MANTECH Publications

Journal of Transportation Engineering and Its Applications
Volume 3, Issue 1, January-April, 2018

Service Time Reduction through Facility Re-location of Existing Hospital Facilities

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Abstract

This research was conducted to redesign the facility layout of a secondary level hospital. The aim of the current research is to relocate departments based on the closeness priority between them and to reduce service time and the overall movement cost. Here, Systematic Layout Planning (SLP) technique under process layout approach was used to arrange the departments within the predefined facility boundary. Then movement cost for existing and proposed layout is calculated in MS Excel based on an established mathematical model. The model has four attributes, namely travel frequency or number of trips, trip difficulty rating, baseline travel cost and distance between departments for determining the movement cost. The calculation evaluates the effect of different proposed layouts based on movement cost and shows a significant reduction in movement cost from the existing layout. Among four proposed layouts, optimal layout shows 47% reduction in movement cost compared with the existing layout.

Keywords: *Service time; hospital facility layout; movement cost; Systematic Layout Planning*

I. INTRODUCTION

The layout planning seeks to reduce the movement time and to maximize the total closeness rating between each pair of departments. In order to spatially locate interrelated units such as departments, machines etc. the layout problem subjects to some design criteria and area limitations, with one or multiple objectives.

The problems occur with unequal area and irregular shaped facility layout and those problems cause variations on the basic

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formulation, involving alternative objective functions, constraints, distance metrics, cost measures, and facility shapes. An efficient facility layout design can reduce costs up to 10-30% [1]. Layout problem can be practiced in various sectors such as in industrial facility design, hospital layout, VLSI component placement, warehouse organization, service centre layout etc.

Facility layout planning in service industries including hospitals and retail stores have received more attention now a days due to the increased competition as well as requirements for improved customer satisfaction. The layout design of hospitals focuses mainly on the requirement of functional and organizational structure and the needs of patients. Designing a facility layout for a hospital is a challenging job because of the complexity of functions [2].

Health care facilities like hospital and clinics in Bangladesh are built in small space without proper consideration of facility layout planning that leads to an improper physical location of departments. The wrong placement of different departments causes extra movement of patients, other human resources and sometimes this excess travel leads to traffic congestion.

Therefore, problems such as haphazard flow of patients, large travel path causing the delay of service, improper coordination between departments, hindrance in information flow, late response for treatments are created.

The hospital operations require diversified functions and complex logistics systems that link different departments. The planning and implementation of a required facility design become increasingly obvious to provide a high level of patient services and to achieve the desired efficiency. Thus to realize the advantages of good facility layout for hospitals, the application of process layout to optimize department location is chosen as a research issue. For this research purpose Sylhet Shaheed Shamsuddin Ahmed Hospital was chosen since it is one of the big hospitals in Sylhet Metropolitan.

An exploratory study was conducted on the selected Hospital, which is struggling with high volume of patient flow. Systematic Layout Planning (SLP), a tool for process layout design was used to optimize the interdepartmental flow. The number of trips between departments were

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assessed and a relationship matrix was constructed which represents the relationship (closeness priority) between departments and helps to generate the optimal layout.

The optimal layout provides the best possible arrangement of departments, within a predefined area which results in distance reduction between facility locations. Reduced interdepartmental distance facilitates patient flow as they have to travel fewer paths than before and also enables human resources to be more patient oriented by delivering on-time service.

2. EXISISTING SYSTEMS

The selected hospital is single storied building with 33 departments and the orientation of departments was done without considering any aspect of facility layout design. Due to its inappropriate current layout, it struggles to cope up with wide volume of patients and the system is currently running in haphazard way. Its diversified functions and scope of improvement with large number of departments enticed us to consider it for the target of improvements.

Among all the departments of this hospital, some departments directly cater treatments to the patients while others though not directly related to the treatment of patients but important for proper functioning of hospital. Area of each department and free space is calculated from the coordination of the vertices obtained by AutoCAD design of the hospital.

The patients enter in service channel through ticket counter and receive services from various departments. A simplified patient's flow diagram is given in figure 1 in which arrowhead depicts the direction of patient flow from department to department.

