Title of manuscript:

Using Simulation to Test Ideas for Improving Speech Language Pathology Services

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STATEMENT OF CONTRIBUTION

The Prairie North Health Region provides speech language pathology (SLP) services to children under the age of five. Speech language programs aim to prevent and correct disorders of language, speech, voice and fluency. Speech problems in children can adversely affect emotional, educational and occupational development. In the past several years, this health region has experienced an increase in the number of pre-school children referred for speech language therapy. Indeed, current wait times from referral to first appointment are well in excess of one year and one-tenth of patients do not receive any service before entering school.

In an effort to demonstrate successful operational research (OR) practice, we developed a discrete-event simulation model to test change ideas proposed by SLP therapists in order to improve patient flow. These change ideas involved increasing the percentage of group treatments (rather than having a majority of patients treated individually), using a paraprofessional to complete many of the routine tasks currently covered by the therapists, standardizing appointment durations, hiring additional SLP therapists and incorporating block treatment scheduling. We also tested combinations of the above strategies in order to determine the impact of simultaneously adopting different change ideas.

Our simulation analysis showed that improved patient flow – through reduced waiting time from referral to first appointment, or an increased percentage of children completing all required treatment prior to entering school – could be achieved with the change ideas. Based in large part on our findings, health region personnel have hired a paraprofessional, initiated block treatment scheduling and incorporated greater use of group treatments. As we illustrate in our manuscript, OR models can improve real-world systems by assisting planners with program design and resource allocation decisions.

ABSTRACT:

Speech language programs aim to prevent and correct disorders of language, speech, voice and fluency. Speech problems in children can adversely affect emotional, educational and occupational development. In the past several years, a particular health region in Saskatchewan has experienced an increase in the number of pre-school children referred for speech language therapy. Indeed, current wait times from referral to first appointment are well in excess of one year and one-tenth of patients do not receive any service before entering school. We develop a simulation model to test change ideas proposed by speech language professionals. Some strategies showed considerable promise for improving patient flow and are now being used in actual practice.

KEYWORDS: Health service, Practice of OR, Simulation, Queueing

INTRODUCTION and LITERATURE REVIEW

Analysts use simulation models to measure system performance, understand the impact of random variation, improve operations or to design facilities. By developing models that successfully imitate reality, decision-makers can better understand how a system really works and – perhaps more importantly – make predictions about overall performance when particular variables are changed or different policies enacted in the actual system. Indeed, this "what-if" capability demonstrates the eventual likely effects of different courses of action when it would be overly expensive or completely impossible to physically transform the system. The inherent flexibility of simulation methods has led to their successful use in a number of industries, including manufacturing plants, banking operations, airport security, distribution networks, freeway systems and entertainment theme parks (Kelton et al, 2007).

In this paper, we report on an actual project to develop a simulation model to test ideas for improving access to speech language pathology (SLP) services for children under the age of five in the Prairie North Health Region (PNHR), one of Saskatchewan's 13 health authorities. This particular region serves a population of over 72,000. Situated in the northwest part of central Saskatchewan, it is home to two regional hospitals and several other health facilities. The main communities in this health region include North Battleford, Meadow Lake and Lloydminster (Prairie North Health Region, 2007).

This study was a collaborative effort between Health Quality Council (HQC) and PNHR personnel. Operations research staff from HQC took primary responsibility for developing the simulation model, while PNHR professionals contributed critical expertise about SLP service delivery.

Speech language programs aim to prevent and correct disorders of language, speech, voice and fluency. Speech problems in children can adversely affect emotional, educational and occupational development. PNHR provides SLP services to children under the age of five. The typical patient pathway for SLP clients in this health region is to initially be identified as requiring such services, usually in the form of a referral from the patient's family physician. Patients consequently enter a first-come, first-served queue for SLP services. Their first contact with a therapist involves an assessment – usually a single appointment is sufficient - to diagnose speech and language problems. After their assessment, patient treatment then takes place. These are different exercises done to help address speech and language problems and are repeated as often as needed. Treatments may occur individually or in a group setting (if therapists deem that patients with similar problems would benefit from interaction with other children).

In the past several years, this health region has experienced a steady increase in the number of referrals received for SLP services. Figure 1 depicts overall referral numbers along with the totals received at each community. With this increase in referrals, there has been an accompanying increase in both the number of patients on the wait lists (322 children as of April 2006) and wait time for these services (average wait time of 398 days until first assessment). Should this current trend persist without any process improvement, wait lists and times will continue to escalate.

