

Biomedical Engineering Department Staff Analysis: The Ottawa Hospital Productivity Review

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Abstract – Unbalanced operational workflows preempted staff analysis of the current state of the Biomedical Engineering Department at The Ottawa Hospital. The analysis considered Technologists productivity, management of capital and operating budgets and comparisons drawn with Biomedical Engineering Departments of other academic tertiary teaching hospitals in Canada. The PM and CR times analysis has shown that the department has seen an unfavorable shift from a pro-active approach to reactive approach. The result seeds restructuring the department with addition of supervisor and Biomedical/Clinical Engineer positions. The ultimate goal of this analysis is the realization of an organizational policy that puts the department at the center of all medical equipment acquisitions. As medical device complexity increases over time, need to redefine goals and workflow procedures of the department is realized for the future.

Index Terms – Productivity, Clinical Engineering, Biomedical Engineering, Preventative Maintenance, Corrective Repairs, Technologist

I. INTRODUCTION

The Ottawa Hospital (TOH) is distributed across 3 sites: General campus, Civic campus and Riverside campus (Figure 1).

One hospital, three sites

CIVIC	RIVERSIDE	GENERAL
Civic Campus	Riverside Campus	General Campus
Cardiology Emergency Department Family Health Team Mohs Surgery Clinic Neurosciences Regional Geriatric Program for Eastern Ontario Spinal Surgery Trauma Services University of Ottawa Skills and Simulation Centre (uOSSC) Vascular Surgery Weight Management Clinic – Bariatric Centre of Excellence The Ottawa Hospital Breast Health Centre	Arthritis Centre Eye Care Centre Family Health Team Foustanelas Endocrine and Diabetes Centre Nephrology Shirley E. Greenberg Women's Health Centre	Bone Marrow Transplant Chest Diseases Centre Emergency Department Regional Cancer Program Rehabilitation Centre Robotic Surgery Thoracic Surgery Total Joint Replacement University of Ottawa Eye Institute
Across the campuses		
High-risk obstetrics and prenatal services Mental health Minimally invasive surgery P.A.R.T.Y. (Prevent Alcohol and Risk-Related Trauma in Youth)		

Figure 1: Overview of The Ottawa Hospital (TOH)

In 1998, the Civic Hospital, Ottawa General Hospital and the Riverside Hospital merged and consolidated their services and became The Ottawa Hospital. In subsequent years, the Ottawa

Regional Cancer Centre and The Rehabilitation Centre was amalgamated yielding one of the largest teaching hospitals in Canada. The Ottawa Hospital is now a 1,202-bed care facility with 11 research facilities, standing 5th in terms of overall research funding in Canada and creating an overall impact of \$1.5 Billion solely from research on the Ottawa economy from 2001-2019 [1].

A. Structure of Biomedical Engineering departments

1) The 2019 structure of the Biomedical Engineering Department consists: 0.5 FTE Director, 1 Acting Manager, 1 Biomedical Engineer, 1 CMMS administrator and 31 Technologists out of which 8 are Diagnostic Imaging Technologists (figure 2). Besides Biomedical Engineering, the Director manages two other portfolios.

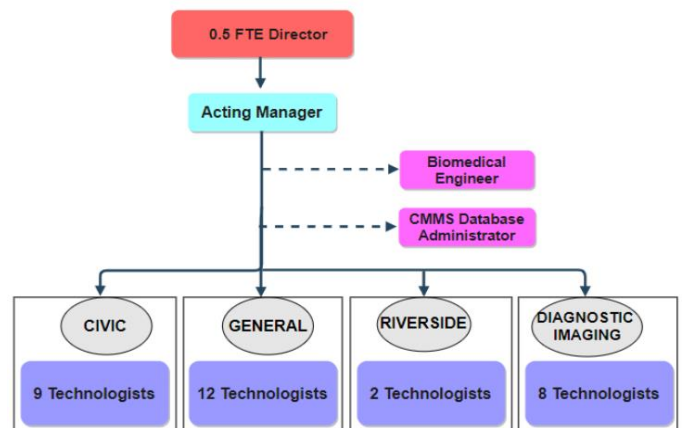


Figure 2: Organisation chart of TOH

2) The 2019 organisational chart of a Canadian paediatric hospital is shown in the figure 3.

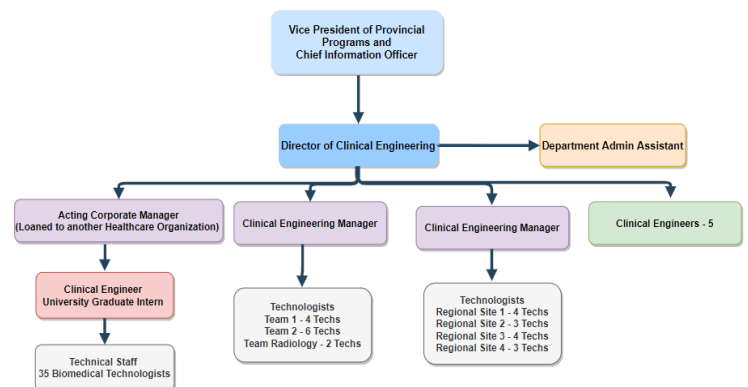


Figure 3: Organisation chart of Canadian paediatric hospital

The organisation manages operations of Biomedical Engineering Department for four other hospitals. The department structure consists of 1 Director, 2 Managers, 4 Clinical Engineers, 1 Clinical Engineering Intern and 26 technologists.

3) The 2020 Organisational chart of a tertiary academic teaching hospital on the Canadian East coast is shown in figure 4.

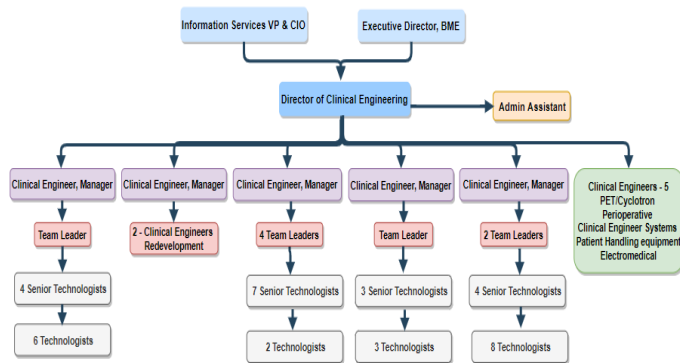


Figure 4: Organisation chart of Canadian tertiary academic hospital on East coast

The network is formed by four major health entities. The department structure consists of: 1 Director, 5 managers, 5 clinical engineers, 5 team leaders, 5 senior technologists and 5 technologists.

