ISSN: 2063-5346
Section A-Research paper

A Novel Heuristic Method for Facility Layout Problem

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Abstract*— The problem of asset placements is widely known as the Facility Layout Planning (FLP) in the manufacturing field. The placement of assets or machines is very important for the manufacturer's planning, especially the large and highly expensive ones. A relatively small change in a machine's position can significantly affect the production flow of materials and expenses. FLP is an optimisation problem that minimises the Material Handling Cost (MHC) while sufficiently meeting the facilities' constraints or requirements and producing feasible layouts. Typically, layout planning is related to the location of facilities (e.g., machines, departments) in a plant. They are known to greatly impact the manufacturing system performance. FLPs are often uniquely designed and thus solved using specific approximate approaches. A new heuristics method is developed for the unequal area FLP (UA-FLP) with fixed flow between departments. The study is considering the orientations of the departments with numerous sizes and aims to minimise the distance traveled by people, material, and other supporting tools in the safest and most effective manner. This work could be used in future as a reference for those researchers interested in exploring this challenging UA-FLP.

Index Terms—*Facility layout problem, metaheuristics, optimisation, unequal area facility layout problem*

I. INTRODUCTION

Given the rapid growth of technology and the pandemic, manufacturers are forced to transform their factories and operations and embrace process automation and IR4.0 to sustain business and production excellence. Transitions to smart factories and smart manufacturing systems remain a huge challenge for global and local manufacturers. The costs of replacing and arranging machines and tools in factories, investment to adopt new technology, expected loss in production during factory and system upgrading and period to recover the return of investment influence the manufacturer's decision to adopt newer technologies (Puyal et al., 2020). The problem of asset placements is known as the Facility Layout Problem (FLP) in the manufacturing field. A relatively small change in a machine's position can significantly affect the production flow of materials and expenses. According to Pérez-Gosende (2021), nearly 50% of operations expenditures incurred in manufacturing plants are associated with the Material Handling Cost (MHC).

Increased workflow, information, and material may all be distributed more easily on a site with an effective structure. If a factory is not planned with efficiency in mind, it can have a negative impact on overall profitability. Wastage results from an ineffective layout. It might be challenging to locate a space for everything as a facility grows. The production line can easily become disorganised if workstations are arranged erratically, and employees may conflict with other operations in trying to finish jobs, which would cut down on the amount of time they could spend working on the final product (Gislam, S, 2019).

An FLP is an optimization problem that minimises the MHC while sufficiently meeting the facilities' constraints or requirements and producing feasible layouts. Past studies have utilised various heuristics and metaheuristics approaches and algorithms to solve equal-area and unequal-area FLPs. There exist several limitations in previous studies including the absence of qualitative factors and theoretical requirements in FLPs, increasing computational time as the problem size increases and the absence of user-friendly optimisation tools for manufacturers. This research aims to solve the unequal-area FLP based on industry-driven layout criteria using improved methods and algorithms.

Methodologically, the properties of heuristics and metaheuristic methods will be studied and algorithms for the improved methods will be developed and tested. From this research, it is expected that the Graphical User Interface (GUI), developed based on the proposed methods, shall be beneficial for manufacturers to determine the feasible facility layout for smart factory transformation planning.

II. PROBLEM STATEMENT

According to the Ministry of International Trade and Industry, one of the goals to support the national vision is to elevate the absolute contribution of the manufacturing sector to the economy from RM254 billion to RM392 billion (MITI, 2018). Prior to the COVID-19 pandemic, IDC's Asia Pacific Insights Annual Survey 2019 revealed that local manufacturing businesses reported declining sales (78%), demand variability (74%), increased competition (37%), lack of innovation (27.8%), and rising internal costs (20.4%) (Kumar, 2021). Given the rapid growth of technology and the pandemic, manufacturers are forced to transform their factories and operations and embrace process automation, IR4.0, big data to sustain business and production excellence.

