactly ten minutes to treat each patient; in that clinic patients never wait. Now picture a similar clinic where patients arrive on the average every ten minutes and where the physician's time with patients averages ten minutes. In this clinic, because of the variability in inter-arrival and treatment times the physician is not always busy, and over time the average size of the queue grows longer and longer as the total amount of work grows at an average rate of 60 minutes per hour but the time available to do that work grows at a slower rate.

  However, if we could predict the arrival and treatment time for each patient, we could prevent the queue from growing large by bringing and having a second physician leave at appropriate times. Though patients would still have to wait, the amount of waiting would be much smaller, and physician utilization would be improved.

  However, in real life the need for healthcare varies considerably over time both on the demand side and the supply side, and it cannot be exactly predicted. A key takeaway from this is that due to both types of variability, healthcare delivery can be both very inefficient and ineffective unless it is very carefully and dynamically planned and managed.
- Health care delivery is not always well coordinated.

  The primary results of inadequate coordination are long delays, including long delays for physicians and consults in emergency departments, for chemotherapy treatment preparation, for Peripherally Inserted Central Catheter lines, and for beds in rehabilitation centres. The consequences of poor coordination are obvious: increased resource consumption, poorer utilization of resources, inconvenience for patients, and perhaps the worst, exposing patients to additional medical problems. And while it is unlikely that healthcare delivery will ever be perfectly coordinated because of its inherent variability, it seems likely that healthcare delivery coordination can be considerably improved.
- Healthcare is provided by and delivered to individuals and teams each having their own needs and priorities.

  On the supply side, it is not surprising that physicians would rather not take calls or perform consults on weekends or in the middle of the night. It is not surprising that physicians would be reluctant to come in to the emergency department when they won't be kept busy while they are there given that they are paid by the government only for the patients they see. It is not surprising that staff may not always want to immediately report when beds become available, as they may justifiably feel they need a little down time It is also not surprising that personnel are so burned out by their work that they no longer really want to do it, despite having started their careers being highly motivated. It is also not surprising that

healthcare delivery process improvements involving multiple departments get stymied when each department has different levels of motivation for improving those processes.

On the demand side, healthcare is needed by individuals having their own priorities. Examples include individuals who smoke, do not exercise enough, eat poorly, or do not follow prescribed medical advise. This lack of alignment results in significantly increased healthcare delivery demand.

- Many healthcare delivery processes are poorly designed or implemented.

  In addition to reasons for the existence of poor processes mentioned in the re-engineering literature [Hammer 1990] [Davenport 1990], an additional reason for poorl healthcare delivery processes is that healthcare personnel are not typically trained to design or improve processes.

- The budgeting process tends to be about adjusting existing budgets, rather than determining the best budget.

  The way budgeting is often done in the Quebec healthcare system, without zero based budgeting [Callaghan 2014], can and most likely often does lead to budgets not directly related to the cost of activities performed. This in turn can result in over funding which is wasteful, or underfunding, which can lead to poor outcomes or increased delays because of the bottlenecks created due to insufficient resources.

- Fragmented care due to lack of systematic follow through

  Of particular concern in Quebec's healthcare delivery system is that before Bill 10, the healthcare delivery system was not responsible for ensuring follow through of care for individual patients, regardless of whether they were receiving care in a specific institution or from more than one institution. When not addressed by the patients and their family members, this lack of ensuring follow through can result in patients not getting appropriate and timely care, and in requiring additional and thus more costly care.

- The referral system

  In Quebec, general practitioners typically refer patients to a specific specialist using an illegible handwritten referral form with minimal information on it. When referred to physicians who don't have near term availability, patients either wait longer than might otherwise be necessary, or need to return to their general practitioner to get an additional referral. When the referral is presented at the specialist's office, there frequently is not enough information to determine the urgency of the patient's need. If this information was consistently (and preferably electronically) available, scheduling could be adapted to provide more time appropriate care to patients.