===== insert Figure 1 about here =====

Waiting lists are a concern, because studies suggest that the sooner the speech problems in children are corrected, the better the chance of success (Jacoby et al, 2002). Excessive waiting also results in many patients not completing treatment before they start school at age five. When this happens, children may enter a learning environment with an underlying disorder not being corrected. This could halt educational progression. Furthermore, responsibility for correcting the disorder in this particular health region is then transferred to therapists in the school system, which introduces a discontinuity in care.

The project comprised four principal objectives with respect to improving SLP patient flow:

- Ensure that every child that is referred for services has at least one assessment. In doing this, it will minimize the number of patients who become too old for service while waiting, renege or decline service, or are discharged without receiving any service.
- Minimize unnecessary waiting. This includes time from referral to the patient’s first assessment.

- Deliver all the "feasible treatments" that each patient requires in the time between their referral and their fifth birthday.
- Maximize the proportion of patients who are discharged because they have completed all the service they require. Health professionals wanted to avoid instances where a patient who still requires services is discharged because he or she has reached his/her fifth birthday.

To the best of our knowledge, there have been no previous attempts to apply simulation modeling to speech language pathology services. However, simulation modeling continues to enjoy a rich history in health care, perhaps due to its natural flexibility to effectively describe actual systems. We outline pertinent references in the following paragraphs.

Fetter and Thompson (1965) were early contributors, using models to simulate a maternity ward, outpatient clinic and surgical suite. System-wide patient flow and capacity analysis have also received some attention. For example, Brailsford et al (2004) developed a stock-flow model for emergency and on-demand health care in Nottingham, England. They determined that admissions from general practice constituted the most substantial impact on system occupancy. Harper and Shahani (2002) modeled bed capacity decision-making for the Royal Berkshire and Battle Hospitals Trust in Reading. Vasilakis and Marshall (2005) constructed a discrete event simulation model to predict length of stay values for different groups of patients (short, medium and long-stay) and how different capacity levels would affect each patient group.

The investigation and improvement of emergency department (ED) patient flow is also a key application of simulation analysis. For example, Pallin and Kittell (1992) used a GPSS/H model to explore the benefits of initiating a policy to refer return visit patients to a private physician, rather than having them come back to the ED. This would serve to limit the number of patients in the system and could ease congestion. Badri and Hollingsworth (1993) simulated an ED to determine how changes in staff scheduling practices and priority rules for serving patients would improve overall performance. Using a model built with the Arena software package, Samaha et al (2003) discovered that the main problems in the ED were related to inefficient processes, rather than a lack of overall resources. Ceglowski et al (2007) built a discrete event simulation model to identify particular bottlenecks in the important flow problem of patients admitted to hospital beds from the ED.

Besides the ED, researchers have analyzed other health care applications using simulation. These include walk-in centres (Ashton et al, 2005), outpatient appointment clinics (Klassen and Rohleder, 1996), renal services (Davies and Davies, 1987), liver transplants (Thompson et al, 2004), phlebotomy and specimen collection centres (Rohleder et al, 2007), bioterrorist attack response (Miller et al, 2006), HIV/AIDS epidemics (Rossi and Schinaia, 1998) and surgical care processes (Kumar and Shim, 2005).

We note that an extensive review of discrete event simulation in health care is provided by Jun et al (1999). Eldabi et al (2007) used an analysis of literature to identify critical themes for future work in this important area.

The remainder of our paper proceeds as follows. The next section discusses the development of our simulation model to explore SLP service delivery improvement. We then provide model results, after which we conclude the paper with some summary comments and directions for further study.

SIMULATION MODEL

Prairie North staff were eager to learn how simulation modeling could test different ideas for improving SLP service delivery. Developing such a model within these services is especially compelling, given the specific circumstances germane to this health care environment. As we described earlier, speech problems may worsen if conditions are not treated early. Emotional and learning difficulties are associated with speech problems. Finally, within this health region, children unable to complete all their required treatment by age 5 are subsequently transferred to therapists within the school system. Unless a seamless transfer is in place, this may introduce a discontinuity in care.

We began our analysis by mapping patient flow processes. This involved identifying the major steps associated with the delivery of patient care, the sequence of those steps, and any variations in the sequences. The second step was to gather data on current system performance. Our main data sources were the region’s information systems and patient chart abstraction. The health region extracted de-identified chart details on 837 SLP patients. Where key information was unavailable from either of these sources, we confidently relied on best estimates from SLP staff.

To describe this queuing system, we required information on specific patient and service characteristics. These are described in the following sections.