In the global landscape, many countries have been transforming their manufacturing industries to smart factories

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and adapting to smart manufacturing. A smart factory has pieces of machinery that are interconnected by a system that makes use of data to cope with increasing demands. Smart manufacturing is a technology that utilises interconnected machines and tools for improving manufacturing performance and optimises the energy and workforce required. Transitions to a smart factory and smart manufacturing system remain a huge challenge for global and local manufacturers. One of the challenges is the return of investment in new technology (Puyal et al., 2020). The costs of replacing and arranging machines and tools in factories, investment to adopt new technology, expected loss in production during factory and system upgrading and period to recover the return of investment influence the manufacturer's decision to adopt newer technologies.

The placement of assets or machines is very important for the manufacturer's planning, especially the large and highly expensive ones. A relatively small change in a machine's position can significantly affect the production flow of materials and expenses. According to Pérez-Gosende (2021), nearly 50% of operations expenditures incurred in manufacturing plants are associated with the Material Handling Cost (MHC). The problem of asset placements is widely known as the Facility Layout Problem (FLP) in the manufacturing field. An FLP is an optimisation problem that minimises the MHC while sufficiently meeting the facilities' constraints or requirements and producing feasible layouts. Typically, layout problems are related to the location of facilities (e.g., machines, departments) in a plant. They are known to greatly impact the manufacturing system performance. FLPs are often uniquely designed and thus solved using specific approximate approaches.

Variants of FLP modelling approaches such as exact, heuristic, stochastic, metaheuristic, intelligent or hybrid methods, require high-level knowledge of formulation and solution approaches (Pourvaziri et al., 2021). Past studies have focused on solving equal-area FLPs using various exact approaches and algorithms such as Branch and bound, Dynamic programming, Cutting plane and Constraint integer programming. The variability in sizes and shapes of machines and the urge to improve space utilisation have introduced researchers to a newer type of FLP called unequal-area FLP (UA-FLP). Recent studies have been focusing on solving UA-FLPs using metaheuristics methods such as Simulated Annealing (SA), Tabu Search (TS), Genetic Algorithms (GA), Particle Swarm Optimisation (PSO) and Ant Colony Optimisation (ACO). Hybrid metaheuristics were also used to solve complicated FLPs with an increased number of facilities (Nordin and Lee, 2016). In addition, Hosseini-Nasab et. al. (2018) mentioned that these optimisation methods are to find optimal solutions for small-sized problems.

There exist several limitations in previous studies. First, qualitative factors such as closeness rating between facilities, plant safety, and flexibility of layouts for future design changes (Hosseini-Nasab et. al., 2018) were not considered in the FLPs. Furthermore, the applications of theoretical requirements are very limited (Pérez-Gosende, P., 2021). For example, the placement of entrance and exit doors and the placement of loading and unloading areas are important key points in a plant layout. Second, metaheuristic techniques have been broadly applied to solve FLPs for over two decades (Hosseini-Nasab et. al., 2018). Moreover, the computational time required to solve a problem increases exponentially with the problem size. Finally, many optimisation methods require high-level knowledge and thus they are not widely employed by practitioners or managers in businesses (Pérez-Gosende, P., 2021).

Therefore, there is an urgent need to develop an FLP that takes into account the qualitative factors and manufacturer's requirements and solve the FLP using improved optimisation approaches. Improved algorithms that provide good suboptimal solutions with less computational time are also ideal. For practitioner usage, a user-friendly tool must be developed for determining the feasible facility layout for smart factory transformation planning. Hence, this research aims to solve an unequal-area FLP based on industry-driven layout criteria using improved methods and algorithms and develop a Graphical User Interface (GUI) for practitioners.

III. LITERATURE REVIEW

A heuristic or local search algorithm is an approximation approach that begins with some provided solutions and attempts to discover a better solution in a broadly specified neighbourhood of the present solution. In the event that a superior solution is discovered, it takes the place of the existing one, and the local search is then carried out from that point on. Heuristic techniques have unavoidably played a key role in algorithms capable of generating good solutions in an acceptable amount of time. Heuristics algorithms can be classified into two categories, which are construction type algorithms and improvement type algorithms. In construction type algorithms, the solution is developed from scratch, while for the improvement type algorithms, the solution is derived from an initial solution (Singh and Sharma, 2006).