- Surgeons being responsible for getting care for their patients

  Should a patient be seen by a surgeon who determines the patient needs a surgical procedure that must be performed within a legally mandated period of time, that surgeon becomes responsible for seeing to it that the patient has the procedure performed within the mandated period of time, even if the surgeon is too busy to do it. While ensuring continuity of care is laudable, it is also a waste of the surgeon's time to have them perform an administrative task that could be better handled by better information systems.

- Poor inventory management

  In at least some healthcare delivery institutions, there is a recurring problem of keeping too large a quantity of supplies on hand, some of which expire before they are ever used.

- Replication of information collection

  This occurs whenever patient histories or the details of specific complaints are taken more than once, i.e. when patients are referred to specialists and when patients obtain multiple types of care. The blame for this is partially due to the lack of fully integrated healthcare delivery information systems across the province, which forces new care providers to re-elicit information elicited from the patients by other care providers. The blame for this is also partially due to the program oriented design of Quebec's healthcare delivery design in which services are provided by programs, e.g. rehabilitation and mental health programs, each of which mostly work independently and do not share collected information.

- Information overload

  With Quebec's move to an electronic health record, over time the amount of information that clinicians will need to digest in order to properly diagnose and treat patients will increase. And while this should lead to better diagnoses and treatment plans, it seems likely to also decrease the number of patients clinicians will be able to treat.

- The limited resources available for healthcare delivery

  The amount of resources that Quebec can allocate to healthcare delivery is limited. Though healthcare delivery in Quebec consumes a smaller percentage of the economy than it does in the United States, that smaller percentage is

nonetheless large and growing over the longer term. As a consequence, difficult decisions have to be made as to the amount of resources made available to the healthcare delivery system.

The challenge is to make the best decisions. Unfortunately, evaluating alternatives when there are many factors is very difficult even for the smartest of individuals. And this is where the operational research approach can make a very positive impact on healthcare delivery.

What Bill 10 Did

Passed in late 2014, Bill 10 mandated that most healthcare delivery institutions in Quebec be amalgamated into CISSSs (Centre intégré de santé et de services sociaux) which are responsibile for ensuring that the health and social service needs of the population in their territories are addressed, either directly or via “corridors” negotiated with other institutions or CISSSs. From a management perspective, Bill 10 gives senior management the ability to specify which services should be provided within individual CISSSs, where within the CISSSs those services should be provided, when they should be provided, and the amount of resources to be used to provide those services.

How The Operations Research Approach Can Help

The first component of the operational research approach used by the British in World War II was the development of an understanding of the military operation from multiple perspectives, including those of users, and specialists from different disciplines. This need to understand operations from multiple perspectives is equally necessary for healthcare delivery. That's because non-healthcare personnel will often not be able to understand the medical nuances and day to day practical minutiae of healthcare delivery, while healthcare personnel will often not be able to relate to the performance nuances that analytics, information systems, and organizational design experts understand.

The second component of the operational research approach used by the British was the use of analysis to optimize performance. Fortunately, the tools and the process of applying analysis, currently called analytics, has matured into approaches discussed in the next section.

The third component of the operational research approach is the dissemination of useful results. This last component is particularly relevant to improving healthcare delivery in Quebec, as it would be easy, but expensive and fruitless, for each CISSS to attempt to improve healthcare delivery on their own.

Analytics

This section suggests ways of using analytics for improving healthcare delivery in Quebec. But before doing so it is necessary to collect relevant data[Kelvin 1883], including the following:

- Healthcare outcomes – to improve healthcare delivery it is necessary to consistently measure generated healthcare outcomes. To do so, there needs to be a standardized way of quantifying outcomes so that they can be compared across patients and institutions, and each outcome score, along with the diagnosis type, must be collected for each patient. And while the process of specifying outcome measures and quantifying outcomes will most likely require a significant amount of effort, it is already underway by organizations such as ICHOM [ICHOM 016].
- Provided healthcare – for each diagnosis type, there should be a count of the number of each type of patients that receive each treatment type.
- The resources needed to provide each unit of each type of healthcare must be measured so that the total amount of resources needed to deliver a specified quantity of different types of healthcare can be determined. Note that this resource measurement should be measured using an approach such as that used in Time Driven Activity Based Costing (TDABC) [Kaplan 2004]. Also note that while it will require effort to gather this data, once gathered, this data will make it possible to create budgets in a rational manner, i.e. using Zero Based Budgeting.
- The resources used to provide each type of healthcare, either on a per unit basis or on a departmental basis.
- The need for healthcare at an individual level, along with relevant demographic information such as gender, age and occupation.
- Prescribed treatments (including medications) and integrated care pathways for each diagnosis type and individual.
- Patient compliance with prescribed treatments and integrated care pathways.

Note that some but not all of this data is currently being collected in Quebec in a variety of systems including SIPAD and Dossier Santé Québec (DSQ).

Descriptive/Diagnostic Analytics

In many cases, appropriately summarizing the data discussed above makes it possible to identify:

- Diagnoses for which particular healthcare providers are not obtaining good outcomes and use that information to move care for those diagnosis to other healthcare providers or improve the healthcare delivered by those providers for those diagnoses.
- Providers where there are significant differences between the two quantities by comparing resources needed to those consumed by combinations of diagnosis type and healthcare type.
- Diagnosis and treatment types with poor patient compliance.
- Successful and cost effective integrated care pathways.
- Patient health trajectories.
- Quality issues.

More sophisticated comparative approaches, such as the use of Use of Data Envelopment Analysis (DEA) [Charnes, Coopers and 1990], can also be used. DEA is a mathematical technique that makes it possible to identify a "best-practice frontier" [Cook, Tone and Zhu 2014], i.e. to identify the best units/departments, i.e. those that produce the most outputs relative to the inputs they consume while producing those outputs. DEA is particularly helpful because in addition to identifying the best units or departments, it also identifies specific goals that units/departments should strive to improve.

Once descriptive/diagnostic analytics has been used to identified issues, an important part of the operational research approach is to use interdisciplinary teams to understand why negative or poor results are occurring, and to suggest approaches to alleviate those issues.

Predictive Analytics

While the use of descriptive and diagnostic analysis approaches is critical to identifying healthcare delivery processes that need to be improved and for identifying approaches to improving them, it is often best to identify how well the proposed changes will work and the likelihood of negative repercussions before implementing proposed changes. This can sometimes be done with predictive analytics.

Modeling Healthcare Delivery

To predict the likelihood of specific outcomes in complex systems, it is often necessary to build a Monte Carlo simulation modelof those systems. The process of Monte Carlo simulation modeling can be thought of as being similar to that of building a model of a train network, running the trains in the model a large number of times with combinations of slightly different characteristics such as car weights, wheel break downs and weather representative of the range those characteristics might take on in real life, and using the results of the individual runs to predict the likelihood and magnitude of different outcomes. The advantage of Monte Carlo simulation models over statistical models (which may still be needed to inform the simulation models) is that simulation models can more readily reflect the numerous interactions typical of healthcare delivery, and they are generally easier for non-technical team members and management to understand and relate to. Because the results of using a simulation model are compiled from the results of individual runs of the model, they make it straightforward to measure the likelihood and magnitude of measured outcomes so that decision makers can use this information to inform their decision making.

Tactical Uses Of Predictive Analytics

Once a predictive model of a part of a healthcare delivery system has been built, verified, and validated, it can be used to:

- Estimate the resources required to provide healthcare delivery to specific standards;
- Estimate the cost of healthcare delivery to specific standards;
- Estimate healthcare delivery performance metrics for suggested alternatives;

Operational Uses Of Predictive Analytics

Predictive models can also be used to help line management make decisions on a daily basis. Example potential application scenarios include:

- Identifying the likelihood and magnitude of possible delays in operating rooms due to the need for turning over several operating rooms at the same time, the lack of available beds in the Post Anesthesia Care Unit (PACU) or in surgical in-patient units, and the quantity of available radiology equipment and staff in the schedule In the operating room. Once identified, using the same predictive analytics capability to try out alternative schedules to try to preclude or minimize those delays.
- Determining the appropriate amount of staff needed for a shift in emergency departments using real time information on the number of open beds in the hospital, the number of each type of patient currently in the emergency department, forecasts of additional patients expected to arrive, and the time of day.
- Identifying potential delays in care for all the clients of a CISSS in context of real time data on the scheduled and forecasted use of resources and to identify the best care pathway for individual patients in context of this data.

