MULTIOBJECTIVE RESOURCE-CONSTRAINTED, PROJECT SCHEDULING PROBLEM IN HABSHA CEMENT SHARE COMPANY

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This is to certify that the thesis prepared by Hiwot Wubishet, entitled: Multi-Mode, Multi-objective Resource- constrained, Project Scheduling Problem, Case of HCSC' and submitted in partial fulfillment of the requirements for the degree of Master of Sciences (Mechanical an Industrial) complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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Abstract

In construction industry project, Project Manager usually manages and executes multiple objectives simultaneously within their portfolio. This involves sharing of limited resources such as funds, equipment, work force, and others among different projects, which increases the complexity of the scheduling process. The allocation of scarce resources then becomes a major objective of the problem and several compromises should make to solve the problem to the desired level of optimality. In such cases, contractors are generally concerned with optimizing a number of different objectives, often conflicting among each other. Thus, the main objective of this research is to develop a multiple objective project-scheduling model under resource constraints. Objectives include time, cost, and resource balancing. The model aims to help project manager in devising schedules that obtain optimal/near optimal tradeoffs between different projects' objectives, namely: duration of projects, total cost, and resource fluctuations. Moreover, the model offers the flexibility in selecting the desired set of objectives to optimize. Management model built in order to achieve the main objective, which involves the development of: (1) a scheduling model that establishes optimal/near optimal schedules for construction industry projects. Management models linked with the designed optimization model, which consequently performs operations of the elitist Multi-objective Genetic algorithm (MOGA) technique, in three main phases: (1) population initialization; (2) fitness evaluation; and (3) generation evolution. The optimization MMMOGA model tested using large scale of cement industry project presented to demonstrate the practicality and efficiency of the proposed model and optimization. Finally, an automated tool using C++ language programming built with a friendly graphical user interface to facilitate solving multi-objective scheduling optimization problems for project manager and practitioners.

Key Word: Project-Scheduling Problem, resource-constrained, project scheduling problem, Single, and multi-mode and objective RCPSP.

Table of Contents

List of Figure

List of Table

Abbreviation

AOA: Activity on arrow diagram

AON: Activity on node diagram

CPM: Critical path method

PERT: Program evaluation and review technique

Act: Activity name

Dur or D: The activity normal duration

ES: Early start

EF: Early finish

LS Late start

LF: Late finish

O.R: Operations Researches

GA: Genetic Algorithms

MM: Multi-Mode

MOGA: Multi-objective Genetic Algorithm

MMMOSCOP: Multi-Mode Multi-objective scheduling Optimization

HCSC: Habesha Cement Share Company

Si The starting date of activity i

Ri: *Resource* number i Required amount of resources in a given

RCPSP:	Resource- constrained project-scheduling problem
T:	Total duration of the project (makspan)
Ti:	Total duration of activity i *f(i):* Fitness value of chromosome
PMX:	Partially Mapped Crossover
OX:	ordering crossover
GUI:	Graphical user interface

Chapter One **Introduction**

1.1 Background of the Study

Facing the globalization and the growing number of international competitors, and in an attempt to promote development and to avoid failure, the manager should predict a good plan. Hence, in project scheduling problems planning and scheduling activities are viewed profoundly important to generate plans and to maximize the utilization of scarce resources. Thus, finding a feasible and efficient plan is a considerable challenge. In this respect, the well-known Resource-Constrained Project Scheduling (RCPS) represents the most important problem in project scheduling. There are many variants of this problem; multi-mode, single mode, with non-preemptive or pre-emptive resources, renewable or non-renewable resources [38]. The classical RCPSP tries to find suitable solution in order to optimize the makespan, i.e. to find the best resource allocation for a given set of activities/tasks. But, in real-life the scheduling problem requires the consideration of several objectives, generally conflicting, as the time duration of the project and the cost of the resources used to perform the activities of the project. Thus, the project manager faces the problem of finding good feasible schedules taking into account multiple objectives and not a single objective. In this context, the notion of optimality replaced with the notion of efficiency and instead of a single optimal solution we deal with a set of trade-offs called efficient solutions or Pareto-optimal solutions. The literature on multi-objective RCPS problem is scant; hence, there are few papers about it. The multi-objective RCPS problem considered as an NP-Hard problem [1]. For that, meta-heuristics are applied. In the literature we can find the Tabu Search algorithm [5] [4], The Ant Colony Optimization algorithm.

The planning and scheduling of activities are important to generate good plans and to maximization the utilization of scarce resources. The planning process consists in generating feasible Course of Action (COA), the Multi-Objective RCPSP tries to find suitable resources allocation and optimize these objectives. This problem can be stated as a set of jobs or tasks, related by successor and predecessor constraints and where each task requires for its realization a various combination of resources/mode. Also, in more complicated projects it is possible to define more controllers like parallel implemented between two activities [1]. In fact dependence of activities is based on their priority of implementation; it means it is possible that implementation of an activity depends on implementation of the others, this is called that project has priority constraints between activities. But in addition to these limitations, May bean other type of constraints, as resources constraints exist in project. So in project planning in addition to considering priority constraints, planning should be compatible with resources constraints. The objective of scheduling and sequencing activities is optimal allocation of limited resources over time. In fact scheduling is determination of activities which must be done in the specified time and sequencing, determine order of activities which must be done. Those project planning problems, which do not have limitations of resources or consider them, are known as project scheduling problems without resource constrained and those problems, which have resource-constrained, and these limitations are considered in planning project, called resource-constrained project scheduling problems (RCPSP). This problem is one of the most complicated problems of operation research which has considerable progress in developing exact solution and innovative methods at recent decades and recently new optimization methods are used to solve it[2].For implementing each activity requires different resources such as time, capital, human power and etc. These resources are often divided into two categories: Renewable like human power and nonrenewable such as capital. Each activity can be implemented in several modes such as manually, semi-mechanized and mechanized. Implementation of each mood needs different type and amount of resources [3]. In resource-constrained project scheduling problems for implementing each activity like i needs rik unit of resource $k = 1,\ldots,m$, at per unit of activity's execution time (di). Meanwhile k resource has bk constraints per unit of time. The parameters (di ,ri , bk)are non-negative and determined. This problem's objective often is determining start time and mode of implementation of each activity for minimizing the project's execution time. It is obvious that the problem solution must provide constraints that are related to activities' logical relations, and consider resource constraints too. There are two optimal and heuristics approach for solving the problem [4]. The realistic solution instances of the problem because of complexity, extension, and difficulty with optimal approaches like mathematical planning, dynamic planning, or branch and bound, is impractical [5]. Computer-generated problems are used to test each of the single objective algorithms. The results of this paper show that the algorithms give optimal solutions to tested problems with time and cost objectives using a reasonable computation time; however, heuristic solutions are more feasible for problems Redacted for Privacy with resource leveling objective .The research clearly indicates that the performances of Public Construction Projects in both the case studies exhibited low accomplishment rates. Consequently, completion time suffered low performances for both the Case Studies [24].

1.2 Statement of the Problem

Scheduling is one of the three basic managerial functions (planning, scheduling, and control) that determine the success of any project. Project schedules, determined using techniques such as CPM and PERT, may not be applicable in practice if resource constraints are not included. The resource-constrained project-scheduling problem is concerned with the allocation of limited resources to competing activities with the objective of optimizing. Habsha Cement treats the resource-constrained project-scheduling problem as a single objective problem where a minimum project completion time desired under limited resources. It does not account for variations in resource levels. Fluctuations in resource levels can generate higher costs and reduce efficiency of the resources. Leveling resources in the resource-constrained project-scheduling problem may not necessarily result in reduction of project costs. This is reasonable because traditional network techniques assume that estimates of activity durations made independently of each other without considering factors such as different activities competing for the same resource. However, if more than one mode of operation are allowed for each activity, where each mode reflects a different combination of resource consumption and different activity durations, a higher efficiency can be expected from the use of resource leveling.

The use of multiple performing modes also incorporates time-cost tradeoff and resource-leveling concept since each mode consists of a different combination of resources resulting in different activity direct costs. The traditional method such as, CPM and PERT resource-constrained project-scheduling problem assumes the availability of resources to be limited at each period. However, there are some resources whose availability is constrained over the project life rather than at each time of project. Thus for successful completion of project resource scheduling is very important task. Resource scheduling futuristic planning of activities and resource leveling in project schedule. In large project, preparing accurate and workable schedules with consideration of resources very difficult task. Therefore, they must have more effective resource schedule, which will reduce the overall project total cost, time and Resource fluctuation, can be obtained if the resource-constrained project-scheduling problem is treated as a multi-mode multiple objective problem rather than a single objective problem for these reason MMMOSCGA model will be developed.

1.3 Research question

The study will also try to answer the following research questions listed below:

- What method and strategy should be use while optimizing a given system to balance a construction industry of multiple objectives?
- What technique and parameter should use to analyze the data?
- How to develop a computer based optimization model for the project scheduling?
- How to check the effectiveness and efficiency of the model?

1.4. Research Objectives

The main objective of this research is to develop a multiple objective project-scheduling model under resource constraints, projects considering minimization time, minimization cost and resource fluctuation. The model aims to solve for Company problems of prioritizing projects under resource-conflict conditions, allocating limited resources, and optimizing all the projects' multi-objectives under certain funding limits. This done by producing optimal/near optimal trade-offs between different selected projects. The model takes into account projects' activities to have one or more resource utilization mode with multi-resources. In order to achieve the stated main objective; the following **Specific objectives** are to attained:

- Develop a computer-based model to automate the schedule of construction industry projects. Objectives include minimum duration, minimum cost, and minimum resources fluctuation on the project makespan.
- Develop a GA algorithm optimization model using C++ programming to optimize the schedule of resource constrained construction projects scheduling.
- Analyzing the MM-MoGA models and their scheduling generation scheme, parallel rules, meta-heuristics, genetic algorithm (GA) solver for project scheduling
- Test and Verify the developed optimization model on real cases study.

1.5 Research Methodology

The general objective of this research was to develop multiple objectives scheduling model. Specifically this study was to minimize total time, cost, and resource fluctuation. The objective will be achieved through (1) literature review, (2) Observation (site Visits), (3) data collection, analysis, synthesis, and (4) case studies. Details on each part are as follows:

1.5.1 Literature Review

Review of relevant materials on project scheduling on their time minimization, cost minimization, and on their resource allocation and leveling based on solution approach. In addition, with their single and multi-mode, single objective and multi-objective RCPSP. The literatures are available from electronic media, journals, and books. Secondary data referred from previous related research studies, real data, existing data, etc.

1.5.2 Observation (Site Visits)

An observation will take place on Habesha Cement Project site to know the practical problems faced for time utilization & their attitude towards dedication, involvement, and commitment for the tasks.

1.5.3 Data collection

To give sufficient explanation for the questions posed it is essential to carryout both quantitative and qualitative research on the status of Habsha cement industries based on primary and secondary sources of data. While primary data is the Chemical and Construction Industry Input Development Institute (CCIIDI) of has been carrying out surveys and collecting data on the Projects of manufacturing industry of medium and large scales for a long time. CCIIDI reports are the best source available on the Cement construction project sector and their use is essential both in the planning and implementation phases of this research. Finally, from the case company necessary data were collected.

1.5.3 Data analysis and synthesis

After collecting all the necessary data, it is organized and analyzed the results are interpreted and used to develop the model .The collected data was analyzed by using Genetic Algorithm technique via C++code Block software. This is helpful to

- Multi-objective scheduling optimization model developed using MOGA to optimize the projects' objectives under specified constraints. The model performs genetic algorithms operations in three main phases: (1) population initialization; (2) fitness evaluation; and (3) generation evolution.
- The developed model is tested and compared using real case study, obtained from literature to prove its validity and ability to optimize such problems successfully and efficiently.
- An automated tool using C++ Code Block language built with a friendly graphical user interface to facilitate solving multi-objective scheduling optimization problems for Project manager, contractors, and practitioners.
- Discussion, recommendation, and conclusion; in the final phase of this research project, recommendations are to be formulated for theoretical improvement and practical refinement of the Functionality model and its uses. The objective is ultimately to help country and practitioners of technology to have access to a theory of technology with practical utility value, to the extent that its applications incrementally help to build a paradigm of technology with exemplar solutions to real world project of scheduling problems.

1.5.4 Case Studies:-

Used as a methodology for two purposes. The first was to take lessons from the organizations that overview of project scheduling problem in their project implementation period. Case selected from the manufacturing industries. The case was Habsha Cement Share Company (HCSC) selected based on representativeness of the level of technology, investment capital, and number of labor employed. In addition to this, the willingness of the company and availability of organized data for analysis to undertake the study plays a significant role in selecting a company for the case study.

1.6 Significance of the Study

Scheduling is concerned with the optimal allocation of scarce resources to activities over time. The project-scheduling problem involves the scheduling of project activities subject to precedence resource constraints. The practical application helps practitioners to plan and execute projects with multi objective project resource constrained environment within time and limited resource. The powerful meta-heuristic i.e. Multi-objective Genetic algorithm will help practitioners to uplift the performance of the project planning, scheduling, and satisfying the various customer specifications. The crashing stochastic PERT network with resource constrained will help the practitioners to trade-off between resource availability and project duration for completion of project with the limited resources.

1.7 Scope of the research

The scope of this research to develop a multi-objective Genetic Algorithm optimization model and generating different alternatives to enhance the minimization of time, cost with resource leveling. A thorough study is conducted to understand the general concept of scheduling models and its application to organizations involved in projects. The case study was conducted in the functional unit where by all projects are executed. Due to the scope and time constraints, the study excludes program and project portfolio management scheduling although, projects are related with both program and portfolio management. The scheduling will do for cement construction industry considering different alternative scenarios.

1.8 Expected Results and Beneficiaries

Expected Results

At the conclusion of the research, the following results obtained.

- Construction industry projects can get an improved scheduling model.
- A multi-objective genetic Algorithm model minimize total project time, cost and also resource leveling and resource allocated.

Beneficiaries

The parties listed here under are beneficiaries of this thesis.

