A Methodology for Evaluation of a Hospital's Vertical Transportation Needs

Robert B. Turnage
Ernst & Whinney

Abstract

This paper presents a case study of an evaluation of a University Medical Center's vertical transportation needs. The Hospital's traffic characteristics are documented and then modeled using a GPSS computer simulation model. The effect of several possible improvements in the Hospital transportation system are predicted through use of the model and the most cost effective alternatives chosen for implementation.

The use of the model and the study's approach is not limited to university medical centers, and can be applied to evaluation of the vertical transportation needs of any size hospital, existing or planned.

INTRODUCTION

Loyola University Medical Center (LUMC) including Foster G. McGaw Hospital is a Friesen facilities design incorporating an extensive automated materials handling system. The materials handling system was a prototype system designed to distribute the bulk of the materials and supplies throughout the medical center. The system's three vertical lifts were to have transported materials from Dietary, Central Sterile Supply, Linen and General Stores. Three passenger elevators and three service elevators were to have served only passenger and patient traffic in the hospital. As a result of serious maintenance and staffing problems the materials handling system was abandoned shortly after the opening of the Medical Center in 1968. The traffic which was to have been transported by the materials handling system's three vertical lifts had to be moved manually on the three service elevators.

In the ten years since the opening of the Medical Center the use of the hospital, ancillary departments and ambulatory care center has increased significantly and the problems associated with elevator usage has grown to an unacceptable level. The results of increased demand and the flow of materials, passengers and patients on the same elevators or excessive delay time and a lack of control of the flow of clean and contaminated traffic.

The average time that a passenger or transporter waits for an elevator in the hospital after pressing the call button is 2.34 minutes with an average standard deviation of 1.54. This delay is almost 2 minutes longer than the architectural standard of 20 seconds (1) and almost 1 minute 50 seconds longer than a hospital standard of 30 seconds.(2) The range of times can run from less than 1 minute to more than 15 minutes wait for an elevator with enough room for a stretcher patient or a large cart. This pattern of delays is disruptive to development of effective operational systems and is a tremendous waste of personnel.

A second result of the increased demand on the service and passenger elevators is that the soiled linen and refuse which were intended to move by way of the automated materials handling vertical lifts now are transported in elevators which are occupied with patients, employees, meals and clean materials. Efforts have been made to limit the contact of clean and dirty traffic by restricting the movement of refuse and soiled linen to certain hours. Because refuse and soiled linen accumulate during the hours of peak activity, restriction of the removal of this material causes an asepsis problem of stored contaminated material on the nursing units.

STUDY APPROACH

The approach taken by this study in the analysis of the vertical transportation system was to:

- determine the existing vertical transportation system
- identify departments dependant on the hospital elevators
- document the departmental interactions with the vertical transportation system
- develop a computer simulation model of the vertical transportation system
- use the simulation model to evaluate the cost-effectiveness of possible solutions to the problem of excessive delay times
- develop a comprehensive logistical plan to recover cost savings through reduced delay times and to increase asepsis control

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Systems Corporation Nursing Care Quality Reporting System. (4) The nursing system recommends a staffing level based on patient acuity. The 11 FTE reduction was applied to units whose staffing was above the recommended level based on patient acuity.

A Logistical Management Plan

The most important issue in the study was the improvement in the comfort and safety of patients being transported within the hospital. The conclusions reached after evaluation of possible solutions was that the hospital needs two additional service elevators to adequately serve the volume of passengers, patients and materials. A logistical management plan is needed to locate the sites for the elevator additions and insure optimal use of all elevators.

The three passenger elevators are located in the lobby of the hospital and adequately serve the flow of visitors, nursing staff and students. The two service elevators between Materials Management and Dietary are well located for the transport of materials and supplies. It was decided that the transport of patients would be adequately served by two service elevators and that the two additional elevators should be dedicated to the transport of patients. The majority of patient transports are between the nursing units and ancillary departments in the south end of the medical center. Engineering and Facilities studies of the area were undertaken and feasible sites identified. The sites were evaluated to:

- minimize travel time to and from the sites.
- maximize patient comfort and convenience.
- maximize asepsis control.
- minimize construction cost.
- minimize disruption to the hospital during construction.

