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# A FRAMEWORK FOR DEVELOPING A PERFORMANCE MEASUREMENT SYSTEM IN HEALTHCARE: A CASE STUDY IN MONTREAL

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**ABSTRACT:** To meet healthcare organisations' goals such as satisfying their customers in terms of service quality, they need an efficient performance management system. This paper provides an approach to implement a new performance measurement system (PMS) for a large healthcare network in the region of Montreal, Canada (CIUSSS Centre-Sud-de-l'île de Montréal – CCSMTL). At the beginning, we present the data collection method in an attempt to understand the current situation, the data is then analysed using SWOT method. Second, we present our approach consisting of five steps to set up a performance measurement system, for this purpose, we used Analytic Hierarchy Process (AHP) and other mathematical tools. Third, we explain an application of our approach by using a real case study. Finally, we discuss how this approach lead to solve organisational issues, meet the CCSMTL needs and promotes cultural change in the strategic, tactic and operational levels. We also discuss the study limits and the future work.

**KEYWORDS:** Performance measurement, indicators, AHP, Healthcare.

## 1 INTRODUCTION

Managers in healthcare and social services sector need engineering tools to contribute to provide high-performance services and achieve customers' satisfaction while implementing innovation and efficiency organisational culture. In the province of Quebec, Canada, the health and social services system is structured into networks called CI(U)SSSs. CI(U)SSSs refer to integrated (University) health and social services centres. They are public bodies under the responsibility of Ministry of Health and Social Services (MSSS). Their mission is to provide general and specialised healthcare and social services to the entire population throughout the province of Quebec while ensuring that these services are accessible, effective, efficient, and of high quality. In Montreal region, where this project is conducted, there are five CI(U)SSSs, which offer services in the West, West-Centre, South-Centre, North and East. Our project is carried out in collaboration with the South-Centre CIUSSS (CIUSSS Centre-Sud-de-l'île de Montréal - CCSMTL). 52 institutions including four hospitals and clinics, 10 community service centres, 14 social rehabilitation centres, 17 residential centres for the elderly, five physical disability assistance centres and two administrative offices have been grouped and merged to create the CCSMTL in April 2015. In its effort to improve the performance of its network and satisfy MSSS's requirements regarding healthcare system performance assessment (MSSS Strategic plan 2019-2023) (MSSS, 2019), the CCSMTL initiated the implementation of its performance model called “integrated Quality-Performance Model” (QPM). The QPM encompasses four performance dimensions: customer, quality-accessibility, mobilization, and optimization (Figure 1).



Figure 1: Quality Performance Model of CCSMTL (CCSMTL, 2017)

Each dimension addresses an aspect of CCSMTL performance. For instance, Customer dimension reflects the CCSMTL performance regarding the satisfaction of its customers (people receiving the service or care, his/her relatives, the community and the population) in regards to services and care provided by the CCSMTL. Within each dimension, the CCSMTL identifies different sub-dimensions, which are measured by using a set of performance indicators. The QPM model is based on the two main dimensions: accessibility-quality and customer, which are called in the CCSMTL the “True North” ( it is a symbolic name, because these two dimensions take the shape of a compass needle and indicate the right direction to a better performance). The other two dimensions (optimization and mobilization) support the True North in achieving its goals. To implement the QPM model in its network, the CCSMTL has implemented a visual performance management system (i.e., control rooms) encompassing a strategic decision room, tactical rooms and visual stations. (Lagacé & Landry, 2016). By definition, a control room is a dedicated space where decision-makers meet regularly to take a look on the current state and initiate discussions to improve future performance. The rooms are hier-

archically structured and allow decision makers to delegate tasks to a lower decision-making level or to request support from a higher level.

However, implementing the QPM model is very challenging for the CCSMTL managers. First, the CCSMTL is a very large network, with 28 different services provided to the customers in several institutions. QPM deployment must be performed at various decision-making levels (strategic, tactical and operational) and network structures (programs, departments, institutions, etc.). Given the diversification of the services offered, this deployment is difficult to achieve. Second, some sub-dimensions of the QPM are difficult to measure. Thus, identifying relevant performance indicators is complex. Third, in order to measure the overall performance of a department or the CCSMTL as a whole, managers need aggregated information that is easy to interpret and visualize to efficiently support decision-making. Additionally, some indicators are interdependent while others may be conflicting (in some cases, trade-offs are inevitable). Finally, several indicators have heterogeneous units of measurement.

The objective of this project is to support the CCSMTL managers to efficiently implement the QPM model. More precisely, the objectives are twofold:

- 1) Identify, select and validate performance indicators relevant for each dimension of the QPM.
- 2) Measure the overall performance of a structure within the CCSMTL (e.g., a department), and translate it into information that is easy to interpret and visualise.

To this end, we propose a framework for developing a performance measurement system (PMS) aiming at implementing the QPM model. The remainder of this article is organized as follows: the next section presents our literature review. Section 3 describes our methodology. Section 4 presents a case study and our preliminary results. Finally, section 5 presents our conclusions, the limitations of our study, and future work.

