CHAPTER 2
LITERATURE REVIEW

The survey of the literature can be broadly divided into following areas that seem to have major impact in defining and solving the problem. These areas are:

- Static environment
- Dynamic environment
- Genetic algorithm

2.1 STATIC ENVIRONMENT

In static environment the material flow does not change over the planning horizon. The literature in static environment is reviewed according to the following areas:

1. Facility layout in manufacturing systems
2. Facility layout in flexible manufacturing systems
3. Design of cellular manufacturing systems
4. Inter-cell layout in cellular manufacturing systems
5. Intra-cell layout in cellular manufacturing systems
2.1.1 Facility layout in manufacturing systems

The facility layout problem in a manufacturing system is defined as the determination of the relative locations for, and allocation of, the available space among a given number of workstations. Some of the researchers dealt with this area.

Tam and Li (1991) presented a hierarchical procedure to solve the continual plane facility layout problems with large number of facilities, which consists of three phases: cluster analysis, initial placement and layout refinement. In the first phase cluster analysis generated a hierarchical structure of the layout. Based on the structure, the second phase produced an initial layout for each cluster which is then refined by the layout refinement phase. The effectiveness of the procedure was demonstrated by experiments involving five to thirty facilities.

Banerjee et al (1992) implemented the concept of reasoning-based interactive facilities layout design methodology by means of an exploratory architecture emphasizing the design of prototype reasoning agents. The architecture addressed the need to provide reasoning environments to couple local layout reasoning with global layout reasoning and captures this need by a communication language environment between the user and the layout optimization process. The proposed interactive reasoning schemes utilize the expectation of user’s handling capabilities by enabling him to communicate at a level of reasoning and not having to worry about many of the underlying reasoning tasks.
Yaman et al (1993) reviewed and classified the facility layout methods into three, namely mathematical approach, heuristic methods and expert systems and concluded that the mathematically based solutions can not be used to solve large scale problems and heuristically based methods were derived solutions for real applications. He also proposed a new heuristic method (effective sorting method) to construct a layout for further improvement. The performance of the heuristic method was illustrated by case studies.

Tretheway and Foote (1994) developed a heuristic method for the facility layout problem including aisle structure. The procedure utilizes the scatter diagram to obtain a relative location between the departments. The algorithm produced powerful technique for pure and near-pure flow shops.

Chiang and Kouvelis (1996) implemented an improved Tabu search Meta heuristic to solve the design of facility layout problem formulated as Quadratic Assignment Problem (QAP) in a manufacturing system, which is simple but computationally efficient and effective in terms of solution quality. This heuristics includes recency-based and long term memory structure, intensification; diversification and dynamic tabu list size strategies and converges with a reasonable speed from any random initial solution to very good layout. This algorithm is further enhanced by the adoption of the sequential neighbourhood search which is superior to random search methods. The computational experiments including statistical analysis and library analysis strongly supports the superiority of this proposed heuristic over existing algorithms.
Meller and Gau (1996) examined the adjacency-based, distance based and weight criteria facility layout objective functions and developed an objective function based on the basic material handling cost structure. The results indicated that it is possible to obtain relatively good solutions to the adjacency-based problems or weighted objective problems by using distance-based search.

Welgama and Gibson (1996) proposed an integrated methodology using Knowledge-based Optimization algorithm for the joint determination of layout and material handling system in a heavy industrial environment with an objective of minimizing the material handling costs, aisle space usage and dead space in the resulting layout. The Knowledge-base consists of facts and rules to determine the feasibility of using the material handling equipment type for a given move. The optimization part determines the layout of machines minimizing the material handling costs and the dead space in the layout using a multi-criteria optimization model. He demonstrated the algorithm through a test problem of 12 machines with 110 moves.

Meller and Bozer (1996) presented the application of Simulated Algorithm (SA) algorithm to solve both the single-floor and multi-floor facility layout problems in a manufacturing system. The multi-floor facility layout differs from single-floor layout in two fundamental ways. First, the impact of the vertical flow and second, the determination of area of feasibility are considered. He compared the performance of the proposed algorithm with both steepest-descent and randomized approaches and found that approach better than other approaches.
Meller and Gau (1996a) presented recent and emerging trends in the facility layout problems, which includes new methodologies, objectives, algorithms and extension to this well-studied combinatorial optimization problems.

Dweiri and Meier (1996) established a vigorous methodology, based on the fuzzy set theory, to improve the facility layout process. The fuzzy set theory is an appropriate tool which uses the natural language that humans use to control complex system such as facilities planning. This method used the distance and the relationship between departments to score the layout. The scoring system, which ranges from zero to ten, can be used to evaluate and compare any layout regardless of the number of departments and their size.

Chiang and Chiang (1998) implemented a set of heuristic procedures like tabu search, a probabilistic tabu search heuristic, a SA heuristic and a hybrid Tabu search heuristic to solve facility layout problems with the QAP formulation. To determine the performance of each heuristic, extensive computational experiments were conducted and the results shown that these heuristic procedures gave the competitive and superior results.

Abdinnour-Helm and Hadley (2000) proposed a pair of two-stage heuristics, GRASP/TS and FAF/TS, for solving the multi-floor facility layout problem. In both heuristics, the objective of the first stage is to obtain a layout with minimal inter-floor flow. Tabu search is used in the second stage to refine the initial layout based on total
inter/intra-floor costs. GRASP/TS apply a GRASP to obtain the initial layout. FAF/TS use an exact procedure FAF from the open literature to obtain an initial layout with minimal inter-floor flow. Computational tests indicate that GRASP/TS compared favourably with other heuristics that do not rely on exact algorithms. FAF/TS is shown to outperform all other heuristics in the open literature.

Castillo and Peters (2003) proposed an extended distance-based facility layout problem based on QAP that concurrently determines the number and shape of departments, the assignment of machines to departments and allocation of part flow volume between pairs of individual machines. The layout problem differs from previous distance-based layout problems in four aspects:

- The number and shape of the departments and the assignment of machines to departments are not determined apriori.
- Each machine type may have several replicas.
- Machine replicas of the same type may have different capacities.
- The part flow volume between machine replicas is not determined apriori.

This proposed formulation considers both intra-department and inter-department material handling costs at the design stage.

2.1.2 Facility layout in flexible manufacturing systems

FMS have emerged in recent years as a viable answer to meet the market demand for increased product variety, short product life cycles, and uncertain demand. From a strategic perspective, an efficient layout design is critical for the implementation of an FMS, since the
layout is difficult to design, costly to modify, and significantly affects the efficiency of the entire system. It has been estimated that 20-50% of the total operating expenses within manufacturing operations are attributed to material handling, and it has been reported that effective layout design will reduce these costs by at least 10-30%. In addition to the material handling costs, the facility layout also impacts the production costs and the work-in-process inventory levels.