Prescriptive Analytics

While it's sometimes possible to identify the best alternative when making a decision for a specific set of criterion without analytical support, when making important and/or complex decisions, it is often better to use prescriptive analytics. This typically entails the use of procedures, often computerized, for identifying and evaluating alternatives; it may also use prior insights obtained by analytics researchers. Examples include:

Locating And Sizing Service Offerings

One of the most important challenges facing the CISSSs now that Bill 10 has passed is to satisfy the needs of the population they are responsible for. To address this challenge, CISSSs will need to make decisions about the quantity of each type of service provided at each of its facilities, the number of each type of staff providing each type of service in each of those facilities each period of each day, alternative treatment modalities, patient acceptance policies, and how and when to change the allocation of staff to specific activities. The CISSSs will also need to decide how to trade services.

One approach to addressing this challenge is to build and use a prescriptive analytics model for providing government mandated healthcare delivery. Such a model could include the resources used by each institution for each service it provides. Prescriptive analytic approaches could then be applied to this model to determine alternative solutions specifying operating levels of each service at each institution and the tradeoffs of doing so. These approaches could also be used to determine the marginal cost of providing each type of service at each institution, which could then be used as the basis for negotiation between CISSSs as to which services, and the quantity of those services, they should provide each other.

Staffing

A significant challenge facing healthcare institutions is the cost of overtime and temporary staffing. These costs can arise when regular staff are off for vacation or illness, or patient demand is greater than normal. One approach to minimizing the cost of overtime and temporary staff is to hire a group of additional staff who agree in advance, possibly in return for an increased salary rate, to be more flexible as to where and when they will work so that they can be used to address staffing shortages. The prescriptive analytics challenge for doing this is to determine the number of each type of staff that should be hired to fill this role, and then when and where they should work.

Scheduling Staff

A related and often time consuming challenge for healthcare institutions is the actual scheduling of different types of staff. This is challenging because of the need to meet the demand for these staff often on a 24/7 basis, staff preferences for vacations and work times, differing staff capabilities, and union rules. Using prescriptive analytics it would be possible to improve this scheduling while very significantly reducing the resources need to do it.

Improving Logistics and Material Management

Existing prescriptive analytic approaches can readily be applied to minimize the resources need for transport of patients, supplies, medication, and food. Other existing approaches can also be used to determine the optimal quantity of supplies to be maintained in individual institutions and units.

Applying Insights Gained From Analytics Research To The Challenges

Given the magnitude of the issues that arise due to variability and lack of total predictability in the need for healthcare and the resulting delays in healthcare delivery, it seems appropriate to apply insights from the mathematical analysis of waiting lines, gained from operational research analysis of waiting. In particular there are three insights that have the potential for decreasing waiting, and the inherent negative effects of waiting on healthcare:

- The pooling of resources

In an environment with considerable variability in the need for any type of service, pooling of resources can often be used to reduced individual waiting, as well as to reduce the variability in that waiting. Table 1 shows the rather dramatic effect of pooling five queues when inter-arrival times are exponentially distributed and service times are also exponentially distributed [Exponential Distribution] with an average time of one time unit; in particular, as arrival rates increase and utilization approaches 100%, the average number of people waiting and the average wait time per person in the pooled queue is one fifth that in the 5 non-pooled queues.