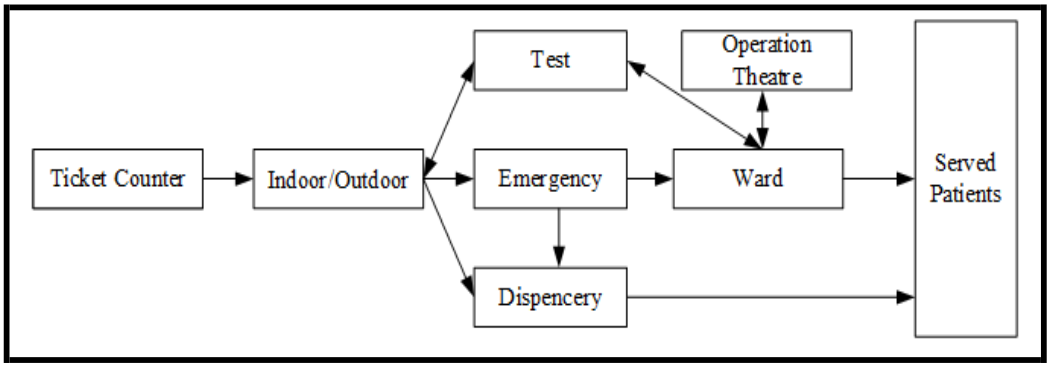


Figure 1: Flow of patients

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SLP tool is used for proposed layout design to reduce movement cost between departments so that total movement cost of systems can be reduced to a minimum level.

2.1 Movement Cost

Movement cost is the prime factor for interdepartmental hospital facility layout development. The mathematical function of movement cost is given by equation-1[3].

$$M_c = \sum_{i=1}^{N}\sum_{j=1}^{N}\sum_{k=1}^{M}(T_{ijk}\pounds_k D_{ij}\alpha_k) \quad (1)$$

Where,

M_c represents movement cost.

N represents the total number of departments.

M represents the total number of travel entities.

T_{ijk} represents the number of trips made from department 'i' to department 'j' by an entity 'k'.

D_{ij} represents the distance from department 'i' to department 'j'.

$\pounds_k$ represents trip difficulty rating of entity 'k'.

α_k represents the baseline travel cost of entity 'k'.

There are various attributes that contribute to the calculation of movement cost. These are:

(i) Distance from department to department, (ii) Trip difficulty rating, (iii) Trip/travel frequency and (iv) Baseline travel cost.

Total movement cost can be calculated as like the table 1.

Table 1: Total movement cost

Entities	**Movement Cost**
Patients	$\sum_{i=1}^{N}\sum_{j=1}^{N}\sum_{k=1}^{5}(T_{ijk}D_{ij}\pounds_k\alpha_1)$
Doctors	$\sum_{i=1}^{N}\sum_{j=1}^{N}\sum_{k=6}^{6}(T_{ijk}D_{ij}\pounds_k\alpha_2)$
Medical Staff	$\sum_{i=1}^{N}\sum_{j=1}^{N}\sum_{k=7}^{7}(T_{ijk}D_{ij}\pounds_k\alpha_3)$
Non-Medical Staff	$\sum_{i=1}^{N}\sum_{j=1}^{N}\sum_{k=8}^{8}(T_{ijk}D_{ij}\pounds_k\alpha_4)$
Total	$\sum_{i=1}^{N}\sum_{j=1}^{N}\sum_{k=1}^{M}(T_{ijk}D_{ij}\pounds_k\alpha_k)$

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3. PROPOSED LAYOUT DESIGN BY SYSTEMATIC LAYOUT PLANNING

In certain types of layout problems, numerical flow of items between departments either is impractical to obtain or does not reveal the qualitative factor that may be crucial to the placement decision. In such situation, the venerable technique known as Systematic Layout Planning (SLP) is used [4]. The current research is mainly focused on quantitative data for rearranging existing departments. Basic steps of SLP involves [4]-

(i) Developing a relationship chart (relationship matrix) showing the degree of importance of having each department located adjacent to every other department.

(ii) Developing an activity relationship diagram from this relationship chart to show the relative importance of each pair of departments.

(iii) Considering space requirement and space availability.

(iv) Adjusting space requirement and space availability in layout generation.

(v) Evaluating alternative layout arrangements.

(vi) Selecting an alternative layout.