Das (1993) presented a four step heuristic methodology for solving the facility layout problem in FMS. The heuristic combines the variable partitioning and integer programming methods to generate an open field type of layout. The facility layout of a FMS involves the positioning of cells within given boundaries, so as to minimize the total projected travel time between cells. He conducted three sets of experiments in order to study the efficiency and effectiveness of the proposed method and found that it given good quality.

Rajasekharan et al (1998) implemented facility layout design in FMS, which involves the positioning of cells within a given area so as to minimize the material flow costs between cells. The facility layout design includes specifying the spatial coordinates of each cell, the orientation of each cell in both a horizontal or vertical position, and the position of each cell’s pickup and drop off points. He proposed GA based heuristic to solve the problem. The performance of GA was analyzed by comparison of the computational results with the existing methods indicates that the heuristic is a viable alternative for efficiently and effectively generating layout designs for FMS.
Djellab and Gourgand (2001) proposed a two stage heuristic procedure to solve the single row facility layout problem in FMS. In the first stage, the procedure uses the particular structure for the problem to construct a feasible layout. In the second stage it exploits the current feasible layout to construct another layout. The performance of the procedure was better when it was compared with existing methods.

2.1.3 Design of cellular manufacturing systems

Souilah (1995) proposed a four stage approach to design an 'optimal' layout. The first stage, called the pre-processing stage transforms the problem at hand into a mono manufacturing process problem. The second state consists of grouping physical facilities into cells to minimize the inter-cell traffic, taking into account some constraints. This stage is called Manufacturing cell Design. The aim of the third stage is to arrange the physical resources inside the cells. This task is performed in two steps. In the first step, an expert system is used to select the material handling system, from which the cell type is derived. The second step consists of solving the assignment problems to find the best location of each resource. This stage is referred to as intra-cell location. The fourth stage is devoted to the location of cells in the shop-floor to minimize the operating cost of the overall system. This operating cost is expressed as the sum of the products (product of distance between cells and material flow). He used SA to solve the problem.

Hassan (1995) reviewed the emerging literature on the GT layout. He consolidated the GT problems into three major steps such as
cell formation, inter-cell design and intra-cell design. He also suggested several design issues of the layout problems. They are:

- The order of performing the major steps of developing the GT layout.
- Data requirements and preparation.
- The factors that should be included in family and cell formation procedures.
- Dealing with exceptional parts and bottleneck machines.
- The impact of the number and size of cells on the layout.
- Consideration of sequence of operations of the parts in family and cell formation.
- Type of cell layout.
- Orientation of cells and consideration of their Input/Output stations.
- Shape of the cell.
- Flexibility of the GT layout.

Tang and Abdel-Malek (1996) proposed a flow-network-oriented approach, which consisted three phases that hierarchically addressed the problem of cellular layout design. The applicability and effectiveness of this approach was illustrated by case studies.

Salum (2000) proposed a two phase method based on total manufacturing lead time (MLT) reduction which incorporates all the structural and operational issues into the simulation model simultaneously. The first phase provides the necessary data such as the total MLT, the volume of the parts flow and the waiting times of parts
between machines through simulation under zero material handling times considering the operational and structural issues. In the second phase, an algorithm is applied to the data obtained in the first phase to construct a layout by sorts the machine pairs in ascending order with respect to the mean similarities and beginning with the first pair it lays out the machines through an interactive computer program. The result provides the information that shows what machines should be next to each other subject to the waiting times of parts and the volume of the parts flow between them that are obtained under the certain assumptions in the first phase.

Bazargan-lari et al (2000) presented the application of a recent integrated approach to the three phases of the design of CM namely, parts/machines grouping, intra-cell and inter-cell layout designs to a white-goods manufacturing company in Australia. This approach enables the decision-maker to provide with multiple efficient alternative solutions according to different cell-partition strategies. It offers the flexibility to assess each alternative against tangible and intangible benefits and criteria.

2.1.4 Inter-cell layout in cellular manufacturing systems

The inter-cell layout problem in CM has not captured the attention of the researchers as much as cell formation. The layout problem however plays an important role in the design of CM. A poorly designed layout will result in poor productivity, increase work in process, disordered material handling and so on. Only a few researchers have dealt with this subject.
Liao et al (1996) compared two approaches for designing line type CMS. The first approach assumes that the processing of products in whole batches through one cell only and in the approach spited the batches and simultaneous processing of a part in different cells. Both design approaches consist of three stages. The first stage determines the best part routings among alternate routings to minimize the operating cost. In the second stage, a specific number of cells is obtained by neural network-based cell formation module in the first approach and a fuzzy rank order clustering (fuzzy ROC) module in the second approach. In the third stage, production sequence is considered to find the best layout with lowest material handling cost. The procedures associated with the proposed approaches are demonstrated with an example, which shows the effectiveness of the proposed approaches for designing production line CMS. Both approaches should be analyzed and compared for different applications.

Jajodia et al (1992) presented a new method CLASS (Computerized Layout using Simulated annealing) that considered both inter-cell and intra-cell layout problems in a CM environment. It addressed the relative placement of equidimensional manufacturing entities within a discrete solution space so as to minimize the total material flow between these entities. The proposed method yielded superior results while compared with other existing approaches.

Wang et al (1998) formulated a model to solve both inter-cell and intra-cell layout problems in a CMS with an objective of
minimizing the total material handling cost with the following constraints:

- To ensure that each machine location is assigned to one machine and each machine is assigned to one machine location.
- To ensure that each cell location is assigned to one cell and each cell is assigned to one cell location.
- To ensure that machines in the same cell are assigned to the same cell location and each machine is assigned to one machine location.

To solve the problem, he proposed an improved simulated annealing algorithm in which a new generation mechanism is introduced that can always generate a neighboring configuration, which satisfies all of the zoning constraints and proved that it produced same solution quality with less computational time when compared with Kouvelis’s algorithm.

Urban et al (2000) proposed a model that does not require the machines to be placed in a functional layout or in a cellular arrangement, but allows the material flow requirements to dictate the machine placement. The model is formulated as an aggregation of the QAP and several network flow problems coupled with linear side constraints. A mixed integer program is presented to find the optimal solution for small problems, and heuristics are developed to solve larger problems.
2.1.5 Intra-cell layout in cellular manufacturing systems

The machine layout has received substantially less attention even though it is related to facility layout problem. The machine layout problem involves the arrangement of machines within a cell so that the total time required to transfer the material between each pair of machines is minimized.