Construction type algorithms are considered as the simplest heuristic approach and the quality of the solution may not be the best result. Among the known algorithms are ALDEP (Seehof and Evans, 1967), CORELAP (Lee and Moore, 1967), MAT (Edwards et al., 1970), PLANET (Deisenroth and Apple, 1972), SHAPE (Hassan et al., 1986), and NLT (Camp et al., 1991). These algorithms have their own set of steps. In general, the first step is facility selection based on certain criteria. For example, CORELAP uses total closeness rating and SHAPE uses distance between facilities. The selected facility is placed at a specific location on the layout either at the centre or the upper left, depending on the algorithm used. The subsequent facilities are added to the layout according to specific criteria. This step is repeated until all facilities are placed in the layout. In NLT, the authors transformed the constraint to an unconstrained model by using the exterior point quadratic penalty function method and used the solution from the previous stage as an initial solution.

CRAFT (Armour and Buffa, 1963), DISCON (Drezner, 1980) and MULTIPLE (Bozer et al., 1994) are among the known improvement algorithms. These improvement algorithms can be easily combined with construction methods. In this respect, CRAFT seems to be the oldest

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improvement-type approach where it begins by determining the centroid of each facility. While DISCON used nonconvex mathematical programming problems and dispersion-concentration. MULTIPLE extends CRAFT applying space-filling curves method.

Metaheuristics, on the other hand, are being employed to approximate the solution of a large FLP instances. The objective of global search heuristics is to avoid becoming trapped in a local optimal solution. This is achieved by adopting specific uphill moves (worst solutions than the current best). Such non-improving solutions are generated using probabilistic criteria such as simulated annealing (SA), population-based methods based on ideas borrowed from genetics such as Genetic Algorithms (GA), and deterministically by stopping reversal moves such as in Tabu Search (TS), or population-based adoption from ant behaviour such as Ant Colony Optimisation (ACO).

The Simulated Annealing (SA) technique derives from the theory of statistical mechanics and is based on the comparison between solving optimisation problems and the annealing of solids (Singh and Sharma, 2006). For the FLPs, multiple implementations of the SA algorithm have been proposed. The homogeneous SA was utilised by Burkard and Rendl (1984). In their approach, the procedure stays at the current temperature until a certain number of trials have been completed before moving on to the next temperature. The temperature is reduced using the variant of the geometric schedule. If all temperatures have been utilised, i.e., k > kmax, then the procedure terminates. Using the single-row and multi-row facility layouts as their implementation patterns, Heragu and Alfa (1992) conducted a thorough experimental examination of two SA-based algorithms. The first approach employs traditional SA heuristic techniques, whereas the second is a hybrid SA algorithm (HSA). Hasan and Osman (1995) were the first to combine SA with TS, and they were followed by Alvarenga et al. (2000) and Vilarinho et al (2003). The hybridisation of several metaheuristics has also been proposed for the solution of FLPs. For reducing the material handling cost (MHC), Mahdi et al. (1998) proposed a hybrid method. SA was utilised to solve the geometrical element of the problem, GA was used to make material handling system decisions, and an exact approach (Hitchcock's method) was used to minimise total material handling utilisation cost. Then, Mir and Imam (2001) proposed a hybrid solution to a layout problem with unequal area facilities. Beginning with an initial solution provided by SA, an analytical search technique determines the ideal locations of facilities in a multi-stage optimisation process. Matai et al. (2013) suggested a new SA to cater Unequal-Area FLPs (UA-FLPs), where adjustments in various control parameters of the improved SA result in an optimal solution. On the basis of their findings, they have demonstrated that this approach can handle large Multi-Objective FLP (MOFLP) problems with number of departments, $n \geq 30$) efficiently. Moradi and Shadrokh (2019) implemented SA to address both equal area FLPs (EA-FLPs) and unequal area FLPs (UA-FLPs). The hardware characteristics and computing times have been examined, and the results demonstrate that the proposed SA is equally capable of handling combinatorial optimisation problems like Construction Site Layout Planning (CSLP) as previous metaheuristics. Furthermore, Sun et al. (2022) proposed 2-opt-based SA and graphic processing units (GPUs) to overcome the problem of single-row facility architecture (SRFLP).