- manufacturing company
- From the paper work expands the knowledge horizon on areas of modeling and optimization.
- The society
- Contractor /project manager
- The Government
- Researchers

1.9. Research Contribution

The main contributions of this research summarized as follows:

- Development of a multi-objective Genetic algorithm scheduling optimization model for n types of project construction industry projects considering resource aspects. Such model enables planners to devise optimal/near optimal schedules for multiple projects that simultaneously: (a) satisfies certain type of resource limits; (b) minimize undesirable resource fluctuations, i.e. increase the efficiency of resource utilization; and (c) maximize contractors' profit.
- Adding flexibility to the developed model in selecting the desired set of objectives to optimize together. In other words, different tradeoffs between different set of selected objectives obtained from the model. The merit of this flexibility is in allowing project manager to examine the impact of one or more objectives over the other on the projects' schedule. Thus, the model can solve individually the time/cost tradeoff, resource leveling, resource allocation, scheduling problems. Alternatively, integration of such problems can be also solved.

1.10. Organization of the study

The study will have seven chapters. The first chapter is problem of the study. It is background of the study, statement of the problem, significance of the study, limitations, objective, and scope of the study. The second chapters are about related literature review, and discusses the limitations of existing approaches third chapter gives a is the framework that provides the overall structures for the procedures that a researcher follow. Fourth chapter explains the mathematical formulation of the problem and the experience with the mathematical models. Fifth chapter describes the Testing of the algorithm, improvements and extensions, and the computerized algorithms and their implementation. Sixth chapter explains how tested problems are generated and used in the experiments, and summarizes the results of the tests performed for the single objective algorithms and of the application of the multiple objective algorithm. Finally, the last chapter summarizes the works done in this study and their limitations, and gives recommendations for further rese.

Chapter Two **Literature Review**

This chapter provides a summary of the relevant research and solution methodologies for the problem of interest. Section **2.1** reviews a classification scheme for the RCPSP, which can be used to organize RCPSP research, Section **2.2** Review of RCPSP Literature, and Section **2.3** RCPSP Analysis detail, specific work that is closely related to the research in this thesis.

Classification and Review of RCPSP Literatures

2.1 Classification of RCPSP Literature

Since the class of RCPSPs encompasses a large number of specific problems, the potential for confusion and duplication of work exists. Different researchers have used different schemes of symbols and notation in order to denote their specific problem, which in some cases were actually the same. Without a standardized classification scheme-using notation, it is difficult to keep a clear view of the research area, directions, and progress. A few groups of researchers have attempted to provide such a classification scheme for the RCPSP and number of optimization objectives considered in this paper. [1] (A classification scheme for RCPSPs serves a variety of purposes. It facilitates the presentation and discussion on the subject, and allows researchers to identify viable research areas, which have remained unstudied or ignored in the field. It also helps identify the characteristics of the problem that one is working on. In Fig.1 four levels classification of RCPSP literatures based on: (1) the single mode, (2) number of optimization objectives considered, (3) the nature of the task time,

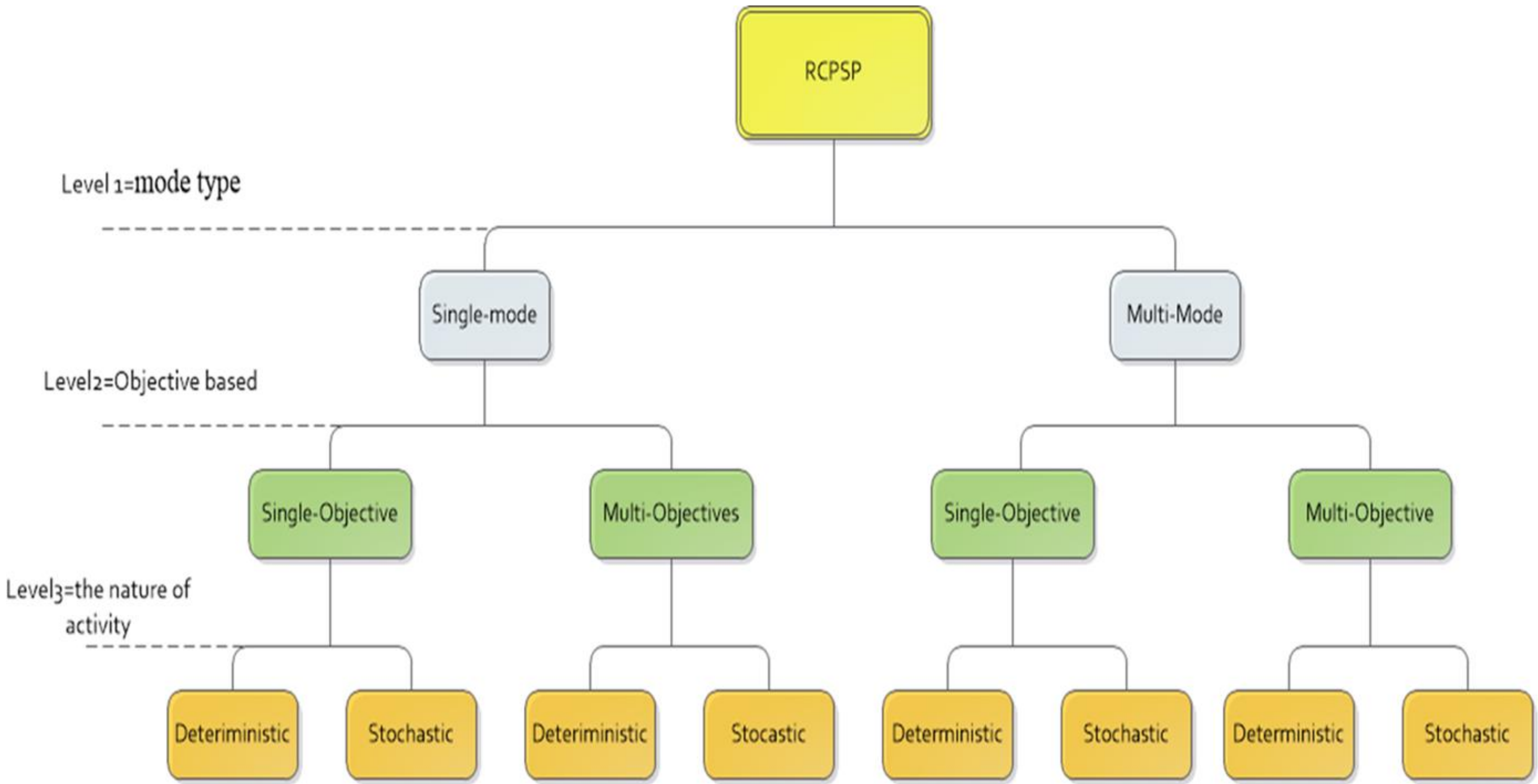

Figure1. 1 RCPSP Classification

Literature Based on the classification, three level categorization can be drawn; from this, the first two letters indicated the number of mode (single or multi). The second two letters indicated the objective (single or multiple) and the last letter indicate the nature of task time (deterministic or stochastic)

- SM_SO_Dt: Single Model Single Objective Deterministic RCPSP with resource leveling
- SM_SO_St: Single Model Single Objective Stochastic RCPSP
- SM_MO_D: Single Mode Multi-Objective Deterministic RCPSP
- SM_MO _S: Single Model Multi-Objective Stochastic RCPSP
- MM_SO_Dt: Multi-Mode Single Objective Deterministic RCPSP
- MM_SO_ St : Multi-Mode Single Objective stochastic RCPSP
- MM_MO_ Dt : Multi-Mode Single Objective Deterministic RCPSP
- MM_MO_ St : Multi-Mode Single Objective Stochastic RCPSP

2.2. Review of RCPSP Literature

In this section, the review of **RCPSP** literature based on the categories in Fig.2.1 presented. There are four main subsections considered; Single Mode Single Objective Resource Constrained Project Scheduling Problem (SM_SO_RCPSP), Single Mode Multi-Objective Resource Constrained Project Scheduling Problem (SM_MO_ RCPSP), Multi-Mode Single Objective Resource Constrained Project Scheduling Problem (MM_SO_ RCPSP), Multi-Mode Multi-Objective Resource Constrained Project Scheduling Problem (MM_MO_ RCPSP). Under each subsections literatures are presented under those, which consider deterministic task time, and those with stochastic task time, which again are considered**.**

2.1.1 Single Mode Single Objective RCSPSP(SM-SO-Dt)

SM_SO_Dt-RCPSP: Resource Constrained Project Scheduling Problem with a single objective with consideration of single mode in which the task times are deterministic was studied in several past researches **[2, 3, 4, 5, and 6]**. Proposed branch and bound algorithm in order to solve resource constraint project scheduling problem that is subject to nonrenewable resource in addition to renewable resource and discussed it differences with respect to those in the literature[1]. In their research they **a**nalyzed the algorithm behavior respect to the changes in instances degree of difficulties and compare its performances in different cases with the CPLEX solver and finally, and on a real industrial data set. Accordingly, they have pointed out that their parameters affecting the degree of difficulty of the problem and they state that a nonrenewable resources with prescheduled procurement have not been specifically studied in the project scheduling literature. This paper deals with resource-constrained project scheduling problem under the weighted late work criterion [3]. And their problem has been formulated using a linear integer programming model and solved by the CPLEX and In order to solve the problem optimally, a depth-first branch-and-bound algorithm is applied based on idea of minimal delaying .they results is generate six different versions of the branch-and-bound algorithm. Computational results on randomly generated problem sets are provided to analyze the efficiency of the priority rules and the branch-and-bound algorithm, alternatives. Moreover, it pointed out that the total weighted late work is calculated based on the summation of the weighted late work of all project activities. The late work criterion determines the quality of a schedule on the basis of the duration of late parts of activities finished after their due dates finally they conclude that RCPSP-TWLW not been studied before. The paper novel scheduling heuristics for Multi–Skill Resource–Constrained Project Scheduling Problem presented by **[4]** proposed and compared to state-of-the-art priority rules, based on task duration, resource salaries, and precedence relations. In this paper five SPR will be presented and evaluated on proposed dataset: known from the literature, like based on a task duration, a resource salary, and task successors' list size. They are also proposed some novel approaches, based on an adjustment between required and available skills. Proposed SPR could be applied to more complex methods, like metaheuristics, i.e. as a method of generating initial population in EA, to make the search more effective. Furthermore SPR can be combined with the EA–based approaches, constructing hybrid metaheuristics, where those methods could be regarded as a local search methods. The goal of the paper is to investigate, whether evaluated methods can be used as robustness enhancement tools in metaheuristics, mostly evolutionary algorithms. They obtained and concluded from the result that no need to make the priority rules too much complicated. [5] However, in this paper they proposed a mixed integer programming model for the problem and parameters tuned meta-heuristic namely.Genetic algorithm proposed to solve it. They considered the following assumptions in the PRCPSP-ST:

- The activities can preempt in discrete time points.
- The number of preemptions for an activity is not limited.
- A setup time is required to start an activity after preempted.
- Initial setup time of an activity is included in its duration.
- Setup times are deterministic and schedule-independent.
- Setups are inseparable, i.e. an activity is started immediately after its setup is finished.
- Setups occurred after preemption require the same amount of renewable resources with that of when the activity is processing.
- All parameters are integers

They attempted to solve the preemptive resource constrained project-scheduling problem with setup time to restart after preemptions. The objective is to schedule the activities in order to minimize makespan of the project subject to the precedence relations and renewable resource constraints. To evaluate the validation and performance of the proposed algorithm a set of 100 test problems is used. According to their result show that the proposed algorithm is efficiently capable to solve the problem .Furthermore, they have suggested the preemptive project scheduling combined with generalized precedence relations or multi-mode case

This paper presented a new Mixed-Integer Linear Programming Model (MILP) for the deterministic single-mode Resource Constrained Scheduling Problem (RCPSP) with renewable and non-renewable resources [6]. Finally, the applicability and the efficiency of the proposed formulation is illustrated by considering three example projects with 12, 16 and 20 activities under the most commonly addressed objective, makespan minimization.

[27] singlemode single objective with continuous we have arbitrarily divided the lower bounds proposed in the literature for the RCPSP according to the way the resource constraints are considered for future research is to close the gap between these two categories. This can be done by developing branch-and-cut or branch-and price methods. Some interesting alternative recent work have been carried in this direction: lagrangean relaxation, which

significantly accelerates the LP resolution. Linear programming based on MRF analysis of the forbidden set structure for given solution were taken.

Single objective major contribution of this work is to investigate several enhanced new feasibility tests that prove useful for deriving new lower bounds that consistently outperform the classical energetic reasoning based lower bound[28],[30]. Proposed several new lower bounds that are based on the concept of energetic reasoning. Furthermore, they found that an effective shaving procedure enables to derive an excellent lower bound that often outperforms the best bound from the literature while being significantly simpler. Presented a 0–1 programming model that computes an enhanced estimate of the total work over the time-interval [t1, t2] for resource k.