## 2 LITERATURE REVIEW

### 2.1 Performance measurement

According to Marin (2020), a PMS is needed in healthcare first to see how things works and plan performance improvement. Second, it is useful to make the right decisions and monitor the organization. Third it promotes the quality of services. Finally, it supports strategic planning and resource allocation. To measure the performance, the author mentions three generations of measurement systems, the first one is based on balanced measurements such as the balanced scorecard (BSC) of Kaplan and Norton (1992), the perform prism of Neely et al. (2002) and the Skandia navigator model developed by Edvinsson and Malone (1997). The second generation of systems intends to map flows and transformations of the strategy such as the strategy map of Kaplan and Norton (2000), the success and risk maps of Neely et al. (2002) and the IC-Navigator

model of Roos et al. (1997). The third generation proposes improvements to the models of the other two generations, especially on how to link the financial and non-financial aspects.

The Supply Chain Operations Reference (SCOR) model (APISC, 2017) presents “the performance” as a grouping or a categorisation of metrics used to express a specific strategy. According to IRIS (Research and socioeconomic information institute) (Hébert & Hurteau, 2016), an indicator is the final deliverable of a data collection for the purpose of achieving a goal. Thus, an indicator must be associated with a precise and measurable objective. In the literature, authors classify performance indicators based on different categorisations. For instance, we can differentiate the indicators by their “external” or “internal” character (Hébert & Hurteau, 2016). According to the authors, internal indicators (activity metrics) are closely linked to the activity of the department or the company. In healthcare, the internal indicators are those which are used to measure and manage activities, practices and resources within the system. External indicators (impact metrics) concern the impact of actions on the market. In healthcare, external indicators show the impact of a health service on its customers (e.g. complaint rate). IRIS proposes another categorisation: 1) health status indicators, which can be expressed positively (e.g. cancer survival rate) or negatively (e.g. mortality rate); 2) resource indicators that are expressed as a function of costs (e.g. health expenditure per person) or not (e.g. number of nurses); and 3) indicators related to the services rendered (e.g. number of surgeries). Merchant (2006) discusses how to choose a set of measures in order to evaluate general managerial performance. In his paper, several other references are presented, which could support choosing the right indicators. From this paper and further readings, we identified the following eight criteria for choosing a performance indicator: validity, relevance, reliability, sensitivity, simplicity, usefulness, sustainability, and specificity.

### 2.2 Normalisation techniques

Normalization consists in making an entire set of values have the same measurement scale, in order for instance to compare them. Goyal et al. (2014) published an article where they report the three most commonly used techniques. The first one is the min-max normalization. It performs a linear transformation on the original data. Assume that an attribute  $A$  varies between a minimum (**min**) and a maximum (**max**) value. The method plots a value  $X_{\text{real}} \in A$  to  $X_{\text{norm}}$  in the range of  $[N_{\text{min}}, N_{\text{max}}]$  (New min-max) by calculating:

$$X_{\text{norm}} = (N_{\text{min}} - N_{\text{max}}) \frac{X_{\text{real}} - \text{min}}{\text{max} - \text{min}} + N_{\text{min}} \quad (1)$$

The second is the Zero-Score (Z-Score) normalization. It is used when the range of an attribute is unknown. It transforms the data by converting the values to a common scale with an average of zero and a standard deviation of one.

The third method is the decimal scaling normalization. The value of  $X_{norm}$  is obtained by using the following equation:

$$X_{norm} = \frac{X_{real}}{10^z} \quad (2)$$

Where  $z$  is the smallest integer such that  $\text{Max}(|X_{norm}|) < 1$ .

To ensure a better normalization, it is necessary to detect outliers in the data to normalise and eliminate them. This step is primordial to ensure reliable normalised values. According to Al Shalabi et al. (2006), future data can be normalised in the same manner as current data.

### 2.3 Aggregation and MCDM techniques

Multiple criteria decision-making (MCDM) tools are a set of techniques allowing managers and researchers to choose the best possible decision or option. They represent an important science section of Operational Research. Two main schools are known: the American school with the models of Saaty, Brown and Keeney & Raiffa, and the European school with the models of Roy, Brans, Mareschal and many others. Mena (2000) described the bases of different MCDM techniques and their uses. The author presented a classification of these techniques according to three main approaches: complete aggregation, partial aggregation, local and iterative aggregation. Complete aggregation methods consider all the alternatives and a weight is assigned to each one of them. Partial aggregation methods create a ranking relationship between the alternatives. These approaches do not necessarily lead to the best result as generally expected (Mena, 2000). Iterative and local aggregation methods are used when there are many or unlimited choices. Table 1 presents the most used MCDM techniques.

Complete	Partial	Iterative and local
AHP (Saaty, 1971) MAUT (Ralph Keeney, Howard Raiffa, 1960) Brown and Gibson (P. Brown, D. Gibson, 1972) (MACBETH) (C. Bana, 1992) WPM (Percy Bridgman, 1922)	ELECTRE (Bernard Roy, 1968) MELCHIOR Promethee (Brans, Vincke, 1980) QUALIFLEX (Ancot, Paelinck, 1982) NAIADE PAMSSEM	Branch and Bound. Goal programming. STEM (Benayoun, 1969) Ziont-Wallenius (S. Zionts, 1974).

Table 1: MCDM approaches examples

The most used approach among complete aggregation methods is the Analytic Hierarchy Process (AHP) (Saaty, 1971) developed by Saaty in the 1970s and improved in the following years. AHP is a well-known method for structuring and analysing complex decisions, based on human intuition and mathematical modelling. Forman and Gass (2001) explain in their article the effectiveness of the AHP method by giving descriptions of successful applications. They developed a relevant academic discourse to compare the AHP method with other competing approaches. The authors illustrate AHP's applications in various fields such as quality management. The main use

of AHP is for solving choice problems in multi-criteria environments and it converts individual preferences into weights.

