

## Improving Optimization Solution for Facility Layout Problem with Thermal Comfort

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### ABSTRACT

Facility Layout Problem (FLP) can be considered as a classical problem in quantitative studies. However, the literature in FLP are largely neglected the thermal comfort as part of the objective function. Today, energy savings for buildings are a major concern in the world as they cover a big portion of energy use. The public room consumes high energy use because of its ability to occupy many people at one time. Issues arise when each person has a dissimilar thermal satisfaction rate, while each area in a room provides a different temperature. There are many factors that influence the people dispersion in the room including the facility layout. However, it is really testing to handle an air-conditioning control ( $A_c$ ) system by considering the mention factors to ensure the thermal satisfaction is increased and energy is reduced. Since lack of report on thermal factors in Facility Layout Problem (FLP) area, this work aims to optimize the temperature setting of an  $A_c$  system at the best point and achieving the finest plan for the facility layout in a room. Further, our ultimate goals to maximize the thermal comfort level and reduce energy consumption are able to accomplish. A non-linear mathematical model is utilized to optimize the thermal satisfaction rate ( $Th_{rate}$ ) and room layout. At the end of the article, we proposed an Evolutionary Algorithm (EA) to find a quality solution or near optimal since it is hard to solve this problem in a reasonable time.

#### Keywords:

Facility Layout Problem; thermal comfort; meta-heuristic algorithm

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## 1. Introduction

Facility layout problem (FLP) can be defined as the facility arrangement in the mill or work area. FLP turns to be a meaningful impact on the production charge including manufacturing, and processing. A good facility placement is able to increase operational effectiveness while the total operating expenses can save up to half of the original expense [1]. The researchers continually

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measure the ability, effectiveness, and benefits of a given layout by using various approaches and methods [2].

Unfortunately, layout problem generally comes with a complex problem and mostly NP-hard [3]. As a consequence, past a decade, researchers aggressively tend to find out the solution in this area via the survey and review the previously published studies. However, these studies are no longer recent [4-6] while it's too specific on a certain aspect as such loop layouts [7], dynamic problems [8] and design through evolutionary approaches [9]. Benjaafar, Heragu, and Irani [10] presented a review study on challenges and progress in factory layout requirements by taking both efforts of academics and industry. However, at the end of this research will introduce a new direction of FLP for different constraints with similar approaches.

## 2. Facility Layout Problem (FLP)

As stated above, FLP shows a variety of biases on the definition of layout problem due to various considerations in articles. Static layout problem is the most frequent formulation araised. Among the first to introduce this type of problem were Koopmans and Beckmann [11]. They interpret FLP as a general industrial problem that aims to construct facilities, so the cost of transportation can be reduced.

Azadivar and Wang [12] define the facility layout problem based on the system's achievement test, where material movement time significantly affects system productivity than its cost. Further, the facility layout problem can be said as an optimization problem, as researchers attempt to use the coding of heuristic approaches to design an optimal or near-optimal solution [13].

### 2.1 Mathematical Formulation of FLP

Facilities Layout Problem (FLP) is classically related to a quadratic assignment problem (QAP) [11] after several decades. Moreover, the formulation of FLP can be Quadratic Assignment Problem (QAP) or Mixed Integer Programmings (MIP) by depending on the way the problem is formulated. QAP and MIP are commonly present in a discrete or continuous form in literature. Moreover, it is essentially an NP-hard problem and is widely used to solve FLP [3, 15].

Assume the problem is to locate the  $n$  facilities in locating  $n$  given locations. There is only one facility can be elected to each location, and vice versa. Basically, every layout has a different total cost of materials handling, where it should first refer to the facilities' position. This refers to the general definition in which each component stream in the different departments and price of component handling are correlating with the unit flow per unit distance.  $Q_{ab}$  is the movement between facilities  $a$  and  $b$ , and  $E_{cd}$  is the location length between point  $c$  and  $d$ . The FLP is shown below.