Patient Characteristics

We needed details on both patient demand and age at time of referral. Both were obtained from health region databases. Patient demand reflected the volume of incoming new patients entering the queue who require services, and was described by referral rates (number of patients arriving per month). There are just over 20 referrals per month for the PNHR's three communities combined. Figure 2 shows seasonal variation in referral rate. September is generally the busiest time for referrals in the region (since this month is when many children start preschool and thus have increased interactions with other children). For each month, the values for the minimum, most likely, and maximum number of referrals received over a five-year range (from 2000 to 2004) were used to compile a triangular distribution for each community. This distribution was then used as the arrival rate in the simulation model to ensure that we incorporated the effects of seasonality.

===== insert Figure 2 about here =====

Figure 3 shows the distribution of patient age at time of referral. This information was vital to our simulation model since pre-school patients referred at an older age may have a greater likelihood of being unable to successfully complete treatments. Peaks in referrals occur around age 18 months and 4 years. According to one PNHR speech therapist (Lamon, 2006), many speech and language problems are detected at 18 months of age, during a routine immunization visit that includes public health language screening. The case of the peak at age 4 is not clear, but may be because such a child may have more verbal communication and problems become more obvious to pre-school teachers, physicians, public health nurses or parents.

===== insert Figure 3 about here =====

Service Characteristics

We needed information on the required number of assessments and treatments per patient, the “hands-on” service time for each care episode, the time between appointments, and particular details about group treatments.

Since the required number of assessments and treatments is not known until “after the fact”, we had to rely on therapists’ best estimates for these values. Based on their experience, they estimated that 80% of patients would have one assessment, 15% would have two, 4% would have three, and 1% four. Therapists also estimated a maximum number of treatments per patient of 250, based on the extreme case where a patient begins treatment at age one month and has one weekly session - the treatment norm for children in this health region - up to age five. The required number of treatments per patient was “roughly” normally distributed, with a sizable number of children needing between 110 and 150 treatments in order for difficulties to be successfully remedied.

Therapists estimated that the amount of time required for different appointments followed a triangular probability distribution as provided in Table 1. Group treatments took longer than individual treatments in order to ensure all patients in the group receive sufficient service. SLP therapists estimated the number of patients per group as following a triangular distribution with minimum, most likely and maximum values of two, two and four, respectively. Chart abstraction indicated that currently 8.77% of treatments are done in a group setting. Finally, we assumed – based on therapist estimates – that a single professional could accommodate a maximum of 50 patients in an active caseload and that therapists had 4.5 hours of direct patient care time available per day. The remaining hours in a professional's day could be consumed with report writing and travel to outlying communities.

===== insert Table 1 about here =====

We constructed our simulation model using Arena, a discrete event simulation software package (Kelton et al, 2007). Simulation modeling allowed us to test various change strategies – prior to actually making the changes - that could address the current wait list problem. By investigating staff suggestions for process improvement and describing critical tradeoffs, these models permitted key insights into this service environment.

A high-level screenshot of the final model is depicted in Figure 4. We completed the model by continuously referring back to the SLP patient flow process map, constantly communicating with the therapists, and comparing the outputs of the simulation model to the performance of the actual system. The red dashed lines identify four major sections of the model. Those boxes outside the dashed lines correspond to "counters" that kept track of clients prematurely discharged from the system (due to age ineligibility, declining further service, or being unable to contact).

===== insert Figure 4 about here =====

Section A (Figure 4, upper left) describes how patients first arrive into the system. The rate at which patients enter was determined by the referral rates of the actual system. Each arriving patient was assigned a unique set of attributes, including age at the time of referral and required number of assessments and treatments. These attributes were based on the distributions described earlier. The patient then moved onto a wait list (if all therapists had 50 patients in their caseloads). Once a patient leaves active service, the next patient on the wait list moves forward and begins required service. As the model runs, a simulated clock ages the patients accordingly. There are checks throughout the model that verify if a patient is still eligible for service based on their age. If the patient reaches one of these checks and is over five years old, the patient is discharged from the system.

Patients who pass through the arrival section without being discharged move on to section B, the assessment section (Figure 4, lower left). Patients continually loop around in this section having assessments until they either complete all they require, or are discharged because they reach age five.

Patients who finish all their required assessments, and are still under the age of five move into section C, the treatment block (Figure 4, right centre). Again, patients continually loop around, receiving treatments until they complete as many as required, or until they are discharged because of ineligibility due to age. Patients were randomly assigned to either individual or group treatments.

Section D (Figure 4, top right) is the discharge stage. In this part of the model, patients exit the system after either completing required services or being discharged for the other reasons described earlier. Various statistics are recorded on all patients exiting the system. This helped to determine the indicator performance in the simulation model.

We selected a few main indicators to evaluate different improvement ideas. According to the SLP therapists, the most important indicator involved the Patient Wait

Time (PWT). This represents the average time a patient spends on the wait list for service, from the moment of patient referral to the first assessment. Obviously, lower PWTs are desirable.

