2024 CMBEC46
Toronto, ON
CMBES/SCGB May 28-30, 2024

Development of a Methodology for Imaging Equipment Replacement Prioritization

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Abstract— **Imaging equipment provides a vital service to healthcare organizations across Canada. Due to limited capital budgets, complex factors must be considered by healthcare leadership as to how devices should be prioritized for replacement. A methodology was developed for prioritization of these high value devices to optimize budget allocation and ensure devices with the highest risk of impacting patients and the healthcare system are replaced first, based on both quantitative data from an equipment database and qualitative data points obtained from operational leaders. This methodology has resulted in an improvement of the prioritization process, and increased confidence in decisions which have the potential to greatly impact both patient care and capital budgets.**

Keywords— **Imaging Equipment, Capital Prioritization, Replacement Planning.**

I. Introduction

Imaging equipment across Canada is often kept in service well beyond the recommended age for replacement [1,2]. Capital budgets for replacing these devices are limited, and with escalating renovation costs an even smaller portion of the capital budget is available for equipment replacement. Thus, there is a growing need to have an efficient and effective methodology to advise health system leadership on which systems should be prioritized for replacement.

A previously developed medical equipment replacement prioritization system developed in Winnipeg [3] was considered, as well as other Canadian replacement prioritization methods [4,5,6]. While each of these systems had their own merits, a need was identified to develop a prioritization system specific to complex diagnostic imaging systems (e.g. CT, MRI, etc). A dedicated scoring system could account for the increased frequency of corrective maintenance expected for these complex systems, incorporate more specific estimated useful life data, and utilize more nuanced technical support information. In addition, the mission criticality of these systems requires greater attention as there are often no redundant or backup systems available. The high cost of these systems increases the need to optimize prioritization decisions due to the significant impact on capital budgets. Furthermore, due to the relatively small number of devices in service relative to general electromedical equipment, additional factors could be investigated which require manual data collection from stakeholders (e.g. clinical efficacy), which would generally not be feasible with the large population of general electromedical equipment.

A preliminary weighted sum scoring system for imaging equipment was first developed for the Winnipeg Regional Health Authority (WRHA) in 2015 [7]. Prior to that time, prioritization of imaging equipment was done solely by clinical stakeholders' votes, which tended to be highly subjective and based on who could present the most compelling story rather than on data. This made comparisons between systems challenging, and voters had to weigh many statements and factors quickly when selecting which system to vote for. The preliminary scoring system was developed as a tool to assist clinical stakeholders in considering multiple factors during their vote.

Building on the success of this initial implementation, the system was adjusted to include more criteria, an adjusted formula, and expanded implementation to a provincial scope.

II. Materials & Methods

A. Formula and Criteria Development

The imaging modalities considered in the new prioritization method were those that fell under the oversight of the Provincial Imaging Advisory Committee (PIAC). This includes all high-end imaging devices in the province with a value over roughly $150,000, including: MRI, CT, interventional (angio/cath), nuclear medicine (PET, SPECT), x-ray/fluoro, and diagnostic ultrasound.

After considering the equipment data that could be feasibly obtained from the WRHA Clinical Engineering Computerized Maintenance Management System (CMMS) and/or from operational leadership, the following five criteria were included in the prioritization formula:

- *Life Expectancy (LE):* Years to predicted End of Life (EOL), based on installation year and the CAR life expectancy guideline [1], which incorporates usage (exams/year). Usage data was extracted from the Radiology Information System (RIS) where feasible, and otherwise estimated by user consultation.
- *Manufacturer Support (MS):* Based on manufacturer/vendor End of Support (EOS) dates (note: if a

feasible upgrade is available that keeps the system supportable, the MS score is divided by 2).

- *Condition (C):* A combination of Reliability (R) and Labour Hours (LH) over the last 3 years. R is the count of repair work orders. LH is the sum of repair work order labour hours completed by vendor or in-house service. Data was extracted from the CMMS for Winnipeg and collected via surveys to operational leadership for all other sites in Manitoba.
- *Clinical Efficacy (CE):* A measure of how well the system features/performance meet current clinical requirements and the resulting impact on patient care; deficiencies may be due to equipment failure or inherent to design/functionality. This data was collected for each piece of equipment based on consultations and surveys with operational leadership.
- *Impact if Down (ID):* Refers to the impact on patient care should the equipment be down or not available for an extended period. The data required for this criterion was collected by examining provincial imaging equipment locations for each modality and validated by operational leadership.