Quadratic Assignment Problem (QAP):

$$\sum_{a=1, a \neq b}^n \sum_{c=1, c \neq d}^n \sum_{b=1}^n \sum_{d=1}^n Q_{ab} \times E_{cd} \times X_{ac} \times X_{bd} \quad (1)$$

$$\sum_{a=1}^n X_{ac} = 1 \quad \forall c = 1, \dots, n \quad (2)$$

$$\sum_{c=1}^n X_{ac} = 1 \quad \forall a = 1, \dots, n \quad (3)$$

$$X_{ac} \in \{0,1\} \quad \forall a, c = 1, \dots, n \quad (4)$$

Based on the equation above,  $a$  can be represented as the facility and  $c$  represent a location while  $n$  is the number of facilities. The condition of  $X_{ac} = 1$  will only be satisfied if the facility  $a$  is appointed to location  $c$ , otherwise, it turns to zero value. Eq. (1) aims to lower the sum of flow multiplying with the length of all facility pairs in each layout. Eq. (2) and (3) are to assure every location only consists of one facility and every facility only can be appointed to one location, respectively.

Moreover, the layout sometimes refers to a discrete that optimized in QAP formulation, occasionally. Discrete can be described through a block shape. At the plant site, it can be partitioned into rectangular blocks with the same area and shape, then each block is assigned to a facility [16]. Otherwise, the facilities with dissimilar size need to be filled in different blocks [17].

Discrete formulations are commonly suggested for several reasons, such as, reduce part backtrack in single row layouts [18], and the layout representation is often used for dynamic layout problems related to equal size facilities [20-21]. The rule of the constraint should be followed whereby one location should be appointed only on one facility at a time, and one facility should be appointed at one location at a time [20, 22].

However, most of the previous research presents the layout in continual, frequently addressed as Mixed Integer Programming (MIP) problems [23-25]. Unfortunately, only a little work is previously seen in the dynamic layout problem in continuous representation. Dunker *et al.*, [24] deal with the unequal size area in dynamic representation for layout problems. They claim that the QAP approach is of little use in resolving the unequal size area.

## 2.2 The Progress of FLP

In the past, FLP problem mostly rely on classical heuristics method such as Genetic Algorithm to solve the optimization problem. After decades, the interest is moving towards Swarm Intelligence as a preferred technique to solve NP Hard Optimization Problem. It is also identified that previous research in FLP often overlooked the importance of user comfort as part of the Hard/Soft Constraint. In this article, we stress on the importance of the thermal comfort as part of the important constraint.

## 3. Thermal Comfort Constraint in Energy Optimization Problem

In reality, thermal comfort standards are a major concern for well-established buildings where cooling and heating systems should follow the standards [26-27]. Public buildings are able to hold many people at a time, this cause the high energy is consumed. Also, the thermal satisfaction may differ for each people even though they stay in the same condition [28]. Thus, it should be examined in thermal issues since it's never is considered before.

Based on ASHRAE [29], the thermal comfort can be described as the satisfaction of a mental condition where it can be expressed through the thermal condition. Six factors may affect thermal comfort. They're divided into four physical factors, such as temperature, humidity, air velocity, and mean radiant temperature, and two personal factors which are clothing insulation and activity level [30].

Doherty and Arens [31] present two ways to assess the thermal comfort; (i) heat-balance and (ii) adaptive approaches. The heat-balance method is analyzed thermal comfort in the scope of climate chamber studies, while an adaptive method utilizes the fieldwork data that involve the people in the buildings [32]. Early than mention above, the Predicted Mean Vote-Predicted Percentage Dissatisfied (PMV-PPD) model has been proposed by Fanger in year 1970 [33]. Then it's become a reference to the next researchers.