A second indicator is the Percentage of Patients Receiving at least One Assessment (PROA). This is the number of patients receiving at least one assessment divided by the total number of discharged patients. Patients not receiving at least one assessment were those who reached age five while waiting for an assessment and thus became ineligible for therapy. The desired effect would be for this indicator to be 100%, as that would mean all patients were seen at least once.

The Percent of Feasible Treatments Completed per Patient (PFTC) is our third indicator. It measures the number of treatments the system is capable of delivering prior to patients turning five years of age. Typically, patients have one appointment per week. Therefore, the feasible number of treatments that a patient could have is determined by taking the minimum of the following two values: the number of weeks remaining until the patient reaches five years old and the number of treatments the patient requires. If, for example, a patient requires 100 treatments but is 40 weeks from being five years old, the feasible number of treatments is 40. If the patient only requires 20 treatments and is 40 weeks from turning five years old, the feasible number of treatments is 20.

The PFTC is the total number of treatments a patient receives divided by the number of feasible treatments for that patient. The desired effect would be for this indicator to be 100%, as it measures how close patients get to receiving all their feasibly required services. Even if a patient is referred late and requires years of treatment, it is still possible for this patient to have a PFTC of 100%, as long as the wait time to first contact is minimal.

Our final indicator is the Percentage of Patients Discharged due to Completion (PDC). This is computed by dividing the number of patients discharged because they completed treatment by the total number of patients who left the simulation model (for any reason whatsoever). Of course, the desired effect would be for this indicator to increase.

We note that our analysis does have some limitations. For example, our simulation model described the PNHR system structure in the PN Health Region. Although much of the theory in this study can be applied to other SLP systems, the actual model and data analysis may not be generalizable. In addition, we had to rely on therapist estimates for several model parameters – albeit confidently provided - for which data were unavailable.

We assumed that all children begin school at exactly age five. In reality, this is not the case since some children begin school before they reach five years old. However, we felt this was a reasonable but necessary approximation since it would have been impossible to directly model the cut off age for various schools in the simulation model.

After preliminary analysis of the data from all three communities (North Battleford, Meadow Lake and Lloydminster), it was decided that only one of the communities should be used as representative of the other two in the simulation model, since each community had similar system structure. Lloydminster was chosen as the candidate on which to base the modeling as it had the average performance of the three places. We assumed that if an improvement could be shown in this community, it would imply a similar improvement in the other two locales.

MODEL RESULTS

We selected a model run time of 1360 days with a warm-up period of 730 days. Further, we conducted 10 replications of each run to reduce the impact of outliers that may have been generated in any particular run.

The simulation model was first run under current system conditions to determine a base case for the four main indicators. Where available, we compared the simulation model to actual data as shown in Table 2. In general, the simulation model reflected actual performance reasonably well. Differences between simulated and actual results may be because several parameters were estimated by SLP therapists.

===== insert Table 2 about here =====

SLP therapists and HQC staff then identified several ideas for improving wait times and system efficiency. Each change strategy tested in the model was compared to the base case performance indicators. The ideas included:

- Increasing the percent of group treatments. Group treatments could enable patients to interact with one another, make treatment sessions more fun for the children, and save time. (Notwithstanding these potential benefits, therapists must exercise caution about which children are assigned group treatments since not all patients may positively react to such a practice environment). The current proportion of treatments done in group settings was 8.77%. We tested the effect of increasing this proportion to 25, 50 and 75% while allowing caseload to increase (as group visits allow more patients to be seen at the same time). We also tested a scenario of including more patients per group. Instead of the current triangular distribution of 2 (minimum), 2 (most likely), and 4 (maximum) patients per group session, a triangular distribution with 3, 4, and 5 patients respectively was used.

- Use of a paraprofessional. Such a person has clinical capabilities but not the full training of a therapist. A paraprofessional could be delegated routine tasks such as preparing clinical material for group treatments, assisting in calling patients' families, sending information to patients, and providing clinical advice. Currently, these duties are performed by SLP therapists. Therefore, a paraprofessional could "free up" valuable therapist time so that more hours of direct patient care could be provided. Rather than adding a resource to explicitly represent a paraprofessional in the simulation model, we simply increased the available therapist hours. For example, we tested the effect of increasing SLP therapists' available time for patients to as much as 6.5 hours per day, from the current value of 4.5.
- Standardizing appointment durations. Currently, assessment and treatment duration vary in length. Under this proposed scenario, assessments would be 60 minutes, individual treatments 30 minutes, and group treatments 60 minutes. This standardization could lead to smooth processes by reducing variation. One disadvantage of this proposed change is that it assumes all patients need the same appointment duration. Learning capacity may vary among individuals, and some

patients may benefit more from multiple short appointments, whereas others would benefit more from longer, but less frequent, appointments.

