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# Scheduling According to Physician Average Procedure Times in Endoscopy Suites

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## Abstract

In 2007 Ontario implemented the first Canadian screening program for colorectal cancer (CRC). As a result, the demand for colonoscopies has increased, creating a need to increase capacity in endoscopy suites. After observing six Ontario endoscopy suites, we decided to focus on improving procedure scheduling. We consider how patient throughput as well as staff and resource utilization would be affected by scheduling procedures based on physician average procedure times. We generate appointment schedules and use them as input to a generic discrete event simulation model. In the simulation, we further consider the impact of adding urgent patients, decreasing room turnover time, and changing the physician to room ratio.

**Keywords:** generic discrete event simulation, colorectal cancer, endoscopy, procedure scheduling

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# 1. Introduction

Colorectal cancer (CRC) is the second most common cancer in the developed world and the third most common worldwide, but with regular screening, it can be detected and treated in its early stages with a 90% cure rate [1]. However, in 2007, only 24% of the eligible Ontario population was screened for CRC. If left untreated until advanced stages, the cure rate for CRC falls to approximately 10% [2].

In response to the low CRC screening rate, in 2007 Ontario implemented the first screening program for CRC in Canada, targeting individuals between the ages of 50 and 74. Its goal is to increase the screening participation rate to 40% by 2011 [2]. All participants at increased risk of CRC or who have a positive result on the screening test are recommended for colonoscopy. As a result, the demand for colonoscopies has increased, creating a need to increase throughput in endoscopy suites, where these procedures are performed.

This paper describes the development of a generic discrete event simulation model to identify throughput gains from scheduling according to physician average procedure times in the endoscopy suite. A literature review provides an overview of factors leading to an efficient endoscopy suite, details generic simulations, and gives some insight into procedure scheduling techniques. The amount of overtime and undertime required by each physician is calculated and used in an attempt to validate the simulation.

# 2. Literature Review

## 2.1 Endoscopy Suite Efficiency

A number of researchers have investigated factors leading to efficient endoscopy suites. There is agreement that shorter room turnover times lead to greater patient throughput [3,4]. However, this observation depends on how many procedure rooms each physician is using. Zamir and Rex state that the suite is more efficient when each physician uses two procedure rooms [4]. In a later paper, Rex et al. make the qualification that although this arrangement is more efficient for physicians, it can lead to a 24 to 41 percent decrease in non-physician staff utilization [5]. Denton et al. investigate assigning OR teams to more than one endoscopy procedure room, finding that patient throughput is greater when these teams are responsible for four rooms versus when there are two teams who are each responsible for two procedure rooms [6]. Patient throughput is also improved through shorter patient recovery times, as found by Grossman et al. in their simulation of an endoscopy lab. They simulated the lab for twenty days and evaluated the increase in patient throughput and reduction in length of stay (LOS) gained by reducing patient preparation, procedure, and recovery times by 25 to 75 percent. Grossman et al. determined that combining improvements in these three areas led to the greatest overall results, but if only one area was to be improved, recovery time reduction would give the best results [7]. These studies indicate that an efficient endoscopy suite maximizes patient throughput by streamlining turnover times, effectively utilizing staff, and minimizing patient preparation, procedure, and recovery times.

### 2.2 Generic Simulation Models

Genericity, also known as composability or reusability, has developed into an important simulation modeling concept. As such, numerous approaches and frameworks of genericity have been discussed and developed. Focussing on hospitals, Fletcher and Worthington provide a categorization of these approaches into four levels of genericity [8]. Their categorization expands on the three level description by Sinreich and Marmor [9]. An adaption of this categorization is shown in Figure 1.