Total Average Arrival Rate (Equally Distributed To The Non-Pooled Queues)	5 Individual (Unpooled) Queues Average # People Waiting	5 Individual (Unpooled) Queues Average Wait Time Per Person	1 Pooled Queue With 5 Servers Average # People Waiting	1 Pooled Queue With 5 Servers Average Wait Time Per Person
2.5000	2.5	1.0	0.1	0.1
3.0000	4.5	1.5	0.4	0.1
3.5000	8.2	2.3	0.9	0.3
4.0000	16.0	4.0	2.2	0.6
4.5000	40.5	9.0	6.9	1.5
4.9500	490.1	99.0	96.5	19.5
4.9950	4,990.0	999.0	996.5	199.5
4.9995	49,990.0	9,999.0	9996.5	1999.5

Table 1 Effect of pooling queues on average queue length and waiting time when service rates are exponentially distributed with a mean service time of 1 time unit and where inter-arrival times are exponentially distributed.

- Limiting the size of waiting lines

  It is often optimal to [Naor 1969] limit the number of people waiting, particularly for service facilities for which we wish to optimize the benefits less waiting costs provided by the facility (as opposed to revenue or profit). The rationale behind this is that when costs are accrued due to the amount of time each person waits, and the number of people waiting becomes sufficiently large, the benefit of allowing an individual to join the line can be less than the extra waiting costs caused by that individual to other individuals that subsequently join the line.

  In healthcare practice, this does not mean that an individual would not be enqueued for service; what it does mean is that that individual would need to join another queue that is shorter. And should the government implement real time information systems for monitoring the status of those queues, they could use the information collected by such a system to signal when particular healthcare processes need to be revised or more resources of this type need to be added to the healthcare delivery system.

- Dynamically assigning staff to tasks

  Another approach to managing variability in demand for healthcare delivery is to dynamically manage the resources allocated to each type of healthcare delivery based on current needs. In this approach, as demand for a particular activity increases, more staff would be allocated to that activity [Ata 2006]. Even better, prescriptive analytics can be used to dynamically assign staff within a CISSS to the tasks and locations where they are most needed, while also minimizing the amount of travel time for those staff [Simão 2010].

Information Systems

Information systems can and should play an important part in improving healthcare delivery. While it is commonly accepted that the use of electronic health records can improve healthcare delivery, there are many other ways that information systems can be used to improve healthcare delivery. Critical to all of these is the need to have an appropriate information systems architecture in which data is stored, in a coded manner so that the data can be searched and analyzed as needed; in particular, all patient data, including but not limited to lab reports, physician notes and prescriptions should be stored as data rather than as scanned images. In addition, that information systems architecture must be sufficiently flexible so that new types of data can be readily added.

Improving Measurement

In general, it appears to be hard to get clinical staff to record measurements such as the time and supplies used for activities. An increasingly practical alternative is to use electronic measurement systems, such as those using Radio Frequency Identification (RFID) and/or Real Time Location System (RTLs) technologies, to automatically track the use of machines, supplies and human resources throughout the system. And while the cost of those technologies appears to be prohibitive, there is good reason to believe these costs can be significantly reduced [AS3993] [Nikitin 2013] by creating not for profit foundations such as that created to produce the very low cost Rasperry Pi [Raspberry Pi Foundation 2015].

In addition, provided that staff are equipped with appropriately secured software, tablets attached to patient beds or assigned to staff performing home visits could be used to speed up other measurement activities such as charting. In particular for staff performing home visits, this use of information systems could make it possible for staff to significantly increase their face time with patients.

Improving Coordination

Another way that information systems could help improve healthcare delivery is by using them to improve coordination. While there are many ways that this can be done, clearly even simple approaches such as four quadrant electronic to do lists, electronic reminders for important and urgent items, and large departmental electronic displays could all help.

An Electronic Referral System

The use of an electronic referral system by general practitioners, where such a system would require those practitioners to electronically specify the information needed to determine the urgency of patient referrals and allow patients to find the nearest available specialist, would facilitate better utilization of specialist resources and reduce patient waiting times. It would also reduce the time government analysts need to determine when additional clinicians are needed.