AHP has been successfully used in performance management for prioritizing and weighting performance indicators (Yaghoobi & Haddadi, 2016). Also, it is widely applied within the BSC framework (Anjomshoae et al., 2019; Modak et al., 2019; Yaghoobi & Haddadi, 2016). In the health sector in particular, AHP is integrated with the BSC for performance evaluation, for instance, Chan (2006) applies the AHP method on hospital balanced scoreboards to identify overall measures to compare performance between healthcare organizations. Regragui et al. (2018) combined the BSC and the AHP to develop a framework for evaluating the performance in hospitals and provide managers with indicators on the strengths and weaknesses of the organisational performance. Other authors such as Leksono et al. (2019) and Marcarelli (2017, 2018) also used AHP and BSC in healthcare.

## 3 METHODOLOGY

### 3.1 Data gathering

Data was collected in order to understand the internal processes of the CCSMTL and its current situation regarding the implementation of the QPM model (indicators selected, reference models used, etc.). We used two methods for gathering information: reviewing relevant documents, for e.g., provided by the CCSMTL; and observation/interviews.

#### 3.1.1 Document review

The CCSMTL attempts to adopt the best practices of several Canadian and international organisations to implement its QPM model. It also uses the guidelines and recommendations of the Law on Health and Social Services of the MSSS. According to the ministerial reference framework for performance evaluation (MSSS, 2012), the Law provides a model for organising the human, material and financial resources in a way that encourages the participation of all actors and promotes responsibility sharing between all stakeholders. Moreover, the Law states that healthcare institutions must obtain health and social services accreditation. In 2017, the MSSS selected the services of "Accreditation Canada" for all the institutions in the Quebec network. Accreditation Canada assesses organizations against standards developed by the Health Standards Organization (HSO). Furthermore, it recommends a set of performance management practices to be implemented using a guide-book on the evaluation of quality improvement and quality indicators (Agrément-Canada, 2014). The CCSMTL is also a member of francophone PLANETREE (Cosgrove, 1994), which is a grouping of health and social services institutions aiming at improving healthcare and social services. PLANETREE provides a model for integrating clinical and management practices centred on the customer. Hence, MSSS, Accreditation Canada, and PLANETREE

all provide several references for selecting performance indicators and implementing a performance management system. The documents studied constitute the first step towards the implementation of the QPM.

### 3.1.2 Interviews and observations

At the beginning, we had limited information on the problem. Therefore, to gather more information, we conducted interviews with CCSMTL experts. Five steps were followed for each interview. i) Set a specific goal for the interview. The main goal, which is common to all interviews, was to evaluate the implementation progress of the QPM model within the CCSMTL. ii) Choose the interview method. According to DiCicco-Bloom and Crabtree (2006), there are three types of interviews: structured, semi-structured and unstructured interviews also called in-depth individual interviews. We adopted the structured interview method. In this method, the participants have a number of structured questions, which they are asked to answer in their own way. iii) Recruiting the participants. We chose the interviewee based on the study needs and progress. We collaborated with a manager involved in the implementation of the QPM who helped us to identify participants who would be interesting for the study. iv) Conducting the meeting, and planning other interviews with the participants if necessary. Examples of questions discussed in the interviews are what are the strategic objectives? What are the practices put in place to achieve these objectives? How the QPM can lead to a better performance? And how does the CCSMTL evaluate the organizational performance? v) Information analysis and result formulation. 10 interviews in total were conducted with 12 senior managers and stakeholders of the CCSMTL, from May 2019 to February 2020. Most of the meetings were one-to-one.

The main objective of the observations was to gather data and identify behaviours and practices that might not be collected otherwise (e.g., interviews). We participated in the QPM Coordination Committee and the QPM Advisory Committee meetings. The Coordination Committee is formed of a limited number of managers from the quality, ethics, organisational performance Department. Its mandate is to ensure successful implementation the QPM in the CCSMTL in accordance with the MSSS strategic plan. Periodically, the Coordination Committee invites the heads of all departments to discuss decisions to be made and collect their feedback. This enlarged group forms the QPM Advisory Committee. Besides, we attended a training on performance improvement led by two managers of the CCSMTL. We also visited two hospitals, two rehabilitation centres and several control rooms.

### 3.2 Data analysis

Through the interviews, field visits, attendance at meetings and events, we collected a large volume of information. In order to identify the strengths and weaknesses related to the current implementation of the QPM model,

we used the SWOT model (Strengths, Weaknesses, Opportunities, Threats). According to Pickton and Wright (1998), SWOT analysis is a tool from which strategies can be developed and which improves organisational performance. It involves the collection and representation of data related to internal and external factors that have, or may have, an impact on the organisation. The SWOT analysis method helps to clarify the strengths to be maintained, the weaknesses to be improved, the opportunities to be taken advantage of, and the constraints to be respected. In the following paragraph, we present our main results and findings (Table 2). These results were discussed and validated with CCSMTL experts.