Heragu and Kusiak (1990) addressed the machine layout problem in automated manufacturing system and presented a Knowledge based system for machine layout (KBML), which is a combination of optimization and expert system approach to solve the problem. He classified the layout problems in the manufacturing system into three:

- Layout of the machines within products cell
- Layout of the machines within functional cells
- Layout of the machine cells on a floor plan.

He formulated two models. Model 1 can be used to multi-row layout problems in which the machines are to be arranged in two or more rows with the objective to minimize the total time involved in making the required number of trips between machines with the constraints: Ensure that no two machines in the layout overlap and the required clearance between each pair of machines is maintained. Model 2 can be used to single row layout problem in which the machines are to be arranged in single row with the objective to minimize the total time involved in making the required number of trips between machines.

KMPL required the following data as input and produced solutions of good quality for the machine layout problem.
- number of machines to be assigned
- flow matrix
- clearance matrix
- relationship indicator matrix
- machine dimension
- location restrictions (if any) for the machines
- type of layout
- type of material handling carrier
- dimensions of the floor plan

Hassan (1994) reviewed the machine layout problems in modern manufacturing facilities and addressed the design issues of machine layout. He examined five issues in the design of machine layout: (1) types of machine layout; (2) differences between the machine and block layout problems; (3) back-tracking and bypassing; (4) material handling and the layout and (5) layout flexibility.

Tanchoco and Lee (1999) introduced a facility layout design procedure to find the best machine grouping along with location of pickup and delivery (P/D) stations and machine layout for each cell based on Segmented Flow Topology (SFT) with an objective of minimizing the total material handling cost. He investigated four combinations. In case 1, both the locations of the P/D stations and the flow paths are fixed. The primary objective is to find the best machine arrangement such that the material handling cost is minimized. The locations of the P/D stations are fixed while the flow path network can be reconfigured in case 2, the objective is to simultaneously determine
the machine arrangement together with the flow path for the given facility. In case 3, the flow path for the given facility layout is fixed while the P/D stations can be relocated anywhere along the cell boundaries. The objective is to find the best machine arrangement and locations of the P/D stations. In case 4, neither pick-up and delivery stations nor flow paths are preassigned. The objective is to simultaneously determine the best machine arrangement, locations of pick-up and delivery stations and flow paths. The cost of machine relocation is often cited as a significant expense item for cell implementation.

Chan et al (2002) presented a heuristic algorithm to solve the problem of machine allocation in CM, accommodating key practical constraints in machine allocation. These constraints include the part-handling factor, the part flow frequency, the travelling distance and part demand, etc. The focus is on the intra-cell machines allocation, because the inter-cell material flows should be minimal in CM. The objective is to minimize the total traveling score in which the travelling distance is covered in a cell in a period. This algorithm used an adaptive approach to relate the machine in a cell by examining the merged part flow weights of machine pair. The algorithm tackles one cell at a time with a maximum of 9 machines, which will be assigned into a 3 X 3 grid space according to the ranking result. The operation of the proposed heuristic algorithm can be categorized into two stages and there are several steps in each stage. Stage 1 involves data collection and data manipulations and Stage 2 deals with the construction of machine layout. To evaluate the proposed heuristic, a numerical data was taken from literature, which
involves five parts processed by 9 machines. It was solved and compared with previous results from the literature and proved that the proposed heuristic was better.

2.2 DYNAMIC ENVIRONMENT

Increasing global competition, rapid changes in technology and the necessity to respond quickly to a cost and quality conscious customer have changed the dynamics of facilities planning. Today’s manufacturing facility needs to be responsive to the frequent changes in product mix and demand while minimizing material handling and machine relocation costs. In today’s market based and dynamic environment the material flow can change frequently over the planning horizon. Literature in dynamic environment is reviewed according to the following areas:

1. Facility layout in manufacturing systems
2. Facility layout in flexible manufacturing systems
3. Design of cellular manufacturing systems
4. Inter-cell layout in cellular manufacturing systems
5. Intra-cell layout in cellular manufacturing systems

2.2.1 Facility layout in manufacturing systems

Rosenblatt (1986) discussed the general dynamic layout problem (DLP). He developed a dynamic programming (DP) approach to solve the multi-period layout selection problem. In each period, a number of potential static layout alternatives need to be generated. The objective is to select the sequence of layouts which minimizes the
overall sum of the material flow costs and relayout costs. If all possible static layout alternatives are considered at each period, the optimal sequence can be obtained. This approach, however, can be computationally prohibitive. Therefore, a heuristic is advocated to generate a set of static layout alternatives in each period. The quality of the overall solution depends strongly upon the number of static layout alternatives generated in each period. He assumed that flow data in each period is given and constant over the planning period. In addition, departments are assumed to be equal in size.

Lacksonen and Enscore (1993) modeled the dynamic facility layout problems as a modified QAP by assuming that the department size as unit, with the objective is to minimize total cost: the flow costs over a series of discrete time periods plus the rearrangement costs of changing layouts between time periods. The constraints considered for this model are

- Ensure that there is exactly one department from the proper time period for each location of each time period.
- Ensure that each department of each time period is assigned to exactly one location of the proper time period.

He reviewed the static layout algorithms and modified five of them, namely: craft, cutting plane, branch and bound, DP and cut trees to handle dynamic facility layout. The modified algorithms are compared on a series of realistic test problems and found that cutting plane algorithm out performed than other four algorithms. The cutting plane algorithm is able to solve a 30 location 2-time-period problem in 200 CPU seconds.
Lacksonen (1997) described a model and improved algorithm which simultaneously handles the static and dynamic facility layout problems, having departments with unequal areas. This algorithm solved a mixed integer programming problem to find the desired block diagram layout. The results showed that a significant cost reduction on a variety of previously published problems and feasible solutions to previously unsolved problems.

Kochhar and Heragu (1999) presented a frame work for the design of multi-floor dynamic facility layout which can respond effectively to the changes in product design, product mix and volume in a continuously evolving work environment. A GA based heuristic was used to solve the design problem and two test cases are presented to illustrate the use of the methodology.

Azadiver and Wang (2000) presented an approach, facility layout optimization technique that takes into consideration the dynamic characteristics and operational constraints of the system as a whole, and is able to solve the facility layout design problem based on the system’s performance measures, such as the cycle time and productivity. In this approach each layout solution is presented in the form of a string that is suitable for analysis by a GA technique. These solutions are then translated into simulation models by a specially designed automated simulation model generator. GA was used to optimize the layout for manufacturing effectiveness while simulation serves as a system performance evaluation tool. Combined with a statistical comparison technique to reduce the simulation burden, the test results demonstrate
that the proposed approach overcomes the limitations of traditional layout optimization methods and is capable of finding optimal or near optimal solutions.