The final location was chosen because it met all the above criterions. The location will provide good flow, adequate aisle and lobby space, and because it would be predominantly external construction, would minimize construction cost and disruption of the hospital during construction.

The final step in the study was to develop a plan promoting optimal use of the elevators. The following traffic control plan was recommended to Hospital administration:

The addition of two service elevators will allow greater management control of the traffic characteristics with regard to asepsis and patient comfort. Traffic will be controlled in the following manner:

- visitors, staff, and students will be served by the 3 passenger elevators.
- the transport of clean and sterile supplies, including dietary carts, will be served by the 2 service elevators located between Materials Management and Dietary.
- the transport of patients will be served by the 2 new service elevators in the hospital.
- the movement of contaminated material, soiled linen, refuse, and dirty OR trays, will be confined to the one service elevator on the south end of the hospital except in emergencies.

The locations of the elevators will promote the proposed traffic plan but optimal use of the facilities will occur only if Hospital administration is dedicated to the logistical management plan.

CONCLUSION

Presented in this paper is a systematic methodology for evaluating a hospital's vertical transportation needs and an application of the methodology to a university medical center. The methodology involves documentation of the hospital's traffic characteristics, modeling the elevator system using computer simulation, and the evaluation of the cost-effectiveness of possible improvements in the vertical transportation system through use of the simulation model.

Used in a university medical center which included an ambulatory care center, a medical school, and a 461 bed general acute care hospital, this methodology resulted in a plan to reduce waiting times, recover over $200,000 in reduced paid FTE's, and improve asepsis control and patient comfort.

REFERENCES

1. This standard was obtained from consultation with engineers from Otis Elevator Company and Browne, J.J., Kelly, J.J., "Simulation of Elevator System for World's Tallest Buildings", Transporation Science, Volume 2, 1969, pp.35-36.
2. The architectural standard was adjusted to a more suitable hospital standard of 30 seconds.
3. GPSS User's Manual, IBM Form Number GH20-0326-4.
4. "Nursing Care Quality Reporting System" is proprietary of Medicus Systems Corporation, 990 Grove Street, Evanston, Illinois 60201.

EXISTING VERTICAL TRANSPORTATION

The current system of vertical transportation can be divided into three subsystems:

- Basic Sciences Building (Stritch School of Medicine -SSOM)
- Burke Ambulatory Care Center (BACC)
- Foster G. McGaw Hospital (FMGH).

The Basic Sciences Building includes six floors and two lower levels and is served by three elevators; two passenger elevators and a service elevator. The demand for the passenger elevator is predominately by faculty, students and staff. The service elevator is used by General Stores and Housekeeping. The elevator service is adequate for the demand especially when considering that the majority of the traffic is able to utilize the stairs as an alternative. Because the Basic Sciences Building's vertical transportation needs seem to be well met and is a fairly independent system, it will be excluded from further analysis.

The BACC is located on the first floor at the south end of the Medical Center and requires very little transportation. Some patients are sent to Radiology and Clinical Labs on the lower level and are often directed to use the elevator in that area. Though this patient traffic often adds to the problems during peak times, the overall effect is small and is not included in this study.

Foster G. McGaw Hospital is a 461 bed general acute care hospital and is served by six elevators: three passenger elevators in the front lobby, two service elevators adjacent to Materials Management, and a service elevator located next to BACC. Almost all of the patient and materials transport occurs in the hospital and is served by only three service elevators. The front three passenger elevators serve the nursing staff, physicians, visitors and some technicians and therapists.

DEPARTMENTS DEPENDENT ON THE ELEVATORS

The departments which are dependent on the use of the elevators for the successful completion of their responsibilities can be grouped by their responsibility for either Patient Transport or Materials Transport.

Patient Transport

Materials Management employs 10 patient transport aides.

Operating Room employs 4 operating room technicians for patient transport and preparation for surgery.

Physical Therapy employs 4 patient transport aides

Radiology is assigned 6 patient transport aides by Materials Management.

Recovery Room/Intensive Care Unit both utilize the staff RN's for the transport of patients to their rooms

Materials Transport

Dietary assigns one dietary aide to delivery the 24 dietary carts as they are filled by the meal preparation line.