Streamlining The Use Of Electronic Health Records

To reduce the additional time needed by clinicans to understand the increased amount of information likely to be collected by electronic health records, it would be helpful to develop and use automated capabilities to summarize patient chart data [Plaisant 1998] in a manner relevant to each type of care giver, including physician assistants, general practitioners, specialists, physicians, dieticians, pharmacists, and therapists. This could potentially be done using capabilities like those provided by IBM's Watson platform [Giles 2011] [Watson EMR Assistant].

Clinical Decision Support Systems

While still relatively new, there appears to be a considerable potential for clinical decision support systems to standardize and improve the diagnosis and treatment of health conditions, particularly in emergency departments [Michalowski 2003] where there is a wide range in the use of diagnostic testing [Ndegwa 2012] and in consult requests. This could also be helpful in planning the details of of care pathways[Rotter 2010] which might otherwise be tedious to create for each patient, which have been found [Rotter 2010] to be “associated with reduced in-hospital complications” and at least sometimes to lead to significant reductions in hospital length of stays.

Patient Follow Up/Adherence Management

Information systems could also be used to ensure that patient/client follow up is performed in a timely manner, and that patients adhere to prescribed therapies. These information systems would need to track progress clients make in their care plans, and when not good enough, contact relevant departments or individuals to get those clients back on track. Diagnostic analytics could also be applied to the data collected by such a system to identify the issues impeding appropriate patient follow up and adherence management so that that these issues are addressed. To minimize the need for additional resources for adherence management, the selection of follow up approaches and their timing should be optimized to take advantage of existing resources that are dynamically underutilized.

Organizational Changes

Organizational Redesign

One approach to minimizing or eliminating the information collection redundancies such redundancies is to use a matrix organizational structure in each CISSS, in which at least certain staff would report to a functional manager, e.g. a mental health provider manager, as well as to a client manager in charge of providing healthcare delivery to groups of patients. Using such a structure would facilitate there always being a team responsible for all types of care for each patient; it would also increase the size of the pool of resources available for providing specific types of care.

Alignment

One of the most successful organizational turnarounds of the 1990s was that of Mobil [Kaplan 1996], which quickly transformed itself from being the worst performing major oil corporation to one of the best. Interestingly, [Kaplan 1996], the key to that transformation was the use of balanced scorecards aligned to the organization's strategy, and a reward structure,

to ensure that individuals at each level of the organization were motivated to work towards goals that help the organization achieve its overall goals. This success story suggests that healthcare delivery in Quebec could also benefit from such an approach, with respect to all individuals involved in delivering healthcare, including physicians.

But it shouldn't stop with healthcare delivery providers. Instead, patients should also be given incentives, perhaps both positive and negative, to encourage them to align themselves to the goals of the healthcare system, i.e. to ensure they do the best can, including exercising, eating well, and addressing negative habits, to take care of and promote their own health.

Making It All Work

Inherent to the operational research approach is the application of multiple disciplines together to address challenges. One possible result of doing that for healthcare delivery in Quebec, i.e. of applying information systems, and organizational redesign together with analytics, is shown in Figure 1. That figure shows a very simple organizational design in which patients request information and care through a portal. That portal is connected to the CISSS's information systems, the information systems are connected to an analytics powered decision support system, that decision support system is connected to a staff portal, and the staff portal is connected to client managers, institutions of the CISSS, and the healthcare providers. Powering the simple design is the analytics powered decision support system which constantly scans information systems to proactively identify opportunities, and efficient mechanisms for implementing those opportunities, for improving patient health. And when it finds those opportunities it alerts appropriate individuals, based on their availability and location, to provide that care, while also communicating its suggestions and presenting a summary of results to client managers.

The key to designing such a system and to getting it to effectively apply these different disciplines together is to build teams including individuals trained in the different disciplines, as well as individuals working at different levels of the system. Not only does this lead to increasing the likelihood of finding and new and better approaches to delivering healthcare, it also helps better engage the energy of all the individuals that the system is composed of.