Balakrishnan and Cheng (2000) developed an improved GA called Nested Loop Genetic Algorithm (NLGA) for DLP in manufacturing systems. The NLGA differs from the existing GA implementation in three aspects as follows:

- Adopted a point-to-point crossover operator to increase the search space.
- Mutation is used to increase population diversity.
- Use a new generational replacement strategy to help increase population diversity.

The NLGA uses a GA with nested loops. The inner loop uses a steady-state replacement approach and replaces the most unfit individual in each generation. The outer loop will replace a large number of unlucky individuals in a generation. The computational results showed that the proposed NLGA is quite effective than other approaches.

Balakrishnan et al (2000) investigated the design of facility layouts based on a multi-period planning horizon called dynamic plant layout problem (DPLP). The DPLP extends the static plant layout problem (SPLP) by assuming that the material handling flows between the different departments in the layout may change over time. The periods in the planning horizon can be of any length; such as weeks, months or years. In addition different periods can be of different lengths. This in turn might necessitate layout rearrangement during the planning horizon.
He proposed an improved pair-wise exchange heuristic for DPLP. It is improved in two ways: The first one involves working backward from the final solution provided by Urban’s heuristic. The second involves combining Urban’s method with DP. The performance of the heuristic was tested with numerical illustration and proved that the new method was effective and efficient.

Diaby (2000) formulated a nonlinear, mixed-integer mathematical programming comprehensive model for simultaneously planning for the setup time reductions and the batch sizes of several products over a finite planning horizon in a capacitated manufacturing environment. It is assumed that by investing in the appropriate amounts of various resources (such as R&D time, equipment, fixtures, tooling, re-layout, etc.) setup times can be reduced. The problem is to determine how much to cut the setup time for each product and how much of each product to produce in each period of the planning horizon so that total costs are minimized, subject to limits on the manufacturing and setup reduction resources. A heuristic method is developed for solving it. The proposed model is broad and can be directly applied in a variety of practical situations including the case where discrete technology choices must be made.

Baykasoglu and Gindy (2001) proposed SA algorithm to solve the DLP, where the demand is not stable because of today's volatile manufacturing environments. To operate efficiently under such environments facilities must be adaptive to changing demand conditions. This requires solution of the DLP. The problem was defined
as a complex combinatorial optimisation problem. The objective of the problem is to minimise the flow costs plus location costs (if included) for each time period and the rearrangement costs between time periods. The constraints considered are

- Ensure that there is exactly one department from the proper time period for each location of each time period.
- Ensure that each department of each time period is assigned to exactly one location of the proper time period.

The efficiency of SA in solving combinatorial optimisation problems is very well known. SA is a problem independent stochastic optimisation technique. If “data structure of the solution” and “neighbourhood structure” can be defined efficiently then it is a very effective tool in solving combinatorial optimisation problems optimally. It has the capability of jumping out of the local optima for global optimisation. This capability is achieved by using solutions have high probability than the current solution. The acceptance probability is determined by a control parameter (Temperature) which decreases during the SA procedure. The proposed SA algorithm was tested with two well-known sample problems from the literature and proved that the results obtained by this method were better than various approaches in literature.

Balakrishnan et al. (2003) investigated the application of hybrid GA for solving the DPLP, which deals with the design of multi-period layout plans. The dynamic problem involves selecting a static layout for each period and then decides whether to change to a different layout in the next period. He found that the available optimal solution
method based on DP is not sufficient enough to solve large DPLP and the heuristics based on GA can solve large DPLP. The objective is to minimise the total cost, which is the sum of the material flow and layout rearrangement costs for the planning horizon with the following constraints:

- Each department must be located and each location must be occupied in every period.
- The 0–1 departmental rearrangement variable takes on a value of 1 only if the department shifts its location at the end of a period.

If the shifting costs are relatively low, it would tend to shift or change the layout configuration more often to suit the changed material-handling flow. The reverse is true for high shifting costs where it could be avoided, as relocations include the associated shifting or rearrangement costs. A computational study is carried out to compare the proposed algorithm with the existing approaches like, CNGA, NLGA and SA and concluded that the proposed algorithm performed better than other approaches for the large size problems.

Braglia et al (2003) evaluated the criticality of layout determination in a dynamic environment, i.e., when the product demands fluctuated over the time horizon identified and adopted an approach base on formulation of indices useful to designers.

Dunker (2004) presented an algorithm combining DP and genetic search for solving a dynamic facility layout problem. While the quadratic assignment formulation of this problem has been deeply investigated there are very few papers solving it for departments of
unequal size. A model described that can cope with unequal sizes, which may change from one period of time to the next. For each period a GA evolves a population of layouts, while the DP provides the evaluation of the fitness of the layouts.

McKendall Jr and Shang (2006) considered the dynamic facility layout problem, where the arranging and rearranging, when there are changes in product mix and demand, manufacturing facilities such that the sum of material handling and rearrangement costs is minimized. He developed Hybrid Ant Systems (HAS) to solve the DFLP, which are modifications of the hybrid ant colony system applied to the QAP (HAS–QAP), never used to solve this computationally intractable problem. The first system is called HAS I, is a direct application of the HAS–QAP heuristic for the DFLP. However, this heuristic uses a random descent pairwise exchange heuristic to improve the set of layout plans after performing $R$ pairwise exchanges using the pheromone trail matrix. The second heuristic, called HAS II, is exactly like HAS I, except that a SA heuristic is used as the local search heuristic, instead of the random descent pairwise exchange heuristic. SA is a stochastic approach for solving combinatorial optimization problems, in which the basic idea comes from the annealing process of solids. In this process, a solid is heated until it melts, and then the temperature of the solid is slowly decreased (according to an annealing schedule) until the solid reaches the lowest energy state (or ground state). If the initial temperature is not high enough or if the temperature is decreased rapidly, the solid at the ground state will have many defects or imperfections.
The third heuristic, called the HAS III heuristic, adds a look-ahead/look-back strategy to the pairwise exchange heuristic within the HAS I heuristic. Similarly, the pairwise exchange heuristics for HAS I and III randomly selects a period $t$ and the locations $i$ and $j$ of two departments for exchange, and the change in the total cost $\Delta(f)$ is obtained. If $f > 0$, then the exchange is accepted. Otherwise, it is rejected, and the heuristic starts from the beginning. If the exchange is accepted in the simple pairwise exchange heuristic in HAS I, then the exchange is performed, and the current solution is updated. This process is repeated for $N \cdot N \cdot T$ iterations. However, if the exchange is accepted in the pairwise exchange heuristic in HAS III, then the exchange is performed, and the current solution is updated. In addition, the changes in the total cost of performing the exchange in the preceding $(t-1)$ and succeeding $(t + 1)$ periods are considered. If the exchange is accepted for both periods, update the current solution and consider the exchange in the preceding and succeeding $(t-2$ and $t + 2)$ periods. If the exchange is accepted for only one of the periods, say $t-1$, then update the current solution, consider the exchange in the previous $(t - 2)$ period, and reject the exchange in period $t + 1$. Continue considering the exchange in the preceding or succeeding periods until there are no more periods to consider or the exchange does not improve the solution ($\Delta f \leq 0$). If the exchange is rejected for both periods, then repeat the above process for $N \cdot N \cdot T$ iterations. To test the performance of the meta-heuristics, two data sets taken from the literature are used in the analysis. The results show that the HASs are efficient techniques for solving the DFLP.
2.2.2 Facility layout in flexible manufacturing systems