Since then, various studies have been published. Oseland [34] has proposed a two-level method for the thermal satisfaction rate of 30 peoples in a dissimilar situation. Besides that, both of Predicted Mean Vote (PMV) and Actual Mean Vote (AMV) are actually had a difference in natural air circulation and air-conditioned room [35]. Thus, Humphreys and Nical [36] has proposed their work to overcome the limitation of PMV by introducing ISO-PMV. In research of Djuric *et al.*, [36], they use the Predicted Percentage Dissatisfied (PPD) model to measure the thermal comfort then implemented into a single-objective optimization algorithm in order to lower the total charge. Contrary, Langevin *et al.*, [37] present revised PMV-PPD curves for field offices parallel with the development of each comfort parameters.

More than that, PMV also has a deficiency in reflecting the difference in thermal sensations of a person where it is just played as an average model. This has been proven by Zhao *et al.*, [38], then, they propose a data-driven technique to interpret the thermal constraint. Zhao *et al.*, [39] have used an adaptive approach in proposing a multi-linear one-class classifier to solve the personal thermal compliant. By using this approach, the boundaries between comfort and discomforts level can be found and able to be solved. By neglect, the internal temperature alteration, He *et al.*, [40] propose the different approach in solving the thermal issues by analyzing the occupants' satisfaction in one room with one desk fan. In recent years, field studies highly endorse the researchers to analyze the comfort factors in an actual situation to ensure the result is more reliable.

In a large public room, the building is able to hold a big amount of people at one time. Moreover, the different area has a different temperature level as observed in this study. Since every person has a different thermal satisfaction rate, then they tend to find and stay at a suitable area in a room that is able to satisfy their thermal sensation level. Thus, with these two important issues which are the different area in a room have a different temperature and different thermal satisfaction rate for every people, it is really significant to control an air-conditioning system. Then, the maximum thermal comfort and the minimum energy usage can be achieved.

Many studies have been done before, the main aim is to optimize thermal comfort while reducing energy usage of the HVAC system, especially for large buildings. Nagarathinam *et al.*, [41] have considered the thermal sensitivity needs and an efficient air circulation system. They use a predictive control method to minimize the energy utilization of HVAC systems. Moreover, Chen *et al.* [42] introduce a reinforcement learning control strategy (model-free Q-learning). This method is implemented to optimally take charge of the air-conditioning and window system, simultaneously. However, the factor of thermal sensitivity differences are not considered in [41-42].

In the past study, a control method for  $A_c$  systems are suggested by Wang *et al.*, [43] with the aim to increase the thermal satisfaction rate by setting the best temperature point. They deal with the differences between dwellers in a huge public room as the main factor [43]. However, various factors can influence the effectiveness of HVAC system including the facility layout in a room. Basically, the facilities are placed in a large room to fulfill the people's needs and work with, like bookshelves, tables, and chairs in a library. In a large room, there is always have a hardware configuration of an  $A_c$  system and is considered the temperature in a room is balanced. However, there are still present the parts in a room that feel hotter than other parts. It's maybe caused by the improper facilities placement in some areas where it actually comfortable for human temperature but it is filled with facilities. Moreover, different area surely has a different temperature, while, different facility arrangement will show different effectiveness of air-conditioning systems.

As shown at an early point, a study on the facility layout problem (FLP) in a large room is seen not have any recorded or discussed by any previous researchers. Thus, the aim of this work is to develop a room layout and optimize the temperature setting of an  $A_c$  system, meanwhile, the thermal satisfaction factor and energy productivity are assessed for a big room. This research combines the

principle of facility layout problem (FLP) in order to solve the critical issues of maximizing thermal comfort with lower energy usage for the building. The selected articles that have been shown in Table 1 are intended to understand the relationship between energy-efficiency and optimization problems. In addition, the comfort elements and other constraints are also been showed and considered in the previous optimization problem (Table 1).