A formula to combine the criteria was developed based on risk (probability x severity) in which the sum of factors relating to the probability of a catastrophic failure (LE, MS, and C) were multiplied by the impact of the system being unavailable (ID). The Clinical Efficacy (CE) score was then included as an additive factor, as the multiplier should only be used on those subcomponents which logically affect other subcomponents [4]. The formula is summarized as:

$$\text{Priority Score} = (\text{LE} + \text{MS} + \text{C}) * \text{ID} + \text{CE} \qquad (1)$$

The maximum values for each of these factors are outlined in Table 1. These were determined by attempting alignment with a previously developed scoring methodology for general electromedical equipment in Winnipeg [3] that was guided by the Analytical Hierarchy Process, as well as through analyses of various weighting options, comparison to past prioritizations, and stakeholder (operational & radiologist) feedback.

Table 1 Criteria and maximum values

Criteria	Max Values
Life Expectancy (LE)	10
Manufacturer Support (MS)	20
Condition (C) = Reliability (R) + Labour Hours (LH)	15
Clinical Efficacy (CE)	15
Impact if Down (ID)	2

Table 2 Sample scoring bins for the Clinical Efficacy (CE) criterion

Clinical Efficacy	Score
Has all required features for clinical requirements; provides safe and efficient patient care	0
Has all required features, but lacks features that could potentially help improve patient care, safety, clinical efficiency, and/or workflow	2
Lacks features, resulting in a minor negative impact to patient care and/or safety	6
Lacks features, resulting in a moderate negative impact to patient care and/or safety	10
Lacks features, resulting in an extreme negative impact to patient care and/or safety	15

For each of the additive factors (LE, MS, C, and CE), various score grades within each criterion were developed after analyzing the range and distribution of data. The data showed that ultrasound systems required different scoring gradients than other more complex imaging systems. As one might expect, more complex systems such as CT showed a higher repair rate than less complex systems. Therefore, the gradients used for ultrasound units were aligned with the previously developed general biomedical equipment scoring bins [3] rather than those for the remaining imaging modalities. A sample from the complete set of grading bins [8] is shown in Table 2, for the CE criterion.

A matrix structure was developed to determine the value of the Impact if Down (ID) multiplier based on the downtime impact and usage (Figure 1).

		Downtime Impact			
		No patients transferred (rescheduled)	Patients transferred within site	Patients transferred to alternate site <1hr	Patients transferred to alternate site >1hr
CAR Usage	Low	Low (ID = 1.0)	Low (ID = 1.0)	Med (ID = 1.3)	High (ID = 1.7)
	Med	Med (ID = 1.3)	Med (ID = 1.3)	High (ID = 1.7)	Extreme (ID = 2.0)
	High	Med (ID = 1.3)	High (ID = 1.7)	Extreme (ID = 2.0)	Extreme (ID = 2.0)

Fig. 1 Matrix for Impact if Down (ID) Multiplier Factor

B. Implementation

Following the collection of all the data outlined above from CMMS reports and stakeholder consultations, a score was calculated for each device using equation (1). The systems were then sorted from highest to lowest score and the

initial prioritization list was created. Various stakeholder consultations were then arranged. The list was filtered for each region, site, and area of use and reviewed in isolation with the relevant operational management. Notes were taken on feedback provided for systems that could be moved down the list or recommendations to be considered higher. Following this, the lists were divided into four modality groupings and reviewed by the respective subcommittees of Manitoba's Provincial Imaging Advisory Committee (PIAC): CT & MRI, Nuclear Medicine, Ultrasound (includes echo and fetal assessment), and X-ray (includes cath, angio, and fluoro). Each of these committees discussed relevant qualitative factors that may not be addressed by the score and adjusted the rankings within their respective subcommittee modality groupings. The four reprioritized lists were then sent for final review and collation by the PIAC Executive Committee, which consists of the radiologist chairs for each of the subcommittees, provincial Diagnostic Imaging (DI) medical & operational leaders, and representatives from Clinical Engineering and Medical Physics. The role of the executive committee is to discuss and propose adjustments to the final merged list, and ultimately determine the adjusted ranks and final list. At both the Subcommittee and Executive Committee levels, the adjustments are completed on a consensus basis; however, in the case of an inability to obtain consensus, the decision to move a system up would be finalized via vote.

III. Results

A representative data set showing the PIAC prioritization scores along with the initial rank and adjusted rank following stakeholder consultation and prioritization adjustments are shown in Table 3 below.

The new prioritization formula resulted in a more robust initial prioritization, leading to increased stakeholder support for the system. This enabled the prioritization process to move away from a method of stakeholder voting on each item, and instead to a committee review of the initial list with adjustments by consensus.