4) The 2017 Organisational chart of a tertiary academic teaching hospital on the Canadian West coast is shown in figure 5.

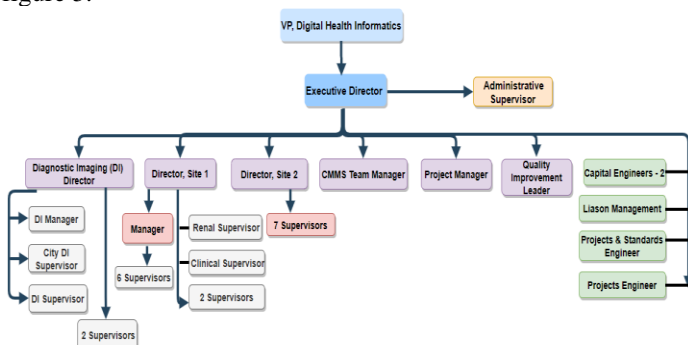


Figure 5: Organisation chart of Canadian tertiary academic hospital on West coast

The collaboration is between four health authorities. There are 184 employees – including 1 Executive Director, 3 directors, 6 Admin staff, 6 Biomedical Engineers, and 18 supervisors, with the rest being senior technologists, consultants, and technologists.

Canadian tertiary academic hospital – East coast	Canadian tertiary academic hospital – West coast	Canadian Pediatric Hospital	TOH – The Ottawa Hospital, Ontario
Clinical + DI >6 hospitals >1 Director >5 Managers >5 Engineers, >8 Team Leads >36 Techs >2 Admin >(4-6 CE interns, Std Techs)	Clinical + DI + Renal + Lab >26 Hospitals >1 Exec Director >3 Directors >3 Managers >5 Engineers >22 Team Leads >153 Techs >5 Admin >(2-4 CE interns, 20-25 Std Techs)	Clinical + DI + Lab >18 hospitals >1 Director >2 Managers >4 Engineers >20 Techs >1 Admin >(1-2 CE interns, 1-2 Std Techs)	Clinical + DI + Lab >3 hospitals >0.5 Director >1 Managers >1 Engineer >36 Techs >2 Admin >(1 CE interns)

Figure 6: Summary of all organizational structures discussed above

Thus, if we compare other healthcare organizations with TOH, our structure looks flat (figure 6).

B. Productivity

One of the earliest definitions of productivity defines productivity as “a measure of efficiency with which we turn out goods or services” [2].

The Biomedical department is responsible for activities like:

1. Preventative Maintenance: scheduled maintenance activity
2. Corrective Repairs: unscheduled maintenance activity
3. Incoming inspections
4. User training and education
5. Strategic planning and pre-procurement technology evaluation
6. Assistance in equipment purchasing decisions
7. Management of Clinical Assets
8. Alerts and recall notifications
9. Incident investigations
10. Disposal of Assets

A task should be included into productivity calculations if a client can reasonably be charged for that service [2].

	Productive	Non-Productive
Chargeable	<ul style="list-style-type: none"> Incoming Inspection Inservice Training Installation Scheduled Inspection Product Evaluation Equipment Modifications Patient Monitoring Hazard Reports Parts Ordering Technical Consultation Preacquisition Planning Service Contract Management Design Services Rounds Repairs 	<ul style="list-style-type: none"> Administrative Meetings Reading General Journals Non-Job Related Classes Employee Activities Non-Work Related Committee Meetings Vacation, Holidays Sick, Break Time
Non-Chargeable	<ul style="list-style-type: none"> Service Training Work Related Departmental Meetings Reading Technical Journals Parts Inventory Test Development Reviewing Codes Updating Manuals Work Related Committee Meetings Shop Cleanup 	

Figure 7: Distribution of activities into chargeable and non-chargeable categories [2].

Activities mentioned in figure 7 may be performed by various staff including Technologists, Engineers, Managers and Clerks.

An assessment of technologist’s tasks at TOH yielded time captured (blue) and not captured (red) in the CMMS (Figure 8).

Chargeable	Non-chargeable	
Preventative Maintenance	Parts inventory	Productive
Corrective Repairs	Asset database management	
Risk Management – A&R, Incident investigations	Departmental meetings	
Incoming inspections	Updating manuals	
Installations/project coordination	Parts ordering – general Service	
Parts ordering – associated to asset	Training – in-house & external	
	Shipping & receiving	Non-productive
Vacations	Shop cleanup	
Sick times	Handling deactivated assets	
Hallway conversations	Equipment packaging	
'Clinical rounds'		

Figure 8: Distribution of activities at TOH into 4 categories

The Biomedical Engineering Department’s operational budget (used for covering operational costs of devices) is “assumed” funded for one to one replacement of aged equipment.

Clinicians may put business cases forward to purchase net new equipment to support their clinical needs. If approved, this additional equipment expands the existing fleet size and puts a strain on the fixed operating budget that are not adequately compensated for these cases.

Planning projects are the bigger projects that may span from 1-3 years. Over the planning and implementation cycle, the intent or needs of the project change or the project extends the estimated timelines which puts additional burden on the capital and operating budget.

ii) **Non-TOH Funding:** Medical equipment is also purchased through well intended non-TOH funding resulting in unknown and unplanned incremental operating costs and labor hours that are not adequately accounted.

