Management Summary

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Problem Summary

This project extends the simulation of the patient transit process at Auckland Hospital in Auckland, New Zealand with a model consisting of two buildings with a total of nine floors of the hospital where most of the transits take place. The simulation was developed by Ivo Matthijssen and further extended by Jordi Timmermans.

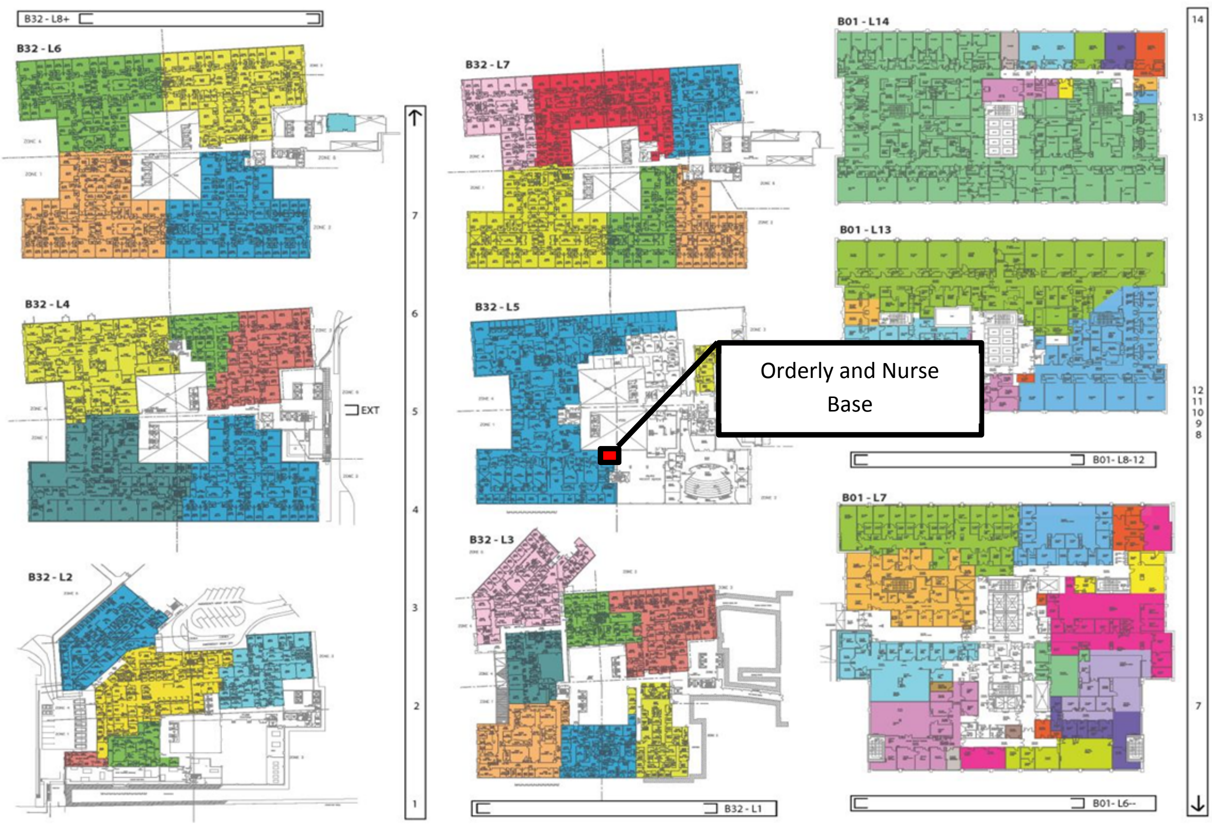

Figure 1 Map of the Patient Transit Simulation Model

Orderlies transport patients from their wards to treatment rooms and back to their wards once the treatment has been completed. Some transit patients in certain conditions may also require a transit nurse to assist with the transit. Most transits take place in building 32 and 01 and the simulation has been developed to model the nine floors where a major proportion of the transits occur. The orderly and nurse base is located at level 5 of building 32 as shown in Figure 1 where the dispatcher is also located.

The dispatcher uses the Transit Booking System (INFRA) which shows all the booked requests. The task of the dispatcher is to schedule all the orderlies and transit nurses in such a way that the patient arrives at most 15 minutes before their appointment and at least at their appointment time. However, this is not always possible, so we are also interested in ensuring a patient arrives between 15 minutes before and 15 minutes after their appointment time.

The initial goal of the project is to use historical data obtained from the Transit Booking System and calibrate the existing simulation model to represent the Auckland Hospital's transit system as accurately as possible.

Solution Approach

The simulation was developed in Java using Eclipse as the integrated development environment (IDE) with SSJ library to define the simulation model. Matlab was also used to optimise the difference between the historical data and the simulated patient drop off times. Jordi Timmermans used Matlab Builder JA and the Matlab Optimization Toolbox in his initial calibration of the model, but we do not have a license for Matlab Builder JA (Jordi used his TU Eindhoven license).

Instead we developed "wrapper" code to link Java and Matlab directly (i.e., not through Matlab Builder JA). Using our wrapper we have experimented with both `fmincon` (from the Optimization Toolbox) and `fminsearchbnd` (a bounded version of `fminsearch` which was available from Mathworks' Matlab Central File Exchange). We have utilised these functions to calibrate the speed of each nurse, orderly and elevator, as well as the delay times at each ward and elevator. The objective function value that we are trying to optimise is a weighted sum of the mean and standard deviation of the differences between the historical data and the simulated patient drop off times. The active set algorithm in the `fmincon` function finds the minimum of a constrained nonlinear multivariable function using Sequential Quadratic Programming (SQP) and an active set method to solve each QP. This is essentially a descent method (follows the derivatives "downhill"). The `fminsearchbnd` function finds the minimum of unconstrained multivariable function while allowing for bounds using the Nelder-Mead Simplex method, a derivative free method.