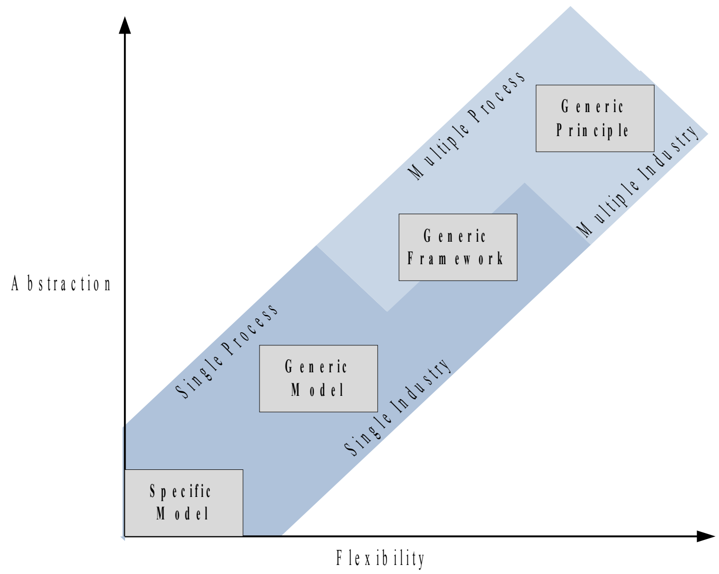


*Figure 1: Four levels of genericity for simulation models [8]*

This categorization is based on the level of abstraction and flexibility of each model. The four types of models are listed in the boxes with a dark blue background indicating that they apply in one single process and industry and a light blue background indicating that they apply to multiple processes or in multiple industries. The categories range from specific models, which are developed for a single process in a single industry at a single location to generic models, which can be applied to multiple sites in a single industry, and further to generic framework and principle models, which are applicable to multiple processes and in multiple industries, respectively. Most health care simulations are specific models, as they focus on individual hospital units [10]. However, generic health care models are becoming more prevalent. See, for example [9,11,12].

## 2.3 Procedure Scheduling

Scheduling procedures into operating rooms accurately is difficult due to the uncertainty associated with surgical procedures. Dexter et al. found that surgeon's mean procedure times provide reasonably accurate estimates of the actual procedure duration. However, scheduling based on these times fails to minimize overtime or undertime [13]. Since most surgical times have been found to follow a left truncated lognormal distribution, some surgeries may take much longer than their mean due to the long tail of this distribution [14-17]. Thus, Alvarez et al. suggest that the 75$^{th}$ percentile may be a better predictor of procedure durations [18].

## 3. Methodology

Although endoscopy procedures tend to be shorter and less variable than surgical procedures, similar scheduling techniques can likely be applied to improve throughput and utilization in the endoscopy suite. Procedure scheduling data from six Ontario hospitals showed wide variation in the amount of time scheduled for endoscopy procedures, as shown in Table 1. For instance, the minimum time scheduled for colonoscopy procedures at these sites is 20 minutes, but the maximum time is double this at 40 minutes. Furthermore, most of the hospitals were unsure of why they scheduled according to these procedure durations. It should be noted that hospital C actually schedules according to physician average procedure times, rounded up to the nearest five minutes.

*Table 1: Variation in scheduled procedure durations (minutes) among six hospitals*

| Hospital | Colonoscopy | Gastroscopy | Colonoscopy + Gastroscopy | Flexible Sigmoidoscopy |
|---|---|---|---|---|
| A | 25 | 15 | 35 | N/A |
| B | 20 | 20 | 20 | 20 |
| C | 20 | 15 | 25 | 20 |
| D | 40 | 20 | 60 | 20 |
| E | 30 | 15 | 45 | 15 |
| F | 30 | 15 | 45 | 15 |

If we consider physician-specific times for colonoscopy procedures at hospital B, we obtain the means and standard deviations shown in Table 2. These data are based on procedures performed in fiscal year 2008. Hospital B schedules colonoscopy procedures for 20 minutes, but all physicians except B3 have procedure times less than 20 minutes. Additionally, there is a range of 10 minutes between the lowest and highest mean procedure times. Similar observations were made for other endoscopy procedures at this site, indicating that the hospital could benefit from physician-specific procedure scheduling.

*Table 2: Average physician procedure durations for colonoscopies at hospital B*

| Physician | Colonoscopy Cases (2008) | Mean (min) | Standard Deviation (min) |
|---|---|---|---|
| B1 | 464 | 19 | 7 |
| B2 | 285 | 14 | 5 |
| B3 | 29 | 23 | 7 |
| B4 | 168 | 15 | 6 |
| B5 | 488 | 19 | 8 |
| B6 | 326 | 16 | 6 |
| B7 | 290 | 13 | 5 |

*Means and standard deviations have been rounded up to the nearest minute.*

The extent to which a hospital could benefit from physician-specific scheduling depends on factors such as the number of procedure rooms assigned to a physician, the rate of urgent patient arrivals, room turnover time (the time between when the current patient leaves the procedure room and the next patient enters it), and recovery capacity. Thus, we decided to build a discrete event simulation model of the endoscopy suite from patient arrival to discharge in order to determine the benefits of physician-specific scheduling. We created a generic model so that it could be used to assess potential throughput gains in any endoscopy suite, a particularly important consideration given the requirement that Ontario hospitals increase endoscopy throughput as a result of the colorectal cancer screening program.