- Increasing resources. Each community currently has a single SLP therapist. We tested the impact of increasing the number of SLP therapists available in a community to two, three, and four.
- Block scheduling. Currently, when patients reach the front of the wait list, they will have their assessment(s) and, if required, begin treatment. Treatments continue periodically until they are no longer needed or the patient reaches school age. With block scheduling, patients only have ten treatments successively. They then return to the end of the wait line, allowing another patient to begin his or her block of ten treatments.

We also tested several combinations of the above individual strategies in order to demonstrate potential improvement of simultaneously adopting different change ideas.

Table 3 lists the effect of various change strategies on quality indicators. As listed in the first row of the table, the base case patient wait time from referral to first assessment as determined in the simulation model is well over one year. Only 8% of patients complete all their required treatments and one-tenth of pre-school patients do not even get assessed due to waiting.

===== insert Table 3 about here =====

Our model showed particular benefits associated with each change idea. For example, increasing the percentage of treatments done in a group helped reduce the average wait time from referral to first assessment by close to 47%. Using a paraprofessional more than doubled the percentage of patients who completed all their required treatment.

Standardizing appointment durations helped reduce variability and almost tripled the percent of patients discharged because of finishing all their required treatment. However, this strategy may not be optimal for all patients, as not all patients have the same learning capacity.

Adding one extra SLP therapist generated major improvements. The percentage of patients being discharged due to completion nearly doubled, and patient wait time decreased to 218 days. We note that PWT could be almost eliminated by quadrupling the number of SLPs.

Block scheduling increased the number of patients that received at least some service prior to entering school. From the base case performance, this improved to 95%. Nonetheless, block scheduling was the only change strategy which decreased system performance as measured by PFTC and PTC. This occurred since this change idea advocates spreading appointments among the pre-school children, rather than isolating treatment on a caseload of patients until successfully remedied.

Although these change strategies showed improvements within the system, there was no single change that eradicated wait lines completely. We tested the combined change strategies and discovered that the strategy of having two SLPs, one paraprofessional, and maximizing group visits (75% of visits done in groups with 3 to 5 per group) resulted in a virtual elimination of wait times and ensured that all referred patients had an assessment. The large majority of feasible treatments (94%) were completed using this strategy.

CONCLUSIONS

This report shows that at present, many patients have difficulty accessing services for SLP programs in the Prairie North Health Region. Current wait times are well in excess of one year, and one-tenth of patients do not even get assessed due to waiting. Only one-quarter of the treatments that could be feasibly delivered to patients prior to their fifth birthday are completed.

Simulation gave us a valuable, structured approach by which to analyze patient flow and system capacity issues. We were able to demonstrate how different strategies would most likely play out in the real system before physically making the changes. Our modeling predicts that providing treatments to more patients in groups would lead to substantial improvement. This measure is especially favourable since it does not require additional resources to the system, a particularly troublesome issue within this health region. The most intensive option for group treatment that we tested assumes that 75% of patients are treated in a group, and the group has 3 to 5 patients. While SLP therapists were confident that this was possible, it would have to be field tested to verify that patients progress as well as if they had individual treatments.

If the goal of quality improvement is to eliminate waiting time and ensure that all patients are adequately assessed, then our analysis shows that additional change strategies requiring more resources will be required. Quadrupling the number of SLPs could accomplish this goal. However, an alternate, less resource intensive strategy would be to add one SLP, deploy paraprofessionals, and maximize use of group visits as described above.

We note that this paper is directly relevant to practice since we tested strategies for improving service delivery, with many such change ideas proposed by SLP therapists themselves. Moreover - based in large part on the results of this analysis - PNHR has subsequently adopted specific improvement strategies. For example, they are now using 10-week block scheduling and employing more group treatments. They have also hired a paraprofessional to permit SLP therapists more direct patient care time.

We are aware of some future possibilities for our modeling effort. In particular, we noted that when patients are referred for SLP services within this health region, they are placed at the bottom of the wait list, regardless of their age and the severity of their problem(s). Health region personnel may want to consider dynamic priority based scheduling in which each patient would be assigned an urgency score based on their condition before being put on the wait list. Higher patient scores would imply greater urgency. Their score increases over time as they wait for an appointment. When the next available slot is open in the caseload, the patient with the highest score would be contacted for an appointment.

Additional possibilities could include analyzing adult SLP patient flow. Given the scope of the current project, we restricted our attention to pre-school patients. However, adult patients experiencing speech difficulties are also subject to lengthy wait lists and flow problems.