The funding may come from research grants, physician/trust accounts, one-time funding or donations from the TOH foundation. The funds provided by these entities is only directed towards the initial purchase of medical devices

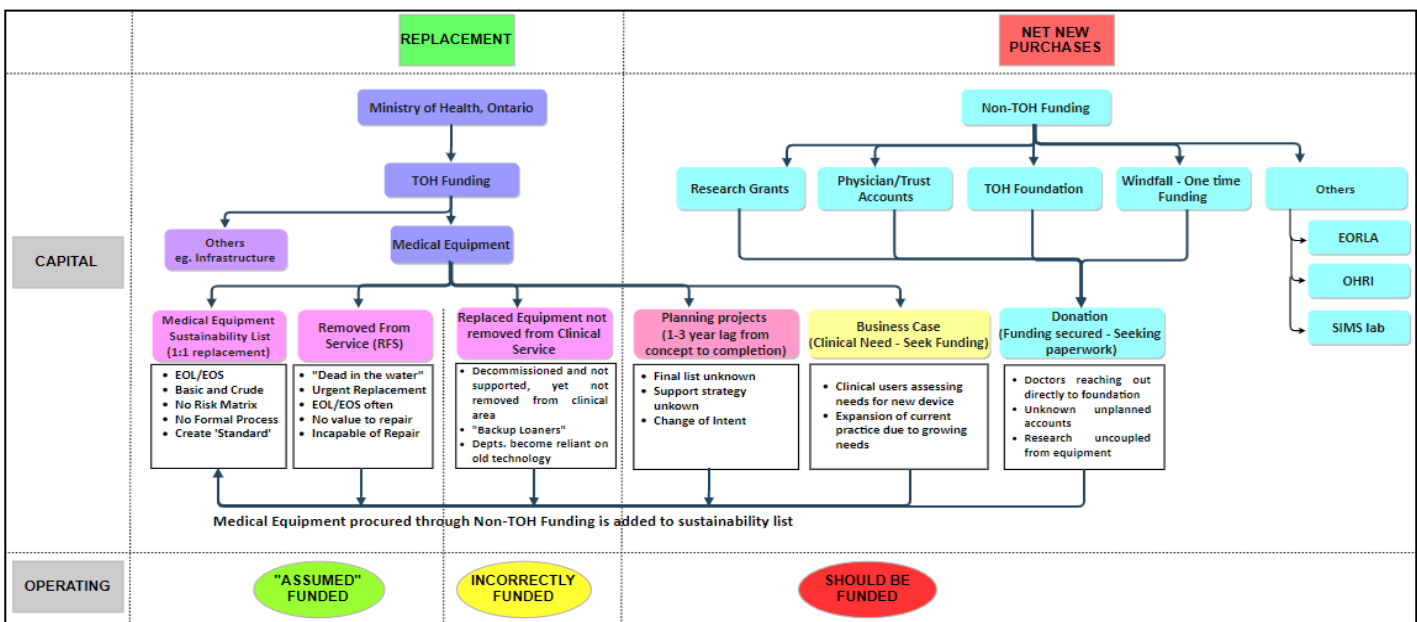


Figure 9: Medical equipment funding at TOH

C. Medical Equipment capital funding at TOH:

Medical device procurement is divided into two main categories Biomedical engineering Department and by other means (figure 9):

i) **TOH Funding:** The capital budget is preferably directed towards replacement of existing medical devices that may be End of Life (EOL) or End of Service (EOS). This planned list is known as the sustainability list. Medical equipment that failed in service before it was able to be replaced requires funding.

without considering the lifecycle costs incurred for maintenance services, service contracts, training of technologists, parts replacement costs, etc.

TOH is affiliated with the University of Ottawa medical school research which often requires specific medical equipment. Research equipment can be procured by research teams and not through the hospital and is not distinguished from ‘standard of care’ clinical equipment. This poses a risk as research equipment may have different maintenance needs and should not be considered a part of the clinical care fleet.

Other groups like EORLA (Eastern Ontario Research Lab Association), OHRI (Ottawa Hospital Research Institute) and

SIMS lab (Skills and Simulation lab) also purchase equipment for which TOH Biomedical Engineering Department either performs maintenance or is involved in other workflows. For these groups, Service Level Agreements have not been laid out making servicing of equipment for these entities by the TOH Biomedical department a ‘grey area’. Medical equipment procured in this manner has become normalized which ends up on the sustainability list, further eroding capital budgets in future years.

D. Roles and responsibilities of Clinical Engineers (CEs) and Biomedical Technologists

The roles and responsibilities of CEs and Technologists are well known and best described by the Health Care Technology Life Cycle [3], though it may expand beyond those listed here. There are two main phases of the lifecycle: Planning and Management with the tasks being distributed between Clinical Engineers and Technologists. The diagram has been edited to demonstrate TOH functions (figure 10).

1. The Planning Cycle starts with assessment of requests that clinical users put in and budgeting the requests. This enables to analyze the valid and invalid requests. Once the capital planning list is generated, data collection and technical analysis is done which leads to acquisition. The acquired devices are deployed to clinical areas which might require work from technologists. The replacement list is generated and acted upon by the CE where inputs from technologists may also be used as they are most aware of concerned clinical areas. Throughout the Planning cycle, inputs and co-operation from other departments is also required such as finance, procurement and facilities. These activities are most often carried out by CEs.

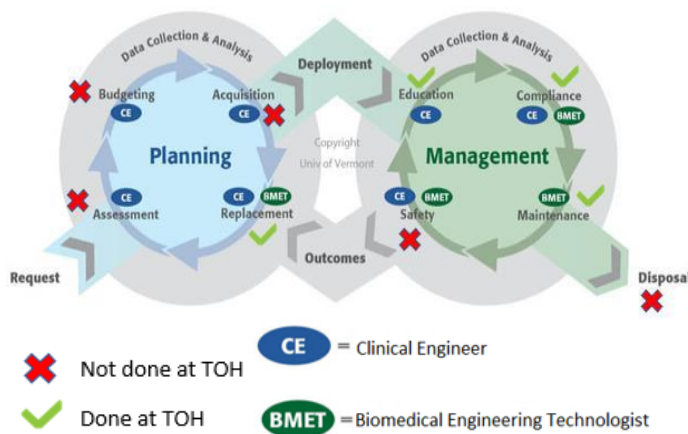


Figure 10: Health Care Technology lifecycle [2]

2. The Management cycle is other important phase of the life cycle and consists of education/training of technologists, management of safety by monitoring alerts and recalls and conducting incident investigations for any patient safety incidents that may be reported through the PSLS (Patient Safety Learning System) in the hospital, regulatory compliance, maintenance in terms of PMs (Preventative

Maintenance) and CRs (Corrective Repairs) and the disposal of end-of-life medical devices. Here it is imperative to have an established process to decommission end-of-life assets safely and effectively.