IV. Discussion

The new scoring methodology utilized several improvements from the previous version. First, it incorporated condition data extracted by the CMMS or based on vendor service records rather than a qualitative assessment. Secondly, optimization of the scoring bins and introduction of the ID multiplier also resulted in a more optimal initial list that better aligned with stakeholder and leadership interpretation of priority. Ultimately, the more robust scoring system, along with support from DI operational leadership for this work led by Clinical Engineering, resulted in more efficient PIAC meetings at the subcommittee and executive levels, and eliminated the need for an item-by-item vote.

Despite the improvement in scoring meteorology, adjustments are still required to the initial ranks, for a variety of reasons. One situation requiring adjustments was for systems used for procedures (ex: a c-arm in the operating room). These systems tended to get ranked lower than the perceived urgency of replacement and needed to be manually adjusted to a higher rank. This was likely due to there not being an appropriately high category in the ID matrix (Figure 1) to account for procedure systems, and highlighted the need to develop another procedure-based category in a future scoring revision.

Another reason adjustments to rank were required was due to operational knowledge of upcoming changes in service (for example, if service adjustments were being made that were expected to lead to an increase or decrease in the number of patients exams for a modality at a site).

Some adjustments were also made due to differences in vendor support for EOS systems, which is not accounted for by the scoring system. For example, two systems may have received similar scores for the MS criterion; however, the

Table 3 Sample prioritization scores, initial and adjusted ranks

Site	Modality Type	Manufacturer	Model	Priority Score	Initial Rank	Adjusted Rank
Eriksdale	Ultrasound	Philips	iU22	53	1	1
Roblin	Ultrasound	Philips	iU22	50	4	2
Misericordia	General Duty X-ray	Philips	Bucky Diagnost	35	15	3
St. Boniface	Echo Ultrasound	GE	Vivid E9	51	2	4
HSC	Rad/Fluoro (Cysto)	Siemens	Uroskop	48	6	5
St. Boniface	Rad/Fluoro	Siemens	Axiom Luminos dRF	12	53	6
Victoria	Ultrasound	GE	Logiq E9	51	3	7
Churchill	General Duty X-ray	Del	CM40 KW	44	10	8
HSC	CT	GE	Revolution CT	32	18	9

vendor for one of the systems may cooperate well with customers and still provide parts and labour on a best effort basis; while another vendor may be much more restrictive and either not have any part supply or not be willing to offer any technical support at all past the EOS date. Systems known to be in the latter situation tended to have their ranks adjusted to be higher up the priority list.

There are also some situations where a system needs its priority rank raised due extreme service frequency. The bins and max values for the R and LH criteria were based on analysis of all systems, looking at the average number of annual service events and labour hours, and accounting for some standard deviation. Occasionally, a system will have repeated service events that are significantly higher than what had been determined to be a 'high service' system. For example, more than 36 service events in a 3 year period resulted in the maximum number of points (10) for Reliability [8], based on the extremes that were seen during the data analysis. A system could have double the amount of service events and still would only receive 10 points in highest bin. In those extreme situations, the system may require a manual adjustment to a higher rank.

Finally, another reason for manual adjustments to rank is to align with Capital Planning initiatives and timelines. Occasionally, a system will be planned to move to an alternate location upon replacement, and funding should be requested on a timeline that aligns optimally with the building infrastructure being ready for installation (this could mean either prioritizing higher, or delaying replacement and prioritizing lower, depending on the situation). Another scenario is when it is known that extensive renovations will be required to a space to account for changing operational or site-based needs, or to meet accreditation requirements not currently met by the existing space. Recognizing the need for a longer planning cycle for extensive renovations may require the system to be prioritized for funding sooner to allow time for the construction consultant engagement, planning, and associated timeframes.

Overall, having the initial scored and sorted list allowed more time for discussion of these additional factors and scenarios that are difficult to score, and less time was spent discussing and voting on a system-by-system basis. Feedback collected from operational, financial, and medical leadership who were involved in the process was very positive and supportive of the scoring system and the approach used for implementation of it.

V. Conclusion

A new scoring methodology to prioritize imaging equipment for replacement was developed. The scoring method greatly aided and improved the overall process of imaging equipment prioritization by reducing time involved and providing greater confidence in the final result over the previous voting method. The new formula provides an excellent starting point with limited need for significant adjustments by the reviewing committees, resulting in a quicker and more efficient process based more on data and less on subjective interpretation.

Future work will include incorporation of a better risk model for systems used in procedures, and inclusion of more accurate downtime data based on a recently implemented data collection process.

Acknowledgment

The authors would like to thank Shared Health Clinical Engineering and Diagnostic Imaging medical and operational leadership for their support and consultation with this work.

Conflict of Interest

The authors declare that they have no conflict of interest.

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