Al-Qattan (1990) presented a branch and bound method for forming flexible manufacturing cells. This method created a number of alternative solution based on the seed part node which enhance the flexibility of manufacturing cell design and opportunity to evaluate different options and choose the one which is the most cost effective.

Afentakis et al (1990) formulated a mathematical model for both static and dynamic problems in FMS. This model examined the influences of a number of system parameters on several relayout strategies and derives guidelines for FMS relayout based on a series of experiments with realistic size problems.

Andrea D’Angelo et al (1996) investigated an automated printed circuit board manufacturing plant to select the statistically significant variables and determine the relative impact on system performance. Mathematical simulation tools and statistical interference are employed to construct appropriate regression models able to predict system behaviour when multiple variables are involved. The Response Surface Methodology (RSM) was used to get near optimal solution for maximizing the productivity of the system in terms of manufacturing area layout was obtained.

Yang and Peters (1998) developed a design method for flexible machine layout problem (FMLP) for dynamic and uncertain production environments. The FMLP is a multiple-period design problem with uncertainties in product demand in each period. They suggested that layouts can respond to demand changes in two ways:
through robustness to changes in production requirements and through adaptability of the layout to these new requirements. A robust layout is one that is good for a wide variety of demand scenarios even though it may be not optimal under any specific demand scenarios. For a specific planning horizon, a robust layout design procedure attempts to minimize the total expected material handling costs over this horizon. An adaptable (dynamic) layout is one that is able to be rearranged to respond to changing production requirements in order to decrease the material handling costs. The rearrangement costs will hopefully be offset by the reduction of material handling costs. The design procedure generates a flexible layout for a set of unequal size machines over a planning horizon by optimizing the tradeoffs between increased material handling costs and machine rearrangement costs as the production requirements change over time. It may choose robust layouts, adaptable layouts, or a combination of the two. The basic approach is to determine a robust machine layout over a planning time window. A planning time window is a set of consecutive time periods where a layout rearrangement occurs only at the beginning of the first time period. The number and length of the planning time windows are determined based on the tradeoffs between material handling costs and machine relayout costs. Thus, the strategy is to modify the layout at the beginning of each time window, but not to change the layout within these time windows. Hence, a pure robust strategy will have a one time window equal to the entire planning horizon, whereas a pure adaptable strategy will have as many windows as periods in the planning horizon. In their publication, the strategy is to choose the quantity of time windows that minimize the total cost and includes robust and adaptable strategies.
A mathematical model is developed as an integer programming formulation with the objective of minimizing the material handling cost and machine rearrangement cost. The problem formulation is computationally prohibitive for a realistic size problem. Therefore, they used the concept of the combined adjacency graph/integer problem formulation for a machine layout design problem from literature and solve the robust machine layout design sub-problems.

### 2.2.3 Design of cellular manufacturing systems

Bazargan-Lari (1999) presented an application of recently developed multi-objective inter- and intra-cell layout design methodologies in CM environment to a dynamic food manufacturing and packaging company in Australia. It addressed a number of issues related to the practical implementation of CM structures such as closeness relationships, location restrictions/preferences, machine/cell orientations and aisles. The problems identified in the company are:
- Large and unnecessary volume of shop floor material handling cost,
- Difficulties and confusion over production planning,
- Long products lead times resulting in losing customers,
- High overhead costs,
- Increasing number of accidents and injuries on the shop floor caused by poor layout of machinery and the lack of proper aisle structures for movement of the lift-trucks.

The solutions provide a safer shop floor, significant reductions in material handling cost, waste, need for large capital investment and the number of lift-trucks needed on the shop floor. The performance of the model became more fine-tuned to the company's requirements as the
layout design model was adjusted to the feedback from the company. This process reconfirms that the travelling cost is not the sole criterion to generate the layout designs. Some of the expected benefits through the final designs are: safe working environment, 30% reduced material handling cost, half a million dollars reduction in purchasing bar-coding machines, reduced number of lift-trucks needed, increased employees efficiency and reduced waste.

2.2.4 Inter-cell layout in cellular manufacturing systems

Wang et al (2001) proposed a model to solve both inter and intra facility layout problems in CMS. He considered the concept of product life cycle as planning horizon, with varying demand during the period. The objective of the model is to minimize the total material handling cost of the planning horizon with following constraints.

- To ensure that each machine location is assigned to one machine and each machine is assigned to one machine location.
- To ensure that each cell location is assigned to one cell and each cell is assigned to one cell location.
- To ensure that machines in the same cell are assigned to the same cell location and each machine is assigned to one machine location.

The model is solved by simulated annealing algorithm and the performance of the algorithm was tested with different problem size from m=8 (c=3) to m=20 (c=8), which are generated randomly. The computational results showed that the proposed SA can obtain
satisfactory solutions with reasonable time. But he did not consider the relayout.

