Integrating Simulation and Optimization for Optimizing Hospital Layout: Case Study of Hospital 115

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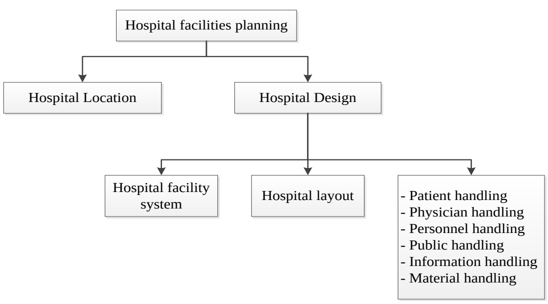
Abstract. Recently, the hospital facility layout problems have had much attention in operations research. Almost, the layout of the considered hospital does not meet the demand of healthcare. The main purpose of this research is to build an integrated simulation and optimization model to solve the hospital facility layout problem. Particularly, a Genetic Algorithm (GA) was deployed in the optimizer module. The solutions were generated under GA approach and analyzed based on the Simulation module under two objectives customer moving time, and customer waiting time. Each layout solution is presented by a string of binary numbers. The solution which can minimize the two objectives is selected as the best hospital layout candidate.

Keywords: Simulation optimization, Healthcare operation, Genetic algorithm, Facility layout

1. INTRODUCTION

Facility layout is one of the critical problems in manufacturing systems. The facility planning hierarchy is applied to kind of different types of facility, in there, the Hospital facilities planning is a specific type, Figure 1



In this hierarchy, the Hospital layout problem will be focused. The procedures for modeling applications a hospital facility layout problem are similar to types of manufacturing or non-manufacturing. The traditional engineering design process can be applied for designing hospital layout, the general step as followed:

Step 1: Define or redefine the hospital facility layout objective

Step 2: Analyze the problem

Step 3: Determine space requirement for all activities

Step 4: Evaluate the alternative facility layout

Step 5: Select a prefer facility layout

Step 6: Implement and maintain the layout design

The hospital facility layout problem has more attention in operation research. All most, the facility of hospital does not meet the demand of health care. Because of, the volume of patients to be treated is increasing rapidly year by year, that the hospital operation cannot control. Further, there are many factors such as the current and future population of service region, the status of hospital organization or quality of the current health care service, which also influence the layout facility design.

The problem of hospital facility has more consideration as below:

Minimize the movement distance of patient between doctor's room and another room.

There is no overlapping for type of patient flow paths, the facility easy to access.

Using efficiency, the available area of hospital.

For the future expansion, depend on the growth in volume of patient.

The rest of this paper is organized as follows. The next section will present a brief literature review of studies on hospital operations, especially simulation based research. Section 3 provides the overview of the hospitals under investigation. Then, it describes the simulation models developed for our study. Results and discussions are given in Section 4. Finally, conclusions and future research directions are shown in Section 5.

2. LITELATURE REVIEW

2.1 A review of Simulation Optimization

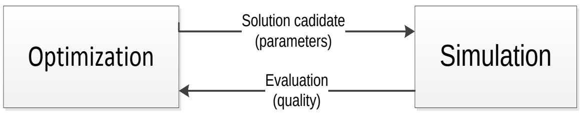
The simulation optimization study (Michael C. Fu 2005), (M. C. Fu 2002), (A. Gosavi 2003) is still quite prefer in operations research. The approach of meta-heuristic optimization has been successfully applied in solving combinatorial optimization tasks such as layout problem or production scheduling. The approach of simulation optimization by using meta-heuristic algorithms, that is offering a huge diversity of optimization algorithms with a variety of simulators as evaluator candidates of solution in a generic way. Some meta-heuristic algorithms applications for optimization to find solution, for example, genetic algorithms, tabu-search, simulated annealing, etc. Generally, there are two main interactions pattern between Simulation and Optimization, control optimization and parametric optimization (A. Gosavi 2003)

2.2 Simulation optimization in Healthcare

A design and management in a health care centre is proposed by Vanda De Angelis (De Angelis, Felici et al. 2003). In paper, they present a methodology that interactively uses simulation system, estimation of objective function and optimization to calculate and validate the optimal of servers. The methodology composed several of technically complex elements such as simulation, estimation, optimization to solve the two main problems about minimize the average total time spent in the system, and minimize the budget for University of Rome health care center.

In case of improve the health care services levels, Hamid Reza Feili (Feili. 2013) use simulation and optimization techniques to determine the best allocation of resources in "Shariati" emergency. In their paper, by analyzing the patients' behavior in hospital, the authors solved two kinds of resources to optimize: first the human resources of the emergency department, and the equipment such as patient beds to determine the best allocation of resources and its applications in hospital Emergency.

Eduardo Cabreraa (Cabrera, Taboada et al. 2012) presents an Agent Based simulation model to design a decision support system for Emergency Department. The objective is to optimize the performance of complex systems, and minimize patient length of stay in the dynamic



Healthcare EDs. The optimization is used to find out the optimal ED staff configuration, which includes doctors, nurses, and admission personnel.

The paper of Mohamed A. Ahmed (Ahmed and Alkhamis 2009) using simulation integrated with optimization to design a support tool for an emergency operation at hospital in Kuwait. The author presents a methodology to optimal number of doctors, nurses and equipments to reduce patient time in the system and maximize patient throughput. The results for that experimental show that the simulation optimization model generates optimal solution for staffing allocation that 28% increase in patient throughput and reduce 40% patients' waiting time.