Housekeeping is responsible for the removal of refuse and soiled linen from the nursing units.

Materials Management employs 7 materials technicians responsible for the transport of patient chargeables, stock supplies, sterile trays, and Pharmacy Unit Dose Carts.

Once the major users were identified, the departmental managers were interviewed in order to gain an understanding of the personnel involved in the transport functions, the schedules involved, and how the department affects and is affected by the hospital's vertical transportation system.

In addition to manager interviews a large amount of data collection on traffic characteristics was required in order to quantitatively describe the present vertical transportation system. The types of data collection necessary are described below:

The transport of materials and personnel by the major users must be observed and the trip characteristics documented. Most important to the study are:

- the delay times spent waiting for elevator service.
- the delay times identified by elevator and floor.
- the type of personnel used.
- the amount of time spent in the elevator traveling between floors.
- the type of transport
- the time of transport.

An understanding of the present utilization of the existing vertical transportation system was gained through documentation of the elevator passenger characteristics. The following data was collected while observing the transportation of patients and materials at random intervals so as to have representative data for each elevator over all hours of the day:

- the time of occurrence.
- the number of patients being transported and the mode of transport.
- the number of material transports by cart.
- the number of material, report, or specimen transports by non-bulk distribution.
- the number of housekeeping personnel transporting refuse, soiled linen, or housekeeping carts.

The overall average for the elevator delay times in the hospital was found to be 2.34 minutes and a standard deviation of 1.54. Table 1 further describes the elevator delay characteristics when broken down by elevator banks.

Delay Analysis by Elevator

Elevator Bank	Delay (Mins.)	Range (Mins.)
BACC (1)	2.8	1 - 17
MM&D (2)	2.4	1 - 10
Front Pass (3)	1.8	1 - 3

*Delay-wait
(n) - n number of elevators in bank

The most important result of the data analysis is an understanding of the current transportation system, of each department's involvement and requirements, and of the impact of any change on the hospital as a system.

Table 2 presents a summary of the elevator user characteristics. Although data were analyzed in detail for each department and each elevator bank, more detail will not be presented here for sake of brevity.

Table 1
Frequency of Elevator Delay Durations

Length of Wait (mins.)	Frequency (% of Total)	Cumulative Frequency (% of Total)
0 - 1	15	15
1 - 2	37	52
2 - 3	22	74
3 - 4	13	87
4 - 5	4	91
5 - 6	2	93
6 - 7	1	94
7 - 8	3	97
8 - 9	1	98
9 - 10		
10 - 11	1	99
11 - 12		
13 - 14		
14 - 15		
15 - 16		
16 - 17		
17 - 18	1	100

Table 2
Elevator Users Characteristics

TYPE OF TRANSPORT AND DEPARTMENT	# OF PERSONNEL	USES PER DAY		AVERAGE DELAY PER TRIP	% OF TOTAL TRIP SPENT IN DELAY
		PATIENTS	TRIPS+		
PATIENT TRANSPORT					
Physical Therapy	4 PTA	51	204	1.67 min.	20%
Radiology	4 PTA	54	216	2.75 min.	27%
Materials Management	10 PTA	100	400	2.14 min.	35%
Operating Room	4 T	40	80	2.60 min.	33%
Recovery Room/ Intensive Care	* RNs	40	80	4.67 min.	47.1%
MATERIALS TRANSPORT					
Materials Management (100 orders per day)	7 MTA		300	2.14 min.	35%
Dietary			120	2.14 min.	
Housekeeping			100		

+ TRIPS - Represents a move from one floor to another floor requiring one use of the elevator

PTA - Patient Transport Aide

T - Tech

* - Responsibility for all RNs in recovery room/ICU

MTA - Materials Transport Aide

USE OF SIMULATION MODEL

The Simulation Model

The basic elevator model was developed to simulate characteristics of an elevator in a heavily utilized, intermittent demand type environment which is usually the case in hospitals. When the demand is heavy and the traffic flow is not predomoinantly one direction, the elevator reacts solely to calls. If the demand is low and the elevators are allowed to come to rest, then the individual elevators can be programmed to come to rest so that the next random demand can be met with a minimum of travel time. Or if the demand is predominantly one direction, as can be the case in an office building, the elevators can be programmed to effectively respond to this type of traffic pattern. In such a case, all but one of the elevators would be programmed to orient on the ground floor from 7:00 a.m. to 10:00 a.m. and during this time period to carry passengers up and then return directly to the ground floor. The single elevator would be left to carry 'down' traffic. From 4:30 p.m. to 5:30 p.m. the situation would be reversed.