2.2.5 Intra-cell layout in cellular manufacturing systems

Rheault et al (1996) considered the CM layout problem in dynamic environment and presented dynamic cellular manufacturing system (DCMS). The system is composed of 4 modules; loading and routing module, dynamic cell configuration, scheduling module and system monitoring that sustained the turbulent environment of small make-to order manufacturing and subcontractors with an objective of minimizing the overall cost for transferring unit loads and relocating workstations. The loading and routing module determine product routing considering the available capacity for the planning horizon, setup or operation similarity, etc. The dynamic cell configuration module chooses the optimal location of all workstations within the zones. Decision criteria are exclusively economic and they consider the inter-zone material handling cost and the cost of relocating stations. This module needs many inputs such as the inter-zone distances matrix, the handling costs of unit loads, the cost of configuring workstations within a specific zone, the unit load for each product, the lot sizing, the actual position of workstations and any specific variables appropriate to the situation. In the scheduling module, workstation loading, product routing and cell configuration are known for some time horizon. Based on these results and on data concerning the processing times, setup times, handling times and operation sequences of active products, this module will determine a production schedule. Known and suitable scheduling rules will be used in this module in order to optimize the
related performance needed such as minimizing makespan or respecting
the due date, etc. The fourth module, system monitoring maintains the
system stable by activating the appropriate module when a certain
variable has reached a certain threshold. This module monitors any
deviations between the schedule and the state of the production. When a
deviation has exceeded a predefined threshold it activates the most
suitable module to correct the situation. The arrival of a new job is
automatically considered if it must be produced within the planning
horizon. This module will verify the compatibility with the dynamic
families before activating the adequate module.

Seifoddini and Djassemi (1997) presented a procedure for the
sensitivity analysis of the performance of CMS to product mix
variations and a flexibility range representing the capability of the
system in dealing with these variations are determined using simulation
modeling. The sensitivity analysis of the performance of CMS subject to
product mix variations serves two purposes. First, it determines whether
a particular manufacturing situation is suitable for conversion to CM.
Secondly, it can be used to evaluate the capability of a CMS in dealing
with product mix variations. For the performance evaluation in the
sensitivity analysis, performance measures such as mean flow time, and
work-in-process (WIP) inventories are used. The impact of changes on
the performance of the CMS is evaluated by estimating the mean flow
time and WIP inventories for the system under a varying product mix.
To determine the capability of the CMS to deal with these changes,
estimates of the mean flow time and WIP inventories for job shop and
CMSs are compared. The range of changes in the product mix for which
the performance of the CMS is superior to that of the job shop system is
designated as the flexibility range of the CMS. The sensitivity analysis is performed in three phases. First, a machine-part matrix is used to develop a CMS. The machine-part matrix is chosen such that the associated CMS is superior to the corresponding job shop system. A simulation model for the performance evaluation of the manufacturing system under job shop and CM is developed. Then the mean flow time and WIP inventories for the two systems are estimated by simulation. Finally, variations in the product mix are introduced to the model and the simulation process is repeated for a range of variations. By comparing the performance of the job shop and CMS for a varying product mix, the range of changes for which the CMS keeps its superiority to the job shop system is determined. Such a range can be designated as the flexibility range of the CMS in dealing with product mix variations. The simulation results showed that as the changes in the product mix increase the superiority of the performance of the CMS to the corresponding job shop system diminishes.

Chan et al (2004) developed a heuristic approach called the MAIN (Machines Allocation INter-relationship) algorithm for intracellular machine layout design in CMS considering both static and dynamic environment machine layout to minimize the total cost which is the sum of material handling cost and relocation cost. It begins by analyzing a single period with a fixed quantitative demand and machine assignment is based on a set of proposed objective functions together with merging techniques. For the multiple periods planning horizon, the demand fluctuations are simulated and layouts are generated to fit different demand profiles. Each layout is then processed further. He
considered the maximum number of machines can be assigned into a grid is limited to nine machines as a 3X3 grid was going to be used and there are only nine potential machine location zones on it. For the model, he also assumed that a machine can be assigned to any location and the part traveling distance is estimated by measuring the rectilinear distance from the centre of the source machine to the centre of the destination machine. The experimental results showed that the proposed heuristic algorithm can achieve an average deviation of 4.8% in contrast with optimal solutions for a single-period layout.

2.3 GENETIC ALGORITHM

GA was proposed by J.H.Holland, is a stochastic search method that mimics the metaphor of natural biological evolution. GA was used by some of the researchers’ for various areas like Cell formation problem, Computer-aided process planning (CAPP), and Facility layout in manufacturing systems, Scheduling and design of CMSs. In the following text some of them are discussed.

Hsu and Su (1998) proposed a GA-based procedure to solve the cell formation or machine-component grouping (MCG) problem. GA is a robust adaptive optimization method based on principles of natural evolution and is appropriate for the MCG problem, which is an NP complete complex problem. The objective is to minimize (1) total cost, which includes inter-cell and intra-cell part transportation costs and machines investment costs; (2) intra-cell machine loading imbalance; and (3) inter-cell machine loading imbalance under many realistic considerations. An illustrative example and comparisons demonstrate the effectiveness of this procedure. The proposed procedure is extremely
adaptive, flexible, and efficient and can be used to solve real MCG problems in factories by providing robust manufacturing cell formation (MCF) in a short execution time. Zhao and Wu (2000) presented a GA approach to the MCG problem with multiple objectives: minimizing costs due to inter-cell and intra-cell part movements; minimizing the total within cell load variation; and minimizing exceptional elements (EEs). Manufacturing cells are formed based on production data, e.g. part routing sequence, production volume and workload. Also, he discussed the implication of part alternative routings and the method we suggest to deal with it. Special genetic operators are developed and multiple experiments are performed. Finally, the results obtained with the proposed algorithm on the tested problems are compared with those of others.

Uddin and Shanker (2002) addressed generalized grouping problem where each part has more than one process routes. The problem of simultaneously assigning machines and process routes (parts) to cells is formulated as an integer-programming problem. The objective of minimization of inter-cell movements is achieved by minimizing the number of visits to various cells required by a process route for processing the corresponding part. A procedure based on GA is suggested as a solution methodology. The working of the proposed algorithm is illustrated with a numerical example and found that it can be a powerful tool for solving grouping problems. Zolfaghari and Liang (2003) proposed a new GA for solving a general machine/part grouping (GMPG) problem. In the GMPG problem, processing times, lot sizes and machine capacities are all explicitly considered. To evaluate the
solution quality of this type of grouping problems, a generalized grouping efficacy index is used as the performance measure and fitness function of the proposed GA. The algorithm has been applied to solving several well-cited problems with randomly assigned processing times to all the operations. To examine the effects of the four major factors, namely parent selection, population size, mutation rate, and crossover points, a large grouping problem with 50 machines and 150 parts has been generated. A multi-factor \((3^4)\) experimental analysis has been carried out based on 324 GA solutions. The multi-factor ANOVA test results clearly indicate that all the four factors have a significant effect on the grouping output. It is also shown that the interactions between most of the four factors are significant and hence their cross effects on the solution