2.3 Facility layout

The most common approach is to formulate the FLP as a Quadratic Assignment Problem (QAP). The QAP is a special case of the facility layout. The assumption for this layout is equal areas for each department or equipment items as well as fixed and known locations. It was first introduced by Koopmans and Beckham and later applied by Urban, Chiang, and Russell (2010). According to Urban, Chiang, and Russell (2010), they reasoned that the traditional functional layouts or group layout were not necessarily used to put the machines. A model considered the flow assignment and facility locations in discrete solution space, which was built and solved the QAP by using heuristic method.

Flouds (1983) proposed the Graph Theoretic Approach (GTA) to solve the problem of facility layout. In a graph-theoretic approach the departments in the layout are assigned a node in the network. A graph is made up of vertices representing the facilities which are connected by edges representing the desired adjacencies. In case of unequal area, the problems can be solved to optimality by using Graph-theoretic approaches.

Mixed-Integer Programming is another approach to solve the facility layout problem, which uses a distance-based objective (Yang, Allen et al. 2013). A mixed-integer program can be solved the facility layout problem for departments with equal and unequal areas (Lacksonen 1997). A mathematical model was developed for the design of efficient generic layouts and optimal solution can be obtained using MIP approach.

In addition, other types of facility layout, Malakooti (1989) introduced the multi-objective aspect of the QAP and used a heuristic method to generate efficient points. Jannat, Khaled, and Paul (S. Jannat 2010) also focused on the facility layout problems as the multiple objective. In their paper, The authors (S. Jannat 2010) developed the model in which they considered the material handling cost and total closeness rating score. The Genetic algorithm was applied to solve these problems. A Pareto sets solutions used to present the decision makers to find the final solution.

Similarly, in another study of this kind of facility layout problem have been solved by using genetic algorithm. Zouein et al. (Zouein et al. 2002) applied the genetic algorithm to solving site layout problems by considering the affinity weights and geometric constraints between facilities. The geometric constraints govern the relationship between facilities, in terms of the minimum and maximum distance, orientation, and non-overlap with each other. The distance constraint is a predefined value in either the x- or y- direction. Adel Elbaz proposed a GA to deal with facility layout problem of different manufacturing environments with material handling cost criterion. His results showed the effectiveness of the GA approach to solve problems in facility layout. Cheung et al (Sai-On Cheung 2002) made use of the genetic algorithm to search for a near optimal layout solution for a site precast yard by minimizing the total transport cost for a predetermined daily output. Osman et al (Osman, Georgy et al. 2003) developed a hybrid CAD-based construction site layout planning system using the genetic algorithm. The objective of their study was to minimize either the actual transportation cost per unit distance between facilities or a relative proximity weight of closeness relationship between facilities. Maghsud and Solimanpu (Solimanpur and Kamran 2010) considered the optimization the facility layout for a job-shop production system by GA approached.

The above review demonstrate that the application of simulation optimization with using heuristic algorithm to solve the facility layout problem which has been developed recently. However, the hospital facility layout problem is a new research in Viet Nam, there has been little application in this field. Therefore, there is an opportunity to apply the method to solve the hospital facility layout problem in Vietnam.

2.4 Integration environment

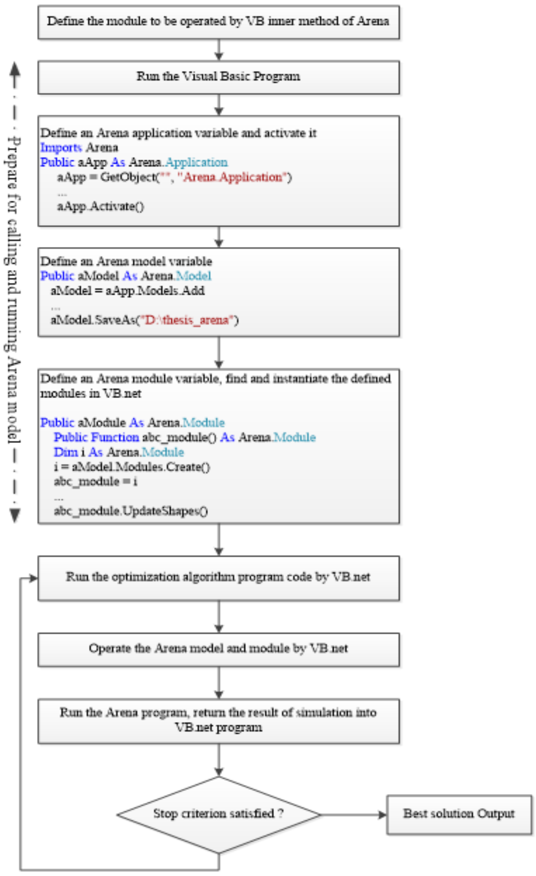
An integration environment between simulation module and optimization module is needed. In this thesis, The Visual Basic is used as integration environment, and Arena 14.00 is used as simulation platform. Arena software can integrate with Visual Basic .NET, which enhances the modeling capability. The optimization algorithm is coded with Visual Basic. NET environment. The controlling of Arena simulation module is performed by Visual Basic .NET, which can modify variable and parameter simulation when Arena is operating, and control the Arena module running. The process is shown as below in Fig. 2.

Step 1: Define and activate an Arena application.

Step 2: Create an Arena project file via Visual Basic .NET program.

Step 3: Create the required control module, operate them in program, and return the results from VB.net to Arena environment.

Step 4: Run the Arena model automatically



Step 5: The results of Arena simulation return to VB.net program

3. METHODOLOGY

The general flowchart of simulation optimization method to develop a hospital facility layout is given in figure. There methodology consists of the two main module, optimization module and simulation module.