**Table 1**

Thermal comfort, technique, and related energy efficiency optimization problem

No.	Heuristic Algorithm / Method	Research problem	Constraints	Ref.
1	Improved global particle swarm optimization (IGPSO)	To optimize an air-conditioning scheduling method, specific on indoor thermal factor	Objective Function: 1. Comfort 2. $A_c$ power consumption Constraints: Predicted mean voted (PMV) comfort index ( air temperature ( $t_a$ ), mean radiant temperature ( $t_{mrt}$ ), activity or metabolism rate ( $m_r$ ), air velocity ( $v_r$ ), relative air humidity ( $rh$ ), and clothing insulation ( $I_{cn}$ )).	[44]
2	Multi-Objective Genetic Algorithm (MOGA)	To effectively manage the energy consumption and building comfort	Objective function: 1. Comfort 2. Power Demand Constraints: Lower and Upper bound $L_{temp} - -U_{temp}$ $L_{rh} - -U_{rh}$ $L_{Lx} - -U_{Lx}$ $L_{Aq} - -U_{Aq}$ ( $temp$ = Temperature, $rh$ = Relative humidity, $Lx$ = Light intensity, $Aq$ = Air Quality)	[45]
3	Multi-Objective Genetic Algorithm (MOGA) & Hybrid Multi-Objective Genetic Algorithm (HMOGA)	To improve indoor building condition for people comfort, while reduced energy utilization	Objective function: 1. Comfort 2. Power Demand Constraints: Lower and Upper bound $L_{temp} - -U_{temp}$ $L_{Lx} - -U_{Lx}$ $L_{Aq} - -U_{Aq}$ ( $temp$ = Temperature, $Lx$ = Light intensity, $Aq$ = Air Quality)	[46]
4	Genetic Algorithm (GA)	To increase the energy effectiveness and internal comfort in building	Objective function: 1. Comfort 2. Energy consumption Constraints: 1. Parameter of controller agent (Temperature Controller ( $e_{Thermal}$ ), Illumination Controller ( $e_{Lux}$ ), Air Quality Controller ( $e_{CO_2}$ ))	[47]
5	Hybrid Multi-Objective Genetic Algorithm (HMOGA), & Pareto front	To develop a fuzzy inference model for electricity usage and temperature with an excellent optimizer	Objective function: 1. Comfort 2. Energy consumption Constraint: Lower and Upper level $L_{temp} - -U_{temp}$ ( $temp$ = Temperature)	[48]

6	Multi-Objective Genetic Algorithm (MOGA), & Pareto optimal front	To develop a control system behavioral model with suitable plan for smart buildings	Objective function: 1. Comfort 2. Energy consumption Constraint: Lower and Upper level $L_{temp} - -U_{temp}$ ( $temp$ = Temperature)	[49]
7	Genetic algorithm, Hopfield neural network optimization & a hybrid optimization method	To solve the burnable poison placement (BPP) problem to improve the outcome aspect and nuclear reactor security.	Objective function: 1. Improve the placement of burnable poisons in reactor core Constraint: 1. Energy function (Value of neurons' output)	[50]

#### 4. Methodology

We define FLP with consideration of thermal constraint as follows.

##### 4.1 Problem Formulation

This study proposes a three-layer optimization method. Firstly, the difference in outside temperature is considered in determining the room layout. Secondly, based on the given outside temperature, a mathematical model of thermal satisfaction rate ( $Th_{rate}$ ) is proposed. At this stage, the goal is to achieve the maximum  $Th_{rate}$  with the resolved room layout plan at the first level. Finally, further optimization is done by another mathematical model to get better results for the temperature setting of an air-conditioning control ( $A_c$ ) system with high energy efficiency.

For the first layer of optimization problem, only the temperature is studied where it affects the human thermal sensation difference. However, there are many factors that can influence  $Th_{rate}$  as well, and they can also be inserted into the model like a temperature factor is considered. Literally, a big room can be split into several areas. Parts of them can be installed with the facilities and the others can be employed by people.