Boulif and Atif (2006) proposed new branch-&-bound-enhanced GA to solve the MCF problem, which is based on GT principles, using a graph partitioning formulation. First, the problem is solved with a GA, using a binary coding system that has proved superior to the classic integer coding systems. A new Branch-and-Bound (B&B) enhancement is then proposed to improve the GA's performance. The results obtained for medium-sized instances using this enhancement are better than those obtained using the GA alone. Jeon and Leep (2006) developed a methodology which can be used to form manufacturing cells using both a new similarity coefficient based on the number of alternative routes during machine failure and demand changes for multiple periods. The methodology is divided into two phases. A new similarity coefficient, which considers the number of available
alternative routes when available during machine failure, is suggested in Phase I. The primary objective of Phase-I is to identify part families based on the new similarity coefficient by using a GA. A new methodology for cell formation, which considers the scheduling and operational aspects in cell design under demand changes, is introduced in Phase II. Machines are assigned to part families by using an optimization technique. This optimization technique employs sequential and simultaneous mixed integer programming models for a given period to minimize the total costs which are related to the scheduling and operational aspects. James et al (2007) presented a hybrid grouping GA for the cell formation problem that combines a local search with a standard grouping GA to form machine-part cells. He proved that the hybrid grouping GA is outperformed the standard grouping GA by exceeding the solution quality through a set of test problems and by reducing the variability among the solutions found.

Li et al (2005) presented a GA, which, according to prescribed criteria such as minimizing processing time, could swiftly search for the optimal process plan for a single manufacturing system as well as distributed manufacturing systems. By applying the GA, the CAPP system can generate optimal or near-optimal process plans based on the criterion chosen. Case studies are included to demonstrate the feasibility and robustness of the approach.

Cheng et al (1996) investigated the problem of designing loop layout system with both of minsum and minmax congestion measures and proposed a common layout for FMS is loop network with machines arranged in a cycle and materials transported in only one direction
around the cycle. Congestion is a common measure for evaluating a loop layout. A hybrid heuristic of GA and neighborhood search (NS) is developed for solving such problem and preliminary computational results are reported. Tiwari and Vidyarthi (2000) proposed a GA based heuristic to solve the machine loading problem of a random type FMS. The objective of the loading problems is to minimize the system unbalance and maximize the throughput, satisfying the technological constraints such as availability of machining time, and tool slots. The proposed GA-based heuristic determines the part type sequence and the operation-machine allocation that guarantee the optimal solution to the problem, rather than using fixed predetermined part sequencing rules. The efficiency of the proposed heuristic has been tested on ten sample problems and the results obtained have been compared with those of existing methods.

Cochran and Chen (2002) proposed GA to search for best weight assignments in multi-objective daily production planning problems. This approach takes snapshots of a factory's inventory, equipment capacity and demands to generate a near optimal shop floor daily production plan. The implemented system runs on a daily basis at midnight for 40 minutes and generates the following day's production plan. Tests of this system in a large-scale semiconductor manufacturing facility show the proposed approach generates production plans of high quality in reasonable run times under many factory conditions. Adel El-Baz (2004) described a GA to solve the problem of optimal facilities layout in manufacturing systems design so that material-handling costs are minimized. He considered the various material flow patterns of
manufacturing environments of flow shop layout, flow-line layout (single line) with multi-products, multi-line layout, semi-circular and loop layout. The effectiveness of the GA approach is evaluated with numerical examples. The cost performance is compared with other approaches. The results show the effectiveness of the GA approach as a tool to solve problems in facilities layout. Hicks (2004) described the GA based optimization method that minimizes material movement for a given schedule of work. The model includes geometric information on resources and building constraints. The tool may be used for brown-field or green-field layout design problems. It has been applied using data obtained from an engineer-to-order/make-to-order capital goods company. The algorithm produces layouts that significantly reduce the total distance travelled by components in both green field and brown field situations.

Todd and Sen (1999) demonstrated how a computational intelligence technique known as the GA can be used to optimize design, manufacturing and construction schedules for multiple objectives such as minimizing cost and time and maximizing utilization. The system generates a number of near-optimal project scenarios from which a single solution can be selected and implemented by the project manager. ElMaraghy et al (1999) presented a scheduling approach, based on GA, to address the scheduling problem in manufacturing systems constrained by both machines and workers. The GA algorithm utilizes a new chromosome representation, which takes into account machine and worker assignments to jobs. A study was conducted, using the proposed scheduling method, to compare the performance of six dispatching rules.
with respect to eight performance measures for two different shop characteristics, i) dual-resources (machines and workers) constrained shop and ii) single-resource constrained shop (machines only). An example is used for illustration. The results indicate that the dispatching rule which works best for a single-resource constrained shop is not necessarily the best rule for a dual-resources constrained system. Man (2000) proposed a canonical GA approach and a prospective MOGA approach as solutions for different practical problems like earliness/tardiness production scheduling planning (ETPSP) problems with multi-process capacity balance, multi-product production and lot-size consideration. Simulation results as well as comparisons with other techniques demonstrate the effectiveness of the MOGA approach, which is a noted improvement to any of the existing techniques, and also in practice provides a new trend of integrating manufacturing resource planning (MRPII) with JIT in the production planning procedure.

Gonçalves et al (2005) presented a hybrid GA for the job shop scheduling problem. The chromosome representation of the problem is based on random keys. The schedules are constructed using a priority rule in which the priorities are defined by the GA. Schedules are constructed using a procedure that generates parameterized active schedules. After a schedule is obtained a local search heuristic is applied to improve the solution. The approach is tested on a set of standard instances taken from the literature and compared with other approaches. The computation results validate the effectiveness of the proposed algorithm. Torabi et al (2006) investigated the lot and delivery scheduling problem in a simple supply chain where a single supplier
produces multiple components on a flexible flow line (FFL) and delivers them directly to an assembly facility (AF). It is assumed that all of parameters such as demand rates for the components are deterministic and constant over a finite planning horizon. The main objective is to find a lot and delivery schedule that would minimize the average of holding, setup, and transportation costs per unit time for the supply chain. We develop a new mixed integer nonlinear program (MINLP) and an optimal enumeration method to solve the problem. Due to difficulty of obtaining the optimal solution in medium and large-scaled problems, a hybrid genetic algorithm (HGA) is also developed. The proposed HGA incorporates a NS into a basic GA that enables the algorithm to perform genetic search over the subspace of local optima. The two proposed solution methods are compared on randomly generated problems, and computational results show that the performance of HGA is very promising because it is able to find an optimal or near-optimal solution for majority of the test problems.