Single objective wiz daynamic they proposed, developed, and tested a new hybrid metaheuristic approach called the Neurogenetic approach, which is a hybrid of a neural network approach and the genetic algorithms approach. The objective is minimizing the makespan and problem formulated by upper bound .The NG approach gave better results than either NN or GA approach alone for the same number of schedules generated [29]

2.1.2 SM_SO_RCPSP with Stochastic Task Time

SM_SO_St: Resource constrained project-scheduling problems with single optimization objective with consideration of stochastic (probabilistic) task time consideration **[6]**. Presented a paper on resource constraint project scheduling problem under uncertainty difference of problem types, different probability models can chosen to estimate the underlying probability distribution. They have proposed a hybrid estimation of distribution algorithm propose for solving the RCPSP with a criterion to minimize the makespan. By applying the combined local search with permutation based local search and Forward–Backward improvement, the exploitation was enhanced. Based on the PSPLIB benchmarks, the Taguchi method of DOE they used to determine a suitable parameter setting of the HEDA, and the simulation results and comparisons with some existing algorithms demonstrated the effectiveness of the HEDA. Moreover, they suggested future work is to develop the adaptive

HEDA for the RCPSP and design effective HEDA for some generalized RCPSP, such as multi-mode RCPSP and stochastic RCPSP

2.2.2. Single Model multi-Objective Resource-Constrained Project Scheduling Problem (SM_MO_RCPSP)

2.2.2.1. SM_MO_RCPSP with Deterministic Task Time

SM_MO_D_RCPSP: past researchers have worked on resource constrained project scheduling problem having multiple optimization objectives with consideration of a in which the task times are deterministic **[30,7, 8, 9,]**. [30] the problem of scheduling a project has been addressed with the aim of assisting project managers at the early stage of designing project schedules. Thus, as part of the problem, two priority Optimization objectives were considered for managers at that stage, minimize the project makespan and maximize the project effectiveness level(maximize the effectiveness level of the sets of employees assigned to the project activities).a multi-objective evolutionary algorithm has been proposed to solve the problem. The algorithm was tested many times on each of the instances, and after each one of the runs, the algorithm provided the non-dominated solution set of the last population or generation. They suggested future work, that is develop approaches that automatically estimate the effectiveness levels of the employees from available information about the participation of the employees in already executed projects. These approaches will complement this algorithm

[7] Introduced a multi objective Particle Swarm Optimization (PSO) based approach for the solution of with the purpose of minimizing cost and minimize makespan of the resource constrained project-scheduling problem. Resource optimization problems in project management have been solved either as resource leveling or as resource allocation problems with non-negative integer. They have included Constraints impose the precedence relations between activities; limit the resource demand imposed by the activities being processed at time to the available capacity. Finally, force the finish times to be non-negative. They have applied designed Multi-objective practical swarm Optimization algorithm for real-like problem instances. They evaluate their performance of the PSO based on approach As a result

, the application of PSO to project scheduling they got as achievable finally they have pointed out that PSO is meta-heuristic approach is good to solve project scheduling problem and the inclusion of much problem specific knowledge is needed for the heuristic the development of meta-heuristic algorithms for the RCMPSP and their comparative study with the PSO approach is among the future research areas suggested by the authors**.[8]**presented paper considers multi objective RCPSP in which the minimum cost and the number of time optimized. The model proposed ICA/PSO hybrid algorithm which is made of Particle Swarm Optimization (PSO) and Imperialist Competitive algorithms (ICA) were used for solving resource constrained project scheduling problem (RCPSP) minimizes t used a meta-heuristic algorithm namely modified for deterministic resource constrained project scheduling problem. The problem is hypothetically solved is consists of finding a combination of the number of resource. They have solved different standard problems available in PSPLib library from the existing literature to test the performance of the proposed method. Based on the results, they concluded that the proposed method showed this algorithm had good performance as compression to the other much promising performance. As future research interest, they have designate Furthermore ,this algorithm could be used for solving these kinds of problems in multi-mode situation of activities or having general precedence relations or making more limitations on the resources for example the existence of renewable and non-renewable resources. **[31]** Four discrete-time model formulations for the FRCPSP and investigate the model efficiency in terms of problem size, solution quality, and runtime. According the author such a complete study on the FRCPSP has not yet been published, however, its superiority comes at the cost of larger numbers of variables and constraints, which, under a limited memory capacity, can restrict the problem size that can be handled by the commercial solver. Further research may continue on improving its model formulation, including applications of stronger valid inequalities for its specific polyhedral structure and dominance rules. A more efficient solution method, both exact and heuristic methods for real-world applications, may also be further studied.

[32] Multi objective non-regular objective]. This paper presented a solution procedure for the resource-constrained project-scheduling problem with generalized precedence relations (RCPSP-GPR) with the objective of minimizing the makespan of the project. The RCPSP-

GPR extends the RCPSP to arbitrary minimal and maximal time lags between the starting and completion times of activities. The procedure is a depth-first branch-and-bound algorithm. Even nonregular measures of performance, such as the maximization of the net present value of the project or resource leveling can handled. Benchmarking the procedure has been programmed in Visual C++ for use on a personal computer

SD95] Single mode multi objective wiz continuous introduced a heuristic that is based on a unique genetic algorithm (GA) to solve the resource-sharing and scheduling problem (RSSP).The problem is to select a single mode for each operation and accordingly to schedule the resources, while minimizing the makespan time, The full solution, i.e., the schedule related to the DNA encoding,

is generated by solving a linear-programming (LP) problem the results shows that GA solved all the problems (10 runs each), and reaches optimality in 75% of the runs, had an average deviation of less than 1% from the optimal makespan, and a runtime that was much less sensitive to the size of the problem instance.

2.2.2.2. SM_MO_RCPSP with Stochastic Task Time

SM_MO_St_RCPSP: resource constrained project scheduling problem with multiple optimization objectives with consideration of stochastic task time consideration in **[10].** Introduced a heuristic method for the RCPSP_OM for multi objective single RCPSP with uncertain task times. They minimized first the duration of the project, then the cost of reworked tasks. To optimize the parameters of the proposed method they used the scheduling of the project undertaken Taguchi technique. And to get insight of the performance of the MS project tool which use simple heuristic rules allowing to quickly elabrprtea project scheduling by taking into account given constraint. Their finding is that the duration of rework is a convex increasing function of overlap as a future research interest, they have suggested the more power full and realistic project scheduling method as tabu search, genetic algorithm, or stochastic approaches, taking into consideration the characteristics of industrial application arising from practice[96].

multi objective wiz stochastic duration. studied a resource-constrained project scheduling problem in the presence of perturbation on activity durations. *Robust scheduling* is employed as the methodology to solve this problem. We measure the robustness of a schedule as the expectation of the difference between the actual makespan after execution and the planned makespan. his problem is molded as a multiobjective optimization problem.where makespan minimization, robustness maximization, and stability maximization standard deviation minimization are considered simultaneously.to solve the problem hybrid multiobjective Evolutionary algorithm proposed, Experimental result showed that they proposed approach is feasible and effective for the resource-constrained project scheduling problem with stochastic durations and that the proposed H-MOEA performs better than normal MOEA. According the author the suggested future work, they planned to employ the hybrid multiobjective evolutionary algorithm to investigate the project scheduling problem under dynamic environment. It is also worthwhile to focus on the design of more efficient hybrid MOEAs for solving large-scale problems in future work. [38]

[39] This paper presents the survey of methods and models that are put into the historical context and are categorized according to their working principles. It aims to supplement and update existing RCPSP surveys. The current state of the research field is assessed and potential research venues are identified. Methods dealing with uncertainty are proactive or reactive. Proactive methods work better in cases when the uncertainty is quantifiable while in other

[49] Presented a paper on application of innovative Evolutionary Algorithm-based approach, called mapping of task ID for centroid-based adaptation with random immigrants (McBAR), and applied this to search for optimal schedules as solutions to the problems. They also presented to legitimize sub algorithms of McBAR based on the quality of solutions they obtained in solving the problems. In this paper multi-objective multi model stochastic dynamic resource-constrained +project scheduling problems involving an increasing number of tasks. And mathematically formulation of static sub problem. Several test problems from the literature were solved, and the McBAR is found to be generally superior in performance to the other techniques after the first increase in the number of tasks in the environment. Based on the comparison results, they have concluded that the general stability of McBAR's

performances demonstrates the relevance of McBAR for solving the types of dynamical problems investigated in this paper. The suggested future work is plan to model McBAR's performance in solving the problems through design of experiment.

2.2.3. Multi-Mode Single Objective Resource constrained project scheduling problem (MM_SO_RCPSP)

2.2.3.1. MM_SO_RCPSP with Deterministic Task Time

MM_SO_D RCPSP: Resource constrained project scheduling problem with a single objective with multi model in which the task times are deterministic was studied in several past researches. **[11]** Presented new mixed –integer linear programming models for the deterministic single- and multi-mode resource constrained project scheduling problem with renewable and non-renewable resources. First they proposed new RTN-based network representation methods, and then they transformed them into mathematical formulations including a set of constraints described precedence relations and different types of resources finally they applied to the objective, the makespan minimization based on several problem.

A paper by **[12]** introduced a metaheuristic algorithm approach to muliti-mode resource constrained project scheduling problem. The purpose is to create a smoother distribution of resource usage i.e. to minimize the fluctuation of the resource usage. Using some heuristics for generating one or more near-optimal individuals in the initial step can improve the final solutions *obtained by meta-heuristic algorithms*, which according to the paper, the scheduling algorithm efficiency evaluated by different criteria and have resulted in better performance provide for suitable performance over all objectives classified multi-objective methods in three categories. This problem involves optimization of several objectives including resource utilization, QOS metrics, cost, reliability factors, finally they provided survey on various multi project resource constrained scheduling algorithms used for evolutionary computing comp **[40]** they developed a formulation for the new problem and term it a multiple mode per operation, resource collaboration, and constrained scheduling problem (MRCCSP).also new characteristic consider multiple product families multiple orders (jobs) per family; precedence restrictions among the operations that constitute a job; alternative modes for the performance of an operation. The objective of the MRCCSP is to minimize makespan.

[41] Multimode single objective. The Multi-mode Resource Constrained Project Scheduling Problem (MRCPSP) is one of the most important problem s in the context of project scheduling. This paper involves a Mode identity and Resource Constrained Project Scheduling Problem (MIRCPSP) to minimize the project makespan. The problem formed in this NP-hard, forcing us to develop a meta-heuristic algorithm, namely, the Genetic Algorithm (GA), to obtain a global optimum solution or at least a satisfying one, Taguchi experiment design employed as a statistical optimization technique to calibrate the effective parameters of GA in order to have a robust algorithm. The obtained results show that the performance of the proposed genetic algorithm is quite satisfactory. [33]Multimode single objective with dynamic, presented an exact procedure for a general resource-constrained project-scheduling problem where multiple modes are available for the performance of the individual activities and minimum as well as maximum time lags between the different activities may be given. The objective is to determine a mode and a start time for each activity such that all constraints observed and the project duration minimized.

[34] multimode single objective with discrete, this paper presented results from an extensive computational study of the multi-mode resource-constrained project scheduling problem when activities can be split during scheduling under situations where resources may be temporarily not available. All resources considered are renewable and each resource unit may not be available at all times due to resource vacations, a branch-and-bound procedure applied to solve a number of small project scheduling problems with and without activity splitting. The problem formulated by 0-1 integer.

[35] Multi- mode single objective with discrete optimization, presented a genetic algorithm for the multi-mode resource-constrained project scheduling. They also introduce the preemptive extension of the problem, which allows activity splitting (PMRCPSP). To solve the problem, they applied a bi-population genetic algorithm problem (MRCPSP), their computational results for the MRCPSP, they found that procedure is amongst the most competitive algorithms. Further include this work are e.g. the adaption of the algorithm to other project scheduling problems, such as the DTRTP.

SD77] multi-mode single objective proposed and investigated two new ideas. On the one hand, they Transform the problem of single objective MRCPSP to bi-objective one to cope with the potential violation of nonrenewable resource constraints. Secondly they build the fitness function not on a priori grid of the bi-objective space, but on an adaptive one relying on clustering techniques. The proposed a new EA to solve the MRCPSP. They suggested future work, in multi-objective evolutionary algorithms since it may promote diversity and avoid premature convergence of the algorithms.

2.2.3.2. MM_SO_RCPSP with Stochastic Task Time

MM_SO_St_RCPSP :Multi-mode resource constrained project scheduling problem with single optimization objective with consideration of stochastic task time consideration were presented in **[14], 15]**. **[14]** introduced a combinatorial practical swarm optimization (CPO) to solve it, our objective was the minimization of the makespan with an uncertain task processing time. In this paper, procedure has been fruitful in the assignment of different modes to the activities. They are also used a local search method to optimize the sequence associated to each assignment. Results of this paper were provided very competitive terms of percentage of problems solved to optimality and average deviations and comparing average deviations and percentages of optima they found, CPSO algorithm outperforms the simulated annealing algorithm and it is close to the PSO algorithm.

[15] This paper introduced a new multi agent learning algorithm (MALA) for solving the multi-mode resource-constrained project scheduling problem (MMRCPSP), in which the activities of the project can be performed in multiple execution modes. Objective of the paper minimize the total project duration, finally the justified that the result showed their method is new for the specific problem

2.2.4. Multi-Mode Multi-Objective Resource constrained project scheduling problem (MM_MO_RCPSP)

2.2.4.1. MM_MO_RCPSP with Deterministic Task Time

MM_MO_D RCPSP: Resource constrained project scheduling problem with a multi-objective and consideration of a line with multi-model in which the task times are deterministic was studied in several past researches [16, 17, and 18]. [16] They introduced the concept of schedule robustness and developed a bi-objective resource-constrained project scheduling model. The objective of this paper is maximization of robustness and minimization of makespan, also developed tabu search algorithm in order to generate an approximate set of efficient solutions, the algorithm are tested and compared on large set of benchmark problem. Among the future research directions indicated in the article one is the present model need to be include non-renewable resource as well as multiple execution modes for each activity. Secondly they suggested to investigate present work in an interactive strategy, which is to reduce the number of proposed schedule. Multi-mode resource constrained project scheduling problem using a heuristic algorithm optimization approach was discussed in **[17]**. The optimization objectives include net value (NPV) maximization and makespan minimization, with and without resource constraints. To solve the problem the author has proposed a heuristic algorithm. To prove the efficiency of the proposed heuristic algorithm, they solved number of test problems from the literature, and based on the results, they have showed that the algorithm is an efficient and effective algorithm, which accordingly, gives better results than other methods compared. Parameter tuning analysis to improving the solution performance and the consideration of other realm of constructive approaches such as simple priority rule-based heuristics and enumeration-based exact procedures. Are among future research areas pointed out in the paper. **[18]** Presented work is to holistically review the relevance and applicability of single and multi-objective performance dimension of RCPSP. It applied to real project management tools and techniques in Nigeria and sub-Saharan Africa. According to the author observation, they found that there is no article in literature focusing on the relevance and benefits of multi-objective RCPSP. Finally the summarized the multi-objective approach in practical situations was found to be the natural way of solving RCPSP. Resource constraint psp with a multi-objective multi-mode in which the task times are dynamic was studied in several past researches. [42] Presented a multi-objective optimization model for multi-project scheduling on critical chain, which takes into consideration multi-objective, such as overall duration, financing costs and whole robustness. To solve this model cloud genetic algorithm is proposed and the algorithm designed to generate priority of multi-project scheduling activities and obtain plan of multi-project scheduling on critical chain. They solved number of test problems from the literature, and based on the results, they have showed that the cloud genetic algorithm is an efficient and effective algorithm, which accordingly, gives better results than other methods compared. **[43]** This paper first mathematical model of this problem is established, and the solution via the genetic algorithm is also developed. Also it concentrated on the optimization problem of resource-constrained project scheduling, time and resource optimization. Finally, the numerical experiment is adopted to verify the effectiveness and efficiency of the proposed model and algorithm. suggested future work includes two aspects: (1) performance analysis of genetic algorithm for solving this problem comparing to other heuristic ones such as particle swarm optimization, artificial immune system, and so on need further study; (2) more complex scheduling models considering other dynamic factors including disruptions is another direction needing further explored