The Planning and Management cycles work together in harmony to provide optimum outcomes and benefits in terms of cost savings to the healthcare organisations over long terms.

II. BACKGROUND

A) Benchmarking in Hospitals

In 2006, AAMI commissioned ECRI Institute to conduct a study to weigh the pros and cons of developing benchmarks to assess the activities of clinical engineering (CE) department [4]. This study stated that neither the management committee nor the operations group accentuated the CE department’s role in patient safety [3]. Since maintenance activities are assigned majority of the department budget, only these activities were measured even though it was highlighted that CE department perform many other valuable activities to the institution as they were difficult to quantify [3]. This study also pointed out that to successfully determine the effectiveness of the benchmarking among CE departments, comparisons of CE departments in other institutions must be done by establishing peer groups for which each organization must allocate resources for preparing a central database of information with regards to the medical equipment so that feasible information can be assimilated [3].

B) Evolution and need for Clinical Engineering Departments

The main role of clinical engineering was directed towards patient safety in the late 1960s and early 1970s when the first CE departments were established [5]. There have been various research, development and implementation activities for creating an effective staffing model for CE departments (also referred to as ‘Biomedical Engineering Department’) which can be dated to as early as 1982 when the first article by American Society for Hospital Engineering (ASHE) for CE Staffing was published in 1982 [4].

The CE role expanded to equipment acquisition, user training and user education with the main theme being equipment management process lifecycle starting from selection, testing, acquisition, training and final disposition [5].

Not all Clinical Engineering departments are the same. “Teaching hospitals invest roughly six times as much annually as non-teaching hospitals and urban hospitals invest about four times as much as their rural counterparts” which shows that clinical engineering departments in teaching institutions generally support a larger equipment inventory value than their colleagues in non-teaching hospitals [6].

Mostly criteria like ‘hospital size’, ‘number of devices’ and ‘equipment replacement value’ are correlated with the clinical engineering budget, the number of technologists in the department the number of CEs and the total number of technical staff in the department (technicians plus engineers)

when designing clinical engineering staffing patterns in hospitals [5].

C) CE Staffing Literature Review

Others have investigated the relationship between the total number of CE staff and operating beds/”staffed beds” [3] and determined that most CE departments fall around 2.5 FTEs per 100 operating beds and 0.5% of hospital staff and about 5 FTE per 100 adjusted discharges [8]. As a function of number and cost of capital devices, the correlation is 1 FTE per 600 devices and 1 FTE per \$9 million (USD) in assets [8].

Administrative support positions increase proportionally as the number of full-time employees (FTE) grows. Only 50% of the hospitals that have FTEs between 8 and 16 have administrative personnel whereas almost all CE departments that have more than 17 FTEs have such administrative personnel [8].

In a more recent study conducted in 2017 across 201 healthcare organizations, states that “on average, there are almost 14 biomedical technicians (BMETs) per clinical engineer, 23.29% of Clinical Engineering Department (CED) personnel are either managers or clerical staff, 26% of staff are dedicated mainly to maintenance tasks and one FTE per 1083.72 devices (SD 545.69). As a result, in correspondence with this value, most of the workload in CEDs is spent on performing maintenance tasks [9].

Table 1 shows a summary of the two papers reviewed above:

Author, year of publication	Results of study
Wang et. al (2012)	2.5 FTEs/100 operating Beds 1 Admin personnel/17 FTEs 1 FTE/600 devices 1 FTE/\$9 million USD in assets
Miguel et. al (2017)	1 Admin personnel/14 FTEs 1 FTE/1083.72 devices ± 545.6(SD)
The Ottawa Hospital (2019)	0 Admin personnel/ 35 FTEs 1 FTE/918 devices

Table 1: Summary of results from Wang (2012), Miguel (2017) and TOH (2019)

III. PROCEDURE

Staff productivity evaluations are based on following reports derived from the Computerized Maintenance Management System (CMMS): medical equipment asset inventory list, Preventative Maintenance (PM) history from 2016-2019, PM forecast report from 2020 to 2023, Corrective Repairs Work Order (WO) report from 2016-2019 and operating and capital budget from 2014-19.

The following assumptions and constraints should be considered:

1. Forecasted data for future years 2020-2023 was linearly extrapolated and the number of technologists’ positions would remain constant.
2. Diagnostic Imaging (DI) equipment, hours and technologists are not in the scope of this report. This is

because DI has a unique workflow and requires different metrics for productivity evaluation.

A) Productive work hours at TOH

The calculation of productive work hours per technologist was done as follows:

- 52 weeks/year * 37.5 hours/week = 1957.5 hours (According to the collective agreement between the union and the hospital)
- Statutory holidays in Canada: 12 days * 7.5 hours/day = 90 hours. (From union collective agreement [8].)
- Sick Leave: The HR system was queried and the average sick leaves per year per technologist was calculated to be 60 hours per year.
- Vacation Leave: vacation entitlement based on seniority (table 2) as per the Collective Agreement.

NO.	DESCRIPTION	Days/weeks
1.	Less than one year of completed continuous service (CCS)	1.25 days per month of CCS
2.	After one year of completed continuous service	3 weeks
3.	After three years of completed continuous service	4 weeks
4.	After eleven years of completed continuous service	4 weeks plus 1.25 days
5.	After twelve years of completed continuous service	5 weeks
6.	After twenty or more years of completed continuous service	6 weeks
7.	After twenty-seven or more years of completed continuous service	7 weeks

Table 2: Vacation leave hierarchy at TOH Biomedical Engineering Department

Based on current staffing, the following vacation entitlements are used:

NUMBER OF WEEKS	NUMBER OF TECHNOLOGISTS
3 weeks	2
4 weeks	8
5 weeks	10
6 weeks	5

Table 3: Summary of entitled vacations for technologists

The average calculated vacation leave is 5.3 weeks/year or 199.8 hours per year for each Biomedical Engineering technologist. (Note: Diagnostic Imaging technologists were included in the vacation calculation). The vacation entitlement of 5.3 weeks/year is comparatively higher than other healthcare organizations which is a factor of aging workforce.