Table 2 shows that there are enough indicators in the CCSMTL that measure quality-accessibility (Strengths). Some of them are dependent with each other while others may be conflictual (Weaknesses). However, we observed a lack of indicators within the customer dimension (Weaknesses), which is yet the heart of the QPM model and the most important component. We also had difficulties in finding indicators in the optimization dimension while most of mobilization indicators are measured by the human resources (HR) department (Weaknesses). We observed that the QPM model is rather well implemented at the strategic level compared to operational or tactical levels (Strengths). There is a major interest of senior managers in orienting the employees to use the QPM. However, up to now the QPM is not much used by the employees. Another interesting finding is that the majority of the indicators are used to meet administrative objectives that respond to ministerial constraints (Threats). These indicators do not meet all the objectives of the QPM. There are several practices to ensure service quality and customer satisfaction, but there is a lack of indicators measuring these aspects. We observe the absence of an indicator performance system. Each department/program measures its own indicators independently of the other departments/programs or the higher hierarchical level. However, department managers can propose other indicators according to their needs (other than the indicators proposed by senior managers and MSSS). Senior managers need to exanimate the performance state in a specific department without having to check all associated indicators. This is not possible with the current performance measurement system. We also find that sometimes the indicators are not related to the established priorities and their primary objectives.

	Strengths	Weaknesses
Internal	<ul style="list-style-type: none"> <li>- Sufficient number of quality-accessibility indicators.</li> <li>- Most mobilization indicators are centralised at HR department.</li> <li>- MQP is well implemented at the strategic level.</li> </ul>	<ul style="list-style-type: none"> <li>- Lack of overall indicators.</li> <li>- Interdependent indicators.</li> <li>- Some indicators are not linked to a specific goal.</li> <li>- Lack of customer dimension indicators.</li> </ul>

	<ul style="list-style-type: none"> <li>- Several practices ensuring service quality are implemented.</li> <li>- Departments are free to suggest other indicators.</li> </ul>	<ul style="list-style-type: none"> <li>- Few indicators in optimization and mobilization dimensions.</li> <li>- Lack of QPM use at the operational level.</li> <li>- Inadequacy between the QPM dimensions and the indicators used in practice.</li> <li>- Lack of impact indicators.</li> </ul>
External	Opportunities	Threats
	<ul style="list-style-type: none"> <li>- Several performance models and practices are proposed by institutions such as Planetree, Accreditation Canada, MSSS, etc.</li> </ul>	<ul style="list-style-type: none"> <li>- Ministerial constraints. (Strategic Plan 2015-2023)</li> </ul>

Table 2 : SWOT analysis for the CCSMTL

### 3.3 Performance measurement system proposed

Based on the previous analysis, we developed a performance measurement system following an approach revolving around five main phases: (You will find the parameters list in the appendix).

- *Phase1: Structuring an indicator system*

In order to have a full picture of the performance, we need to have overall indicators built from several measures, from the operational to the strategic level. This requires having a network of interrelated indicators known as performance measurement system (Speklé & Verbeeten, 2014). This phase aims to shape the overall structure of this indicator system. it presents an organigram for an organisation with hierarchical structure that have  $N$  hierarchical levels, assuming that each department  $D(\mathbf{hdep})_{j,k}$  has an hierarchical level  $j$  vis-à-vis the main headquarters  $D()_{j=1}$  and a number  $n(\mathbf{hdep})$  of sub-departments indexed with the letter  $k$ . The sub-department  $D(\mathbf{hdep})$  takes the index  $(\mathbf{hdep})$  as (higher-department) that refers to the department name of the higher hierarchical level. For example,  $D(\mathbf{rehabilitation})_{4,2}$  is the second sub-department under the department rehabilitation and of a hierarchical level 4.

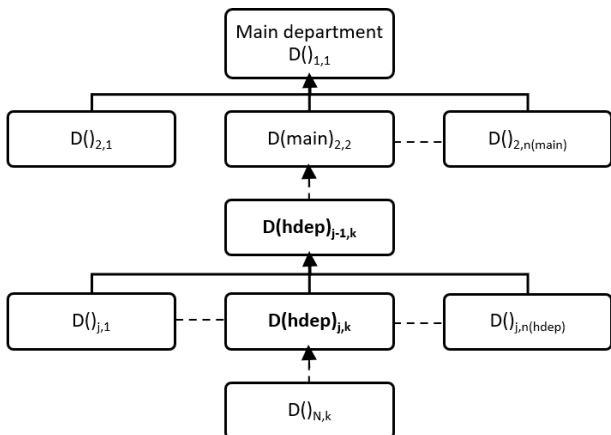


Figure 2 hierarchically structured organization design

- *Phase2: Proposing performance indicators*

In this phase, the literature review is used to select indicators that meet a number of criteria (see Section 2). In collaboration with CCSMTL experts and stakeholders, the appropriate indicators were chosen for each department using the balanced score card (BSC) approach (Kaplan & Norton, 1992). First, we created the appropriate strategy map (Kaplan & Norton, 2000) for the CCSMTL by taking into consideration the QPM dimensions (each QPM dimension is equivalent to one of the BSC axes). Second, based on these strategic objectives, we identified indicators for each QPM dimension as well as the data collection method needed for each indicator. Sometimes, we chose existing indicators and other times we proposed new ones. Finally, the validity of each indicator was checked against the following eight criteria (mentioned in Section 2):

- 1- Validity (measurable): the indicator measures the results.
- 2- Relevance: the indicator is associated with an objective.
- 3- Reliability: the indicator is coherent with the program.
- 4- Sensitivity: the indicator is sensitive to changes.
- 5- Simplicity: information is easy to collect and to analyse.
- 6- Usefulness: the information is useful for decision-making.
- 7- Specificity: the indicator allows to locate the problem and facilitates the choice of corrective actions.
- 8- Sustainability: the indicator remains relevant over time.