### 3.1 The Generic Discrete Event Simulation Model

The generic discrete event simulation model uses hospital-specific data read in from Excel input files to create a simulation for each hospital site. Input data include the hospital's endoscopy block schedule, an approximate wait list length for each physician performing endoscopy procedures, the case mix of each physician, scheduled durations of each frequently (10 or more times per year) performed procedure, the physician-specific mean, standard deviation, and minimum procedure durations for each of the frequently performed procedures or data from which this information can be calculated, and the average turnover time for each procedure. Many of these inputs can be calculated from a year's worth of hospital data that include the procedure type, the physician who performed this procedure and the duration of the procedure.

The simulation consists of two parts: a scheduler and a simulation model built using Arena. The scheduler generates a wait list for each physician using his/her procedure case mix. This wait list is assumed to be in order of patient priority. Using this wait list, the scheduler generates two 20-day endoscopy schedules according to the hospital's block schedule. The first schedule uses the durations the hospital currently schedules for each procedure. That is, if the hospital currently allots 20 minutes to a colonoscopy procedure, this is the amount of time allotted by the scheduler. The second schedule uses physician-specific average durations for each procedure. In each case, procedures are assigned to a block until there is no longer enough time remaining in the block to schedule an additional procedure. A portion of a generated schedule is shown in Figure 2.

| | A | B | C | D | E | F | G | H | I | J |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Week | Day | Block Start | Block End | Arrival Time Room 1 | Arrival Time Room 2 | Time Between Arrivals | Procedure Start | Start - Arrival | Procedure |
| 2 | 0 | Mon | 07:30 | 12:30 | 06:10 | | 370 | 08:10 | 120 | ""ERCP"" |
| 3 | | | | | | 06:30 | 20 | 07:30 | 60 | ""GASTRO"" |
| 4 | | | | | 06:50 | | 20 | 07:50 | 60 | ""GASTRO"" |
| 5 | | | | | | 07:50 | 60 | 09:50 | 120 | ""ERCP"" |
| 6 | | | | | 08:10 | | 20 | 09:10 | 60 | ""COLONOSCOPY + GASTR( |
| 7 | | | | | | 08:30 | 20 | 09:30 | 60 | ""GASTRO"" |
| 8 | | | | | 09:50 | | 80 | 10:50 | 60 | ""COLONOSCOPY"" |
| 9 | | | | | | 10:10 | 20 | 11:10 | 60 | ""COLONOSCOPY"" |
| 10 | | | | | 10:30 | | 20 | 11:30 | 60 | ""GASTRO & DILATATION"" |
| 11 | | | | | | 10:50 | 20 | 11:50 | 60 | ""GASTRO"" |
| 12 | | | | | 11:10 | | 20 | 12:10 | 60 | ""COLONOSCOPY + POLYPE |
| 13 | 0 | Mon | 14:00 | 18:00 | | 13:00 | 110 | 14:00 | 60 | ""COLONOSCOPY"" |
| 14 | | | | | 13:20 | | 20 | 14:20 | 60 | ""COLONOSCOPY + POLYPE |
| 15 | | | | | | 13:40 | 20 | 14:40 | 60 | ""COLONOSCOPY"" |
| 16 | | | | | 14:00 | | 20 | 15:00 | 60 | ""COLONOSCOPY"" |
| 17 | | | | | | 14:20 | 20 | 15:20 | 60 | ""COLONOSCOPY"" |
| 18 | | | | | 14:40 | | 20 | 15:40 | 60 | ""COLONOSCOPY"" |
| 19 | | | | | | 15:00 | 20 | 16:00 | 60 | ""COLONOSCOPY"" |
| 20 | | | | | 15:20 | | 20 | 16:20 | 60 | ""COLONOSCOPY"" |
| 21 | | | | | | 15:40 | 20 | 16:40 | 60 | ""COLONOSCOPY"" |
| 22 | | | | | 16:00 | | 20 | 17:00 | 60 | ""COLONOSCOPY"" |
| 23 | | | | | | 16:20 | 20 | 17:20 | 60 | ""COLONOSCOPY + POLYPE |
| 24 | | | | | 16:40 | | 20 | 17:40 | 60 | ""COLONOSCOPY"" |
| 25 | 0 | Tues | 07:30 | 12:30 | | 06:30 | 830 | 07:30 | 60 | ""COLONOSCOPY + GASTR( |
| 26 | | | | | 07:05 | | 35 | 08:05 | 60 | ""COLONOSCOPY + POLYPE |
| 27 | | | | | | 07:25 | 20 | 08:25 | 60 | ""COLONOSCOPY"" |
| 28 | | | | | 07:45 | | 20 | 08:45 | 60 | ""COLONOSCOPY"" |
| 29 | | | | | | 08:05 | 20 | 09:05 | 60 | ""GASTRO"" |
| 30 | | | | | 08:25 | | 20 | 09:25 | 60 | ""COLONOSCOPY + GASTR( |
| 31 | | | | | | 09:00 | 35 | 10:00 | 60 | ""COLONOSCOPY"" |
| 32 | | | | | 09:20 | | 20 | 10:20 | 60 | ""PEG"" |