DESCRIPTION	HOURS
Total FTE time per tech per year	1957.5 hours
Statutory Holidays	90 hours
Vacation Leave	199.8 hours
Sick Leave	60 hours
Training	- (Not captured)
Available work hours per year	1607.4 hours
70% Productivity hours per year per technologist	1157.3 hours

Table 4: Summary of breakdown of hours for 1 FTE.

Training: The hours spent on training per year for Biomedical technologists is not well captured and is not available for this report.

Efficacy: A generally agreeable and published efficacy factor of 70% was used to calculate the efficient hours per technologist per year [7]. Therefore, 70% of 1607.4 hours = 1157.3 hours/FTE which is used in further calculations (Table 4).

B) Yearly PM and CR calculations

Table 5 captures details like cancelled PMs, Closed/complete PMs, training hours, etc. to compare these values to the forecasts. The table is divided into five parts: Preventative Maintenance (PM), Risk Management, Training (in-house and external), Corrective Repairs (CR) and Technologists hours and devices. Values for 2016 to 2019 were obtained from the WO reports and future years 2020-2023 were linearly extrapolated.

The average length of time per PM includes the time to complete the maintenance and the time to log the call into the CMMS. The average time does not include locating equipment or travel time.

for each year is based on the 'date purchased column in CMMS.

During these calculations, cancelled or pending WO hours have not been considered to improve accuracy.

C) Capital and Operating Budget

Key parameters of the operating budget are shown from 2014 to Q4 2020 with comparisons between budget allocated and spent (Table 6).

The operating budget is divided into:

- a) Labour services: This category accounts for the budget spent in salaries to the technologists. Since the number of technologist positions has remained constant since 2014, there is not a large variation.
- b) Equipment maintenance contracts: This is the budget spent on maintenance contracts with vendors of devices. These are usually multi-year but may need to be renewed or the conditions changed when required.
- c) Computer software maintenance: The budget spent for maintenance of software or other software-based activities like

Year	ACTUAL				FORECASTED			
	2016	2017	2018	2019	2020	2021	2022	2023
Preventative Maintenance								
Total number of PMs	8369	8178	8090	7234	6853	6523	6838	6517
cancelled PMs	1426	2154	2041	74	--	--	--	--
closed, complete PMs	6944	6025	6050	7164	--	--	--	--
PM Hours not being done (VSMs, Baxter Sigma Pumps)	4585	4603	4633	4735	4759	4807	4855	4903
Generated PM hours	11007	10687	10447	10124	9268	8852	9231	8846
Actual PM hours (closed, complete)	9225	8403	7725	5897	5146	4080	3013	1947
Hours that will be spent if all PMs are done	13810	13006	12358	10632	9905	8887	7868	6850
Risk Management (hours)								
Hours spent	112	109	111	70	--	--	--	--
Training (in-house & external) (hours)								
Hours spent	150	195	90	105	--	--	--	--
Corrective Repairs								
Total number of CRs	8703	9258	9733	10620	11135	11758	12380	13003
Forecasted CR Hours (generated CRs for 2016 to 2019)	14282	14065	15600	15960	16597	17256	17915	18573
Actual CR hours (closed, complete)	14257	14030	15575	15938	--	--	--	--
Total "Actual" hours spent on CRs and PMs	23482	22433	23300	21835	25865	26108	27146	27419
Total "Required" hours spent on CRs and PMs	28067	27036	27933	26570	30314	30542	31515	31771
Technologists, hours and devices								
Total technologists	23.4	23.4	23.4	23.4	23.4	23.4	23.4	23.4
Total hours for all technologists (1607 hours)	37604	37604	37604	37604	38568	38568	38568	38568
Available technologist hours with 70% productivity (1124.9 hours)	26323	26323	26323	26323	26323	26323	26323	26323
Total number of devices	19405	20149	20770	21483	22156	22818	23510	24183
Number of devices per technologist	829	861	888	918	947	975	1005	1033

Table 5: Calculation of hours spent on PMs, CRs, Training, Risk Management and available hours.

Here to calculate the total PMs per year, the Preventative Maintenance (PM) history from 2016-2019, PM forecast report from 2020 to 2023 and Work Order (WO) report from 2016-2019 was used. These reports catalogue various details like Asset Description, ECRI Asset Category, hours charged, WO Status and Closed date .

The number of cancelled PMs have gone down for the year 2019 as the PMs for Infusion pumps and Vital Signs Monitors were generated before and had to be manually cancelled but as of 2019, appropriate changes to the system have been made so that those PMs are not generated. A decision was made in prior years to PM these devices on a 'best effort' due to shortfall in available resources. The total number of devices

electronic medical record implementation may be accounted in this category.

d) Purchased services: These services may account for the consultants being brought in to offload the work being done by the technologists or contributed to planning and capital acquisition projects.

e) Medical parts: Budget spent on purchasing parts to keep the existing fleet operational.

Year	Budget	Labour Services	Equipment Maintenance Contracts	Computer Software Maintenance	Purchased Services	Medical Parts
FY2014	Allocated	\$2.1 M	\$1.6 M	\$10 K	\$1.3 M	\$1.7 M
	Spent	\$2 M	\$1.4 M	\$47 K	\$1.4 M	\$2.1 M
FY2015	Allocated	\$2.1 M	\$1.6 M	\$10 K	\$1.2 M	\$1.6 M
	Spent	\$2 M	\$1.6 M	\$0	\$1.2 M	\$2 M
FY2016	Allocated	\$2.2 M	\$2.4 M	\$10 K	\$375 K	\$1.7 M
	Spent	\$2.1 M	\$2.6 M	\$0	\$624 K	\$1.7 M
FY2017	Allocated	\$2.2 M	\$2.9 M	\$362 K	\$219 K	\$1.7 M
	Spent	\$2.2 M	\$2.8 M	\$229 K	\$47 K	\$2.2 M
FY2018	Allocated	\$2.4 M	\$3 M	\$386 K	\$219 K	\$1.7 M
	Spent	\$2.3 M	\$3.2 M	\$229 K	\$3 K	\$2.2 M
FY2019	Allocated	\$2.4 M	\$3.2 M	\$386 K	\$219 K	\$2.1 M
	Spent	\$2.2 M	\$3 M	\$196 K	\$10 K	\$2.9 M
FY2020 (Oct)	Allocated	\$1.2 M	\$1.8 M	\$198 K	\$112 K	\$858 K
	Spent	\$1.1 M	\$1.3 M	\$15 K	\$7 K	\$1.8 M

Table 6: Calculations of various components of the operating budget

Capital budget is allocated for purchase of new devices and may also include implementation costs in exceptional cases (table 7).