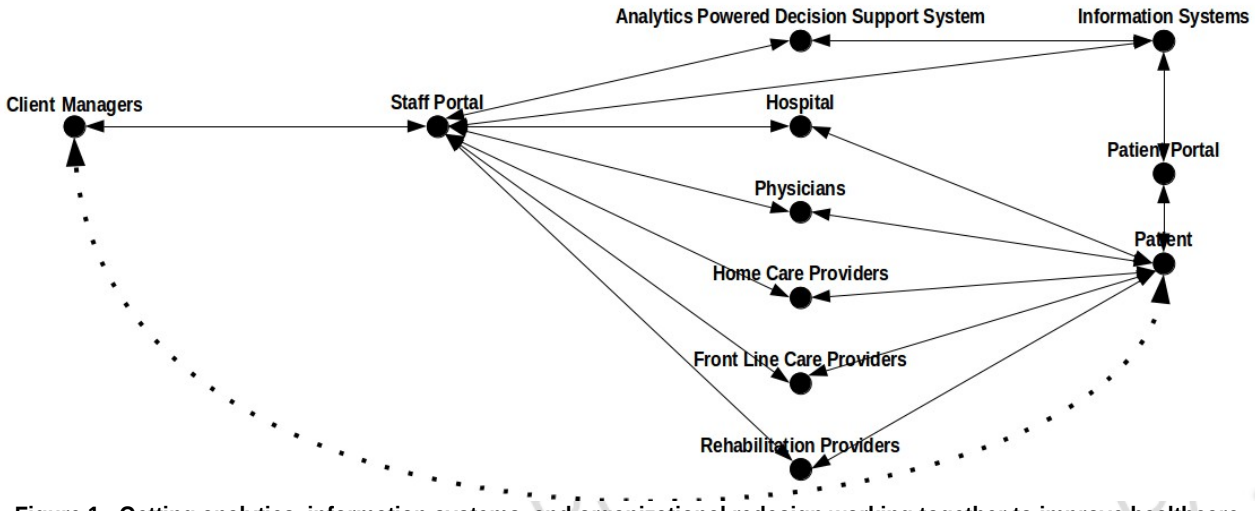

Figure 1: Getting analytics, information systems, and organizational redesign working together to improve healthcare delivery in Quebec.

Also inherent to the operational research approach, as it could be applied to improving healthcare delivery in Quebec, is to disseminate the results of these operational research teams, so as to ensure that all of the CISSSs in Quebec benefit from the effort of these teams as soon as possible.

References

- AS3993 UHF Reader IC, EPC class 1 gen 2 reader IC for mobile applications, http://ams.com/eng/Products/UHF-RFID/UHF-RFID-Reader-ICs/AS3993
- Ata B., Shneorson, S., Dynamic Control of an M/M/1 Service System with Adjustable Arrival and Service Rates, Management Science, Volume 52, Issue 11, 1778-1791, 2006.
- Callaghan, S., Hawke, K., Mignerey, C., Five myths (and realities) about zero-based budgeting, http://www.mckinsey.com/insights/corporate_finance/five_myths_and_realities_about_zero_based_budgeting, October, 2014.