[44] Studied multiobjective resource-constrained project scheduling problems (MORCPSPs), especially those problems where all the performance measures are regular. They developed several algorithm and sated several result. A multiobjective optimisation problem (MOP) can be formatted by vector of decision variable .Their finding ROFs have received much more attention in the literature than non-regular objective functions, especially the project completion time or makespan. As a result, many more techniques and algorithms have been proposed for these problems. They conclude that, there is no algorithm in the literature specifically designed for MORCPSP with ROF. According to the author future research begin with biobjective MORCPSP makespan+WET, makespan+NPV, makespan+RL, etc. Finally, it is necessary to produce exact algorithms capable of calculating the real Pareto fronts for the most important MORCPSPs

[45] In this research, two heuristic algorithms are developed to solve a multi-mode resource-constrained multi-project scheduling problem (MMRCMPSP). The first, called a parallel scheduling algorithm, includes a combination of an activity- and a mode priority rules; the second, a genetic algorithm. The objective is to maximize the weighted profit of projects. They generate number of test problems from the literature, and based on the results, they have showed that the genetic algorithm is an efficient and effective algorithm for MMRCMPSP, which accordingly, gives better results than other methods compared. Finally the suggested future work a simple genetic algorithm is initialized; more efficient and robust GA is left.

[**46]** Introduced an alternative heuristic method for scheduling repetitive projects with limited resources and multiple modes in the light of minimizing project duration. The framework of the project scheduling system is constructed so that the heuristic method is implemented. The alternative heuristic method for scheduling the resource-constrained, multi-mode and repetitive project is expected to be efficient and beneficial to both researchers and practitioners. Furthermore they suggested future research will be address the issues of considering cost, resource leveling, and more uncertainties of a project in the heuristic algorithm and practical implementation of the heuristic algorithm. [TF 25] The author has developed a heuristic planning and scheduling model, which uses two new criteria: the tightness degree of completion due-dates and resource tightness degrees. The performance of proposed heuristic scheduling rules varied significantly throughout the scheduling cases, which contained different degrees of completion due-dates and resource tightness. The proposed model proved throughout these scheduling experiments to be applicable, practical, flexible, and efficient **[47]** Multi-mode multi objective with discrete RCPSP is a combinatorial optimization problem, *NP-hard in the strong sense*, where a set of activities must be scheduled on a set of available renewable resources available in limited quantity. It consists in finding a *non-preemptive* (with no interrupted activities) schedule of minimum *makespan* (its end date) subject to precedence constraints and resource constraints. An extension of this problem dealing with specific resources, called the *RCPSP with consumption and production of resources* is also treated. They proposed MILP formulations for the RCPSP based on the concept of event the Start/End formulation and the On/Off formulation.

Multi-mode multi-objective, discusses the multi-mode project payment scheduling problem with bonus –penalty structure in which the activities may be performed with several modes and there is a bonus– penalty structure at the project's deadline[76]. A two-module simulated annealing heuristic is proposed to solve the mixed integer non-linear programming models for the contractor and the client, and a satisfactory solution, which consists of payment event set, event schedule, and payment amount set, may be found through iterations between the heuristic's two module. The bonus–penalty structure may advance the project completion effectively and improve the profits of the two parties in the meantime can be obtained

2.2.4.2. MM_MO_RCPSP with Stochastic Task Time

***MM_MO_St_RCPSP*:** Multi-Mode resource constrained project scheduling problems with multiple optimization objectives with consideration of stochastic task time consideration and were presented in **[20, 21, 22, 23, 24-27]**. **[20]**Introduced first deterministic multi-resource allocation model that is convex and hence tractable for realistic problem sizes and then they extended model to accommodate uncertain. The problem formulated by stochastic programming which is stochastic formulation assumes knowledge about the first two moments of the uncertain parameters and optimizes the α-VaR of the project makespan. Although VaR is a nonconvex risk measure. - To implement and evaluate these approaches they used an example data set from the. Based on the result they have concluded that accommodates distributional ambiguity, which seems crucial in view of the lack of historical data. They identified their problem very similar to the one considered they arise in several other application areas and secondly they are considered static resource allocation. According to the authors, possible future research extensions on this work It would be instructive to investigate the dynamic problem, which is significantly more involved since the underlying stochastic process becomes decision-dependent

[21] Introduced Multi Objective Genetic Algorithm **(MOGA**) based Resource usage and the Prioritization of the Constraints in the Software project planning. This is used for the minimization of the resources for the usage in the project development and to fix the precedence of the constraints. The problem can be formulated as finding a schedule of the activities. By taking resources and the precedence of the constraint and represented by vector. Based on the result they have concluded that MOGA is the most suitable method for solving this type of problem. According to the authors, possible future research extensions on this work based on the optimistic usage of the resources as well as the reduction of the impact of the change management include such considerations as analyzing the sensitivity of the final solutions to the model mix.

[23] The purpose of this paper is to provide a broad overview variants and extensions of the RCPSP that have been proposed in the literature. They restricted their self to deterministic approaches (for an introduction to stochastic problem. in addition to popular variants and extensions such as multiple modes, minimal and maximal time lags, and net present value-based objectives, the paper also provides a survey of many less known concepts, These studies show that the use of the RCPSP with all its extensions is not limited to applications in its original field, the scheduling of projects. The RCPSP and its generalizations are also perceived as a collection of powerful tools that allow to describe many highly complex optimization problems from other areas. Hence, algorithms originally designed for project scheduling can be transferred to problems from other fields. They believed that this underscores the importance of research on models and methods for project scheduling, the multi-mode RCPSP is often referred to as MRCPSP. Clearly, if only one mode per activity and no nonrenewable resources are given, we obtain the standard RCPSP.

This paper Potts mean field feedback artificial neural network algorithm is developed and explored for the multiobjective resource constrained project scheduling problem [24]. Objectives such as minimization of total project cost and leveling of resource usage are also considered. The MRCPSP that considers the renewable resources, nonpreemption and minimizing of project duration can be formulated. They conclude that neural networks based heuristics have been applied to the MRCPSP. So, research in this approach is still in its infancy. tested this approach on some well-known MRCPSP benchmark problem instances in the literature and the computational results are very encouraging as they compare very well with some of the best results in the literature from techniques such as priority rule-based heuristics. The approach is new and give new result .finally they suggested future work to developing some hybrid approaches involving the Potts-MFA approach and some of the other successful approach such genetic algorithms, to further improve the results.

[25] Presented a stochastic multiple mode resource constrained project scheduling problem (S-mrcPSP) with the uncertainty of durations. An effective multi-objective estimation distribution algorithm (moEDA) proposed to solve S-mrcPSP to minimize its robustness and expected makespan. Where a free slack based heuristic method is adopted to achieve better performance. The proposed method applied to solve various benchmark RCPSP.

Mathematical model formulated by decision variable. For clarifying the practical viability and efficiency of the proposed moEDA, they compared it with awGA, NSGA-II and SPEA2 by large instance j30 of 30 activities x 3 modes in psplib and demonstrated moEDA is then found that better than others. According to the authors, possible future research to determine the accuracy of the proposed moEDA in response to variations among the parameters and the performance of moEDA will improved particularly for the implementation of more efficient structure learning algorithms

[26] Presented a multi-objective manpower-scheduling model regarding the lack of clarity on the target values of employers' objectives and employees' preferences, to solve this model a fuzzy goal programming developed. The developed fuzzy goal programming model has been converted to two crisp single-objective linear programming models. Two crisp single-objective models have been solved by a numerical example and the Lingo 9 software. The obtained results have shown that two-phase method totally provides better and more efficient solutions than max–min operator, among their future research, some other work regulations, legal constraints, employers' objectives, and employees' preferences can be considered to expand the presented model. Moreover, other fuzzy solution approaches can be applied to compare the results in order to achieve the most efficient schedule.

[49] a multiobjective optimal control model was established to solve a multimode resource-constrained multiple project scheduling problem (MRCMPSP) in a large scale hydropower construction project under a fuzzy random environment. Presented an extension of the multimode resource-constrained project scheduling problem for a large scale construction project where multiple parallel projects and a fuzzy random environment are considered. This is a multiobjective optimization process for minimizing the weighted project makespan and project cost and maximizing the project quality, with decision makers determining suitable project scheduling and mode selection. To deal wiz uncertainties they used a hybrid crisp approach for transform the fuzzy random parameter into fuzzy variables. The combinatorial-priority based hybrid particle swarm optimization algorithm developed to solve proposed model. The results and analysis were presented to highlight the performance of their optimization method, which was proven to have the characteristics of generality, reduced calculation time, high velocity, high effiency, and high precision compared to the standard

PSO algorithm. This paper noted that MRCMPSP excepted value model was formulated with some assumptions. They draught if may not represent the precise construction and environment as result of this they suggested future research would be the consideration of more restriction rather than assumptions

2.3 RCPSP Analysis

The method applied to conduct the research was based in a Literature Review which aims to identify Multi-objective resource constrained project scheduling Articles related to the topic in question were found through the Web of Science portal. The research attempted to identify articles with the following keywords related to resource constrained project scheduling problem, multiobjective resource constrained project scheduling algorithm, project scheduling problem with stochastic and deterministic duration:, and benefits. After refining the research, it was raised a total of 118 items published between the years of 2000 and 2016, distributed as shown in

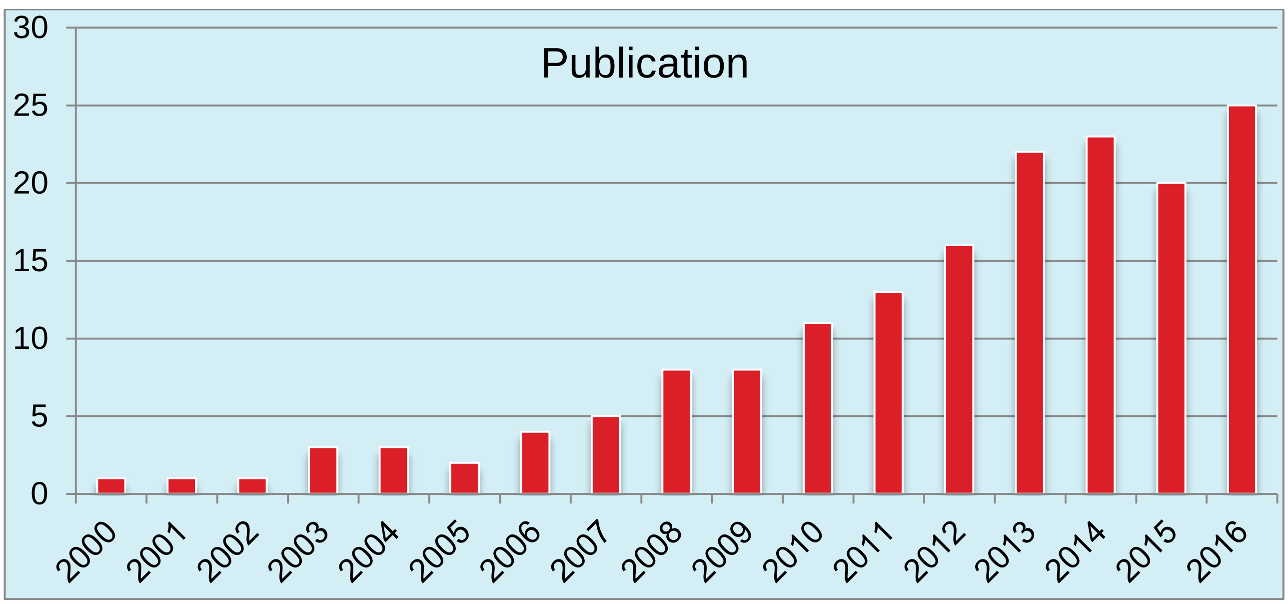

Figure2. 1 Articles distribution with the year of published

It is indicated that there was an increase in the publication of articles, when compares the 2000s to the 2007s. The year of 2016 is not matured regarding the total of articles published due to the cutoff date. In relation with the citations analysis, these 118 articles, distributed between the years 2000 and 2015 as shown in Figure 2, where can be observed an exponential increase of citations with forecast to continuous increasing as the data for 2015 is not maturated.

2.3.1Journals and Conferences

The main journals that published articles relating to this theme, It is observed that the Journal of European journal of operational research, computer, &operational research, Expert Systems with Application and International transaction journal showed the largest number of articles related to the topic.