Hospital traffic can be characterized as heavy from 6:00 a.m. to 6:00 p.m., intermittent, and predominantly omnidirectional. The model simulates this type of traffic and predicts the effects of changes in traffic and/or elevator capacity.

Experimental Frame

The simulation model was used in this study to predict waiting times for elevator usage in a hospital environment. The model can be adjusted to simulate most elevator systems, thus enabling planners to better judge the cost-effectiveness of any proposed system. The effect of additional elevators to a hospital could be judged on the basis of the reduction in average waiting time for elevator access. The cost of each elevator would be weighed against the incremental benefits of reduced waiting time and the value of that time saved. The elevators for a proposed facility could be planned so as to achieve a target average waiting time and variance.

Numerous other statistics of the characteristics of the proposed system can be obtained from the model. The possible statistics include:

- the waiting time at each floor.
- the distribution of time spent by passengers in the elevator.
- the distribution of total travel times.
- the distribution of the number of passengers in the elevator.
- the distribution of the number of passengers in the queues at each floor.

The Simulation Input Requirements

The basic operating characteristics of the hospital's elevators have to be determined by observation or consultation with a representative of the manufacturer.

The operating characteristics of the elevator required are:

- the time required for the elevator to travel between floors.
- the time required to open and close the doors to the different types of cabs.

The design parameters are also required, such as:

- the number of elevator banks.
- the number of elevators in a bank.
- the number of floors served.
- the capacity of each elevator.

The characteristics of the flow of the different types of traffic are required in the form of:

- an arrival distribution at each elevator bank and at each floor.
- a distribution of the arriving passengers' destinations by floor.

Once the above input requirements are documented, they have to be translated into GPSS (3) input tables, equations, and/or constants.

EVALUATION OF POSSIBLE SOLUTIONS

Upon obtaining the inputs necessary for simulation of the vertical transportation system at LUMC, setting up the model, and testing of the model, a vehicle was available for quantitatively measuring the effectiveness of improvements to the system. Most important was the prediction of the effect on delay times of the addition of an elevator or elevators. Graph 1 summarizes the results of using the simulation model to predict the effect on delay times of adding service elevators to the hospital. A number of possible solutions were analyzed with the aid of the simulation model. The alternatives are reviewed here individually and a logistical management plan developed from the most cost effective one.

Changing Departmental Schedules

A change in the schedules of some departments so that the demand for the elevator is spread over a greater time period would require very little capital expenditure. To reduce the average delay time of 2.34 minutes for the period of time from 6:00 a.m. to 6:00 p.m. would require activities involving vertical transport to be scheduled outside of that time period. Very little of the traffic to and from Physical Therapy, Radiology, Operating Room, Recovery Room, or Dietary could be rescheduled to the low utilization hours of 6:00 p.m. to 6:00 a.m. These departments account for 45% of the traffic of the service elevators serving the hospital. The patient transport function of Materials Management could not be rescheduled for this later time period unless its customer departments could reschedule their activities. If the removal of trash and soiled linen by Housekeeping were scheduled to be performed between 6:00 p.m. and 6:00 a.m., the trash and soiled linen which accumulate during the day would have to be stored on the nursing floors. This accumulation on the nursing units would not be acceptable because of asepsis control and fire and safety problems. The only traffic which could be rescheduled is approximately one-fourth of the materials traffic and the impact of removing this traffic (12% of hospital transport traffic) would

Hospital Elevator Simulation (continued)

not be worth the cost of hiring personnel to transport these materials at night. Schedule adjustments therefore, would not effectively impact the vertical transportation problems.