The capital is divided into allocated which is the capital budget allocated for that year, carryover which is the budget that could not be spent in the previous year and was thus added to current year and total budget for the year which is the sum of allocated capital and carryover from previous year.

Year	Capital Allocated	Carryover (Previous Year)	Total (Capital + Carryover)
2015/2016	\$22.9 M	\$3.9 M	\$26.8 M
2016/2017	\$16.7 M	\$8.9 M	\$25.7 M
2017/2018	\$9.5 M	\$7.5 M	\$17 M
2018/2019	\$6.9 M	\$8.9 M	\$15.9 M
2019/2020	\$5.6 M	\$8.6 M	\$14.2 M

Table 7: Overview of capital budget

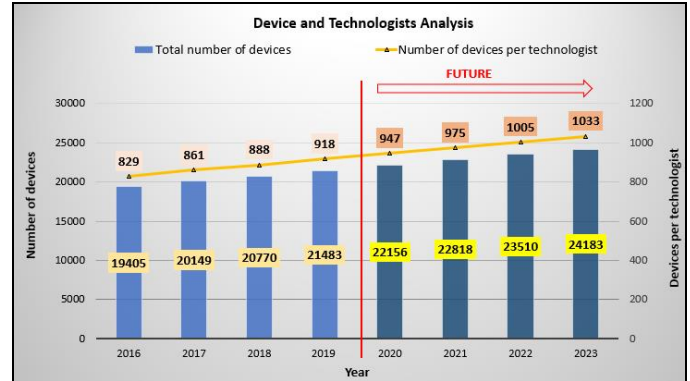
IV. RESULTS AND DISCUSSION

A) Increase in device count

The number of devices has increased by 10% over the last 4 years even though the number of technologists has remained constant (graph 1). Thus, the number of devices per technologist has increased every year which has increased the work load and responsibility for each technologist. This trend coupled with lack of workflow management and work distribution, has caused an erosion in the quality of work. Burdened resources are often unable to fully service newer more complex devices in the absence of appropriate training and meet the maintenance strategy of existing devices, creating a vicious cycle.

The increase in number of devices is due to the purchase of net new (i.e. not 1:1 replacement) equipment every year. It must also be noted that the addition of newer devices to the current fleet may happen without getting rid of the old equipment. Often such equipment is stored in the corners of

hallways as “backup equipment” or “donated” from one department to another department instead of being decommissioned.

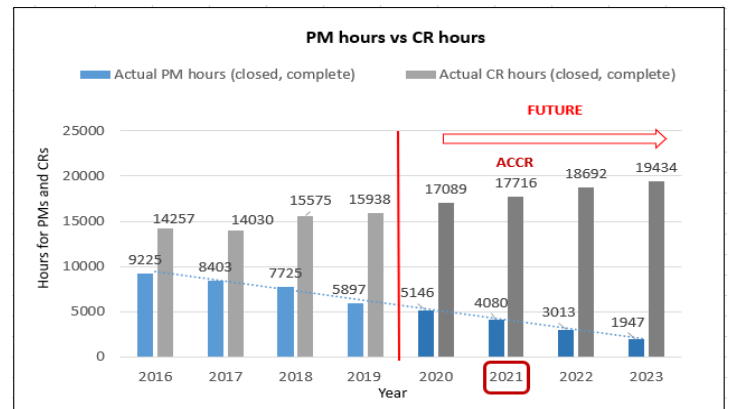


Graph 1: Portraying growth in number of devices and number of devices per technologist

The increase observed is representative of the growth of TOH considering the increase in incoming patients and expansion of clinical areas year over year.

B) PM hours vs CR hours

Preventative Maintenance (PM) is a pro-active strategy where devices are scheduled for maintenance and allows the department to efficiently manage devices and eliminate risk of device failure during clinical use [14].



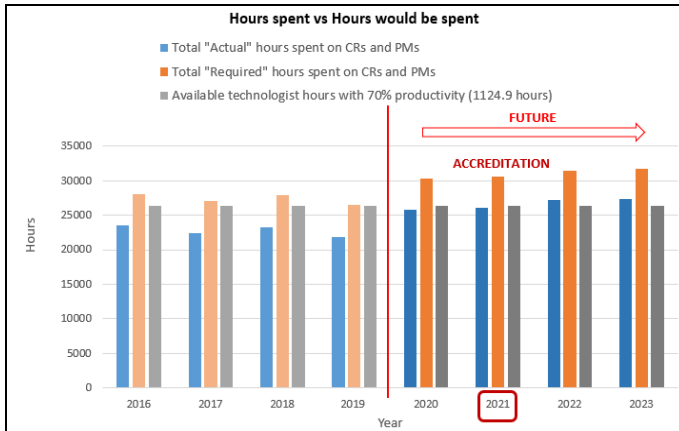
Graph 2: Comparison between PM and CR hours over last 4 years and predictions for the future

Corrective Repair (CR) is a reactive strategy where broken devices are brought to the attention of the department and are fixed on a best-effort basis [14]. Performing regular PMs ensure that CRs are kept to a minimum and increase life and durability of the equipment.

The analysis demonstrates that PM hours follow a declining trend although traditionally it is expected to be flat-lined. On the other hand, the CR hours have increased every year (graph 2).