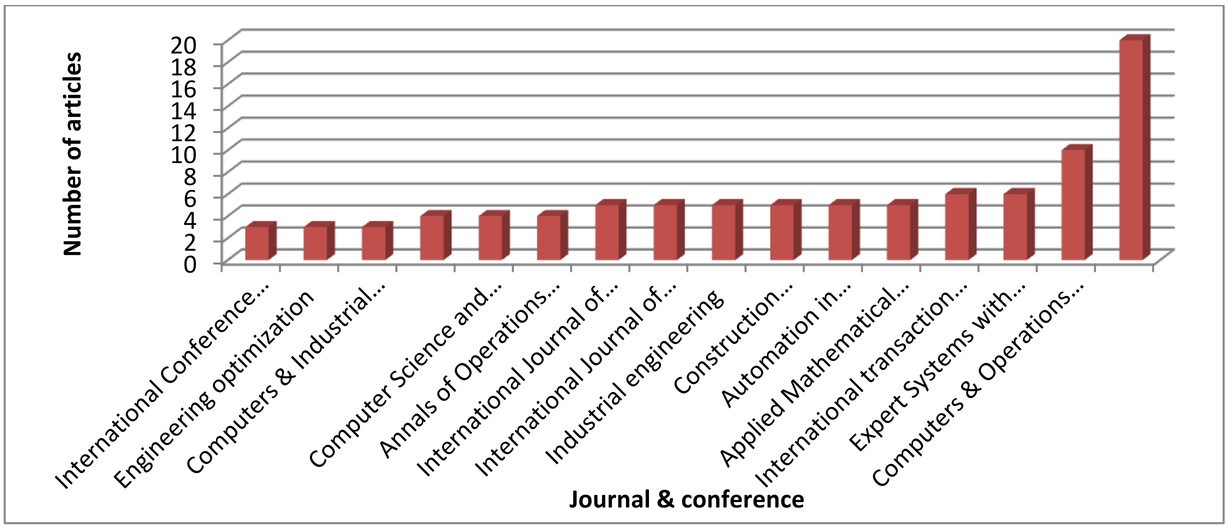

Figure 2. 2 Journals with the high level of publications

Moreover, among the journals with the highest number of publications, one can notice the presence of different sectors. Therefore, it is evident that the subject RCPSP has been implemented and analyzed in different areas. The literature review provided a better understanding of the process of implementation of RCPSP.

2.3.2 Objective-based Type of Problem

The Figure 3 shows the multi and single objective with year of published.it is observed that the multi objective showed the largest number of article written present in multi objective.

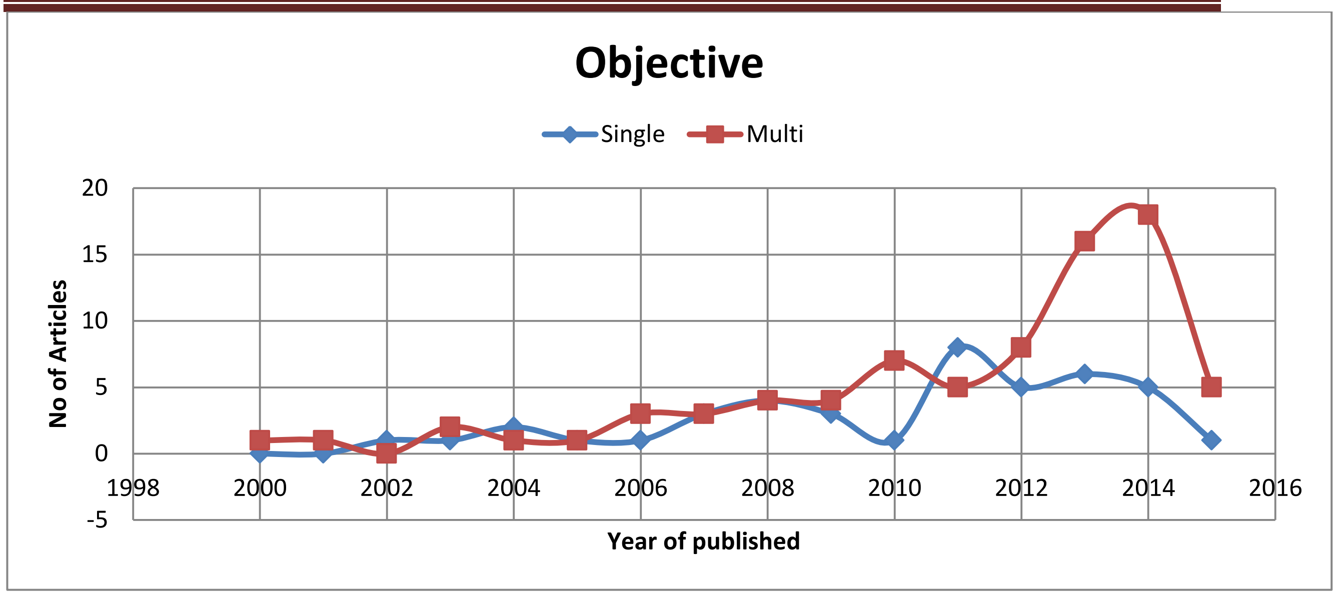

Figure2. 3 Multi & single objective with their publications year

It indicated that there was an increase multi- objective article, when compares the 2005s to the 2014.the year 2015 is not matured regarding the total of articles published due to the cutoff date.

Moreover, during the last few years, multi objective optimization has rec vied growing attention: the number of publications related to this subject between2000 to 2015 exceeds 79

2.3.3 Methodology

The methodology of that published articles based on the solution. It is observed that Genetic algorithm, Mathematical model, and Heuristic showed the largest number of author use that method.

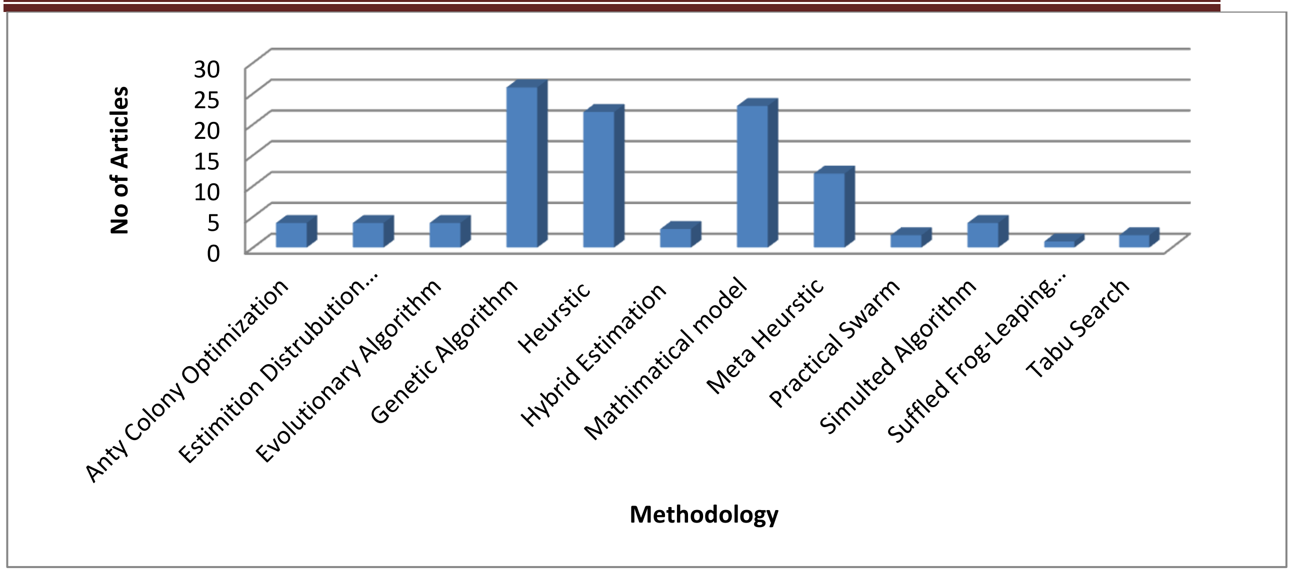

Figure2.4 Methodology with the high level of publications

2.3.4 Nature of task time approaches

The result from the survey of the nature of the task time considered, literatures with the deterministic task time dominate those with stochastic time consideration. The exceptions include years 2000 and 2005, in which balanced number of articles were published from both types, and 2012, where most of the articles published were of the stochastic task time. The years 2000-2004, 2006 and 2010 mark the times where little or no attention was given for the probabilistic nature of task time in RCPSP problems. Generally, in the years 2010 and onwards it is observed that there is a relative increase in publications in both the deterministic and stochastic RCPSP literature.

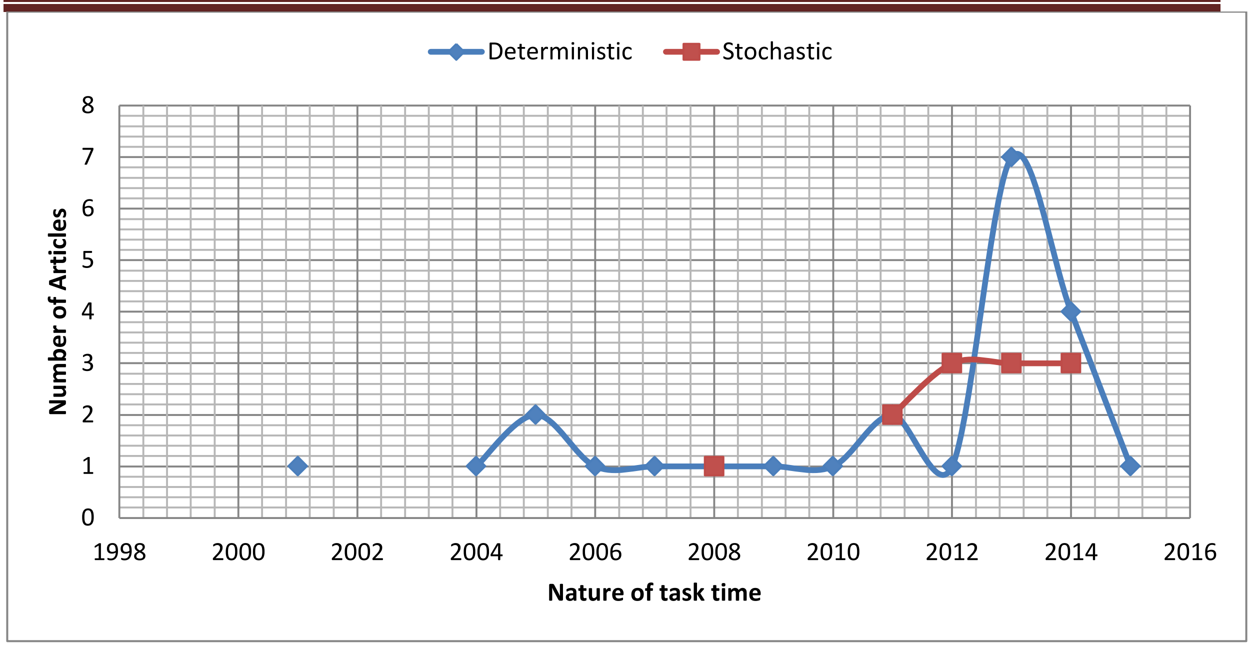

Figure2. 5 Nature of Task Time with Number of articles

2.3.5 Experimental dataset

As shown in Fig. 7, majority of the literatures considered Randomly Generated analysis of problems in the literature to test the performances of the methods they have proposed, this covers 41 (45%) of the total articles in the years of publication included. The literature with the benchmarking to test the performance of the proposed methods ranked second with 34 (16%) of the total articles and those in which example considered closely follow Real world dataset with 15 (15%) articles of the total. Papers in which solution of both real world dataset and benchmark analysis and, one or more hypothetical those papers with considered rank fourth and fifth, each having 13 (8%) and 15(4%)of the total articles considered, respectively.

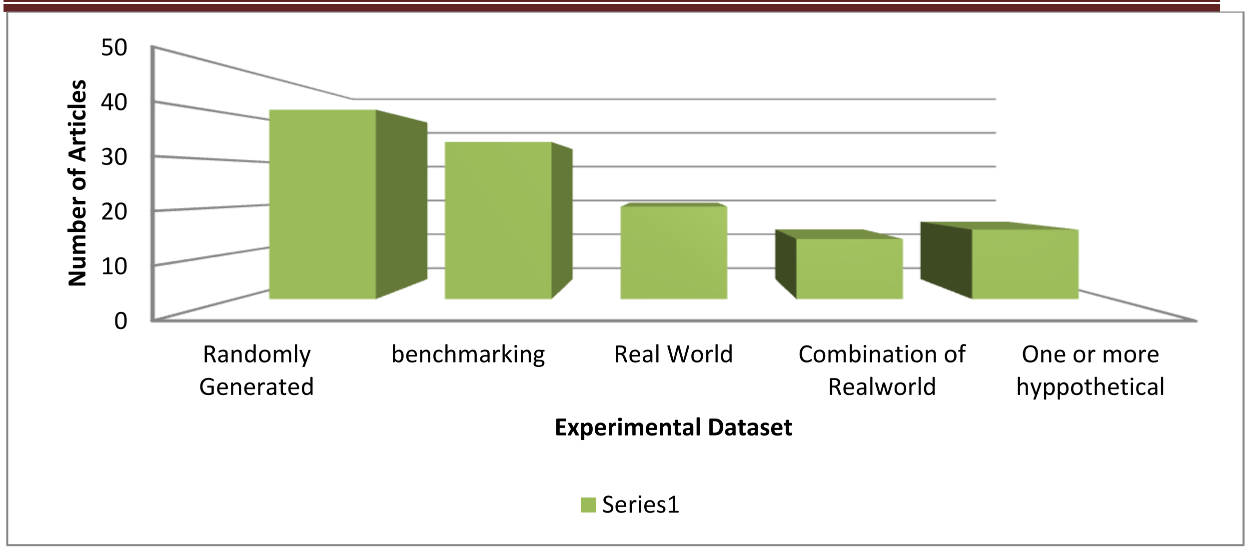

Figure2. 6 Experimental dataset with the Number of articles

2.3.6 Category

From Fig. 7 shows that deterministic RCPSP problems Categories of literature with SM_SO_Dt have the highest number of articles published in the years accounted for in this study with 10 articles, which is 21% of the total. Categories, MM_MO_St, MM_MO_Dt, SM_SO_St rank second to fourth respectively. It can be observed that categories of RCPSP literature with stochastic versions have got little attention. Moreover, one can see that no article was published with SM_MO_St category in the years considered, which indicates a clear gap in the literature with this category.