Sch Proc Times Room 1 / Actual Proc Times Room 1

*Figure 2: An example of a generated block schedule*

The basic structure of the Arena simulation model is shown in Figure 3. Patients arrive according to the time between arrivals from the generated block schedule. They are then assigned a procedure type, physician, mean, standard deviation, and minimum procedure duration, and room turnover time. Following this, the patient is delayed until 20 minutes before his/her procedure time to allow for registration and admission processes to occur. Then, the patient waits for a procedure room and physician (endoscopist). Once obtained, his/her procedure is performed, after which he/she is sent to recovery and the procedure room is turned over to prepare it for the next patient. Similar pathways are created for each procedure room, with the 'Wait for Room' and 'Wait for Endoscopist' processes being common to all rooms.

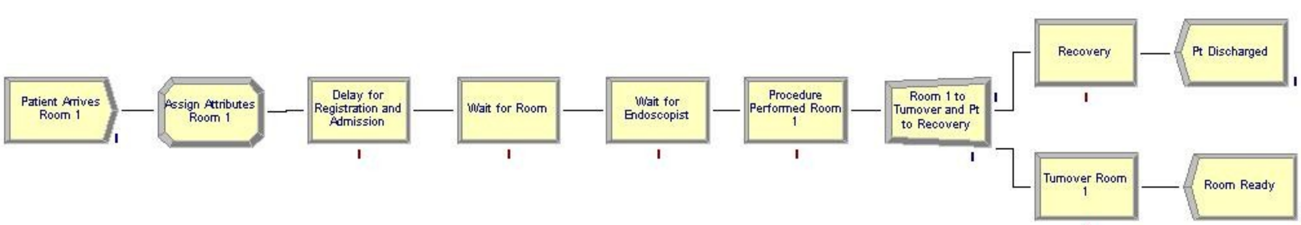


*Figure 3: Basic structure of the Arena simulation model*

The procedure duration used in the simulation was generated from a lognormal distribution with parameters equal to the mean and standard deviation of the corresponding physician procedure duration. Each distribution was shifted by its minimum procedure time to avoid generating any unrealistic values. Figure 4 shows the lognormal fit to colonoscopy procedure data for physician B5 (see Table 2). Although the chi square goodness of fit test rejects the lognormal hypothesis in this case, the graph clearly indicates a right skewed distribution, which is well approximated by the lognormal distribution. In addition, this graph is based on human recorded time data, which appear to be biased toward 5 minute intervals. For instance, the highest peak on this graph occurs at a procedure duration of 15 minutes.