These trends show the department is reactive rather than a pro-active strategy, which is a result of inadequate PMs due to lack of available hours and inability to replace old devices in a timely manner. C) Total hours distribution over the years

Initial observation of graph 3 shows that the number of technologist hours available is more than the number of hours spent on CRs and PMs.



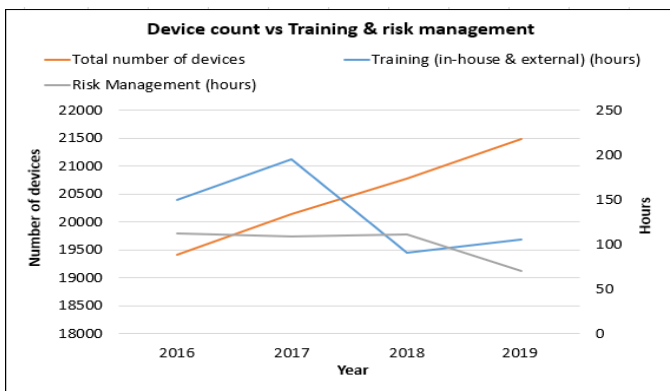
Graph 3: Distribution of technologist hours into spent, available and would be spent

However, besides PM and CR, the technologists also spend time on Incoming inspection, locating devices scheduled for PMs, shipping and receiving, etc. that is not currently captured. If captured, this would justify the available hours and show true value of the department.

As the years progress, the predicted hours spent on PMs and CRs increase in such a manner that the balance between available hours and actual hours seems to decline due to increase in number of devices as the years go by.

D) Analysis of device count vs training and risk management

Although the number of devices have increased at TOH over the last 4 years, the time spent on training (in-house and external) and risk management (Alerts, Recalls, Incident investigations) activities has gone down sharply (graph 4). This trendline shows that the department does not have compliment of resources to complete and track the risk management work orders.



Graph 4: Trends for device count compared with training and risk management hours

Currently, these tasks are done on a best effort basis with no way to ensure that all the alerts and recalls issued by the vendors as well as incident investigations are performed. This

increases the liability and risk to the organization as analysis and mitigation actions may not be taken by the Biomedical Engineering Department in case of an event.

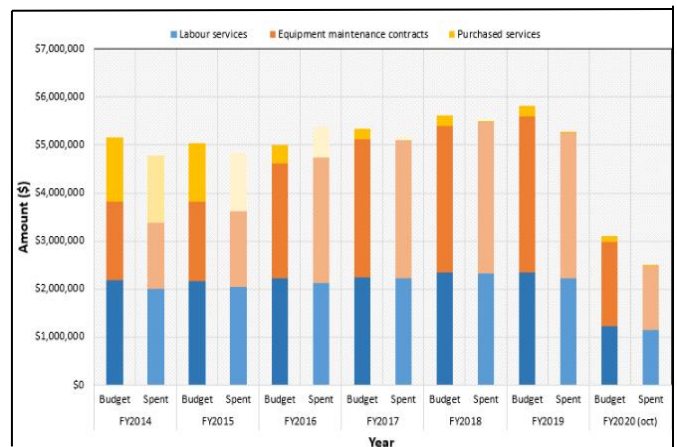
E) Operating Budget Analysis

Spending on purchased services has been cut by 99% over a 6-year period (graph 5). Purchased services may account for the consultants being brought in to offload the work being done by the technologists or contributed to planning and capital acquisition projects.

Maintenance contracts has increased 50% from 1.36M to 2.66M.

The spend on labor services has remained constant as no new technologist positions were created. (graph 5).

In summary, the maintenance strategy of the department has been to rely on service contracts to address the increase in devices and a lack of investment in in-house resources.

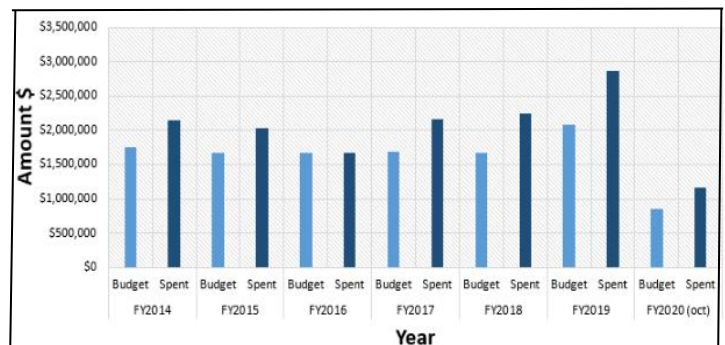


Graph 5: Analysis of the Operating Budget, breakdown into labor services, equipment maintenance contracts and purchased services is shown.

The scope of work that had been done by purchased services has not disappeared, instead it has been offloaded on the current resources in the department without consideration of their existing workload.

Medical Parts:

There has been a trend of overspend over medical parts in the last 5 years (graph 6) which corroborates with PM and CR trends previously discussed.



Graph 6: Operating budget for medical parts

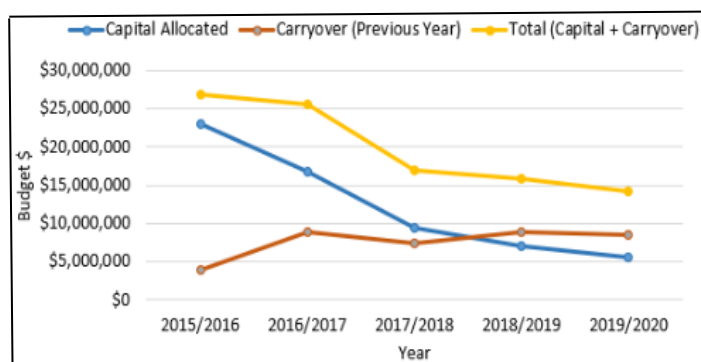
This demonstrates that the current fleet is kept operational by spending more on parts and performing more Corrective Repairs instead of pro-actively replacing devices in a timely manner to minimize the repair costs.

The inability of performing capital planning and acquisition points to the need for Biomedical/Clinical Engineers who can analyse the clinical needs/asks and drive planning and purchasing of medical devices.