This model provides information to assist planners in making program design and resource allocation decisions. It is based on the most recent available information. However, the practice environment may change quickly; new practice standards may evolve, or patient demand may shift upwards or downwards. It is important that users of this model in the future re-calibrate this model as new information becomes available, so that it can continue to be a useful resource for planning purposes.

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Betty Puff, Administrative Assistant

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REFERENCES

Ashton R, Hague L, Brandreth M, Worthington D and Cropper S (2005). A simulation – based study of a NHS walk-in centre. J Opl Res Soc 56: 153-161.

Badri M A and Hollingsworth J (1993). A simulation model for scheduling in the emergency room. Intl J Ops Prodn Mgmt 13: 13-24.

Brailsford S C, Lattimer V A, Tarnaras P and Turnbull J C (2004). Emergency and on-demand health care: Modelling a large complex system. J Opl Res Soc 55: 34-42.

Ceglowski R, Churilov L and Wasserthiel J (2007). Combining data mining and discrete event simulation for a value-added view of a hospital emergency department. J Opl Res Soc 58: 246-254.

Davies H and Davies R (1987). A simulation model for planning services for renal patients in Europe. J Opl Res Soc 38: 693-700.

Eldabi T, Paul R J and Young T (2007). Simulation modeling in healthcare: Reviewing legacies and investigating futures. J Opl Res Soc 58: 262-270.

Fetter R B and Thompson J D (1965). The simulation of hospital systems. Ops Res 13: 689-711.

Harper P R and Shahani A K (2002). Modelling for the planning and management of bed capacities in hospitals. J Opl Res Soc 53: 11-18.

Jacoby G P, Lee L, Kummer A W and Levin L (2002). The number of individual treatment units necessary to facilitate functional communication improvements in the speech and language of young children. Am J Speech-Language Pathology 11: 370-380.

Jun J B, Jacobson S H and Swisher J R (1999). Application of discrete-event simulation in health care clinics: A survey. J Opl Res Soc 50: 109-123.

Kelton W D, Sadowski R P and Sturrock D T (2007). Simulation with Arena. McGraw-Hill: New York.

Klassen K J and Rohleder T R (1996). Scheduling outpatient appointments in a dynamic environment. J Ops Mgmt 14: 83-101.

Kumar A and Shim S J (2005). Using computer simulation for surgical care process reengineering in hospitals. INFOR 43: 303-319.

Lamon P (2006). Personal communication.

Miller G, Randolph S and Patterson J E (2006). Responding to bioterrorist smallpox in San Antonio. Interfaces 36: 580-591.

Pallin A and Kittell R P (1992). Mercy Hospital: Simulation techniques for ER processes. Indus Eng 24: 35-37.

Prairie North Health Region (2007). http://www.pnrha.ca/bins/index.asp, accessed 5 April 2007.

Rohleder T R, Bischak D P and Baskin L B (2007). Modeling patient service centers with simulation and system dynamics. Health Care Mgmt Sci 10: 1-12.

Rossi C and Schinaia G (1998). The mover-stayer model for the HIV/AIDS epidemic in action. Interfaces 28: 127-143.

Samaha S, Armel W S and Starks D W (2003). The use of simulation to reduce the length of stay in an emergency department. In: Chick S, Sanchez P J, Ferrin D, Morrice D J (eds.) Proceedings of the 2003 Winter Simulation Conference, pp. 1905-1909.

Thompson D, Waisanen L, Wolfe R and Merion R M (2004). Simulating the allocation of organs for transplantation. Health Care Mgmt Sci 7: 331-338.

Vasilakis C and Marshall A H (2005). Modelling nationwide hospital length of stay: Opening the black box. J Opl Res Soc 56: 862-869.