The genetic algorithm (GA), developed by John Holland et al. in 1975, is a sophisticated stochastic search and optimisation approach based on evolutionary theory concepts. According to Singh and Sharma (1996), GA has received more attention in the recent decade than any other evolutionary computation algorithm. To solve FLPs, numerous GA algorithm implementations have been explored. Tam (1992) pioneered the first GA method for FLP. The post order sequence of the nodes in a slicing tree is used to describe a solution to a coding scheme created for facility layout. Balakrishnan et al. (2003) created a hybrid GA to overcome the dynamic layout problem that Rosenblatt had previously addressed (1986). Two techniques are used to produce the initial population: a random method and an Urban's procedure (Urban, 1993). The crossover is performed by a dynamic programming technique, and the mutation is conducted through the CRAFT heuristic (Armour and Buffa, 1963). Nordin et al. (2009) used hybrid meta-heuristics, specifically GA-SA, to tackle UA-FLPs. Four main components of the block layout problem are taken into account in the multi-objective GA given by Aiello et al. (2012) to solve UA-FLPs: handling costs, adjacency requests, distance requests, and aspect ratio of departments. Hernandez (2013) proposes an interactive GA that employs the decision maker's expert knowledge to solve the UA-FLP, where the decision maker's knowledge leads the search process by adjusting the parameters to their preferences at each generation of the algorithm and taking into account a large number of departments, $n = 20$. Furthermore, in 2019, Lin and Yingjie proposed a pre-processing stage for the initial layout and the optimisation of the layout solutions are presented by GA. The proposed algorithm demonstrates an effectiveness, and it can be used in solving large layout problems.

Similar to SA, Tabu Search (TS) is deterministic and based on neighbourhood search with local-optima avoidance. The fundamental idea of TS is to allow climbing moves when there is no better neighbouring solution. Many authors have applied this meta-heuristic to FLPs. Skorin-Kapov (1990) proposed using TS in FLP to solve QAP problems. The approach is built in a flexible way that enables user interaction and allows the user to adjust the parameter setting, such as the tabu list size, the iteration limit, a search diversification parameter, and the quantity of new starting solutions, at any time throughout the run. Ching and Kouvelis (1996) designed a TS algorithm for solving FLPs. They employed a neighbourhood based on the interchange of two facilities, as well as a long-term memory structure, a dynamic tabu list size, an intensification criterion, and diversification techniques. To find near-optimal solutions, Hasan and Osman (1995) created a TS with a hashing algorithm. Chiang and Kouvelis (1996) created a TS algorithm to solve an FLP using a neighbourhood based on the exchange of two facility locations, as well as a long-term memory structure, a dynamic tabu list size, an intensification criterion, and diversification

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techniques. Scholz et al. (2009) suggested a slicing tree and TS-specific method (STaTs) for solving UA-FLP. They solved fixed and flexible facilities in UA-FLPs using a slicing tree representation and a bounding curve. To find better solutions, their TS includes four sorts of neighbourhood changes. Kothari and Ghosh (2013) used their developed algorithm to determine the optimal facility layout for a problem size of n = 23. There are two TS implementations: one that uses an exhaustive search of the 2-opt neighbourhood and one that uses an exhaustive search of the insertion neighbourhood. Lakehal et al. (2022) introduced Biogeography Based Optimisation meta-heuristic BBO and a parallel hybrid BBO with tabu search PBBO-TS algorithm to solve the facility layout problem. Parallel computing is implemented to diversify the search, to increase the performance of the BBO algorithm, and to accelerate the speed of the running time.