- Charnes, A., W. Cooper, & E., Rhodes (1978) Measuring the efficiency of decision-making units, European Journal of Operational Research vol. 2, pp.429–444.
- Clinical Decision Support System, https://en.wikipedia.org/wiki/Clinical_decision_support_system, accessed August 25, 2015.
- Cook, W.D., Tone, K., and Zhu, J., Data envelopment analysis: Prior to choosing a model, OMEGA, 2014, Vol. 44, 1-4.
- Cunningham, W. P., Freeman, D., McCloskey, J. F., OR Forum—Of Radar and Operations Research: An Appreciation of A. P. Rowe (1898–1976). Operations Research 32(4):958-967. http://dx.doi.org/10.1287/opre.32.4.958, 1984.
- Davenport, T.H., Short, J.E., The New Industrial Engineering: Information Technology and Business Process Redesign, Sloan Management Review, pp. 11-27.
- Davenport, T. H., Analytical Integration In Healthcare, Analytics-Magazine.org, January/February 2012, 19-23.
- Exponential Distribution, https://en.wikipedia.org/wiki/Exponential_distribution, accessed May 14, 2016.
- Giles, T., Wilcox R., IBM Watson and Medical Records Text Analytics, http://www-01.ibm.com/software/ebusiness/jstart/downloads/MRTAWatsonHIMSS.pdf and http://www.medtechmedia.com/files/medtech_images/IBM_110615_Final_PPT.pdf, 2011.
- Hammer, M., Reengineering Work: Dont' Automate, Obliterate, Harvard Business Review, July-August, 1990.
- ICHOM, www.ichom.org, last visited March 20 2016.
- Kaplan, R.S., and Anderson, S.R., Time Driven Activity Based Costing, Harvard Business Review, November, 2004.
- Kaplan, R.S., and Norton, D. P., “The Balanced Scorecard: Translating Strategy Into Action”, 1996.
- Kelvin, W. T., Electrical Units of Measurement, Popular Lectures Volume 1, 1883-05-03.
- Kriesel, D., “A Brief Introduction to Neural Networks”, http://www.dkriesel.com, last visited March 120, 2016, 2007.
- Lindsey, G. Some Personal Recollections of Army Operations Research on Radar in World War II, *Canadian Military History*: Vol. 4: Iss. 2, Article 8, 1995.
- McCloskey, J. F., The Beginning Of Operations Research, Operations Research, Vol. 35, No. 1., January-February 1987 (http://pubsonline.informs.org/doi/pdf/10.1287/opre.35.1.143).
- Michalowski, W., Rubin, S., Slowinski, R., Wilk, S., Mobile Triage Support System for Pediatric Emergencies, Journal of Decision Support Systems, vol. 36 no. 2, 2003, 161-176.
- Modha, D., **Introducing a Brain-inspired Computer** *TrueNorth's neurons to revolutionize system architecture, http://www.research.ibm.com/articles/brain-chip.shtml, last visited March 21, 2016.*
- Naor, P. 1969. The regulation of queue size by levying tolls. Econmetrica. 37,1 15-24.
- Ndegwa,S. *Clinical Decision Support Systems for Diagnostic Imaging* [Issues in emerging health technologies issue 117]. Ottawa: Canadian Agency for Drugs and Technologies in Health; 2012.
- Nikitin, P. V., Ramamurthy, Shashi, and Martizez, R., Simple Low Cost UHF RFID Reader, 2013, http://www.ee.washington.edu/faculty/nikitin_pavel/papers/RFID_2013.pdf
- Plaisant, C., Mushlin, R., Snyder, A., Heller, Li, J., Heller, D., and Shneiderman, B., LifeLines: using visualization to enhance navigation and analysis of patient records, Proceedings AMIA Symposium, pages 76-80, 1998.
- Powers, Patrick, Quebec's e-Health Journey – Assessing The Path Forward, ElectronicHealthcare, Vol 10. No. 3 2012.
- Raspberry Pi Foundation, https://en.wikipedia.org/wiki/Raspberry_Pi_Foundation, accessed August 23, 2015.
- Rotter T, Kinsman L, James EL, Machotta A, Gothe H, Willis J, Snow P, Kugler J, Clinical pathways: effects on professional practice, patient outcomes, length of stay and hospital costs (Review), The Cochrane Library 2010, Issue 7.
- Simão, H. P., George, A., Powell, W. B, Gifford, T., Nienow, J., Day, J., Approximate Dynamic Programming Captures Fleet Operations for Schneider National, Interfaces, Vol 40. No 5. 2010.
- Watson EMR Assistant, http://www.research.ibm.com/cognitive-computing/watson/watsonpaths.shtml#fbid=2NymwtqCxfW, accessed May 14, 2016.
- Wetherbe, J. C., and Montanari, J. R., Zero based budgeting in the planning process, Strategic Management Journal, Volume 2, Issue 1, pages 1-14, January, 1981.
- Whang, S. The Value Of System State Information In Information Systems, working paper, 1986.