- *Phase 3: Indicator normalization:*

This phase allows us to put on the same scale indicators having different measurement units (cost, time, number, etc.), that are calculated differently or having different targets (e.g., emergency wait time and consultation wait time). The normalization purpose is to make very different indicators comparable with each other in phase 4.

To this end, we adopt the min-max normalization because we can distinguish the minimum and maximum limits in our data. To do so, we use Equation (1) (Section 2). We adjust the equation's parameters according to our need as follows:

$$Xi_{\%} = 100 \times \frac{Xi_{real} - \min_i}{target_i - \min_i} \quad (3)$$

- $Xi_{\%}$  : the normalised value of the indicator  $i$  expressed in percentage.
- $Xi_{real}$  : the real measured value (before normalization).
- $\min_i$  : the worst value of the indicator  $i$  (before normalization).
- $target_i$  : the value to be achieved for the indicator  $i$  (before normalization).

In other words, we set  $[N_{min}, N_{max}] = [0, 100]$  to express the normalised values as percentages.

In some cases, the minimum value is the best and the maximum value is the worst (e.g. the waiting time expected to be as low as possible). In these cases, the worst value is considered as the maximum and the best value as the minimum. In most cases, the historical minimum is not a significant value. For example, if there are falls in the historical data such as a very high demand following a disaster. In those cases, we chose the minimum as the worst value after outliers' elimination to obtain a logical and acceptable value. Finally, to ensure continuous improvement, we chose the maximum value as the target to reach. This allows us to measure the progress toward a specific goal.

After phase 2 and phase 3, each department  $D_{jk}$  identify and normalize a set of indicators for each dimension (**dim**) of the QPM. we call them internal indicators  $X_{i\%}^{dim} = (X_i^C, X_i^A, X_i^M, X_i^O)$ , where  $X_i^C$  designates the set of internal indicators for the customer dimension,  $X_i^A$  for accessibility quality dimension,  $X_i^M$  for mobilization dimension and  $X_i^O$  for optimization dimension.

• *Phase 4: Indicator weighting*

In this phase, weighting the indicators at the same level within one dimension is performed. We chose the AHP method. According to Kumar et al. (2017) AHP is the most popular MCDM method due to its simplicity in procedure. AHP allows us (easily) to weight the indicators without having to make a choice between them.

Basically, AHP is a decision-making tool in a multi-criterion environment that follows five steps. First, model the complex problem in a hierarchical structure that contains the choices and the criteria. Second, weight the elements of the hierarchy by making a set of judgements based on pair-wise comparisons of the elements (using comparison matrix). Third, check the consistency of these matrices, this step is clearly described by Brunelli (2014). Fourth, calculate the weights for the choices and finally, prioritize choices according to their weights.

In our case we use step two, three and four of the AHP method that allows us to weigh the indicators. First, for every department  $D_{jk}$  we draw 4 matrices, one for each QPM dimension. Using these matrices, we make the pair-wise comparison between the indicators. Second, we check the consistency of these matrices. Finally, we calculate the weights for each indicator. Consistency checking and weights generation is done by following algorithms in AHP, for this purpose, we have developed a computer tool using VBA language to roll out these algorithms.

AHP offers flexibility by using pairwise comparison matrices. The size of a given matrix corresponds to the number of indicators chosen in phase 2 ( $X_{i_{real}}$ ) and normalised in phase 3 ( $X_{i\%}$ ) for one dimension of the QPM. The managers in each department are responsible for comparing the indicators and filling the matrices. Next, the coherence of the matrices is checked. If the comparisons are coherent, the weighting coefficients (**Wi**) are generated, if not,

the pairwise comparisons are repeated. Finally, a performance index ( $PI^{dim}$ ) that measures each dimension (**dim**) of the model is calculated for each department  $D_{jk}$  as follow:

$$PI_{jk}^{dim} = \sum_i^N Wi \times Xi_{\%} \quad (4)$$

- $PI_{jk}^{dim}$  : Performance index per dimension (**dim**)
- $Wi$  : The weight associated to each indicator
- $Xi_{\%}$  : Internal indicators

• *Phase 5: Indicator aggregation*

Using equation (4), each department  $D_{jk}$  in level **j** will have four performance indices that evaluate the four dimensions of the QPM ( $PI^C, PI^A, PI^M, PI^O$ ) $_{jk}$  (one per dimension). Then, these indicators are transferred to the higher department  $D_{j-1,k}$  in the level **j-1**.  $D_{j-1,k}$  measures its internal indicators ( $X_i^C, X_i^A, X_i^M, X_i^O$ ). Next, we weigh the internal indicators and level **J** indicators together in the same way as in phase 4 (Figure 3). Finally, the department  $D_{j-1,k}$  calculates its own performance indices ( $PI^C, PI^A, PI^M, PI^O$ ) $_{j-1,k}$ . these performance indices will be transferred to level **J-2** and subsequently until the main department at level **1**.