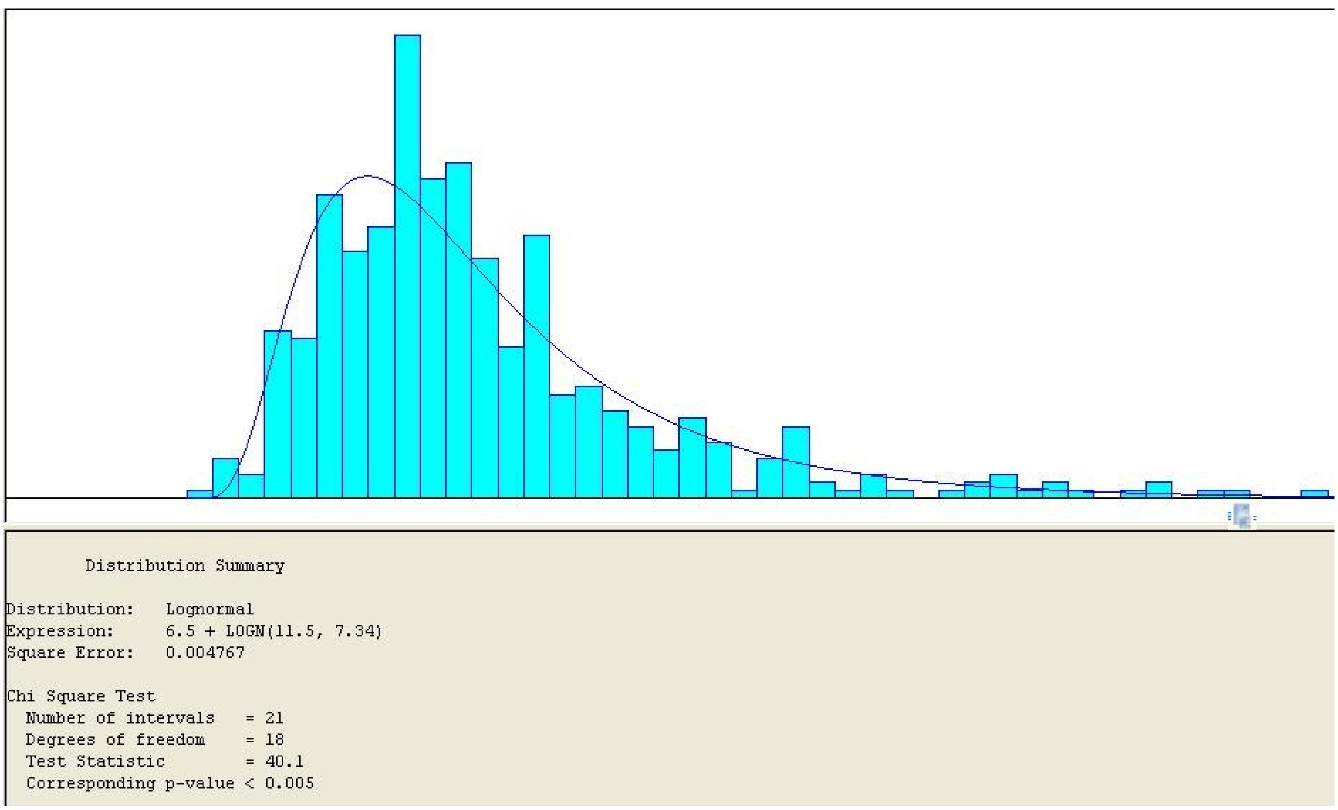


*Figure 4: Input distribution for colonoscopy procedures, physician B5*

We are currently working to validate the model using overtime and undertime data from hospital B. Preliminary results indicate that, in general, the model has more overtime and less undertime over a 20-

day period than the hospital, as shown in Table 3. It is evident that the simulated data differ significantly from the actual data. There are four reasons for this. Firstly, we likely performed too few replications of the simulation. Secondly, the simulation design restricts the amount of undertime that can be achieved in each block because patients are only available for their procedures 20 minutes before their scheduled procedure times. Thirdly, the simulation allows urgent patients to be seen if there are not any regularly scheduled patients waiting for a room or physician, even if not all of the scheduled patients for the current block have been seen. In the actual hospital, this would rarely occur. Fourthly, blocks tend to be scheduled more fully in the simulation than they are in the actual system, which explains why the actual system has a lot more undertime than the simulation. Addressing these issues should improve the validity of the model.

*Table 3: Actual and Simulated Overtime and Undertime Values*

| | **Overtime (min)** | | **Undertime (min)** | |
|---|---|---|---|---|
| **Physician** | **Actual** | **Simulated** | **Actual** | **Simulated** |
| B1 | 19 | 560 | 211 | 12 |
| B2 | 15 | 147 | 112 | 14 |
| B3 | 1 | 251 | 192 | 75 |
| B4 | 0 | 58 | 175 | 12 |
| B5 | 210 | 267 | 124 | 62 |
| B6 | 14 | 117 | 139 | 0 |
| B7 | 9 | 50 | 128 | 24 |

## 4. Conclusions

Colorectal cancer is a prevalent disease with a low screening rate in Ontario, which the province has addressed by implementing a colorectal cancer screening program. This program has increased demand for follow-up colonoscopy procedures, hence pressuring hospitals to increase patient throughput. We observed six Ontario endoscopy suites and found that endoscopy block time was not fully utilized. Further data analysis showed variation in average procedure times depending on who performed the procedure. This was because, in general, all procedures were scheduled for the same amount of time, regardless of the physician performing the procedure. Thus, we recommended that each site schedule endoscopy procedures according to average physician procedure times.

To demonstrate the throughput benefits of this recommendation, we developed a generic discrete event simulation model of the endoscopy suite. A key contribution of this simulation is its genericity, as it can be used to model the endoscopy operations of any site, based on input data. We are currently working to validate the simulation using overtime and undertime data.

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