Marco Dorigo (1992) developed Ant Colony Optimisation (ACO). This metaheuristic mimics ant behaviour in order to create routes from the colony to the food. ACO has been employed to solve FLPs, with Gambardella et al. (1999) being the first to do so. McKendall and Shang (2006) constructed and compared three hybrid ant colony algorithms for the problem of dynamic facility planning. They use an ant colony in conjunction with three local search algorithms: (1) a random descent pairwise exchange technique, (2) a simulated annealing algorithm, and (3) a look-ahead/look-back procedure. For the purpose of resolving FLPs, Singh (2010) presented an ant system with local search incorporated. Hani (2007) applied hybrid ACO with Global Local Search (GLS) to QAP, whereas Singh (2010) and Lina (2012) applied hybrid ACO with Local Search (LS) to QAP and two-layered models, respectively. Komarudin (2009) used an Ant System to address the UA-FLP problem. Lina et al. (2012) solved two-layered model FLPs by combining ACO and local search. Chen (2013) modified McKendall and Shang's (2006) HAS I and HAS II and worked with a large number of departments (*n* = 30) to implement his approach. To get Pareto-optimal solutions to the problem, Liu and Liu (2019) introduced a unique pheromone update method that combines Pareto optimisation based on local pheromone communication and global search based on niche technology. To deal with the non-overlapping constraint between departments, the authors used a combination of local search based on the adaptive gradient approach and the heuristic department deformation strategy.

IV. METHODOLOGY

There exist several limitations in previous studies. First, qualitative factors such as closeness rating between facilities, plant safety, and flexibility of layouts for future design changes (Hosseini-Nasab et. al., 2018) were not considered in the FLPs. In addition, the applications of theoretical requirements are very limited (Pérez-Gosende, P., 2021). For example, the placement of entrance and exit doors and the placement of loading and unloading areas are important key points in a plant layout. Second, metaheuristic techniques have been broadly applied to solve FLPs for over two decades (Hosseini-Nasab et. al., 2018). In addition, the computational time required to solve a problem increases exponentially with the problem size. Finally, many optimisation methods require high-level knowledge and thus they are not widely employed by practitioners or managers in businesses (Pérez-Gosende, P., 2021).

This study focuses on the method that very easy to implement even with a very minimal knowledge on heuristics and metaheuristics.

a) *Research Methodology*

First, the properties of the proposed heuristic will be reviewed. Second, the algorithm of the improved method will be designed for the UA-FLPs. Then, the proposed algorithms are tested and refined.

Specifically, the methodological procedures are as follows:

i. Analysing the properties of the proposed heuristic approach (The Origin Heuristics or TO)
ii. Developing the algorithm for TO for solving UA-FLPs and testing the best operators for the proposed approach.
iii. Computational testing and refinement of the algorithms.
iv. Comparing the performance of TO with existing algorithms

b) *Data Collection*

The algorithm requires input data such as number of facilities, fixed rectangular boundary of size W (floor breadth) x H (floor height) and flow for each facility. The data will be gathered from the manufacturing industries (secondary datasets).

A. *Formulation of an Optimisation Model*

The layout of a factory involves the decision to allocate all facilities, machines, equipment, and staff in the manufacturing operation at the safest and most effective manner. However, the focus will be given towards two-dimensional static Unequal Area FLP (UA-FLP) for analysis and illustration purpose. The formulation of the two-dimensional static UA-FLP is very demanding which can be easily and largely adapted with certain rules and preferences giving a generic approach to the layout design problems. According to Hasda in 2017, the rectangular facilities are located in a rectangular layout space in an orthogonal manner. The investigation carried out is restricted and are limited to the following.

1. The research focus is on fixed rectangular UA-FLPs dimension.
2. The areas of the rectangular facilities are known in advance.