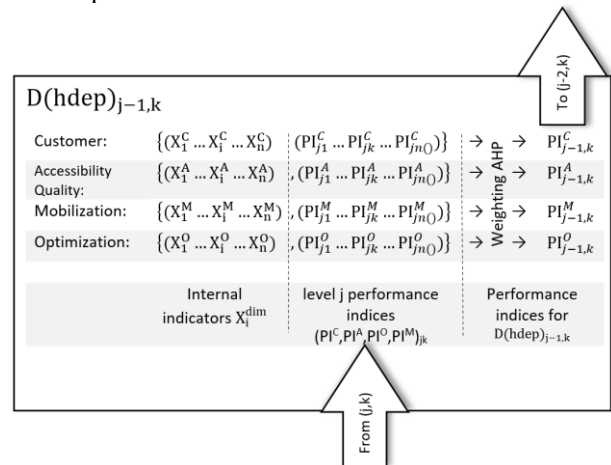


Figure 3 : QPM indicators' calculation in department  $D_{j-1,k}$

## 4 CASE STUDY

This section shows how we implemented the performance measurement system that we proposed. The purpose of this case study is to:

- Simulate our approach under real conditions
- Verify the applicability of this method
- Detect the weaknesses to be corrected and improve the approach.

Given the large size of the CCSMTL, we have chosen a particular department referred to as **DI-TSA-DP**. It hosts 2200 customers and processes approximately 10,000 service demands annually, mainly in the South-Central territory of Montreal and in the whole province of Quebec. 2150 employees and 58 doctors work in this department.

DI-TSA-DP contains three principal sub-departments: sub-department **DI-TSA** provides care for customers with an intellectual disability or an autism spectrum disorder, sub-department **DP** provides care for customers with physical disability and sub-department **RMVS** offers rehabilitation services in substitute living environments like in nursing homes for the elderly.

We started the implementation process by collecting data on DI-TSA-DP department. To do so, we planned five meetings and visits with the managers of DI-TSA-DP to present our approach, gather information on the department and sub-departments to illustrate our approach. Since it is not possible to entirely apply the approach on DI-TSA-DP in a short time (all data was not available at the moment of writing this article), we have selected three sub-departments (in three successive hierarchical levels) to illustrate our approach.

The SWOT analysis results (Section 3.2) are particularly valid for DI-TSA-DP. The QPM model is implemented in a very superficial way. DI-TSA-DP does not measure the performance in relation to each dimension of the model and there is no well structured performance measurement system that allows QPM model implementation.

Currently, DI-TSA-DP has installed its main tactical room and tactical rooms in each of the sub-departments (DI-TSA, DP, and RMVS). Similarly, they are deploying the operational rooms for all team units. In certain units, these control rooms are not fully implemented. So, each unit has a deployment rate of its control room. According to this deployment rate, we have chosen to work on **DP** sub-departments. DP also contains three sub-departments: **AT** sub-department which allows the customers with a physical disability to obtain specialized assistant devices (prosthesis, wheelchair, etc.), **LN** that offers services for people with a physical disability due to neurological or locomotor impairments, and **SL**, which provides care for people with language or sensory disability. We have chosen to work on LN sub-department it has the highest deployment rate. Under LN, there are nine team units, each unit has its own control room. In short, this case study focuses on DI-TSA-DP in the first level then DP in the second level, and finally LN in the third and last level. The five step-approach is applied as follows:

*Phase1: Structuring an indicator system*

In (Figure 4), we show a simplified organizational chart of DI-TSA-DP department. This organigram shows only the department and sub-departments necessary to illustrate our approach. For example, the LN sub-department named  $D(DP)_{3,2}$  is the 2nd sub-department under DP and of hierarchical level 3, with the hypothesis that the department DI-TSA-DP ( $D()_{1,1}$ ) is the main department. Furthermore, we present the 9 team units under the LN sub-department. The figure shows the three decision-making levels. In each level there are the control rooms. For instance, in the tactical level there is a main tactical room for DI-TSA-DP and other sub-tactical (considered as tactical rooms for DI-TSA, DP and RMVS).

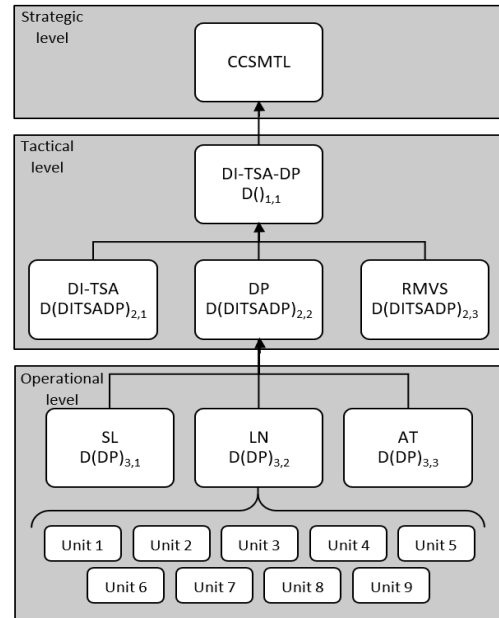


Figure 4 : DI-TSA-DP Reduced Flowchart

- *Phase2: Proposing performance indicators*

In this phase, we planned working meetings of two hours each with managers and stakeholders of each sub-department to choose the performance indicators according to their performance objectives. We started from the operational to the tactical levels. So, we began the meetings first with two of the team units, second with LN, then with DP and last with DI-TSA-DP. Our progress in this meeting process is stopped at the LN sub-department level, also the team units do not use enough indicators that measure all the QPM dimensions. For these reasons, we limit the study on presenting an example in the LN sub-department and then the aggregation process to the higher level in the next phases.

In Table 3, an example of internal indicators ( $X_1^{dim}$ ) proposed for the department LN ( $D(DP)_{3,2}$ ) is presented. These indicators will be used in the operational room.