Relationship Matrix is also called nearness priority matrix. Relationship matrix specifies the degree of importance (closeness) between each pair departments focusing on quantitative factor. Total number of trips of travelling entities such as patients and human resources (doctors, medical staffs, and non-medical staffs) that occurs between two departments indicates how much they have importance in placing near each other. At first, data about the number of trips of travelling entities for every pair of departments were collected. These were the secondary data that were collected from hospital records for each day over a period of one month. Then data of one month is summed up for each entity and converted into one week to get the average travel frequency per week since travel frequency can fluctuate one week to subsequent week. After that, travel frequency matrix is generated by using this data and based on this matrix a simplified travel frequency matrix was obtained which is showed in Table 2. In layout design it is considered that the desired closeness between a given department pair is a function of and proportional to the travel frequency between the departments.

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The relationship value chart is constructed based on total number of trips. The maximum number trip is identified from the total number of trips between all departments. Then relationship or nearness priority is categorized by dividing range of 0 to the maximum number of trip (600) in five equal divisions (range), each showing a specific degree of importance or closeness. For each range of importance one letter code is placed. A typical relationship value chart is given in Table 3.

Table 2: Specified travel frequency of 33 departments

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**
1	---	85	53	96	17	55	3	45	29	36	36	36	13	14	46	58	87	87	69	27	22	**127**	43	14	8	37	40	35	15	21	27	27	33
2		---	5	0	0	0	0	12	6	11	25	20	0	0	18	9	32	29	4	7	0	6	2	0	2	14	0	0	0	1	0	0	0
3			---	**302**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	3	0	2	0	**414**	0	0	0	0	0	0
4				---	0	0	0	**136**	43	33	49	53	0	0	**306**	**200**	**394**	**333**	**138**	0	0	6	6	0	2	**117**	0	0	0	0	0	0	0
5					---	0	0	0	0	0	0	0	0	0	0	1	3	3	0	14	0	5	0	0	1	0	0	0	8	0	0	0	0
6						---	0	2	0	2	4	8	0	0	0	3	4	5	7	60	0	0	0	0	0	9	0	0	7	0	0	0	0
7							---	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	49	0	0	0	0	0	0
8								---	23	0	0	0	0	0	0	0	0	0	0	7	1	6	1	0	2	0	**177**	0	0	0	6	1	0
9									---	0	0	0	0	0	0	0	0	0	0	0	0	6	2	0	2	0	92	0	7	0	2	0	0
10										---	18	18	3	0	0	0	0	0	0	0	2	6	2	0	2	0	47	8	7	6	0	0	0
11											---	23	3	0	0	0	0	0	0	8	3	6	2	0	2	0	70	8	7	6	0	0	0
12												---	3	0	0	0	0	0	0	13	3	6	2	0	2	0	76	10	7	6	0	0	0
13													---	0	3	5	5	5	0	0	0	2	0	0	1	0	77	0	0	0	0	0	0
14														---	0	0	0	0	0	0	0	18	0	0	0	0	0	0	38	36	36	36	0
15															---	8	8	8	0	10	0	3	3	0	2	0	**437**	1	0	0	0	6	1
16																---	13	10	0	2	0	3	3	0	2	0	**285**	5	0	0	0	6	9
17																	---	24	0	10	0	5	3	0	3	0	**563**	6	0	0	0	6	18
18																		---	0	10	0	5	3	0	3	0	**476**	5	0	0	0	6	16
19																			---	10	3	6	3	0	2	0	**197**	3	0	0	6	6	0
20																				---	45	2	1	14	1	21	0	0	0	**144**	**144**	**144**	0
21																					---	7	5	0	2	3	0	0	7	10	9	10	0
22																						---	9	1	9	5	1	1	1	6	6	6	2
23																							---	0	2	1	2	1	1	14	14	14	3
24																								---	0	0	0	0	0	6	6	6	0
25																									---	3	0	0	1	3	3	3	1
26																										---	**168**	1	0	0	6	6	0
27																											---	0	0	0	0	0	0
28																												---	0	3	2	2	0
29																													---	20	20	20	0
30																														---	0	0	0
31																															---	0	8
32																																---	8
33																																	---

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Table 3: Relationship Value chart

Value	Closeness	Number of trips per week
A	Absolutely necessary	200-249
E	Especially important	150-199
I	Important	100-149
O	Ordinary Important	50-99
U	Unimportant	0-49

Table 4: Relationship matrix

I				
1				
	A			
2		I		
	U		U	
3		E		O
	U		U	
4		U		
	O			
5				

A relationship matrix is developed based on relationship value chart. A letter code is placed in this matrix for relating two departments diagonally. Table 4 represents a typical relationship matrix for five departments.