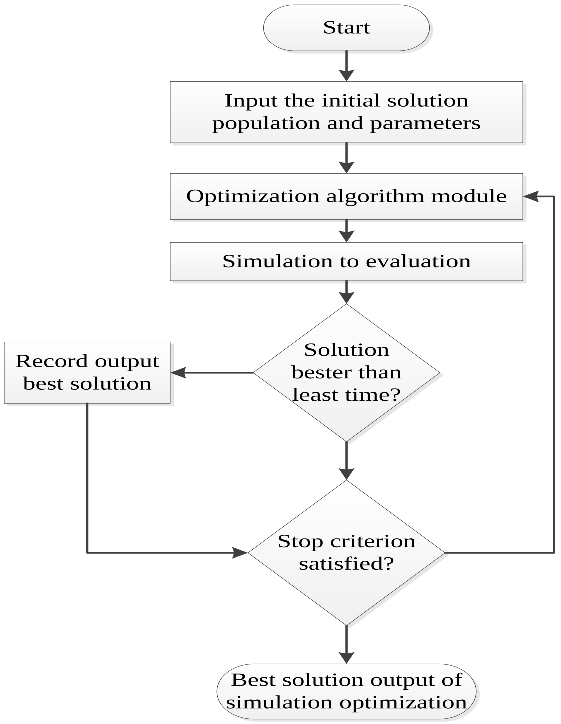


Figure 3.1: Simulation Optimization flow chart

In the optimization module, the genetic algorithm (GA) is approached, which is to find out the alternatives for the system. The GA starts with set of initial solution populations. A new generation is created by selecting parent chromosome from the current generation and modifies them with crossover and mutation operation. In the simulation module, this is considered as an evaluation function (objective function). Then, the chromosomes in new generation are evaluated the value of fitness by simulation. The process would continue until the termination criterion is satisfied. Finally, the best layout is output.

The detail flowchart for methodology is representative deeply that.

An input initial solution represent as a layout of hospital should be generated automatically, that the layout has to satisfy the constraints such as the geometrical constraints. The relationship and connecting between departments layout should be maintained. One simulation has to build and run first, its output is presented as the fitness of the chromosomes. Next, selection operator will select the best chromosomes base on fitness value for crossover. In crossover operation, genes from parent chromosomes will be selected and created a new offspring. After crossover is performed, mutation operator changes randomly the new offspring, mutation could be exchanging two gens, for example. Finally, when GA operators have been done, new chromosomes represent as a new alternative solutions of layout are created. Whenever the new layout is generated with all satisfied the constraints, the simulation module should be able to start automatically to evaluate fitness of chromosomes. If fitness value is better than last time, so record the result as the best solution. The genetic operation is normally stopped when the terminated criterion condition is satisfied.

4. SIMULATION OPTIMIZATION APPLICATION FOR LAYOUT PROBLEM

I apply simulation optimization to solve the hospital facility layout problem. There are two modules will be created. First module is optimization; second module is simulation.

Optimization module is guidance for simulation module. In the Optimization module, I use Genetic algorithm to find the optimal layout. The simulation module is the objective function with stochastic time.

4.1 Genetic Algorithm in optimization

The Genetic algorithm in optimization will be explanted step by step, as a figure 4.1:

1. Firstly, a set of parameter (mutation (%), crossover, population size) and initial solutions was randomly generated.
2. The solutions were set as current generation.
3. Then, the next step is to decode the current generation. Decoding the current generation yields set of X- Y coordinates of workstations.
4. After that, the set of X-Y coordinates was inputted to our model in which some more layouts will be created which its corresponding X-Y coordinates.
5. The layouts will be checked whether the X-Y coordinates of its corresponding departments are feasible or not.
6. If the X-Y coordinate is feasible then the x-y coordinate of the workstations will be put into layout. Because of the feasibility of X-Y coordinate, the layout will also feasible.
7. The distance between each pair of workstation/ department will be calculated in rectilinear distance.

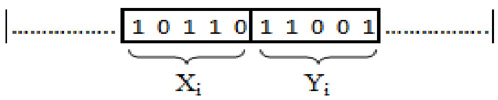
8. The coordinate of each department, the distance matrix, flow chart, etc Will be used as inputs to a simuation model with the function of flow distance.
9. There are N layouts which will return N fitness values. Those values will be compared and the one corresponding with smallest flow distance will be recorded as the best layout.
10. The stopping condition for our procedure is checked, if it is satisfied then stop, otherwise move to step 11
11. Select amount of good layouts as parents to the next generation
12. Crossover was performed.
13. Mutation was also performed with some specific conditions

All individuals were recorded and used as Current Generation in step 2. Repeat the procedure until the stopping condition is reached

4.2 Encoding

The basic GA is applied to search for the global optimization of the facility layout. To start a genetic operation, encoding of a chromosome is needed. There are several types of encoding, including, binary encoding, permutation encoding, value encoding, and tree encoding. Of all the encoding types, binary encoding is the most common. In this thesis, binary encoding is used.

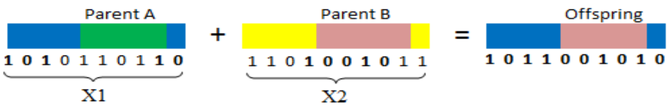
There is a pair of coordinates X-Y which is representative one workstation position, and this workstation will be encoded to be a string of binary bits. In binary encoding every chromosome is a string of bits 0 or 1. A workstation coordinates will be encoded as follow:



The selected number of bits is 10 in order to represent the values of chromosome. A chromosome sequence as $\{X_1Y_1X_2Y_2\ldots X_nY_n\}$.

4.3 Crossover operator

Crossover operator is applied to each pair of bit strings X or Y from two parent chromosomes. The two point crossover operator will be applied for each individual crossover operation.