LN: $D(DP)_{3,2}$		
Dimension	Indicator name	$X_1^{dim}$
Customer	Customer satisfaction rate	$X_1^C$
	Complaint rate	$X_2^C$
Accessibility Quality	Bed occupancy rate	$X_1^A$
	Respect of access deadlines	$X_2^A$
	Average length of stay	$X_3^A$
Mobilization	Staffing level	$X_1^M$
	Hours of service (HPS)	$X_2^M$
	Employee satisfaction rate	$X_3^M$
Optimization	Reference number change rate	$X_1^O$
	Project progress rate	$X_2^O$

Table 3: LN department indicators

Subsequently, we checked the validity of each indicator using the eight criteria presented earlier in section 3.3 (Validity, Relevance, Reliability, Sensitivity, Simplicity, Usefulness, Specificity, Sustainability). Sometimes, an



indicator does not satisfy the totality of these criteria, in this case, either we change it with another indicator or we try to solve this lack in criteria. For example, some indicators were not “simple” because we do not have the means to collect the necessary information. So, we try to find if we can get the information in other ways: audits and consultations, reports (accidents/incidents), computer tracking system, surveys, balance sheets (e.g. financial reports). These are the methods of data collection in DI-TSA-DP.

• Phase 3: Indicator normalization

We use the indicator Average length of stay ( $X_3^A$ ) to present the normalisation method (Table 4). For confidentiality reasons, the values in the following tables are not the real values measured at LN department, but modified ones.

Indicator:	$X_3^A$ : Average length of stay (DMS)
Real value ( $X_{3\text{real}}^A$ ):	17 days
Target:	10 days
Min (worst value):	50
Normalized value ( $X_3^A\%$ ):	$X_3^A\% = 100 \times \frac{X_{3\text{real}}^A - \min}{\text{target} - \min} = 82.5\%$

Table 4: A3 indicator normalisation

In the same way, using equation (3), we calculated all the normalised indicators (Table 5).

	$X_1^C$	$X_2^C$	$X_1^A$	$X_2^A$	$X_3^A$	$X_1^M$	$X_2^M$	$X_3^M$	$X_1^O$	$X_2^O$
$X_{i\%}^{\text{dim}}$	85	93	91	86	82.5	92	81	87	80	92

Table 5: LN Normalized indicators

• Phase 4: Indicator weighting

In this phase we do the weighting using the pairwise comparison matrices of the AHP method. These matrices must be filled in with the responsible of each sub-department during the meeting. Thus, the following are fulfilled with LN's manager:

Customer:			Accessibility/Quality:			
	$X_1^C$	$X_2^C$		$X_1^A$	$X_2^A$	$X_3^A$
$X_1^C$		2	$X_1^A$		1	4
$X_2^C$	1/2		$X_2^A$	1		5
			$X_3^A$	1/4	1/5	
Mobilization:			Optimization:			
	$X_1^M$	$X_2^M$	$X_3^M$		$X_1^O$	$X_2^O$
$X_1^M$		1/2	1/2	$X_1^O$		3
$X_2^M$	2		1	$X_2^O$	1/3	
$X_3^M$	2	1				

Figure 5: Pairwise comparison matrices for LN

Then, we enter our matrices on a Visual Basic for Excel application that we developed. This application checks the consistency of these matrices and generates the weights using the AHP algorithm.

	$X_1^C$	$X_2^C$	$X_1^A$	$X_2^A$	$X_3^A$	$X_1^M$	$X_2^M$	$X_3^M$	$X_1^O$	$X_2^O$
$W_i$	2/3	1/3	0.43	0.46	0.1	1/5	2/5	2/5	3/4	1/4

Table 6 : weights for indicators of LN department

In some cases, the weighting is done intuitively, for example for the customer dimension  $X_1^C$  is twice as important than  $X_2^C$ , so intuitively we can deduce that  $W_{C1}=2/3=2 \times W_{C2}$ . Last and not least, we calculate a performance index  $PI_{32}^{\text{dim}}=(PI^C,PI^A,PI^O,PI^M)_{32}$  that measures each dimension of the model using equation (4):

	$X_1^C$	$X_2^C$	$X_1^A$	$X_2^A$	$X_3^A$	$X_1^M$	$X_2^M$	$X_3^M$	$X_1^O$	$X_2^O$
$W_i$	2/3	1/3	0.43	0.46	0.1	1/5	2/5	2/5	3/4	1/4
$X_{i\%}^{\text{dim}}$	85	93	91	86	82.5	92	81	87	80	92
$PI_{jk}^{\text{dim}}$	$PI_{32}^C=87.6$		$PI_{32}^A=87.7$			$PI_{32}^M=85.6$		$PI_{32}^O=83$		

Table 7: Performance indices of LN sub-department

• Phase 5: Indicator aggregation

Each sub-department in level 3  $D(DP)_{3,k}$  will follow the same steps of phase 1, 2, 3 and 4 to get its performance indices. the following indicators will be calculated in SL, LN and AT:

SL $D(DP)_{31}$	LN $D(DP)_{32}$	AT $D(DP)_{33}$
$PI_{31}^C, PI_{31}^A, PI_{31}^M, PI_{31}^O$	$PI_{32}^C, PI_{32}^A, PI_{32}^M, PI_{32}^O$	$PI_{33}^C, PI_{33}^A, PI_{33}^M, PI_{33}^O$