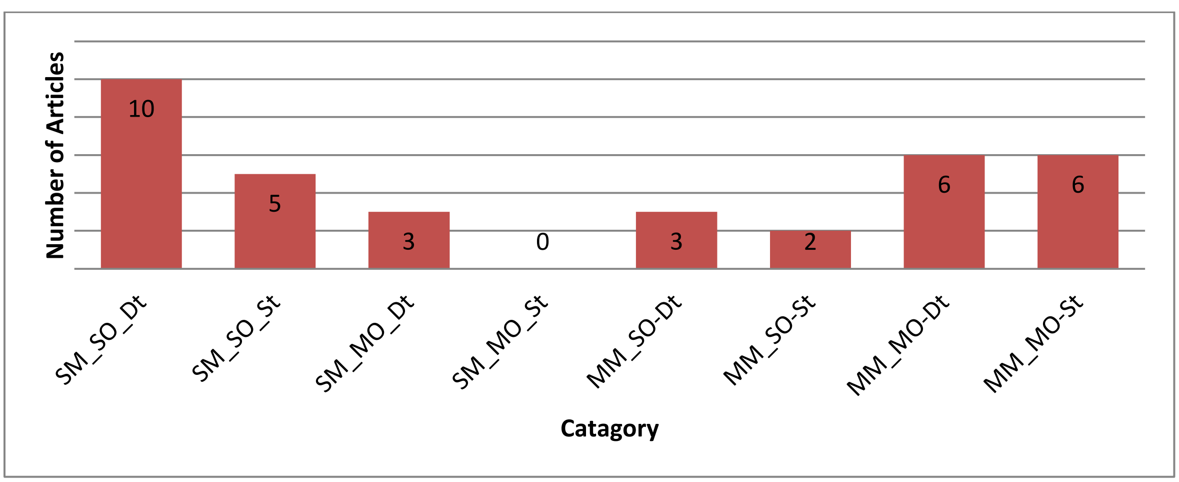

Figure2. 7 Category with the Number of articles

2.4 Summary of Literature Review

Achieving optimal scheduling of a project attracted the attention of many researchers, who employed various techniques including linear programming, dynamic programming, expert systems, neural networks, and genetic algorithms, resource-limited model, and resource leveling model. A searching technique using Genetic algorithms adopted in the model. The method produced suboptimal solutions and did not seek total cost minimization. presented an automated model that utilized dynamic programming formulation and incorporated a scheduling algorithm and an interruption algorithm, so as to automate the generation of interruption during scheduling also introduced a computer program to apply GA in order to schedule resource constrained projects to minimize makespan.. But the model depends on providing external resources to provide planners with additional flexibility in arranging schedules and provide planners with diversity of resource supply, and also the model needs in-depth discussion on issues of determining the limit of internal resource to minimize operational costs. State of the past research we conclude Optimization of genetic algorithm based multi-objectives optimization model for the multi-resource scheduling of construction industry projects. It is necessary to develop a more efficient algorithm to obtain good and near optimal solutions for practical construction industry projects in which computational efficiency and multiple objective issues are of concern, it is also noted that In the past few years, there has been a boom in applying Multi Genetic Algorithms (GA) to solving the real world problem.

Chapter Three **Research Design and Methodology**

3.1 Research Design

Research design is the framework that provides the overall structures for the procedures that a researcher follow the data that the researcher collects and the data analysis the researcher conducts [60].so, In order to achieve the objectives of the research the following tasks performed during the research investigation.

3.1.1Phase One: in the first phase, the thesis topic was selected and a research proposal was written and presented. Next, a research plan was developed and implemented in order to address the research topic. Definitions researched for inclusion in the thesis to facilitate an understanding of the research topics. In addition, the article "A Genetic Algorithm Application for Multi-objective Multi-project Resource Constrained Project Scheduling Problem" by[63] that uses optimization models in a construction industry scheduling used as the basis for conducting further research on the topic of NSGA-II in construction industry.

3.1.2Phase Two: The second phase of the research included a literature review of previous research that was available in construction industry project related journals including, this research used a systematic literature review on RCPSP. After browsing relevant research and publications a systematic review was used to screen related articles, and also identifying deterministic and stochastic articles. Finally based on the Multi-objective Genetic Algorithm meta-analysis, articles that related to RCPSP were categorized based on the single-objective and multi-objective. Single and multimode, deterministic and stochastic so, as to identify pattern and/or distribution. From a wide set of academic studies, Google and Google scholars search engines, Science Direct, Springer, Jstor, Emerald, Taylor & Francis, ProQuest and world science DBLP database, and other free or subscribed journal were used as a source to search RCPSP literatures. More than 600 bibliographical entities, which are written in English language were searched and collected using the term \Multi-objective RCPS\Multi-objective RCPSP with single and multimod\Multiobjective RCPSP with stochastic Duration as a search phrase(s). These include journal articles, book chapters, technical reports, and articles from various conference proceedings. But for this research, the term article is used and it means any one of them. All of them were kept for initial review.

After the initial scan using a systematic review, 128 articles that were published since 2000 which are related to RCPSP are identified. The number of articles and year of publications, objective-based type of problem, methodology, nature of task time approaches, category, and experimental data set for all the 128 articles summarized and presented.

3.1.3 PhaseThree: *The third phase* different research methodologies that are used, depending on the type of research that are undertaken. In this research interview, descriptive survey research method is used as the researcher wants to identify and explore the correlation among the identified variables with the firms' competitive position. In this methodology, extracting data relevant to the research topic and analyzing and learning the software programs used for the research. In order to gain an understanding of the research approach two courses were taken lp programming and operational research. Introduction to Operations Research, where the basic principles and advantage of optimization software.

3.1.4 Phase Four: In this phase the problem description and mathematical formulation was written and the research hypothesis was developed

3.1.5 Phase Five: In this phase a construction industry project was selected for inclusion in the research project as a case study to demonstrate the applicability of using C++ computer models to verify project schedules. In order to select a case study project, different projects were analyzed based ontheir type, size, complexity, and origin of the information. Several networks reviewed in order to find an appropriate network that could be used to validate the capabilities of the mathematical model. The network needed to take into account the availability of cost information. A construction industry with real normal costs, indirect cost, makespan of the project and resource usage information was required for the research. Although communication with some local companies was established, finding a real network with cost related resource information was impossible due to company policies about not releasing cost information. Therefore, a construction network with normal and crash cost from the book "*Construction Project Scheduling and Control"* selected. The network selected for the case study originally consisted of a list of thirty four activities with their respective identification numbers (ID), immediate predecessor activities (IPA), immediate successor activities(ISA) cost information, and some general information, and it was customized to suit the requirements of the research project (Mubarak, 2005).

3.1.6 Phase Six: In this phase the computer software programs to be used for the research were selected and they included Maple 2015 software, which is a commercial mathematical software the model software known as Multiobjective genetic algorithm (MOGA). Information from the case study industry construction project was input into maple2015. Although commercial scheduling software such as c++ may be used to analyze and project scheduling problem, the diagram generated is in an Activity on Node (AON) .

3.1.7 Phase seven:- Single-Modes, Multi-Objective Genetic Algorithm Optimization Model Developed

As mentioned earlier in Chapter 2, both mathematical and heuristic approaches were found to be inefficient and inflexible when solving practical construction scheduling optimization problems. This led to focusing on using metaheuristic techniques in solving multi-objective construction scheduling optimization problems. Among the different metaheuristics, MOGA is selected in this research as it stands out for its fast Multiobjective approach, elitism approach, and its overall capability to maintain a better solution spread. This step of research methodology involves the development of the multi-objective scheduling optimization model using NSGA-II to optimize the mentioned objectives without violating the set constraints. The designed model performs genetic algorithms operations in three main phases: (1) population initialization phase that generates an initial set of *N* possible solutions for the problem; (2) fitness evaluation phase that calculates the mentioned objectives of each generated solution; and (3) generation evolution phase that seeks to improve the fitness of solutions over successive generations using the NSGA-II technique. The model is intended to be used in the initial planning stage for the project(s) being considered for bidding as well as during the construction phase. Usually, during construction, the project(s) being executed may fall ahead or behind the planned schedule. Moreover, new project(s) may be considered with the existing ones. Thus it is very important for the model to accommodate such changes and additions by updating the planned schedules during the construction phase. The model can be applied to solve the total time of the project, indirect coast of the company, resource leveling and resource allocation, scheduling problems for either single or multiple projects. On the other hand, the model solves the time/cost tradeoff problem for only single project where each individual project has its unique time/cost tradeoff. Detailed description of the model development will explained later in Chapter 4.

3.1.8 Phase Model and Testing After developing the multi-objective optimization model, it tested using different case studies from literature. The testing is done with respect to three optimization problems:

1.Time/costtrade-off

2.Resource leveling and allocation The model testing results are compared with the actual results obtained from literature to prove its credibility and validity in optimizing such problems. Moreover, the model implemented on Habesha share company project problem to demonstrate its capabilities in optimizing scheduling of projects. with single-modes and multi-resources activities. Such demonstration integrated the problems of Time/cost-based scheduling together with resource leveling and allocation which is the main scope of this research. The results and analysis of the model implementation and testing described in details in Chapter 5.

3.1.9phase nine; Automated Tools: MM-MOGA

Finally, an automated tool named MOSOGA, an acronym for **M**ulti-**O**bjective **SC**heduling **OP**timization using **Genetic A**lgorithm(MOSCOGA), is designed and built to provide a platform for performing optimization of single projects scheduling. The tool is built with a friendly graphical user interface using the C++ language. The C++ offers the potential of being available across many platforms. It is a very powerful high-level language, an object-oriented programming language encompassing imperative, declarative, functional, generic, and component-oriented programming language. The automated tool detailed description presented in Chapter 6.

3.1.10 Phase Ten In this phase the results of the research were summarized and included in the thesis.

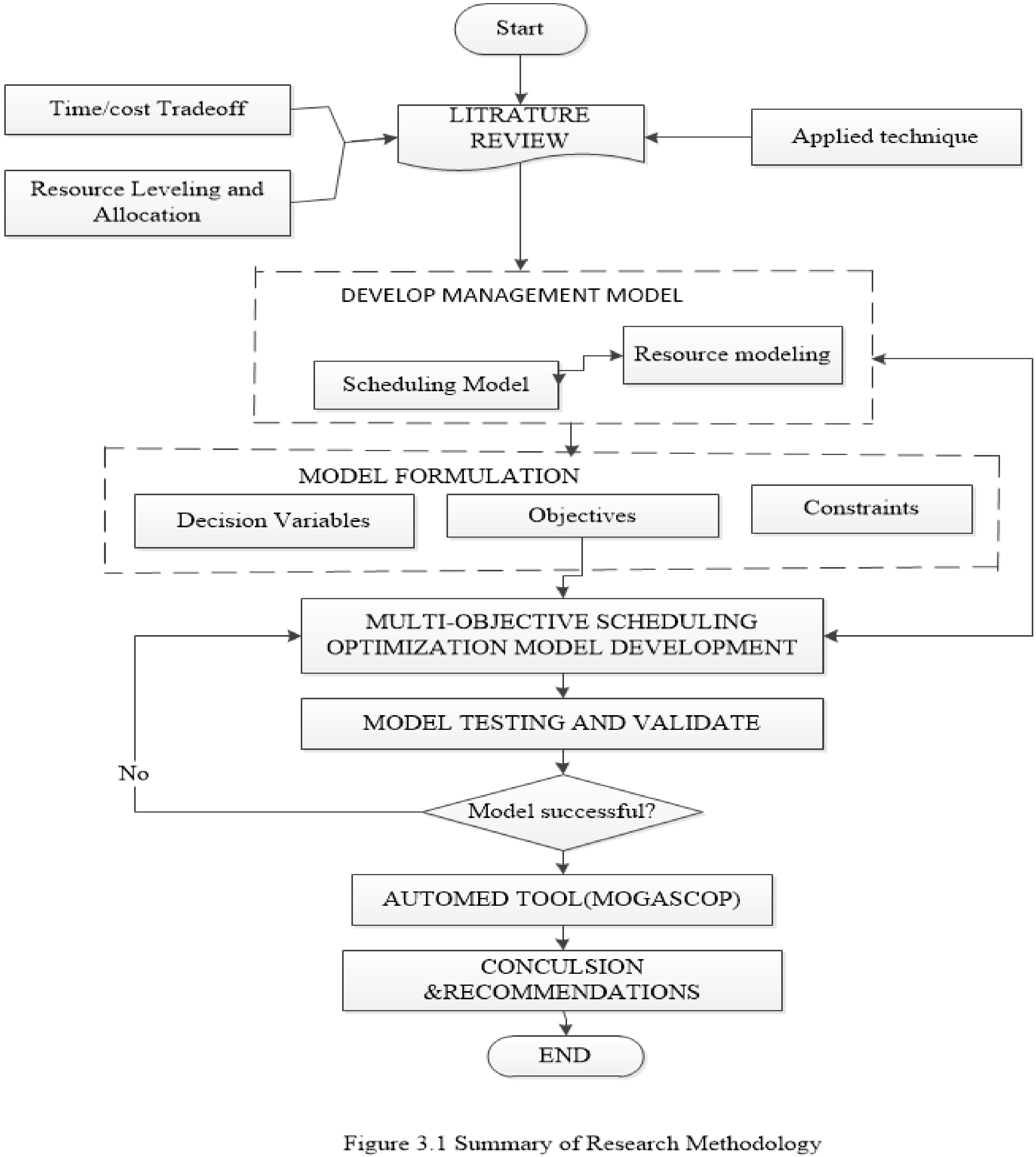

Figure3.1 Summary of Research Methodology

Chapter Four **Empirical Data and Mathematical formulation Model**

4.1. HCSC Profile and empirical data

HCSC incorporated in September 2008 as per the commercial code of 1960 of the Federal Democratic Republic of Ethiopia with a business objective of entering the fast growing Ethiopian cement market and exploit the market opportunity. The project idea launched in October 2008 and shares floated for public subscription. At moment, the company has fully paid capital of Birr with more than 1,102,982,000.00 and more than 16,500 shareholders. HCSC manufacturing plant is located in Oromia regional state welmera wereda in Holeta town, which is 35 km from Addis Ababa at optimum distance from the raw materials deposits and the main cement market, Addis Ababa, and its surroundings. HCSC is now finalizing the construction of a 3,000-ton clinker and 4,500-ton Portland Pozzolana Cement per day capacity plant, which will have close to 1.4 million ton per year capacity at full capacity operation. The Plant is expected to be operational and join the market in the mid of January 2017. The types of cement to be produce are Ordinary Portland Cement (OPC) Class 42.5 and Portland Pozzolana Cement (PPC) Class 32.5. After the cement plant becomes operational, the company also plans to produce and market, Aggregate, Ready Mix Concrete, and Gypsum Boards. The over view of project planned and the revised scheduling of the HCSC illustrated at table 4.1 below. Finally we organize the data as according to their ,precedence-resource usage relationship resource.as we can see scheduling of the HCSC not allocate the resource with in each activity ,the required resource during the project life cycle we gather the data from the report of the company .