In the Chromosome parent 1, one random of the X-string (X_i) will be chosen. The Chromosomes parent 2 will decide two or three random of X-string ($X_{k,\, k\neq i}$) to take part in the crossover operator. With n encoded jobs, for each pair of parent chromosomes there is a maximum number of 2n children chromosomes will be created

For example, Parent 1 is now in turn taking X_2 (*1010110110*); the Parent 2 take X_1 and X_3. The two-point

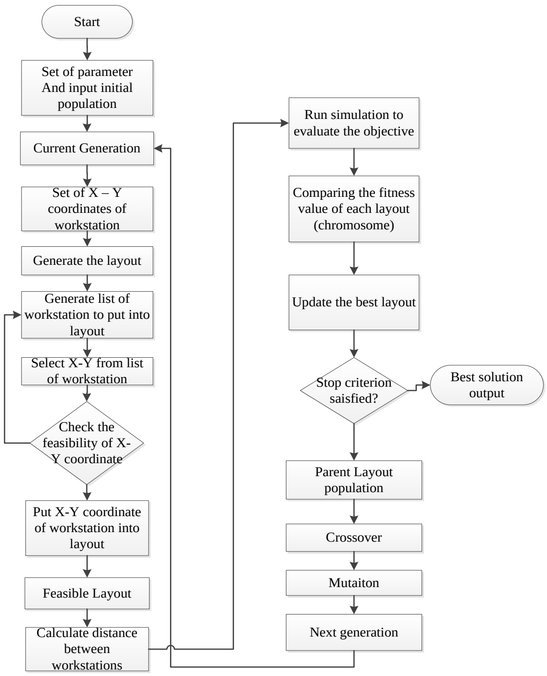


Figure 4.1: Genetic algorithm procedure

Crossover operator will be applied for each individual crossover. Each crossover operation will create 2 new offspring strings. Hence, 2 crossover operations will generate 4 new offspring strings. The offspring chromosomes will be randomly selected from the set of these strings.

4.4 Mutation operator

The mutation operation in this hybrid GA is the result of the full crossover operation described above. When the parent chromosomes are identical, the crossover operation will not create any new chromosome. Therefore, the mutation operation is needed to create a new population of chromosomes.

The bit inversion (selected bits are inverted) mutation operation is conducted by changing a random bit of X_i-string or Y_i-string of a chromosome. As a result, a parent will generate 1 offspring for a certain chosen bit.

4.5 Selection operator

Each pair (Xi, Yi) of a workstation is checked for the feasibility with the previous selected workstations in the layout. Hence, the generated layout is always feasible. The list of workstation means that the list of X-Y coordinate of workstation is generated randomly by the permutation operator. In case of finding no feasible layout solution after a number of iterations of order list generating, the parent chromosomes will be considered as the offspring chromosomes. The program stops either when maximum number of generations is reached, or until the population does not improve. Figure 4.2

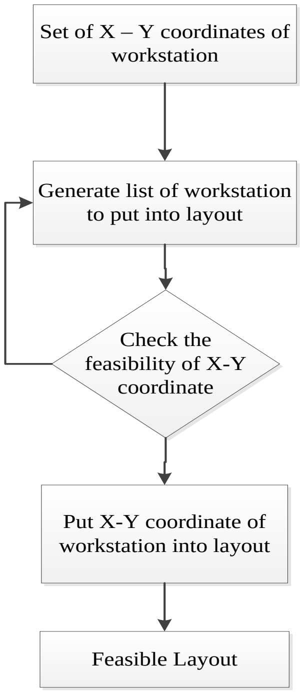


Figure 4.2: Selection operator policy

After the selection operator procedure generated layout, this is always feasible. The GA Roulette wheel is applied for select the best chromosome with the best value of fitness. The basic part of the selection process is to stochastically select from one generation to create the basis of the next generation. The requirement is that the fittest individuals have a greater chance of survival than weaker ones. This replicates nature in that fitter individuals will tend to have a better probability of survival and will go forward to form the mating pool for the next generation

4.6 Objective function for the model

Total travel distances

The objective is to minimize the movement cost, which is equivalent to the minimization of total travel distance between departments location in the hospital layout.

The movement cost is directly proportional to:

Distance between two departments, which depends upon the placement co- ordinates D_{ij}

Travel frequency of entities between departments T_{ij}

Mathematically, the objective function is defined as following:

$$\text{Min: } \sum_{i=1}^{N} \sum_{j=1}^{M} T_{ij} D_{ij}$$

Where:

N represents total number of departments

M represents total number of travel entities

4.7 Fitness function for the model

The fitness function in a GA is a measure of goodness of a solution to the objective functions. The fitness function should be measured directly from individuals of the current population.

$$\textit{Fitness} = \left| \frac{f_i(x) - f_i(x*)}{f_i(x*)} \right|^P$$

Where $f_i(x)$ is the value of objective function. $f_i(x^*)$ is the individual objective optimal values (the optimal value can be achieved). If $p=1$, it implies that equal importance is given to all deviations. The bigger the value of p chosen, the more weight is given to the larger deviation. Here we select $p = 2$

4.8 Simulation model

The simulation model is used as an objective function. The objective function are almost stochastic, the value of the chromosome is the result of a simulation experiment (average total moving time, for example). In simulation model, a variable number of replications per solution are used. The more replication are performed the better accuracy the solution obtained. The objective values of each chromosome are compared based on more replication of their corresponding simulation model

5. OPTIMAL SITE LAYOUT FOR HOSPITAL 115

The People's Hospital 115 is a general hospital giving treatment for patients in more than 20 departments like cardiology, neurology, physical therapy, etc. The patients come to the medical checking area of hospital 115 for diagnoses are guided through the building step by step to complete their process. The information flow in Hospital 115's operation has not been generated into information systems, but the patients have to do it manually by submitting medical checking note.