The departments with relationship value A and E have to place near each other in facility layout design, whereas those departments with relationship values I, O and U can be placed further away according to the strength of closeness. An activity relationship diagram given in Figure 2 is drawn from the relationship matrix. It depicts the closeness priority between departments by specified colour line. Existing departments are represented using number whereas free spaces that are not currently used in service are represented by prefix ‘B’

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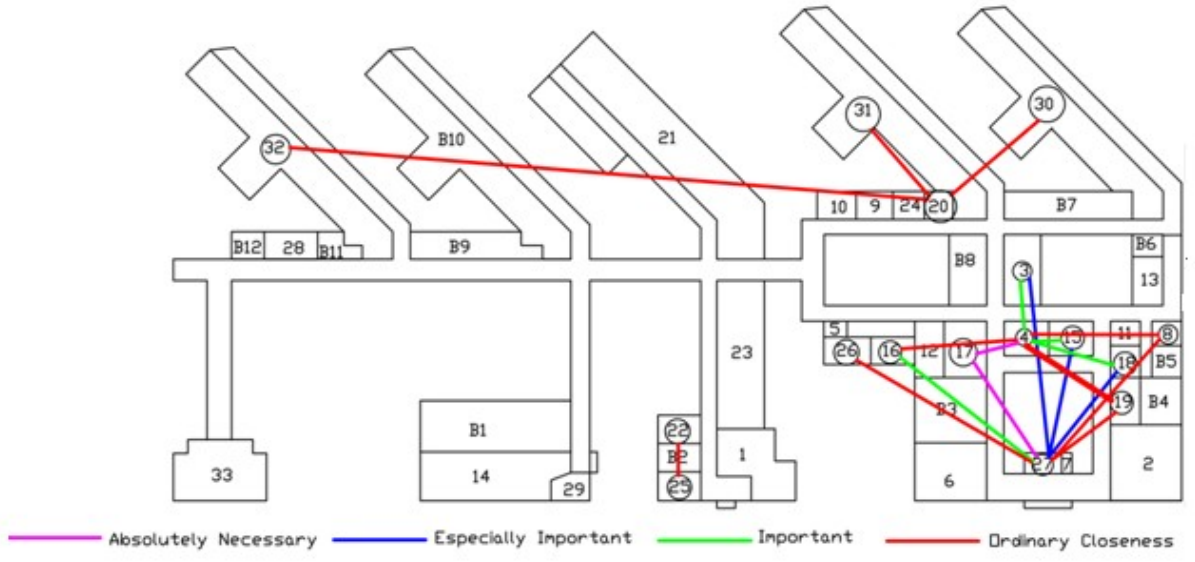


Figure 2: Activity relationship diagram

Space requirement for each department is obtained by direct observation and discussion with expert of respective department. Operation Theatre along with 3 wards requires the maximum space of 274 m^2 and 272 m^2, respectively.

Based on the area requirements 4 layouts were proposed and the optimal layout is shown in figure 3.

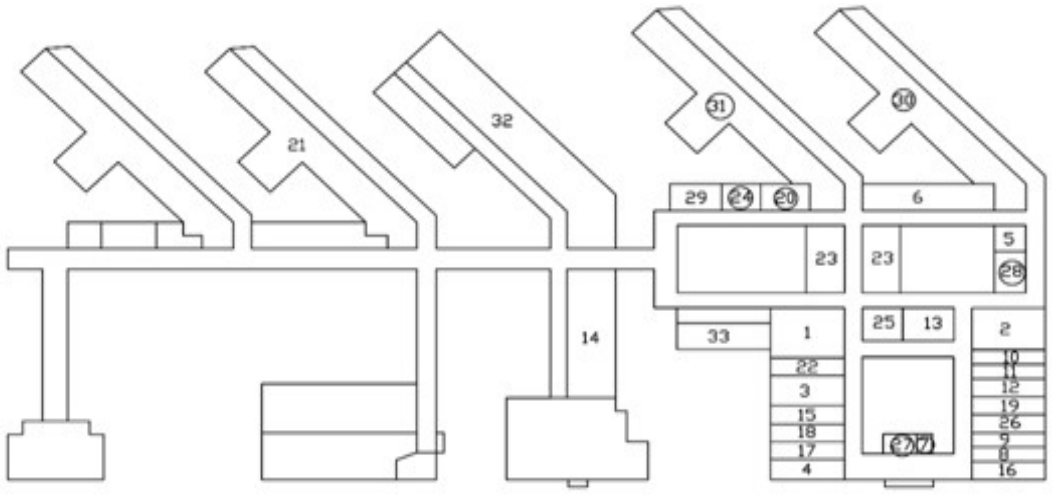


Figure 3: Optimal layout (proposed layout 3)