HABESHA CEMENT SHARE COMPANY								
PROJECT SCHEDULE								
S. No.	Activity	Planed(USD)	Actual Cost (USD)	Duration (in months)	Start	Finish	Predecessor	Successor
				Planned	Planned			
				Actual	Actual			
1	Establishment, Shares Sale, Feasibility Study & Pre production, Tendering, evaluation and award	640,566.90	640,566.90	13	Sep,2009	Sep,2010		
2	Contract Signing				Oct, 2010		1	3
					Oct,2010			
3	Site Acquisition and Loan Process	1,728,323.69	2,133,085.60	12	Nov,2010	Oct,2011	2	4
				54	Nov,2010	Apr,2014		
4	project kick off				Oct, 2011		3	5
					May,2014			
5	Project Management	2,250,000.00	2,250,000.00	24	Nov, 2011	Oct, 2013	3	20
				37	May,2014	May,2017		
6	Design	1,080,000.00	1,080,000.00	1	Nov, 2011	Dec,2011	3	7, 10
				3	May,2014	Jul,2014		
7	Manufacturing and Supply			12	Dec, 2011	Dec,2012	6	8
				24	Jul,2014	Jun,2016		
7.1	Mechanical Equipment	27,099,932.00	27,099,932.00	8	Dec, 2011	Aug,2012	6	8
				18	Jul,2014	Dec,2015		
7.2	General Layout Equipment	350,000.00	350,000.00	8	Dec, 2011	Aug,2012	6	8
				18	Jul,2014	Dec,2015		

7.3	Water Supply and drainage	691,000.00	691,000.00	8	Dec, 2011	Aug,2012	6	8
				18	Jul,2014	Dec,2015		
7.4	Workshop machines	500,000.00	500,000.00	8	Dec, 2011	Aug,2012	6	8
				18	Jul,2014	Dec,2015		
7.5	Erection materials	3,193,300.00	3,193,300.00	8	Dec, 2011	Aug,2012	6	8
				18	Jul,2014	Dec,2015		
7.6	steel structure	13,000,000.00	13,000,000.00	8	Dec, 2011	Aug,2012	6	8
				9	Jul,2014	Mzr,2015		
7.7	Electrical and automation	4,000,000.00	4,000,000.00	4	Sept, 2012	Dec,2012	6, 7.1	8
				6	Jan,2016	Jun,2016		
7.8	spare parts	1,800,000.00	1,800,000.00	4	Sept, 2012	Dec,2012	6, 7.1	8
				6	Jan,2016	Jun,2016		
8	Insurance, Transporting and custom clearing	5,482,088.29	16,280,727.33	12	Mar,2012	Feb,2013	7	11
				22	Jan,2015	Oct,2016		
9	Bank Charge and Interest	4,267,713.68	11,192,058.43	24	Oct, 2011	Oct, 2013		
				38	Apr,2014	May,2017		
10	Civil Works			12	Jan,2012	Dec,2012	6	11
				12	Mar,2015	Feb,2016		
10.1	Construction Inputs supply	11,400,000.00	12,773,644.87	12	Jan,2012	Dec,2012	6	10.3
				12	Mar,2015	Feb,2016		
10.2	Excavation	1,935,000.00	1,935,000.00	2	Jan,2012	Feb,2012	6	10.3
				3	Mar,2015	May,2015		
10.3	Concrete	9,675,000.00	9,675,000.00	10	Mar,2012	Dec,2012	10.1, 10.2	11
				10	May,2015	Feb,2016		
10.4	Back fill	1,290,000.00	1,290,000.00	10	Mar,2012	Dec,2012	10.3	
				10	Jun,2015	Feb,2016		
11	Erection and Installation			10	Oct,2012	July,2013	8, 10	12
				14	Nov,2015	Dec,2016		
11.1	Mechanical Erection	8,415,867.92	8,415,867.92	7	Oct,2012	Apr,2013	8, 10	11.2

				10	Nov,2015	Aug,2016		
11.2	Electrical Installation	1,784,132.08	1,784,132.08	3	May,2013	Jul,2013	8, 11.1	12
				4	Sep,2016	Dec,2016		
12	Testing and Commissioning, Training			3	Aug,2013	Oct,2013	11, 13, 16	20
				5	Jan,2017	May,2017		
12.1	No load test	144,000.00	144,000.00	1	Aug,2013		11	12.2
				3	Jan,2017	Mar,2017		
12.2	Load test	432,000.00	432,000.00	1	Sep,2013		12.2, 13, 16	12.3
				1	Apr,2017			
12.3	Performance test	864,000.00	864,000.00	1	Oct,2013		12.2	20
				1	May,2017			
12.4	Training	500,000.00	500,000.00	3	Aug,2013	Oct,2013	11	20
				5	Jan,2017	May,2017		
13	Availing Utilities (water, power, communication, access road)	4,387,479.50	4,676,321.41	24	Aug,2011	Jul,2013	3	12
				69	Aug,2011	Mar,2017		
14	Quarry machinery and mine development	1,523,358.49	1,529,559.28	8	Jan,2013	Aug,2013	3	14
				10	Mar,2016	Dec,2016		
15	Consultancy and local project management	6,324,799.00	10,077,751.35	24	Nov,2011	Oct,2013	3	20
				37	May,2014	May,2017		
16	Working Capital	6,036,028.48	6,466,356.78	6	May,2013	Oct,2013	14	12
				9	Sep,2016	May,2017		
17	Contract Variation		2,200,000.00					
18	Vehicles and Bulk Trucks	388,468.64	3,630,703.25					
19	Miscellaneous							
20	Project Completion and Acceptance	500,000.00	1,467,149.69		Oct31,2013		12	
					May31,2017			
	Total Project Cost	121,683,058.67	152,072,156.89					

Table 4.1 The overview of HCSC Project scheduling

The data organized based on their planned and actual scheduling

Table 4. 2 **Activity data of Case Study in Habsha Cement Share Company**

Activity No.	**Activity description**	**predecessor**	Resource			**Plan duration(in month)**	**Actual duration(in month)**	**Direct cost**
			Manpower	Machines	Equipment's			
1	Starting node	-	-	-	-	0	0	0
2	Establishment, Shares Sale, Feasibility Study & Pre production, Tendering, evaluation and award	1	100	0	0	13	13	634,161.23
3	Contract Signing	2	6	0	0	1	1	0
4	Site Acquisition and Loan Process	3	5	0	0	12	54	1,711,040.45
5	Design	4	45	0	0	1	3	1,069,200.00
6	Mechanical Equipment	5	53	20	1	8	18	26,828,932.68
7	General Layout Equipment	5	72	22	1	8	18	346,500.00
8	Water Supply and drainage	5	83	12	0	8	18	684,090.00
9	Workshop machines	5	6	9	0	8	18	495,000.00
10	Erection materials	5	65	5	0	8	18	3,161,367.00
11	steel structure	5	12	22	0	8	9	12,870,000.00
12	Electrical and automation	5,6	120	3	0	4	6	3,960,000.00
13	spare parts	5,6	0	0	0	4	6	1,782,000.00

Activity No.	Activity description	predecessor	Resource			Plan duration(in month)	Actual duration(in month)	Direct cost
			Manpower	Machines	Equipment's			
14	Insurance, Transporting and custom clearing	6,7,8,9,10,11,12,13	5	0	0	12	22	5,427,267.41
15	Construction Inputs supply	5	91	11	0	12	12	11,286,000.00
16	Excavation	5	117	5	0	2	3	1,915,650.00
17	Concrete	15,16	72	12	1	10	10	9,578,250.00
18	Back fill	17	78	5	1	10	10	1,277,100.00
19	Mechanical Erection	15,16,17,18,14	110	12	1	7	10	8,331,709.24
20	Electrical Installation	14,19	120	5	1	3	4	1,766,290.76
21	No load test	19,20	79	5	2	1	3	142,560.00
22	load test	21,25,27	79	5	0	1	1	427,680.00
23	Performance test	22	79	5	0	1	1	855,360.00
24	Training	19,20	100	0	0	3	5	495,000.00
25	Availing Utilities (water, power, communication, access road)	3	48	0	0	24	69	4,343,604.71
26	Quarry machinery and mine development	4	5	9	0	8	10	1,508,124.91

Activity No.	**Activity description**	**predecessor**	Resource			**Plan duration(in month)**	**Actual duration(in month)**	**Direct cost**
			Manpower	Machines	Equipment's			
27	Working Capital	26	100	0	0	6	9	5,975,668.20
28	Project Completion and Acceptance	23,24	48	0	0	0	0	495,000.00
29	End of project	28	0	-	-	0	0	0

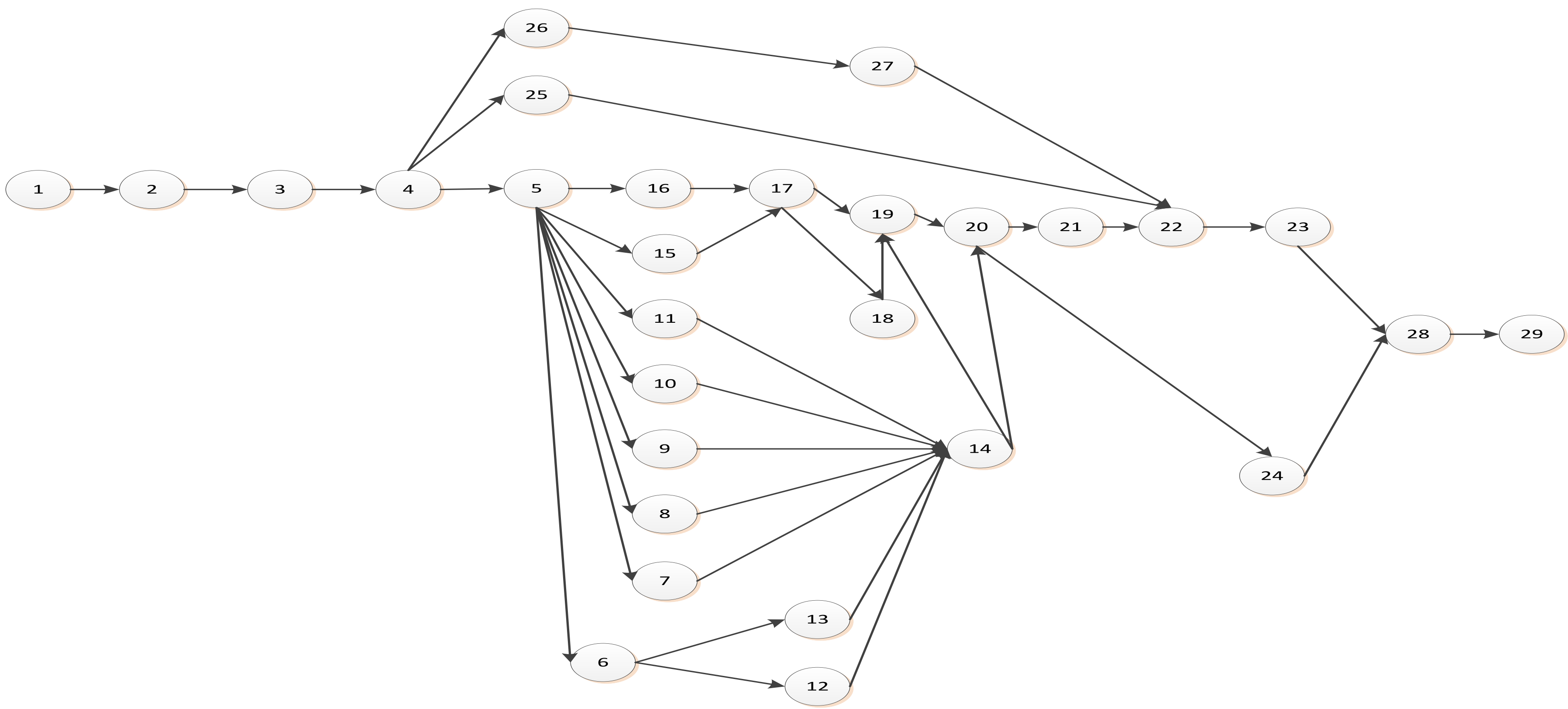

Figure4. 1.Original activity Precedence network

The research interested to work on this project because in almost all resource constrained are becoming the main event which may be caused through different reasons one of which is lower cost of resource usage out of the total cost of the project. Also further, investigate the predecessor and time limitation relationship. Out of the total cost of the project it is known that civil cost is amounts very high present. Which implies most of the cost is given for construction industry but conditions such as design review project delays due to unscheduled of Resource with their predecessor problems and intensive maintenance within short time after the project is completed are becoming the prevailing contusions in industry projects.

This project will assess cost implication of the lower cost of design on the construction industry and resource allocation and will figure out whether cost of project has relation with cost indirect, which is the prevailing condition in most of the road projects .finally it will make conclusions and recommendations based on the outputs.