The hospital has many specialties such as Internal-External Nerve, Internal- External Cardiovascular and Thoracic, Urinary Affairs, Artificial Kidneys, Digestive Interior, Emergency, Health, Diagnostic Imaging, Nuclear Medicine , ultrasound, endoscope etc, and high-tech units such as renal transplantation, TOCE, interventional Cardiology, cardiac Surgery, cancer Treatment.

The operation of hospital follows as the figure below:

Registration: where patients receive medical information sheet.

Counter: where patients pay money for checking health.

There are more kinds of checking health rooms like as Specialist medical check. It includes:

- Internal examination rooms area.
- External examination rooms area.
- Cardiovascular care rooms area.

Area testing (eight testing rooms such as Blood test, Urine test, X-ray, Ultrasound, Endoscopy, CT, ECG, EGG, etc): where patients do testing.

A pharmacy of hospital: where patients buy medicine

The procedure for patients checking health, logical flow of patient:

First of all, patients come to hospital and take the number for registration. After patient pay money at counter, they come to doctor rooms for checking health. After the patient see doctor:

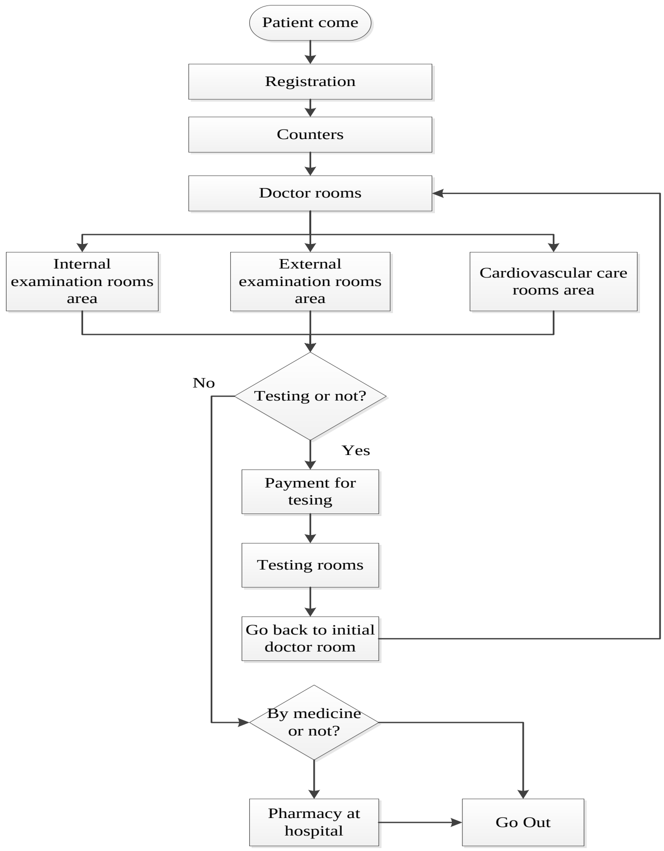
- The doctor will give the description, and patients go to pharmacy or go home. (if patient no need for test)
- Patients go to testing rooms (in case patient need for test). Then they come back initial room to see doctor who checked for them, after that doctor give them the description to buy medicine or go home.
- The patients buy medicine at hospital's pharmacy.

5.1 Hospital layout analysis

The layout of the medical checking at Hospital 115 has 12 zones:

Figure 5.2: Layout plan of hospital (source internet)

We denote for each zone as the figure below follow:



Zone 1: Registration area
Zone 2: Counter area
Zone 3: Internal examination rooms area
Zone 4: External examination rooms area

Zone 5: Cardiovascular care rooms area
Zone 6: Testing
Zone 7: Diagnosis area
Zone 8: Exploratory function area
Zone 9: Hospital Pharmacy

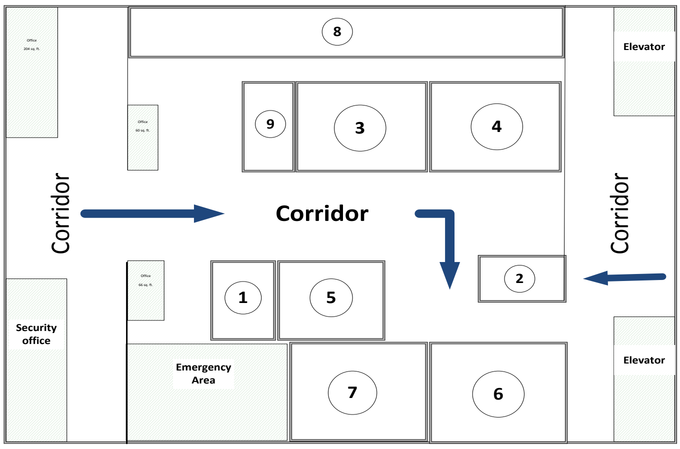


Figure 5.3: Hospital 115 Layout

Registration (Zone 1) area is the first place for any patients who come to the hospital. Here patients will receive their registered number for medical checking, registration for appointment. The payment counter is a Zone 2, pharmacy is a Zone 9. Moreover, there are many rooms inside zone 3, 4,5,6,7 and 8, specifically that:

Zone 3: There are 5 kinds of rooms: General checking room, Endocrinology, Neural, Urology, Digestion, Genecology and Rheumatology.
Zone 4: involved: Dermatology, External examination, Ear nose and throat (ENT), Tropical disease
Zone 5: Cardiology rooms
Zone 6: including Blood testing and Urine testing rooms
Zone 7: for X-ray, ECG, and EGG
Zone 8: including Ultrasound, CT machines,

5.2 Data collection

To run the simulation optimization for the system hospital, we have to firstly collect the necessary data for each work stations, the data include:

The numbers of patients come to hospital per day.