The advantages of having an optimisation model are various. There are finding new solutions that meet the product specifications, look for solutions that achieve the best compromise in terms of performance and design requirements, justifying its technological choices by quantitative data to the decision maker on performance and

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constraints related to the problem. In brief, an optimisation method consists firstly, of writing and formulating the problem by converting all the possible requirements in constructing a plant layout. The facility layout algorithm must generate feasible layouts that satisfy the constraints imposed. It is important to note that any solution procedure should generate a layout that requires minimal manual adjustment and should be sensitive to varying shapes and sizes of individual facilities.

B. Assumptions

The following aspect of the manufacturing system are considered:

1. During manufacturing process, material flow is fixed from one department to the next appropriate departments, until all the processes are completed.
2. The objective is to minimise the sum of total product between flows and distance traveled from one department to another.
3. Each facility has to be assigned only once to a location on the floor plan and its area cannot be overlapped with one another.
4. Need to preserve an empty space (reserved departmentry location) for future new machines installation.

The model is also based on the following expectations:

1. All facilities are of fixed rectangular geometry.
2. Each facility can assume one of two orientations, horizontal or vertical.
3. Distance between facilities is measured rectilinearly from their centroids.
4. A fixed rectangular boundary of size W (floor breadth) x H (floor height) will surround all facilities with no overlapping.
5. All facilities can be arranged besides or below or above each other or both ways in a layout.

C. Objective Function and Constraints

The main objective is to minimize material handling costs (MHCs) between facilities, and it can be stated as follows:

Minimise
$$f(x) = \sum_{i=1}^{n} \sum_{j=1}^{n} c_{ij} f_{ij} d_{ij} \quad (1)$$

subject to:

$$x_1 = O_1 \frac{h_1}{2} + (1 - O_1) \frac{w_1}{2} \quad (2)$$

$$y_1 = O_1 \frac{w_1}{2} + (1 - O_1) \frac{h_1}{2} \quad (3)$$

Equation (1) is the objective function to minimize the sum of total product between the costs, flows and distance travelled from one facility to another from their centroids by using Manhattan (rectilinear) distance, $d_{ij} = |(x_j - x_i) + (y_j - y_i)|$ where x_i and y_i represents the centroid for facility i to be placed in the layout. It is assumed that the cost per unit distance is one. In the model, the constraints perform the tasks of preventing facilities from overlapping, restricting facility extremities to the layout interior and defining the domains of variables. Constraints (2) and (3) are used to ensure that the first facility is placed at the origin, (0,0), that serves as a reference point. It represents the centroid for the first cell to be placed in the layout.

D. The Importance of Constraints

An FLP is an optimisation problem that minimises the MHC while sufficiently meeting the facilities' constraints or requirements and producing feasible layouts. In order to deal with the UA-FLPs as constrained optimisation problems, there few constraints need to be considered. There are listed as follow:

1. Every department must be located inside the designated facility without any cross-over between any two departments. Departments are not permitted to exceed the facility's boundaries. (Liu, J., & Liu, J., 2019).
2. Non-intersecting (non-overlapping) constraints of the model that force the facilities to lie on the ground without any overlapping. (Liu, J., & Liu, J., 2019).
3. Fixed rectangular shapes. (Nordin, N. N., et. al., 2009)
4. Static flow between facilities does not change with their arrangement and remains the same after a complete facility layout is generated by the algorithm.
5. The area of each department is set in each iteration, but its length and width may change depending on the pre-processing method chosen.
6. The first facility is placed at the origin, (0,0), that serves as a reference point.
7. Total wastage ≤ total usage
8. Flexible layouts for future design changes.
9. The input or output placement – This is one of the crucial points because it illustrates the entrance and exit or loading and unloading area of a layout. (Pérez-Gosende, et al., 2021).