Figure 1: SLP Referral Rate by Community

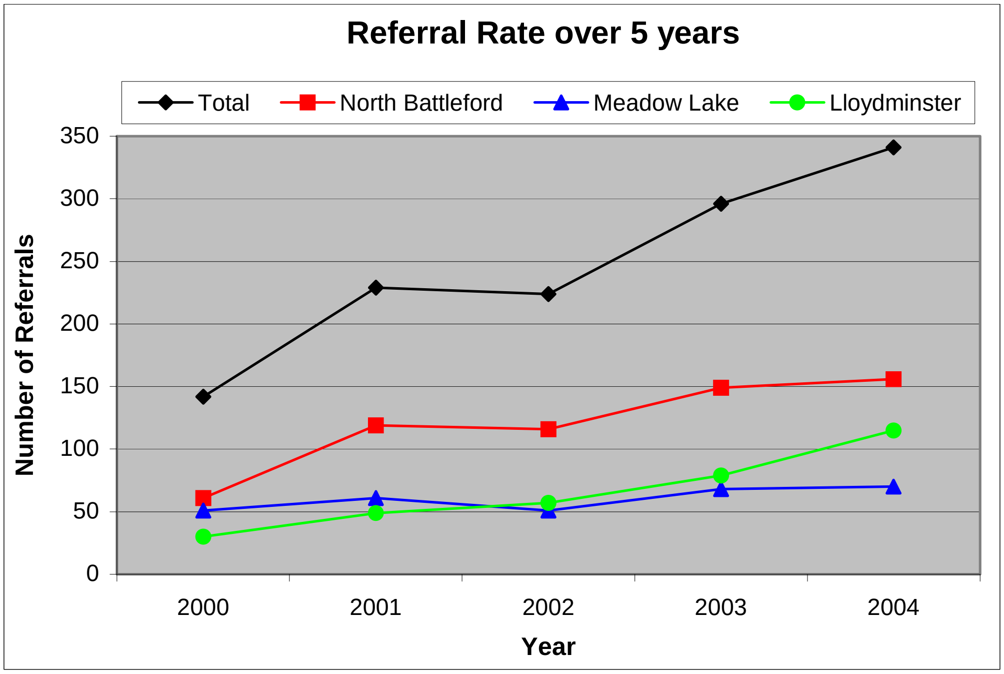

Figure 2: Average SLP Referrals per Month (from 2000 to 2004)