There are 10 samples were selected for the come in number of patient. The expected value is about 1000 patient come to checking health per day.

Example	Number of patient
Day 1	1030
Day 2	990
Day 3	920
Day 4	1100
Day 5	980
Day 6	1050
Day 7	1040
Day 8	1010
Day 9	990
Day 10	1010
Expected value	~ 1000

Table 5.1: Number of patients per day

Percentage of patients to each clinic.

Base on the data collection, the percentage of patients to each clinic as the table above

There are 13 types of diseases as follow:

Types of disease	Ratio
Internal specialist examination	0.15
External specialist examination	0.07
Cardiology	0.27
Endocrinology	0.19
Neural	0.11
Urology	0.04
Digestion	0.04
Rheumatology	0.04
Dermatology	0.04
Gynecology	0.02
Ear nose and throat (ENT)	0.01
Tropical disease	0.02

Table 5.2: The ratio of disease

The routing of testing for each disease types.

According to the Ministry of Health 2012, the testing rule has to follow the routing sequence like as the

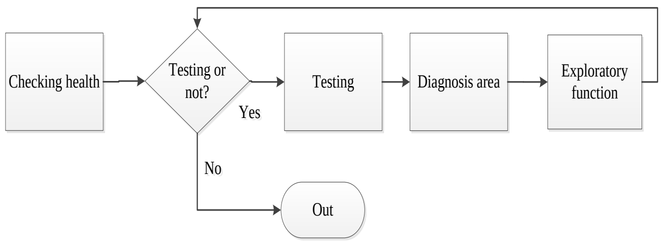


Figure 5.1: the testing rule

To understanding the testing procedures for each disease, we need to make the survey on patients and collect data from hospital. The testing rule will be applied for patients is presented in table

Types of disease	Route sequence
Internal specialist examination	1-2-3-2-6-7-3-9
External specialist examination	1-2-4-2-6-7-8-4-9
Cardiology	1-2-5-2-6-7-5-9
Endocrinology	1-2-3-2-6-7-3-9
Neural	1-2-3-2-7-3-9
Urology	1-2-3-2-6-3-9
Digestion	1-2-3-2-7-8-3-9
Rheumatology	1-2-3-2-7-8-3-9
Dermatology	1-2-4-2-6-7-4-9

Gynecology	1-2-3-2-6-7-3-9
Ear nose and throat (ENT)	1-2-3-2-7-3-9
Tropical disease	1-2-3-2-6-7-3-9

Table 5.4: Route sequence of disease

For example, in figure, The Internal specialist examination has the route sequence as 1-2-3-2-6-7-3-9. It is representative that the patient who has a disease, has to go Registration zone (zone 1) first, and next, they go to the counter to pay for medical checking health at zone 2. After that, they come to zone 3 to see the doctor for internal checking, if the doctor requests the patient to testing, they have to come back the counter (zone 2) to pay money for many kind of test. Next, they go to testing zone first (making blood testing or urine), and go to diagnosis area secondly. After getting the testing result, the paint come back the in initial doctor rooms at internal examination zone to get the consultant from doctor. Lastly, they go to by medicine at hospital pharmacy.

5.3 GA Optimizer

The input data for simulation optimization program are as follow:

For GA optimizer module:

- Area of layout (X-coordinate maximize value, Y-coordinate maximize value)
- The number of workstation or zone of checking rooms
- Maximize of number generation
- Population size
- Percentage of crossover
- Percentage of mutation

For arena simulation module:

- Fixed routing sequence of patients (base on policy of hospital)
- The ratio of diseases are stochastic
- The number of patient come in hospital
- The processing time and resource of each function rooms (depending on the medical zone)
- The distance between locations (get the result from optimization)

After collect all data to input for design simulation model, in this section, I will explain the implementation of the proposed algorithm.

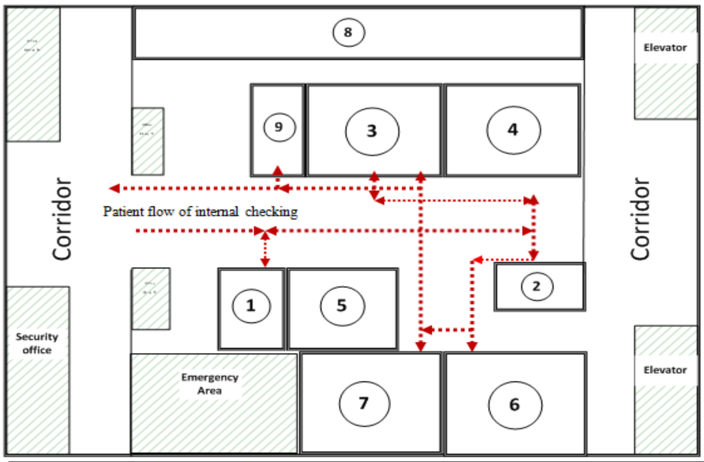
The problem is to optimize the location of 9 Zones (z1, z2…z9) in a floor plan with an area of 102m x 100m.

Parameters for the genetic algorithm are set as follows:

- Number of generations: 30
- Number of chromosomes: 10
- Crossover 0.3 and mutation rate 0.05

A hospital floor plan consists of 9 zones. The total area requirement of each zone is given in table 5. The objective is to fine a design for the systems to result in an overall minimize the total transfer between zone location.