Reprogramming the Elevator Switching Gear

The demand for elevator service at the Medical Center is intermittent and cannot, according to Otis, be met by reprogramming the existing banks of elevators. The front bank of the passenger elevators is programmed with a zoning logic. When demand is down one elevator is positioned at the first floor, another at the third floor, and the third elevator is positioned at the fifth floor. Thus, the elevators are set to respond to the next random demand or call in the most effective manner, But once the demand increases to the point that there are always elevator call buttoms lit up, the elevators simply repsond to calls on the floors and there is little coordination between cars. Loyola's elevators are so over utilized that the zoning logic seldom is a factor in elevator positioning. During most of the 6:00 a.m. to 6:00 p.m. period the elevators are answering calls continually with no time to return to a zoning position.

Hiring Elevator Operators

Elevator operators could be hired to manage elevator traffic for the hours of heaviest demand. To significantly impact the average delay time, the operations would be needed from 6:00 a.m. to 6:00 p.m. Two full-time operators would be required per elevator and at least the hydraulic and two Materials Management elevators would need to be operator controlled. If the operators were to be paid minimum wages, the cost of operator controlling these three elevators would be $33,000 per year, not including fringe benefits. Though the operators might help expedite traffic in crisis situations, the use of operators would reduce average waiting times at most by only 10-15 seconds. If all the reduced waiting time were recovered through reduced FTE's, the potential savings would be only $28,000 per year. The cost is greater than the benefits and is not cost justifiable.

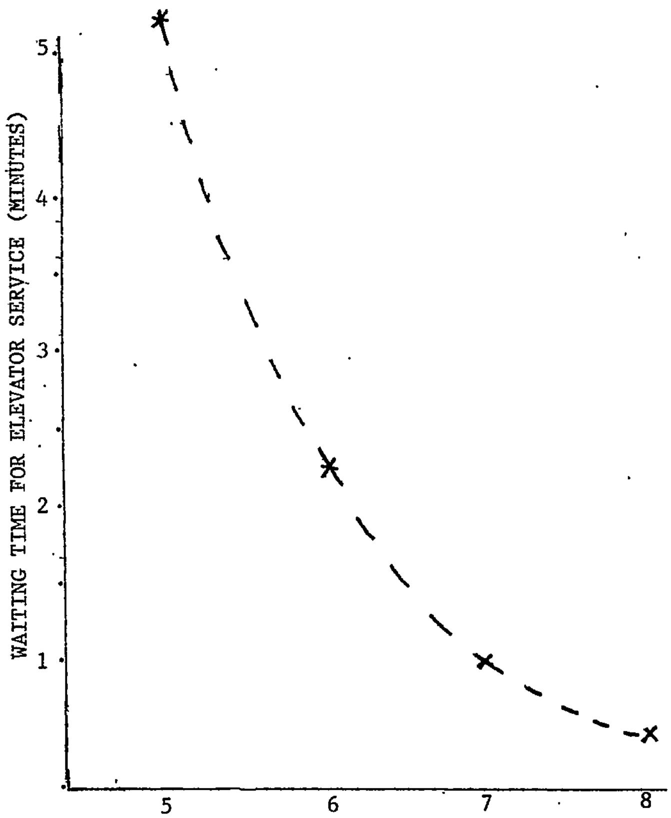
Trash and Linen Removal Devices

The removal of trash and soiled linen could be accomplished by a number of devices. A gravity chute would be relatively inexpensive but would present asepsis, fire and legal problems. Other alternatives include a pneumatic trash and linen removal system, inject-reject automatic elevator system, or a dumbwaiter. Any of these systems would eliminate, at most, 5% of the traffic on the three service elevators in the hospital. Removal of the traffic representing manual removal of trash and soiled linen from the model results in a prediction of an annual savings of $22,000 assuming all time savings are recoverable through reduced FTE's. The pneumatic system would cost $151,000 and would have an economic life of 25 years. Assuming a minimum attractive rate of return of 10%, this investment would represent a present worth of:

$$
\begin{aligned}
PW &= -\$151,000 + \$\ 22,000 \quad (P/A,\ 10\%,\ 25) \\
&= -\$151,000 + \$\ 22,000 \quad (9.077) \\
&= -\$151,000 + \$199,694 \\
&= -\$\ 48,694
\end{aligned}
$$

The other non-gravity systems would result in the same cost savings and could have higher initial costs.