For instance, a library room. A library room can be separated into several parts. Some parts are fulfilled with the bookshelves while another one is employed as reading areas. Furthermore, there are two sets of areas: 1) undecided area which are some area are able to be arranged and can be used for any purpose and 2) decided areas in which it's only can be managed for a specific reason and cannot be altered. Thus, it is assumed  $n$  as undecided areas and  $m$  as decided areas [51].

Given  $z_l, l \in N_n = \{1, 2, \dots, n\}$  as the size of the  $l$ -th undecided area. Meanwhile, assume  $h$  represents the total size that needed to put all facilities. Then, the sum of  $z_l$  must be greater than  $h$ , otherwise, the  $l$ -th undecided area should be neglected. Let  $x_l$  and  $y_l$  was introduced as two binary parameters where both represents the two different conditions.  $x_l$  is indicated in  $x_l = 1, l \in N_n$ . If the condition is fulfilled, then the  $l$ -th undecided area is employed for facilities. Contrary, if  $x_l = 0$ , then the  $l$ -th undecided area is filled by peoples. Noted, only the selected  $k$  areas are taken to filled with facilities, while one other area is simultaneously utilized for facilities and people. These to ensure the required areas to allocate facilities are achieved.

In other condition, binary parameter  $y_l$  is proposed. When  $y_l = 1, l \in N_n$ , then partial  $l$ -th undecided area is placed with facilities, otherwise, it is either filled by facilities or people. This condition involves one area only for allocating facilities and people at the same time. For presenting the number of people that can be held by an area, parameters  $\alpha_{1l}$  and  $\alpha_{2j}$  was suggested.  $\alpha_{1l}$  represents the number of people at the  $l$ -th undecided area while  $\alpha_{2j}$  represents the number of



people at the  $j$ -th decided area. So, it is clearly showing that there have two separate areas is involving.

In this study, it is essential to know the maximum number of people that can be filled at each separate area. Then, parameter  $s$  is utilized to inform the size needed for one person in an area. Based on the given  $s$  value and the size of an area, the above-mentioned number of people can be calculated [51].

As we know, every room provides a dissimilar temperature. Assume  $t_{1l}$  and  $t_{2j}$  represent as the temperature of the  $l$ -th undecided and  $j$ -th decided areas, respectively. Meanwhile, parameter  $t_{in}$  is the temperature point of an  $A_c$  system and  $t_{out}$  is given as the external temperature. Generally, the internal temperature of the room is affected by  $t_{out}$  but it depends on  $t_{in}$  value. But, in these cases,  $t_{in}$  is the main objective that needs to be found. The internal temperature of the room is utilized in the form of  $t_{in\_out}$  parameter.

Additionally, given  $T_{max}$  °C and  $T_{min}$  °C as the maximum and minimum external temperatures, respectively. Assume  $T = (t_{in}, t_{out})$ , while, define  $f_l: T \rightarrow t_{1l}$  as a  $f_l(t_{in}, t_{out})$ , then,  $f_l(t_{in}, t_{out})$  is the function of  $t_{1l}$ . Define  $F_l: T \rightarrow t_{2l}$  as a  $F_l(t_{in}, t_{out})$ , then,  $F_l(t_{in}, t_{out})$  is a function of  $t_{2l}$ . Given  $\gamma_t \in \mathbb{R}$ , where  $\mathbb{R}$  is a set of real numbers and  $\gamma_t$  represents the  $Th_{rate}$  of people at the temperature  $t$  °C,  $t \in \mathbb{R}$ . Next, define  $g: t \rightarrow \gamma_t$  as a  $g(t)$ , then it is a function of  $\gamma_t$ . Thus, a mathematical formulation of the following cases can be developed while  $Th_{rate}$  can be improved [51].

The formulated problem is in the form of non-linear and it is NP-hard as it is derived from most FLP classical problem in heuristics. Hence, it's really hard to solve those models effectively. Because of that, the section below will explain more about the heuristic algorithms as an excellent solution for the suggested model.