Figure 5.5: Patient flow of internal checking



No.	Zone	Dimensions	Area requirement (m^2)
1	Registration area	16.5 x 16.5	272
2	Counter area	11 x 16.5	182
3	Internal specialist examination	27.5 x 27.5	756
4	External specialist examination	27.5 x 27.5	756
5	Cardiovascular care	16.5 x 16.5	272
6	Testing	27.5 x 27.5	756
7	Diagnosis area	27.5 x 27.5	756
8	Exploratory function area	44 x 16.5	726
9	Hospital Pharmacy	27.5 x 16.5	454

Table 5.7: X-Y coordinate convert to binary

No.	Zone	X	Y
1	Registration area	0101100101	0101100101
2	Counter area	1110001011	0101100101
3	Internal specialist examination	1001001001	1010101111
4	External specialist examination	1101010100	1010101111
5	Cardiovascular care	1000001010	0101100101
6	Testing	1101010100	0010001001

7	Diagnosis area	1001001001	0010001001
8	Exploratory function area	0111101111	1110001011
9	Hospital Pharmacy	0101100101	1010101111

The layout is divided two side, the distance between each location is calculated as the figure5.8.

5.4 Result and analysis

When I finished data analysis, the simulation optimization program will be run with the initial population. There is a chromosome of initial layout within set of first generation. The initial chromosome is representative the layout in figure below:

[0101100101 0101100101 1110001011 010110010 1100100100 11010101111 1101010100 1010101111 100000101 00101100101 1101010100 0010001001 1001001001 0010001001 0111101111 1110001011 0101100101 1010101111]

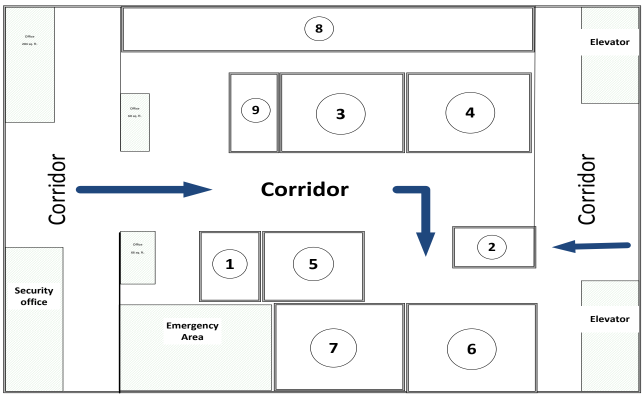


Figure 5.8: The initial layout

Simulation module will be run (10 replication) to evaluate the objective value of this layout; the objective is the total average moving time of patient. The result show as:

Layout	Arena - simulation			
	Moving	half Width	Waiting	half Width
Initial	3116.64	8.52	125.84	1.01

Table 5.8: The result of initial layout

I assume that the value of fi (x*) is 3000, it is the individual objective optimal values (the optimum value can be achieved). So the fitness is

Fitness

$$= \left(\frac{fi(x) - fi(x*)}{fi(x*)}\right)^2 = \left(\frac{3116 - 3000}{3000}\right)^2 =$$

0.00149

The fitness is approached the zero value, it means that, the chromosome has best value for selection.

I run the Simulation optimization program with 30 numbers of generation and 10 initial chromosomes. The result shows that:

Gene-ration	Fitness	Objective - Average-Moving	X1	Y1	X2	Y2	X3	Y3	X4	Y4	X5	Y5	X6	Y6	X7	Y7	X8	Y8	X9	Y9
1	0.000664	3077.32	771	274	659	403	899	402	271	410	387	266	751	560	459	564	207	560	995	560
2	0.001179	3103.01	273	394	539	401	667	266	899	273	721	409	481	560	225	572	1007	572	739	560
3	0.001179	3103.01	273	394	539	401	667	266	899	273	721	409	481	560	225	572	1007	572	739	560
4	0.001723	3124.51	275	274	403	410	147	402	899	266	659	410	719	572	463	564	963	568	231	560
5	0.002201	3140.75	771	410	667	273	403	410	515	258	211	394	719	560	463	560	1007	568	227	560
6	0.002120	3138.12	915	402	659	409	771	274	131	266	387	394	719	564	483	564	207	560	999	560
7	0.003367	3174.08	793	400	667	273	411	402	515	258	211	394	719	560	495	560	975	568	227	560
8	0.005042	3213.02	915	402	659	401	799	274	131	266	387	394	719	564	483	564	239	564	995	560
9	0.00986	3298.00	15	28	25	40	41	40	79	26	64	41	207	56	963	56	711	56	48	56

	7		9	2	9	2	5	2	5	6	3	0		0		0		0	7	0
10	0.012774	3339.06	771	401	543	394	275	410	915	258	643	274	707	560	175	564	971	572	483	560
11	0.017461	3396.42	787	402	403	266	523	394	915	266	275	402	483	564	707	564	963	560	231	560
12	0.023059	3455.56	744	108	340	432	553	336	920	368	165	400	683	562	526	570	105	572	261	571
13	0.027837	3500.53	275	394	387	273	527	402	899	394	659	274	719	560	463	560	975	568	207	560
14	0.029421	3514.58	283	266	405	400	539	266	667	10	731	401	975	572	747	560	161	568	449	568
15	0.037813	3583.37	65	395	278	392	387	256	917	267	706	387	459	561	203	572	751	564	969	564
16	0.039788	3598.41	544	432	706	432	341	332	758	142	174	304	933	570	359	570	102	562	645	572
17	0.051231	3679.03	411	264	473	403	667	394	923	264	515	16	459	568	1003	560	683	568	161	568
18	0.053696	3695.17	275	394	539	401	663	18	923	266	723	393	463	560	239	568	975	568	739	568
19	0.061516	3744.07	519	16	405	272	594	384	259	396	86	395	449	564	751	568	963	560	171	568
20	0.069847	3792.86	930	431	517	175	568	400	411	10	726	324	257	572	547	572	1004	572	737	568
21	0.071460	3801.96	717	108	340	432	557	136	164	368	618	400	683	562	526	562	998	572	262	570
22	0.091948	3909.69	706	12	549	403	475	144	901	16	411	330	106	562	524	560	724	572	268	568
23	0.094235	3920.93	709	336	469	396	514	195	901	48	421	68	619	560	107	568	961	565	468	573
24	0.094710	3923.25	515	16	411	266	923	400	667	273	475	403	449	568	747	568	171	568	975	572
25	0.131926	4089.65	704	276	341	323	517	175	952	48	470	431	547	562	748	568	982	572	257	573
26	0.140988	4126.45	705	400	597	64	453	402	87	402	278	274	455	562	300	572	968	560	107	561
27	0.143565	4136.70	726	322	919	323	341	432	519	272	453	49	983	560	619	560	452	572	107	572
28	0.153137	4173.98	706	12	597	371	10	400	922	16	556	195	523	562	747	568	979	572	256	572
29	0.163504	4213.07	597	10	709	272	257	322	411	275	534	387	1004	561	751	568	213	568	459	562
30	0.217666	4399.64	647	13	421	323	69	400	903	51	726	332	491	562	709	568	108	561	897	565