Results and Analysis

Jordi has previously used the `fmincon` function in Matlab to optimise the difference between the historical data and the simulated patient drop off time for the time period 1 October 2011 to 5 October 2011 as shown in Table 1 to calibrate:

- a uniform speed for the orderlies with patients
- a uniform speed for the orderlies without patients
- a uniform speed for the nurses without patients
- delay times for the pickup and drop off at Radiology
- delay times for the pickup and drop off at building 01 level 13 and 14
- delay times for the pickup and drop off at other locations

Orderlies Speed No Patient (m/s)	0.78
Orderlies Speed With Patient (m/s)	7.81
Nurses Speed No Patient (m/s)	2.58
Delay lift building 32 (min)	0.12
Delay lift building 01 (min)	0.11
Delay pickup (min)	0.89
Delay drop off (min)	0.54
Delay pickup b01 level 13+14 (min)	1.38
Delay drop off b01 level 13+14 (min)	0.97
Delay pickup radiology (min)	0.05
Delay drop off radiology (min)	1.32
Elevator speed (m/s)	0.70

Table 1 Jordi's optimisation result 04 Nov 2011

Jordi's optimisation for difference between the historical data and the simulated for each patient drop off time resulted in a mean difference of 0.02 minutes and a standard deviation of 12.13 minutes with an objective function value of 182.02 seconds.

We have extended this optimisation process by allowing for different speeds for each orderly, nurse and elevator. Different delays at each pick-up and drop-off location have also been allowed for.

The result of the optimisation after 6723 runs using the active set algorithm in the `fmincon` function (which has yet to finish running) is shown on Table 2. Using the parameters below, the mean difference has increased slightly to 0.09 minutes but the standard deviation has reduced to 10.44 minutes with an overall objective function of 160.57 seconds. The results also provide a more realistic estimate for Orderlies Speed With Patient (1.78 vs 7.81 from Jordi's results – note that 7.81 m/s would give a 100m time of just over 12s, so not realistic for a busy hospital).

Mean Orderlies Speed No Patient (m/s)	1.81
Mean Orderlies Speed With Patient (m/s)	1.78
Mean Nurses Speed No Patient (m/s)	2.57
Delay lift building 32 (min)	0.59
Delay lift building 01 (min)	0.59
Delay pickup (min)	1.11
Delay drop off (min)	0.59
Delay pickup b01 level 13+14 (min)	2.00
Delay drop off b01 level 13+14 (min)	1.25
Delay pickup radiology (min)	0.05
Delay drop off radiology (min)	4.00
Elevator speed building 32 (m/s)	0.59
Elevator speed building 01 (m/s)	0.59

Table 2 Optimisation Result active set algorithm `fmincon` function 22 Dec 2011 after 6723 runs

The result of the optimisation after 5140 runs using the `fminsearchbnd` function (which also has yet to finish running) is shown on Table 3. Using the parameters below, the mean difference has been reduced to 7.35×10^{-6} minutes and a standard deviation of 11.15 minutes with an objective function of 167.19 seconds.

Mean Orderlies Speed No Patient (m/s)	1.80
Mean Orderlies Speed With Patient (m/s)	1.77
Mean Nurses Speed No Patient (m/s)	2.57
Delay lift building 32 (min)	0.59
Delay lift building 01 (min)	0.59
Delay pickup (min)	1.11
Delay drop off (min)	0.59
Delay pickup b01 level 13+14 (min)	2.00
Delay drop off b01 level 13+14 (min)	1.25
Delay pickup radiology (min)	0.05
Delay drop off radiology (min)	4.00
Elevator speed building 32 (m/s)	0.59
Elevator speed building 01 (m/s)	0.59

Table 3 Optimisation Result `fminsearchbnd` function 22 Dec 2011 after 5140 runs

The average human walking speed is 1.5 m/s. Jordi's optimisation resulted in walking speeds of 0.78 – 7.81 m/s. Our optimisation resulted in walking speeds of 1.77 – 2.57 m/s which are more realistic. The speed of the elevator from our optimisation deviated further from the average speed of an elevator of 1 – 10 m/s compared to Jordi's result (0.59 m/s compared to 0.7 m/s).

A summary of the obtained optimisation results is shown on Table 4. Currently, the mean difference between the simulated drop off times and the historical data drop off times is less than 0.1 minutes, but the variation still requires improvement as suggested by the standard deviation of more than 10 minutes.

	Jordi	fmincon	Fminsearchbnd
Mean	0.02	0.09	7.35E-06
standard deviation	12.13	10.44	11.15
objective function	182.02	160.57	167.19

Table 4 Summary of optimisation results

Results from the finished optimisation process of the `fmincon` and `fminsearchbnd` will be forwarded to you in 2012.

Future Work

- Optimise using a global optimisation algorithm such as the Simulated Annealing algorithm to obtain a globally optimised solution.
- Check elevator speeds. Does bounding the speed between 1 and 10 make the delay for the elevators longer to compensate or are the elevators really running slower for smoother rides for patients?
- Resolve the orderly-nurse discrepancy in the data. In some cases the orderly in our data is actually a nurse and vice versa or there is only a nurse. We will investigate this further and make the appropriate changes.
- Implement and test schedules.
- Experiment with different dispatching policies.
- Experiment with different values for fast transits.