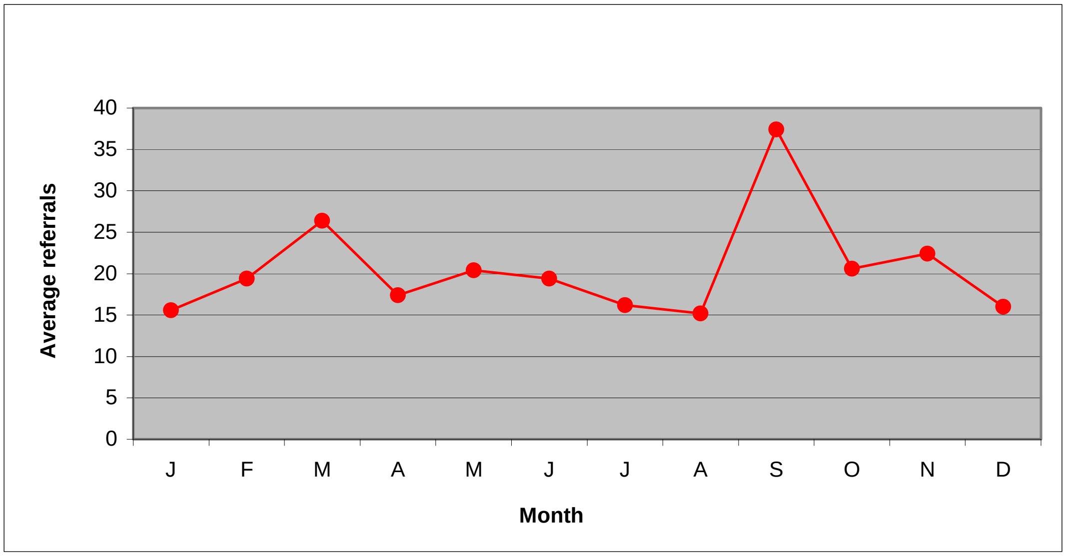

Figure 3: Distribution of Patient Age at Time of Referral

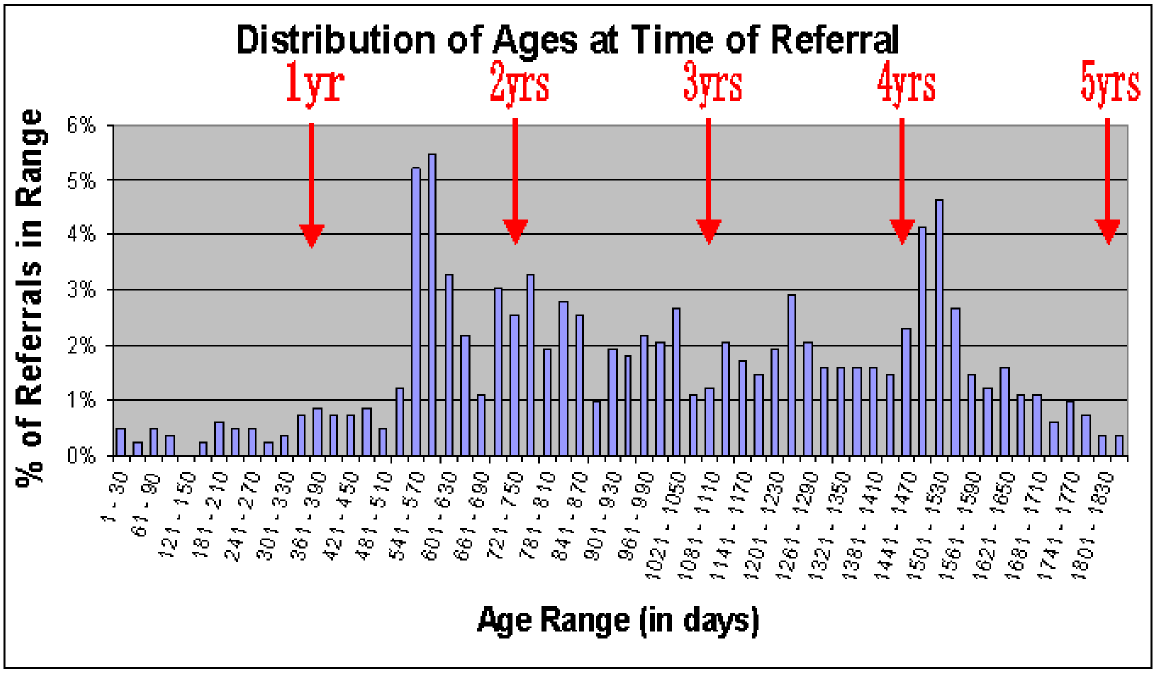

Figure 4: Screenshot of SLP Simulation Model

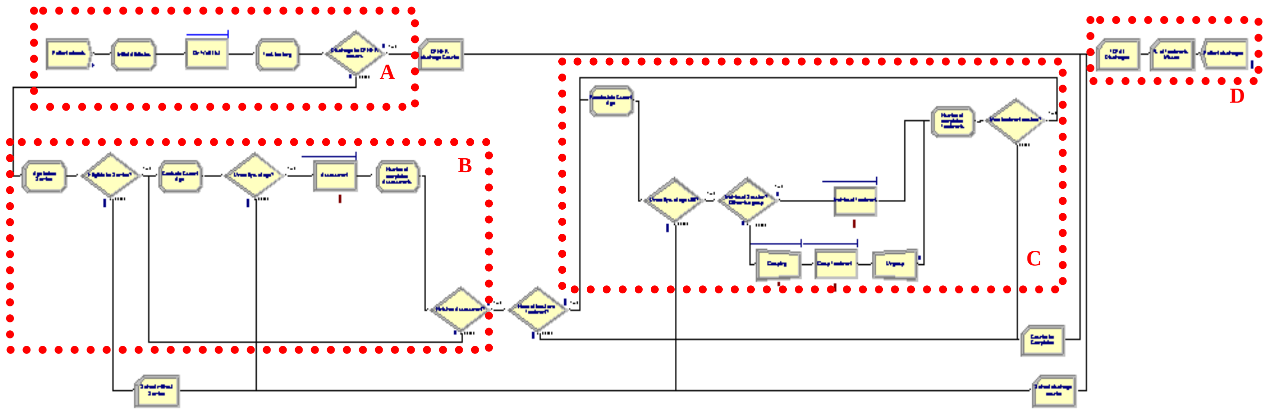

Table 1: Distribution of Appointment Durations

Appointment Type	Appointment Duration (in minutes)		
	Minimum	Most Likely	Maximum
Assessment	60	90	120
Individual Treatment	30	45	60
Group Treatment	60	60	90

Table 2: Base Case Performance Indicators

Performance Indicator	Simulation Model Result	Actual Result
Patient Wait Time (PWT)	458 days	398 days
% Receiving ≥ 1 Assessment (PROA)	89%	82%
% of feasible treatments completed (PFTC)	24%	None available
% discharged due to completion (PDC)	8%	12%

Table 3: Improvements from Various Change Strategies

Single Change Strategy	**PWT (days)**	**PROA**	**PFTC**	**PDC**
Current system performance	458	89%	24%	8%
Increased group treatments (75%)	244	92%	27%	5%
SLP at 6.5 patient-hrs/day (by using a paraprofessional)	421	89%	32%	18%
Standardized appointment duration	401	91%	35%	22%
2 SLPs	218	92%	41%	15%
3 SLPs	67	97%	63%	28%
4 SLPs	4	100%	89%	55%
Block scheduling	415	95%	21%	3%
Combined Change Strategies	**PWT (days)**	**PROA**	**PFTC**	**PDC**
2 SLPs, block scheduling, 50% group, with 2-4 in group	97	99%	50%	11%
2 SLPs, 1 paraprofessional, 75% group, with 3-5 in group	0	100%	94%	68%
3 SLPs, 1 paraprofessional, 50% group, with 2-4 in group	0	100%	96%	73%