From the table of result above, there are 30 generations, they represent 30 layouts. Xi-Yi are coordinate of Zone i with i = 1,2,3,4,5,6,7,8 and 9. I rank the fitness value ascending and chose 5 alternative layouts for comparison.

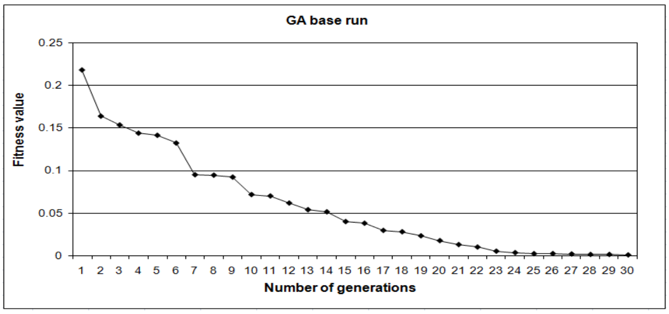


Figure 5.9: The figure of GA run base

Layout	Result			
	Moving distance	half Width	Waiting time	half Width
Initial layout	3116.64	8.52	125.84	1.01
Layout 1	3077.32	7.7	102.12	1
Layout 2	3103.01	9.98	134.94	2.63
Layout 4	3124.51	9.92	134.86	2.24
Layout 5	3140.75	8.04	102.97	1.31
Layout 6	3138.12	9.94	122.51	2.08

Table 5.10: Compare result between alternative layouts

Comparing with initial layout, I see that, the layout 1 and 2 are bester than initial about moving distance. But layout 1 is dominated about moving distance and waiting time rather than other.

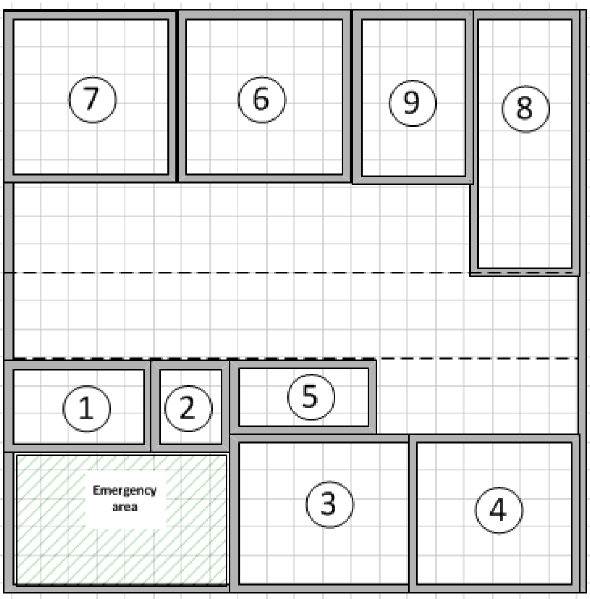


Figure 5.9 The result of Layout 1

Figure 5.10 The result of Layout 2

Base on the comparison, I select layout 1, which is the optimal layout for hospital.

6. CONCLUSION

In this research, a Simulation-optimization approach was applied to solve the Facility layout problem in Hospital 115. Specifically, in the Sim-opt, the Genetic Algorithm was integrated to Simulation. The solutions were generated under GA approach and analyzed based on the Simulation model under two objectives customer moving time, and customer waiting time. Finally, the result is recommended to the hospital to operate

In terms of Theory, the thesis helps expand the literature for research on healthcare operation in Vietnam. Practically, the research provided better layout for the hospital to cover a big demand from 2016. In comparison to the current layout, we can reduce the moving time and waiting time.

Moreover, with this Sim-opt model, the hospital can possible utilize it to plan for new layouts in the future. In particular, when the demand increases or decreases or when there is a need to expand the hospital capacity, we can use this model to plan layout for the expansion with low effort and good moving and waiting time since it would take so much time to plan layout for hospital if one only does it manually.

Despite these contributions, our research also has some limitations:

In this research, because of the complexity of the hospital, we considered group of departments instead of every single department in order to reduce the computational time. This model, as a result, generates results quite quickly but not very precisely. Thus, the model and algorithm for solving large scale system related to the hospital operation is recommended for future study.

Further more, in this research, I just focus on, how to using the simulation optimization to solve the hospital layout, and I skip the changing of policy. It means that the sequence of disease is fixed. Next research, I will skip the optimal layout (layout is presented above) and optimizing the sequence of disease to minimize the total waiting time of patients.

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