The most common constraints that have been applied in solving FLPs is the non-overlapping constraint (Constraint 2). Non-overlapping constraints of the model force the facilities to lie on the ground without any overlapping. Various methods have been introduced to overcome this issue. Additionally, the other crucial constraint is the placement of the input/output area (Constraint 9). This input/output area is very important because it illustrates the entrance and exit or loading and unloading area of a layout. Constraints are significant since it indicates whether the problem is a simple FLP with very little constraints or it is difficult to solve because of too many complex constraints and this will affect the processing time, but the solution quality will be more acceptable. In this study, there nine constraints that have been considered. Every constraint carried their own weightage.

E. Solution Representation for Facility Layout for Heuristics Approaches

The proposed method is a two-stage heuristics algorithm in which the choosing sequence of the facilities are determined in the first stage and placement of the facilities are in the second stage.

The Origin Heuristic

The motivation of the development of this algorithm came from the dilemma faced in the industrial manufacturing field which involved a very high cost when the re-designing the manufacturing plant layout. The redesigning the layout will give negative impact to the supply chain. The Origin heuristic is inspired from the Bottom-Left Fill (BLF) heuristic of bin packing problem, adapting the compactness of packing where the facility fills up the plane based on the shortest distance from the origin at the bottom-left corner. Unlike BLF routines that place the rectangles based on the sequence of the rectangles supplied, their proposed routine would make informed decisions about which rectangle should be packed next and where it should be placed.

In TO, the extensive computational results show that the proposed heuristic can outperform the currently published and established heuristic and metaheuristic methods to produce solutions that are very close to optimal. The algorithm is implemented in three stages: *pre-processing* stage, *operating* stage, and *postprocessing* stage.

Stage 1 *Pre-processing Stage*

In the pre-processing stage, the facilities are initially arranged following four different types of arrangements before it can be placed on the manufacturing plant. There are decreasing of length (DL), decreasing of breadth (DB), decreasing of area (DA) and no fixed arrangement (None) or it can be called as random arrangement. The diagram for all these arrangements is shown in Figure 3.2 except for "none" since there is no fixed pre-processing. For DL and DB, if there are two or more facilities having the same values, the tie will be broken arbitrarily. As for DA, if there are any of the facilities having the same area values, the breadth (length) is used to break the tie and if the breadth (length) has the same figure, the tie will be broken arbitrarily.

Stage 2 *Operating Stage*

Operating stage will be the main processing step, where all the main procedures for the development of The Origin (TO) heuristic will be taken place. A list of facilities is examined, and the placement will be based on the pre-processing stage. The first facility will be assigned at the reference point, at coordinate (0,0). Then, the distance will be calculated for all possible points (corner points for every facility) from the reference point. The next facility is then placed based on minimum distance value that have been selected. The process continue until every facility is assigned, and finally the main objective function, which is the Material Handling Cost (MHC) will be calculated.

Stage 3 *Post-processing Stage*

In the post-processing stage, the quality of solution improved by lowering down any facility that creates tower and assigned to a new placement in the layout. Tower are created when high narrow (i.e., breadth > width) facilities are protruding from the top of the layout. The tower is removed by lowering down and rotated 90^o before being placed. If the solution quality is improved, the new placement of facilities will be considered as the finalised layout.

V. CONCLUSION

The expected outcomes of this study shall contribute to the existing body of knowledge, whereby the newly developed heuristic approach The Origin (TO) is capable of solving industry-driven UA-FLPs with less computational time. Furthermore, rich findings from stakeholders on the usability of the improved methods using the developed GUI will be obtained. The development of proposed algorithms and a graphical user interface (GUI) as a tool for solving FLPs is expected to benefit manufacturing and service industries to obtain cost-effective and optimal design or redesign efficient layouts towards becoming the next-gen factories. This research is in line with the 10-10 framework of Smart Technology and Systems (Next Generation Engineering and Manufacturing) and SGD9 (Industry, Innovation and Infrastructure). The proposed algorithm can be used by other researchers or practitioners to develop their own hybrid methods and it can be used as guidelines for the best layout design based on quantitative analysis by using heuristic and meta-heuristic methods.

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