Moon and Kim (1999) proposed a cell design model with the objective of maximizing the total parts flow within cells considering the data of process plans for parts, production volume, and cell size. A relationship between machines is calculated on the basis of the process plans for parts obtained from process plan sheets. Then the machines are classified into machine cells using the relationship. The model is formulated as a 0–1 integer programming and a GA approach is developed to solve the model. The proposed approach is tested and proved using actual industrial data. The approach provide a best solution constantly, also its procedure is extremely efficient and flexible for
solving large problems for cell design. Moon and Gen (1999) proposed an approach for designing independent manufacturing cells in CM with alternative process plans and machine duplication consideration. Several manufacturing parameters, such as production volume, machine capacity, processing time, number of cells and cell size, are considered in the process. The problem is formulated as a 0–1 integer programming model and solved using GA. It determines the machine cell, part family and process plan for each part simultaneously. Onwubolu and Mutingi (2001) presented GA metaheuristic-based cell formation procedure to solve cell formation problem simultaneously group machines and part-families into cells so that intercellular movements are minimized. The solution procedure was found to perform well on tested large-scale problems and published data sets. Moreover, the proposed procedure compares very favorably to a well-known algorithm, and another TSP-based heuristic available in the literature. The results of computational tests presented are very encouraging.

Ip et al (2003) described a risk-based partner selection problem and formulated where risk of failure, due date and the precedence of sub-project are concerned. Based on the concept of inefficient candidate, the solution space of the problem is reduced first. Then a rule-based genetic algorithm R-GA with embedded project scheduling is developed for solving the problem where fuzzy factors-based rules are proposed in order to modify the partner selection according to different situations in the evaluation process of GA by using the characteristics of the considered problem and the knowledge of project scheduling. Mansouri et al (2003) presented a new model is
for dealing with the existence of EEs, i.e. bottleneck machines and exceptional parts in the form of a Multi-objective Optimization Problem (MOP). These are machines/parts that cannot be exclusively assigned to a machine cell/part family. This model aims to minimize: (1) intercellular parts movements, (2) total cost needed for machine duplication and part subcontracting, (3) the system's under-utilization, and (4) deviations among the cells' utilization. Hence, a MOGA is developed to provide the decision-maker with a set of non-dominated or Pareto-optimal solutions. Comparisons between the developed MOGA and three other MOGAs show its viability in three performance aspects, namely: quality, diversity and CPU time.

Singh et al (2003) applied an integrated approach for simultaneous selection of design and manufacturing tolerances based on the minimization of the total manufacturing cost. The nonlinear multivariable optimization problem formulated in this manner may result in a noisy solution surface, which can effectively be solved with the help of a global optimization technique. A solution methodology using GA and applying penalty function approach with proper normalization of the penalty terms for handling the constraints is proposed. The application of the proposed methodology is demonstrated on a simple mechanical assembly with different tolerance stack-up conditions. Liu (2004) is proposed a GA using sequence rule chain for multi-objective optimization in re-entrant micro-electronic production line. The results are comparison between the proposed algorithm and some other typical sequence rules have been made through the simulations of a practical micro-electronic production line. The static
and dynamic simulation results show that the algorithm has considerable improvements on performances of the micro-electronic production such as mean cycle time, mean number of work-in-process, production rate.

Shiang and Smith. (2004) proposed GA to create automated assembly sequence planners, which will help design and manufacturing engineers analyze increasingly complex and customized products and the dynamic conditions found in modern computer integrated manufacturing (CIM) systems. In the proposed GA, introduce two new genetic operators to help reduce premature convergence in genetic assembly planners. The results bring automated assembly planning and fully flexible CIM systems closer to real-world application. Son et al (2004) proposed a new GA to select the optimal architecture of the neural network and compared with that of engineer’s experience in rolling process. It is shown that learning approach with the optimal structure of neural network could be applied to predict the rolling force for lot of change in hot rolling process and compared between the predicted rolling force by calculated from developed rolling force model and actual rolling force.

Solimanpur et al (2004) proposed a GA with multiple fitness functions to solve; a multi-objective integer programming model is constructed for the design of CMSs with independent cells. The proposed algorithm finds multiple solutions along the Pareto optimal frontier. There are some features that make the proposed algorithm different from other algorithms used in the design of CMSs. These include: (1) a systematic uniform design-based technique, used to determine the search directions, and (2) searching the solution space in
multiple directions instead of single direction. Four problems are selected from the literature to evaluate the performance of the proposed approach. The results validate the effectiveness of the proposed method in designing the manufacturing cells. Azaron et al (2005) developed a multi-objective model for the time-cost trade-off problem in PERT networks with generalized Erlang distributions of activity durations, using a GA. Several factorial experiments are performed to identify appropriate GA parameters that produce the best results within a given execution time in the three typical cases with different configurations. The GA results are compared against the results of a discrete-time approximation method for solving the original optimal control problem.

Rogers and Kulkarni (2005) developed a genetic to solve problems of bivariate clustering for the simultaneous grouping of rows and columns of matrices was addressed with a mixed-integer linear programming model. The solution to the general model found by employing a GA solution technique and applying a simple heuristic was shown to perform as well as other algorithms to find the commonly accepted best known solutions for grouping efficacy. Legrand et al (2006) proposed an optimization procedure using a GA that has been applied to define the optimum orientation of fibres in a uni-directional laminate in which the fibres were allowed to vary continuously across the domain. The domain was divided into two-dimensional finite elements and anisotropic properties corresponding to a carbon fibre laminate with all layers aligned in the zero element axis direction were applied to the laminate. The orientation of the material axis on each element was then prescribed as an independent variable for the GA. Wu et al (2007) developed a hierarchical GA to simultaneously form
manufacturing cells and determine the group layout of a CMS. The intrinsic features of our proposed algorithm include a hierarchical chromosome structure to encode two important cell design decisions, a new selection scheme to dynamically consider two correlated fitness functions, and a group mutation operator to increase the probability of mutation. From the computational analyses, these proposed structure and operators are found to be effective in improving solution quality as well as accelerating convergence.

2.4 NEED FOR THE FURTHER RESEARCH

Although the cellular layout has several aspects in common with the general facility layout problems, it is important to address them as problems in their own right due to the unique characteristics of CM. In today’s competitive market, rapid changes in product variety and their demand are inevitable and to account this, dynamic layout, which is a layout changing in planning horizon, is needed. The DLP has been addressed by a few researchers, who have considered only the demand fluctuation as dynamic environment. In their researches, the components of the total cost are only the material handling cost and relocation cost but not the production loss cost for the time period of shutdown during relayout. The contribution of production loss cost in the total cost is 10% and hence it cannot be neglected.

In this research work, the fluctuation in demand and changes in number of products in the product mix have been considered as dynamic environment. The Production loss cost has been considered in the total cost in addition to the material handling cost and relocation cost. The genetic algorithm has been employed for the cellular manufacturing layout optimization.