F) Capital Budget Analysis

Over the last 5 years, the capital budget for the Biomedical Engineering Department has steadily decreased. The allocated capital has decreased by 75% (from \$22.9M to \$5.6M) whereas the carryover has increased by 55% (from \$3.8M to \$8.5M) (graph 7).

As less money is spent on capital, the age of fleet increases which increases risk of failures and hours spent on Corrective Repairs. There has been inadequacy of appropriate staff required to assist in purchasing new medical devices and keep the fleet functional in a timely manner.



Graph 7: Capital Budget for medical devices

Also, no staff in the department is available to oversee planning of new purchases for the coming years, addressing a gap in planning department and navigating donation requests.

G) Points to be considered:

- **Number of devices per technologist:** The FTE per number of devices at TOH falls between the two at 1 FTE per 918 devices in 2019. However, there is no universal method for determining if an asset must be added to the CMMS as a medical device [15]. The line between medical and non-medical device often is blurred making it necessary for organizations to come up with their own standard definitions. This ambiguity makes it difficult to qualify FTE requirement.
- **Number of admin per FTE:** Currently, TOH falls short at 0 admin personnel for 35 FTEs. Thus, a recommendation can be made to consider appointment of admin personnel to take care of duties like overseeing current PM and CR program, inventory management and defining scope and responsibility of the department.

- **Diagnostic Imaging (DI) Technologists not included:** DI is not in the scope of this report as they have a unique workflow. The average length of time required to service a DI device differs from a non-DI device. Thus, different benchmarks and analysis methods must be applied to analyze the productivity of this sector.

- **Vision for the future:** A radical shift from current workflow and principles is being observed worldwide within Clinical/Biomedical Engineering Departments in healthcare organizations. As device complexity increases with introduction of advanced software technology and medical device integrations, the need to redefine the goals and ways of functioning is seen. Introduction of Electronic Health Record systems and the integration of medical devices make it necessary to realize the impact and assess security needs during planning and maintenance of devices. This broadening of horizons takes the technologists away from basic work like Preventative Maintenance and Corrective Repairs and introduces a level of complexity to their work that must be accounted.

- **Cost cutting in CE departments:** With the cuts in budget by Ministry of Health accompanying recessions and other environmental influences, the need for achieving cost savings in healthcare organizations is eminent [9]. There have been some ripples in the Canadian healthcare organization; for example, in 2009 the British Columbia Ministry of Health directed 4 separate Biomedical engineering Departments to consolidate into one that was appointed as the lead authority and to reduce the operational budget by 10 per cent. Such directives may be released by other provincial healthcare authorities in Canada to achieve cost savings. Thus, organizations must have a broader perspective to be able to onboard such directives if issued in the future.

V. RECOMMENDATIONS

1. **Analysis of service contracts:** Service contracts is an area that currently shows major spends for the department and where a scope of cost savings is seen. An effort must be made to do a cost comparison between in-house maintenance costs and establishing service contracts with external groups (e.g. vendors).

2. **Making a change from current CMMS platform:** One of the major problems faced by the department is lack of functional CMMS platform. The current CMMS does not consider the technological needs of Biomedical department which created problems in day-to-day functioning of the department. With Introduction of a Biomedical compliant CMMS solution, key issues like addition and disposal of assets, creation and accurate recording of work orders and planning and implementation strategizing of new devices will be addressed.

3. Restructuring of the department (Figure 11):

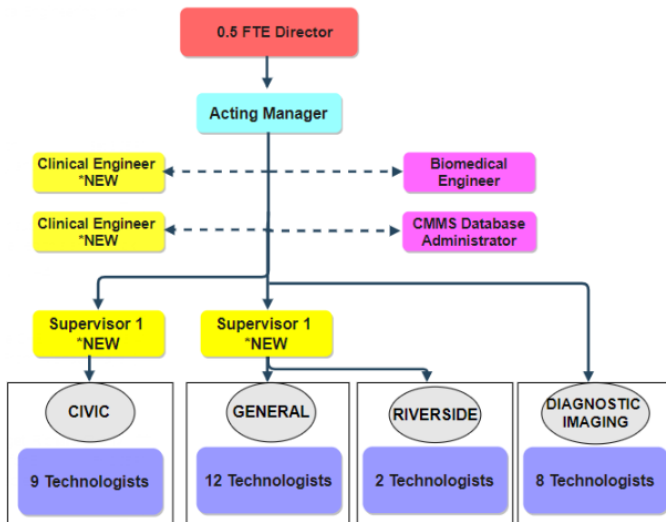


Figure 11: Restructuring of department

The addition of two supervisor positions and two Clinical Engineering positions is recommended.

4. *Creation of policy to make Biomedical department the center of technology purchase and management:* Currently, other entities beside Biomedical engineering also purchase new medical devices without any involvement from the department as discussed in previous sections of this paper. An organization wide policy must be introduced to have Biomedical Engineering Department at the forefront of all medical device acquisitions from TOH as well as non-TOH funding.

VI. CONCLUSION

Justification of the existence, cost and an improvement of the quality of the services provided by the CE departments were valid questions since the 1990s and will probably continue to surface until the field reaches its full maturity [10].

Job satisfaction can be improved by providing appropriate motivation, goals, recognition and continuous training in the form of service courses [10].

Communication between clinical engineers in a certain geographical area can be excellent for the morale of the personnel and may add power to the purchasing base that they each influence. [10].

“Acquiring additional resources can often be achieved through the cancellation of service contracts, provided that the training and parts are available and that the work can be done in a cost-effective manner. In this way, the clinical engineering department becomes more thoroughly involved and supportive and can provide help in the overall technology planning for a variety of specialties found in today's hospital.” [10]

Restructuring the department by taking a top-down approach at TOH will help analyse the productivity of the department

and provide justification to avoid any cost-cutting in the future as budget continues to be reduced in the Canadian Healthcare system.

VII. FUTURE WORK

Further analysis is required to understand the current state of the department and provide more effective strategies and solutions. For example, analysis by site to obtain the number of devices per technologist and a cellular analysis of workload per technologist will help in achieving a balance and reducing waste to achieve greater efficiency.

Formation of a new risk-based PM program will redirect the efforts of the technologists in the right direction without compromising patient safety or the safety function of the devices.

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