GRAPH I
ANALYSIS OF NUMBER OF ELEVATORS
IN THE HOSPITAL AND THE ELEVATOR DELAY TIME



NUMBER OF ELEVATORS SERVING THE HOSPITAL
(PRESENT NUMBER IS 6)

Dumbwaiter Service for Dietary

A dumbwaiter between Dietary and the Cafeteria would improve the supplying of the Cafeteria, return ½ FTE to dietary, and provide a quicker means of returning the trays from the Cafeteria to the dishwasher area. A dumbwaiter could use the existing shaft of the now defunct tray conveyor system, and would cost from $15,000 to $25,000. The quality of the service in the Cafeteria would be greatly improved by a dumbwaiter service and should be considered as an important factor in the justification of such a system. The present worth analysis would be:

PW = - $25,000 + $ 4,000 (P/A, 10%, 25)

= - $25,000 + $ 4,000 (9.077)

= - $25,000 + $36,308

= $11,308

A Pneumatic Tube System for Nursing

A pneumatic tube delivery system from a central point on each patient floor to Materials Management, Radiology, Clinical Labs, and Pharmacy would significantly reduce the amount of time nursing personnel are presently dedicating to the procurement of single supply items and diagnostic reports. According to Engineering and facilities, the conduits for such a system already exist and the cost would be approximately $40,000 to install a system which would have outlets on each nursing floor and in Lab, Radiology, Pharmacy, and Materials Management. The use of pneumatic tube system would return 7.0 FTE's nurses and 2.3 FTE's nursing aides to the nursing department. Implementation of a Hospital Information System (HIS) which encorporates computerized records will reduce the need for nursing personnel to pick up diagnostic reports. If half of this time is reduced by the implementation of HIS, the recoverable savings through a reduction in the total nursing staff is $56,160 per year.

PW = - $40,000 + $ 56,160 (P/A, 10%, 25)

= - $40,000 + $ 56,160 (9.077)

= - $40,000 + $509,764

= $469,764

The Addition of Service Elevators

The addition of one service elevator in the hospital would cost from $150,000 to $300,000, according to Plant and Facilities estimates, and is predicted to reduce elevator delay time to one minute (see Graph 1). This reduction in delay would represent a potential cost savings of $140,000 per year.

PW = - $300,000 + $ 140,000 (P/A, 10%, 25)

= - $300,000 + $ 140,000 (9.077)

= - $300,000 + $1,270,780

= $970,780

The incremental cost of adding a second elevator would be roughly the same as the first and would further reduce the average waiting time to 30 seconds. This reduction in delay time represents a cost savings of $60,00 per year. The rate of return on the incremental investment can be found as follows:

0 = - $300,000 + 60,000 (P/A, i%, 25)

$$(P/A, i\%, 25) = \frac{300,000}{60,000} = 5$$

i = 20%

Since the rate of return on the incremental investment is greater than the minimum attractive rate of return, the investment is justified.

The addition of a third elevator would further reduce average waiting times by approximately 10 seconds. Such a small decrease in waiting time could not realistically be recovered as savings through reduced FTE's.

The addition of the two service elevators was chosen as the most cost effective solution to the vertical transportation problem. The service elevator additions would eliminate the need for a dumbwaiter for dietary. The need for a pneumatic tube system to nursing could be eliminated through use of a hospital information system and a better materials management distribution system. The potential staff reductions were identified from the hospital employees as 6.1 Transport Aides, 13.5 RN's, and 3.3 Other Nursing Personnel. Over $200,000 in annual savings were realized by reducing the budget by 6 Transport Aides and 11 RN's:

6 X $3.25/hr. X 2080 X 1.14 = $ 46,000

11 X $7.20/hr. X 2080 X 1.14 = $188,000

$234,000

The reductions were made possible by developing a Position Control Reporting System which monitors paid FTE's as well as hired FTE's and by reorienting management to control paid FTE's. The reduction in budgeted FTE's was applied to the Transport Aide job classes in Materials Management.

Once the total paid FTE reduction was identified for RN's, the reduction in budget was applied to specific cost centers with the aide of a Medicus