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Table 5: Movement cost of existing and proposed layouts

Entity	Movement Cost				
	Existing Layout	**PLD #1**	**PLD #2**	**PLD #3**	**PLD #4**
Patient	BDT 1,871,395	BDT 1,293,975	BDT 891,940	BDT 866,948	BDT 855,117
Doctor	BDT 667,395	BDT 626,143	BDT 349,293	BDT 352,350	BDT 367,462
Medical staff	BDT 830,791	BDT 642,508	BDT 618,224	BDT 599,734	BDT 600,244
Non-Medical staff	BDT 484,913	BDT 447,741	BDT 235,826	BDT 222,990	BDT 231,248
Total Cost	BDT 3,854,495	BDT 3,010,368	BDT 2,095,282	BDT 2,042,022	BDT 2,054,071

Proposed layout 3 (optimal layout) is designed by using relationship matrix, by changing the existing layout while keeping the same type of department together. In order to design proposed layout 3, same type of departments (e.g. medicine, eye, gynae) and departments with similar activities (e.g. administration, RMO, superintendent and nursing supervisor, sub-assistant caretaker, wardmaster) are grouped together and placed. In addition, diagnostic departments (e.g. blood bank and pathology, electrocardiography, ultra sonogram) are also grouped and maintained proximity to each other. Proposed layout 3 is shown in figure 3.

Existing and proposed layouts are evaluated based on movement cost. Movement cost is calculated separately for each entity to understand the role of each entity in reduction of movement cost. Movement cost of existing and proposed layouts is presented in table 5.

4. DISCUSSION

Calculations were performed in MS Excel to observe the effect of department rearrangements on movement cost. This rearrangement is achieved by designing certain proposed layout.

In proposed layout #1, total movement cost reduced from existing layout is 22%, in which movement cost of patients (31%), medical staff (23%) reduced is greater than the reduction of movement cost of doctor (6%) and non-medical staff (8%).

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Table 6: Comparison of reduction of movement cost of proposed layouts with existing layout

Entity	Reduction in Movement Cost Between			
	Existing and PLD#1	**Existing and PLD#2**	**Existing & PLD#3**	**Existing & PLD#4**
Patient	31%	52%	54%	54%
Doctor	6%	48%	47%	45%
Medical staff	23%	26%	28%	28%
Non-Medical staff	8%	51%	54%	52%
Total Cost	22%	46%	47%	47%

Total movement cost reduction for last three layouts (2, 3 and 4) is more than double with respect to proposed layout 1. For proposed layout 2, 3 and 4 total movement cost is reduced to a great extent from existing layout which is 46%, 47% and 47%, respectively. Movement cost is reduced for these three layouts (2, 3 and 4) are approximately at same percentage which is easily realized from Table 6. Reduction in movement cost for layout 2, 3, and 4 for the patient, doctor, and non-medical staff is greater than medical staff in percentage.

For selection purpose, any consideration is not given to proposed layout 1 and 2, since these layout show a lesser percentage of movement cost reduction. Therefore, from table 6, optimal layout can be considered as proposed layout either 3 or 4 as they hold same percentage. From Table 5, it can be seen that there is a variation in movement cost in amount where proposed layout 3 shows an amount BDT 2,042,022 and proposed layout 4 shows an amount BDT 2,054,071. Due to less movement cost, proposed layout 3 is selected as optimal layout.

CONCLUSIONS

Shaheed Shamsuddin Ahmed Hospital is one of the early established hospitals in Sylhet metropolis, which is now struggling to cope up with the huge patient flow due to its inappropriate existing layout. To overcome this drawback, four modified layout based on SLP technique was proposed. Comparing the proposed layouts with the existing

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movement cost and an optimal layout is selected. The optimal layout shows that 47% movement cost can be reduced over the existing layout.

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