#### 4.2 Meta-Heuristic Algorithm

Nature inspired meta-heuristic algorithm is seen as great potential in solving complex problems which involve various constraint and objective function. Nature inspired meta-heuristic algorithms can be categorized into four major classes which are Evolution based, Physics based, Swarm based and Human based methods. Evolution-based methods are motivated by the laws of natural expansion in living things [52]. Physics-based methods stimulated by the physical laws in the cosmos. Swarm-based method initiates from the collective manners of a group of animals. Meanwhile, human-based methods encouraged by the advancement in the level of searching design [52]. The list of these meta-heuristic algorithms has been shown in Table 2.

For solving the NP-hard problem, a meta-heuristic approach using Evolutionary Algorithm (EA) is proposed as we previously used in [53-55]. In Artificial Intelligence (AI), Evolutionary Algorithm (EA) is classified under the Evolutionary Computation where it is a division of computer science compartment [56]. Moreover, EA is one of best method under meta-heuristic optimization algorithm, generally, popular as Genetic Algorithm (GA) [53, 57]. Figure 1 illustrates the flow of a general Evolutionary Algorithm.

**Table 2**

The list of nature inspired meta-heuristic algorithm [52]

Nature inspired Meta-Heuristic algorithm			
Evolution Based Method	Physics Based Method	Swarm Based Method	Human Based Method
<ul style="list-style-type: none"> <li>• Genetic Algorithm (GA)</li> <li>• Evolution Strategy (ES)</li> <li>• Memetic Algorithm (MA)</li> <li>• Genetic Programming (GP)</li> <li>• Biogeography Based Optimizer (BPO)</li> <li>• Virulence Optimization Algorithm (VAO)</li> </ul>	<ul style="list-style-type: none"> <li>• Simulated Annealing (SA)</li> <li>• Big-Bang-Big-Crunch (BBBC)</li> <li>• Gravitational Local Search Algorithm (GLSA)</li> <li>• Gravitational Search Algorithm (GSA)</li> <li>• Genetic Programming (GP)</li> <li>• Central Force Optimization (CFO)</li> <li>• Black Hole (BH)</li> <li>• Artificial Chemical Reaction Optimization Algorithm (ACROA)</li> <li>• Galaxy Based Search Algorithm (GBSA)</li> <li>• Ray Optimization (RO)</li> <li>• Charged System Search</li> <li>• Small World Optimization Algorithm (SWOA)</li> <li>• Curved Space Optimization (CSO)</li> </ul>	<ul style="list-style-type: none"> <li>• Particle Swarm Optimization (PSO)</li> <li>• Ant Colony Optimization (ACO)</li> <li>• Bacterial Foraging Optimization Algorithm (BFOA)</li> <li>• Cuckoo Search (CS)</li> <li>• Krill Herd (KH)</li> <li>• Dolphin Optimization Algorithm (DOA)</li> <li>• Shuffled Frog Leaping Algorithm (SFLA)</li> <li>• Artificial Bee Colony (ABC)</li> <li>• Dragon Flies (DF)</li> <li>• Bat Algorithm (BA)</li> <li>• Whale Optimization Algorithm (WOA)</li> <li>• Ageist Spider Monkey Optimization (ASMO)</li> </ul>	<ul style="list-style-type: none"> <li>• Tabu (Taboo) Search (TS)</li> <li>• Harmony Search (HS)</li> <li>• Group Search Optimizer (GSO)</li> <li>• Imperialist Competitive Algorithm (ICA)</li> <li>• Firework Algorithm</li> <li>• League Championship Algorithm (LCA)</li> <li>• Interior Search Algorithm (ISA)</li> <li>• Colliding Bodies Optimization (CBO)</li> <li>• Mine Blast Algorithm (MBA)</li> <li>• Soccer League Competition (SLC)</li> <li>• Exchange Market Algorithm (EMA)</li> <li>• Seeker Optimization Algorithm (SOA)</li> <li>• Social-Based Algorithm (SBA)</li> <li>• Group Counselling Optimization (GCO)</li> </ul>