Table 8: Performance indices of level 3 sub-department

Now, these latter indicators will be aggregated to the higher hierarchical level: sub-department  $DP$  ( $D(DITSADP)_{2,2}$ ). Also, DP department measures its own internal indicators. To make the case study more clear, we assume that the DP internal indicators are:  $(X_1^C, X_2^C, X_1^A, X_2^A, X_1^M, X_2^M, X_1^O, X_2^O)$ . Thus, the whole indicators used in DP sub-department are: [(internal indicators of DP)+(level 3 performance indices)]. These indicators are then weighed together as in phase 4. Next the performance indices  $PI_{22}^{\text{dim}}=(PI^C,PI^A,PI^O,PI^M)_{22}$  are calculated using equation (4) the as follows:

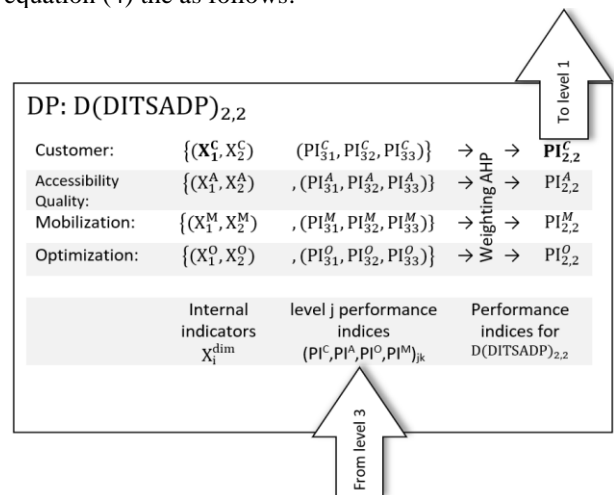


Figure 6 : QPM indicators' calculation in DP department

Finally, the 5 phases are done for the other departments in the same way until reaching the first hierarchical level.

To summarise, first, based on the control rooms deployment rates, we have chosen 3 successive sub-departments (DI-TSA-DP, DP, LN) with which we start our approach. Second, we organised meetings with managers from different hierarchical levels. The purpose of these meetings is to identify performance indicators according to the criteria presented in phase 2, and then gather information on the selected indicators (Value, target, min etc.) and make the pairwise comparisons. To this end, we used an indicators' selection sheet which includes indicators matrix, criteria verification matrix, and four pairwise comparison matrices (one for each dimension). Third, we inserted the collected data in a computer tool that we developed using VBA language on Excel. This tool allows to normalise the selected indicators according to phase 3 instructions, to weight indicators according to pairwise matrices and phase 4 steps, to aggregate indicators using phase 5 steps and to calculate and display the performance indices.

## 5 CONCLUSION

The CCSMTL has developed its quality performance model (QPM model) based on four dimensions (Customer, Quality-accessibility, Mobilization, Optimization). Our project aims to support the implementation of this performance model. To this end, after a SWOT analysis based on collected data, we proposed a five-based approach. The first phase aims to understand the overall structure of the measured system. The second phase support the decision-makers in selecting relevant performance indicators. In the third phase, the indicators are normalised. In the phase 4, AHP method is used to coare and weight the indicators. The last phase consists in aggregating and calculating overall indicators (performance indexes) for each QPM dimension.

Our approach will support the CCSMTL to efficiently implement its QPM model. First, it provides a scorecard that contains a well-structured and understandable indicator system that allows managers to visualise the overall performance in each department and sub-department without having to check several indicators that are not meaningful at the strategic level. Second, managers will be aware of the importance of having performance indicators linked to the four dimensions of the QPM model, starting from their strategic objectives. Third, our approach promotes an organisational culture focused on a quality-performance model and allows departments to compare themselves in a way that fosters a competitive spirit. The following is testimony of a senior manager of the CCSMTL regarding the proposed approach: “The structured interviews enabled the research team to fully understand the organisation’s QPM model and to develop accordingly the solution approach. The data structure proposed is highly relevant in that it addresses both the dimensions and sub-dimensions of the QPM model and is adapted to the hierarchical structure of the CCSMTL. The rigorous process of indicator validation and weighting carried out with stakeholders ensures a better reliability of the indicators

developed, which will optimise their use to eventually support decision-making.”.

This study presents some limitations. First, it does not consider the negative effects of indicator aggregation to create performance indexes. Second, a considerable effect is the interdependency between the indicators. Other approaches can address this problem such as ANP (Analytic Network Process), which is a general form of the AHP method, (Saaty, 1996). These limitations present interesting avenues for further work. Currently, we focus on using the BSC and strategy map (Kaplan & Norton, 2000) to create a more coherent and balanced performance measurement system.

## APPENDIX

Parameters list:

- $i$  : Index for the indicators
- $j$  : Index indicate the hierarchical level  $j \in [1..N]$
- $k$  : Index designates the order of sub-department  $k \in [1..n(\text{hdep})]$
- $D(\text{hdep})_{jk}$  : The  $j$ 'st sub-department under higher-department (hdep) and in hierarchical level  $k$
- $X_{i\text{real}}$  : Real internal indicators
- $X_{i\%}^{\text{dim}}$  : Normalized internal indicators in dimension (dim)
- $W_i$  : Weight associate to Indicator  $i$
- $P_{ijk}^{\text{dim}}$  : Performance index in department  $D()_{jk}$  and the dimension (dim)

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