Evolutionary is based on the concept of biological reproduction. In the context of It starts with generate the initial population of FLP, potential random layouts are produced. Then, objective functions to maximize (or to minimize cost) will be established and potential solution will be evaluated. If the stopping criteria is met, then it will stop, otherwise it will keep iterating until finding the best possible solutions. The process of finding the best solutions by generating new population might include selection of best individuals, crossover (recombination of individuals) and mutation of individual. Individual refers to single solution (or single layout).



```

Start
  T=0;
  Initialize_population, P(t=0);
  Evaluate P(t=0);
  Do While terminationCriterion=False OR max t
    t=t+1;
    P*(t) = P(t=0).selectParent;
    P'(t) = P*(t).reProduction;
    P'(t).mutation;
    Evaluate P'();
    P(t+1)=generateNewIndividual (P', P(t));
  Loop
End
    
```

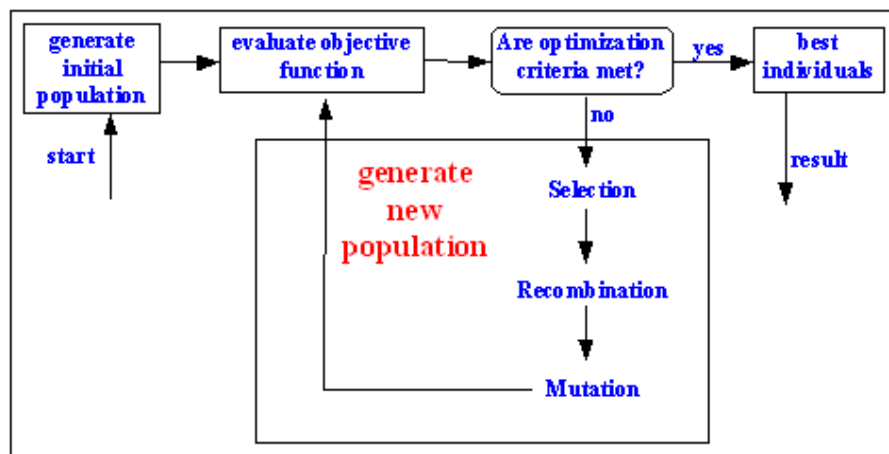


Fig. 1. The flow of Evolutionary Algorithm

## 5. Conclusion and Future Works

Nowadays, the issues of global warming and climate change become a world concern. The government and other parties have raised the effort towards energy saving by reducing energy consumption in various aspects. In many studies, buildings are the largest contributor to the power use and production of greenhouse gases in the globe [57, 59]. Meanwhile, HVAC systems allocate a big portion of the energy usage in buildings [60]. Thus, it is significant to control and effectively conduct the air-conditioning systems in reducing power consumption.

Previously, the problem of HVAC has been solved by using the model predictive control (MPC) as a correct choice and it is improved by much research before this [61-64]. Unfortunately, MPC shows a deficiency in its implementation. This is because the building model simplification and the extrinsic factors do not really fit and have a negative impact on the MPC model.

Nature inspired meta-heuristic approach shows potential in promising potential in solving building optimization problem. It is widely employed in numerous fields in research study such as engineering, medical, computational science, etc. Building optimization system would benefit from various scheduling, controller system, comfort parameters, building inspection and human behavior aspect in achieve the intelligent automation building system that able to reduce the energy consumption and maximize user's comfort inside the building.

In this paper, we presented a formulation to include thermal as part of Facility Layout Problem. Due to the complexity of FLP, we propose EAs as an approach to solve this conflict. The thermal constraint is considered as a new contribution to FLP since there is no evidence before. In our future works will include programming phase to develop the EAs with the related multi-objective and constraints related to thermal as part of our work to solve FLP.

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