4.2ProblemDescription

As the key problem in project management, project scheduling exists in all kinds of reality problems. It represents the conversion of project goals into an achievable methodology for their completion; it creates a timetable and reveals the network logic that relates project activities to each other in a coherent fashion. With more and more complex project management issues, RCPSP and MRCPSP have been proposed and well applied in terms of a single project. The project scheduling problem considered in this paper is from a large scale cement construction project in the southwest region of Ethiopia, in which the main project cement construction project which have no impact on each other, but each project has many activities with precedence relationships and shared resources. With these issues in mind, this paper focuses on a multi-objective resource-constrained project scheduling problems (MRCPSP), which contains path selection problem and activities scheduling problem for multiple projects. The MORCPSP considered adheres to the following assumptions,

(1) The construction project considered in this paper consists of one project, and two dummy project (i.e., S and F) are introduced to denote the start and the completion of the construction project so are not allocated any costs or processing time. Similarly, each project

(i.e.,$i\epsilon N\_i=\{1,2,\ldots,n\}$) consists of n_iactivities(i.e.,$j\epsilon N\_i=\{1,2,\ldots,n\_i\}$) and two dummy activities (i.e., S_i and F_i) which represent the initial and final activities.

(2) Precedence relationships are the fnish-start with a time lag of zero, which means that each activity (i.e.,$i,j\in A$) can be started if and only if all of its predecessors (i.e.,P_ij) have been completed. There is no additional time allocated to activity switching. In addition, when an activity begins, it cannot be interrupted.

(3) Each activity (i,j) must be performed in only one of possible modes, with each activity mode (i.e., $m\in M\_ij=\{1,2,\ldots,m\_ij\}$) possibly having different processing times, different resource requirements, and different quality indexes. Mode switching is not allowed when an activity is being executed.

(4) The shared resources that activities require can be divided into two types, renewable resources (i.e,…,$r\in R$) which are limited period by period, such as manpower and equipment, and nonrenewable resources (i.e.,$k\in K$) which are limited for the entire project, such as building materials and money.

(5) The interrelationship among activities is executed in a certain order using an activity-on-node (AON) representation, in which the node represents an activity and path arrows demonstrate the logical sequencing from node to node through the network.

(6)The starting time of each project is dependent upon the project's priorities and the characteristics of the first activity set in each project and is also dependent upon an unlimited number of other reasons Resource scheduling problems may be divided into two basic categories: resource allocation (fixed resource limits scheduling) and resource leveling

4.2.1. Resource allocation problems

Involve an allocation of limited resources to competing activities with the objective of minimizing project duration.

4.2.2 Resource leveling problems assume that sufficient

Resources are available (i.e., unlimited resources) and attempt to reduce resource fluctuations and to maintain more stable resource levels without stretching a project beyond its optimal duration.

A resource may be classified as one of three categories: renewable, nonrenewable, and doubly constrained. In resource constrained (resource allocation) scheduling problems, the availability of renewable resources, such as machine and manpower, is limited at each time period. The availability of nonrenewable resource, such as money, is constrained over the project life. If a resource is constrained both at each time period and over the project life, the resource is said to be doubly-constrained. In resource scheduling, estimates of activity durations are made independently of each other without considering factors such as different activities competing for the same resource. Furthermore, a normal level of resources (the optimum level of resources under the consideration of expedient completion and minimum costs) assumed for each activity. In many circumstances, these assumptions are made even though there appears to be some relationship between activity durations and the number of resources applied to them. Such relationships have not been traditionally included in estimating activity durations when resource scheduling is performed. The interaction between activity durations and the number of resources can be represented by different performing modes of each activity. Each mode reflects a different combination of resources, and has adifferent activity duration. The time resource interactions also contain the characteristics of time-cost tradeoffs, which can be represented by a discontinuous cost-time curve as defined by [42]. The reason is that each mode of operation consists of a different combination of resources, which also reflects a difference in an activity's direct cost. As mentioned earlier, the objective of resource allocation is to allocate limited resources to competing activities in order to minimize project duration. However, most of resource allocation models do not take into consideration fluctuations in resource levels. Fluctuations in resource levels will increase total project costs due to the costs of hiring, firing, and training human resources, and the costs of leasing or purchasing additional units of equipment. In order to obtain the minimum cost schedule, the resource fluctuations should be minimized or savings due to stable resource levels should be compared to the costs incurred by extending project completion time. Many important characteristics of project scheduling problem will be considered in this research including activity preemption, renewable and nonrenewable resources, variation in resource availability and multiple objectives. Two types of jobs are considered, splittable and nonsplittable jobs. It is assumed that a splittable job can be interrupted (preempted) any number of times, and resume in the same mode after the interruption. A nonsplittable job is a job that must be performed continuously without interruption. At least one mode of operation is available for each job with deterministic duration. Each mode reflects a different combination of resources and has a different job duration. Different categories of resources including renewable, nonrenewable, and doubly-constrained are allocated to each job to satisfy multiple conflicting objectives such as project completion time, project total cost and resource leveling.

4.3. Mathematical Formulation

A zero-one integer-programming model was developed to model the resource-constrained project-scheduling problem. The model characteristics and assumptions summarized below.

(1) Two types of jobs are available, splittable and nonsplittable jobs. It is assumed that a splittable job can be interrupted (preempted) any number of times, and resume in the same mode after the interruption. A nonsplittable job is the job that must be performed continuously without interruption.

(2) At least one mode of operation is available for each job. Each mode reflects a different combination of resources and has a different job with stochastic duration.

(3) A resource can be classified as one of three categories: renewable, nonrenewable, and doubly constrained.

(4) Resource consumption by each job and job duration corresponding to each mode are assumed to be discrete and deterministic.

(5) Activity-on-node diagram is used to represent the network, and looping of activities is allowed.

(6) Activity arrivals are known and take place at the end of deterministic time periods.

(7) No scheduled or directed times are allowed on any intermediate job; i.e., the start and finish time of intermediate jobs are controlled only by factors such as precedence relationships and resource constraints.

(8) Notation based on calendar days than working days is used to represent time periods. The notations and decision variables used in the mathematical model are listed in Table 4.1 Constraints

Table4.3 Definition of Notions and Decision Variables

SYMBOLE	DEFINITION
Notations	
i	Project index (i=n)
n	Number activities in project i
j	job index (j = 1,...,Ni)
N_i	number of jobs in project i
L_i	set of jobs with no successors (or set of last activities) for project i
B	set of all pairs of immediate predecessor activities
m	m mode of operation index (m =
M_i	number of modes available for activities j
k	renewable resource index (k = 1,...,K)
K	number of different renewable resource types
P	number of different nonrenewable resource
	t time period (t = 1,...,max G)

G	Absolute due date of project i(Project i must be completed in or before period If the absolute due date is not specified, Gi is the last period of the scheduling horizon.)
g,	Desired due date of project i (Project i is not late if it is completed in or before period gi.)
1,	Penalty cost of project i per period of lateness (Assumed to be constant for all periods.)
c_i	overhead cost of project i per period
Z_i	completion time of projects i
a_i	Arrival period of project i (Arrivals occur at the end of periods.)
f_{ij}	number of periods required by mode m for activity j, project i
h_{ab}	lead/lag time between activity a and b, project i
d_{ij}	duration of task j if it is executed
ES_{ij}	earliest possible start time of job j, project i
EF_{ij}	earliest possible completion time of activity j, project i
LS_{ij}	latest possible start time of activity j, project i
LF_{ij}	latest possible completion time of activity j, project i
r_{ijk}	amount of type k renewable resource required by mode m for activity j, project i
R_{kt}	amount of type k renewable resource available
D_{kt}	desired level of renewable resource type k in period t (used for the resource

	leveling objective)
Decision Variables	
X_{jt}	= 1 if completed j activities at time t = 0 otherwise.
Y_{jt}	=1 Zj > Tcontract = 0Zj≤Tcontract

1. Job Completion

   For both splittable and nonsplittable activites, each activity can have only one completion period and use only one mode of operation, i.e, each activity can be accomplished only once.

for i = 1,...,I and j = 1,…….,N,

For splittable jobs,

2. Each activity can have only one start time and use only one mode of operation. Restarting activity after preemption is not considered as a start time.
3. **To reduce the number of decision variables,** the lower and upper bounds of each decision variable should be determined in advance. The bounds can be computed by using the time-based bounding technique as follows:

(a) Obtain the ES and LF for each activity from the forward/backward computations by assuming that each activity is performed under the shortest duration mode, and the latest finish time of each terminal activity is set to an absolute due date.

(b) The **EF of activity** j mode m is given by the sum of ES obtained from Step (1) and the duration of activity j mode m. The LS of activity j mode m is computed from the difference between LF obtained from Step (1) and the duration of activity j mode m.

$$\sum_{m=1}^{M_j}\sum_{t=ES_{ij}}^{LS_{ij}} Sijmt = 1$$

For i=1 and j=1 ….N_i

A splittable activity cannot be completed unless the number of active periods ($\sum_q Y$) equals activity duration ($\sum_1 dx, x$) equals one when the job is completed).

$$\sum_{t=EF_{ij}}^{LF_{ij}} d_{ijm}X_{ijmt} = \sum_{q=ES_{ij}+1}^{LF_{ij}} Y_{ijmq}$$

for i = 1,...,I

j ε{splittable jobs}

m = 1

1. Project Completion

   A project is completed only when all jobs (N_1) in the project have been processed ($\sum_j$) .

$$\sum_{j=1}^{N_i}\sum_{m=1}^{M_j}\sum_{t=EF_{ij}}^{LF_{ij}} X_{ijt} = N_i$$

For i=1, ……, I

2. Precedence Relationships

   For splittable activities, a predecessor activities, a, must be completed ($\sum_m \sum_t tX$) before a successor activities, b, can start ($\sum_m \sum_t tS$) for all pairs of predecessor-successor activities, B.

   -

$$\sum_{m=1}^{M_a}\sum_{t=EF_{ia}}^{LF_{ia}} tX_{iamt} + \sum_{m=1}^{M_b}\sum_{t=ES_{ib}}^{LS_{ib}} tS_{ibmt\geq 0}$$

for all pairs (a,b) ε B

i= 1,

For nonsplittable activities , a predecessor activities, a, must be completed ($\sum_m \sum_t tX$) before a successor job, b, can start [$\sum_m \sum_t (t-d)X$] for all pairs of predecessor-successor jobs, B.

for all pairs (a,b)εB

i= 1,

4. <u>Resource Constraints</u>

For renewable resources at each time period t, the total resource consumption at time period t by all

nonsplittable jobs ($\sum_i \sum_j \sum_m \sum_q rX$) and by all splittable jobs ($\sum_i \sum_j \sum_m rY$) must be less than or equal to the available amount of resource k at time period t (R_{kt}).

$$\sum_{i=1}^{n} \sum_{\forall j} \sum_{m=1}^{M_j} \sum_{q=1}^{t+d_{ijm}-1} r_{ijmk} X_{ijq} + \sum_{i=1}^{n} \sum_{\forall j\prime} \sum_{m=1} r_{ij\prime mk} Y_{ij'mt \leq R_{kt}}$$

for j ε {nonsplittable jobs}

j' ε{splittable jobs}

k = 1,...,K

t = 1,...,max G_i

<u>5. Specific Constraints for Splittable Jobs</u>

5.1) A splittable job must use the same mode of operation throughout the process. If a job starts by using mode m' ($\sum_t S = 1$), it must continue to use the same mode. If a job completes by using mode m ($\sum_m \sum_t X = 1$), it cannot start by using mode m' where m' is different from m.

$$\sum_{t=ES_{ij}}^{LS_{ij}} S_{ijm't} + \sum_{\forall m} \sum_{t=EF_{ij}}^{LF_{ij}} X_{ijmt} = 1$$

for i = 1,...,I

j ε { splittable jobs}

m' = 1,………,M_j

m ε {M_j –m’}

5.2) The summation of start time and job duration [$\sum_m \sum_t (t+d)S$] must be greater than or equal to the completion time ($\sum_m \sum_t tX$) . This allows a splittable job to be preempted for f_{ij} periods.

$$\sum_{m=1}^{M_j} \sum_{t=ES_{ij}}^{LS_{ij}} (t + d_{ijm}) S_{ijmt} + F_{ij} = \sum_{m=1}^{M_j} \sum_{t=EF_{ij}}^{LF_{ij}} tX_{ijmt}$$

for i = 1,...,I

j ε {splittable jobs}

5.3) for control over active periods, an active period (the period that a splittable job is being processed) must lie between the start time and the completion time of the job.

(a) The active period [(t-1) Y] must be greater than or equal to the start time of the job

($\sum_q qS$).

$$(\mathrm{t}-1) Y_{ijmt} \geq \sum_{q=ES_{ij}}^{LS_{ij}} qS_{ijmq}$$

for i = 1,...,I

j ε {splittable jobs}

$m = 1,...,M_j$

$t = (ES_{ij}+1),... ,(LS_{ij}+1)$

(b) The active period (tY) must be less than or equal to the completion time of the job ($\sum_q qX$).

$$tY_{ijmt} \leq \sum_{q=EF_{ij}}^{LF_{ij}} qX_{ijmq}$$

for $i = 1,...,I$

j ε{splittable jobs}

$m = 1, ..,M_j$

$t=EF_{ij},\ldots,LF_{ij}$

To assure that the first period a job is active is the same as the start time of the job, and the last period that the job is active is the same as the completion time of the job; the number of splitting period (f_{ij}) must be minimized.

6. <u>Other Types of Dependency Relationship</u>

In addition to the finish-to-start relationship without a lead/lag time, other types of dependency relationship with a lead/lag time can be formulated as defined below. Constraints (6.1) (6.5) assume that job a precedes job b.

6.1) Finish-to-Start Relationship: the start time of job b ($\sum_m \sum_t tS$) must be greater than the finish time of job a ($\sum_m \sum_t tX$); h_{iab}, represents the time difference between the start of b and ending of a.

$$\sum_{m=1}^{M_a} \sum_{t=EF_{ia}}^{LF_{ia}} tX_{iamt} + h_{iab} = \sum_{m=1}^{M_b} \sum_{t=ES_{ib}}^{LS_{ib}} tS_{ibmt}$$

6.2) **Start-to-Start Relationship**: the start time of job b ($\sum_m \sum_t tS_b$) must be greater than the start time of job a ($\sum_m \sum_t tS_a$); h_{iab} represents the time difference between the start of b and start of a.

$$\sum_{m=1}^{M_a} \sum_{t=ES_{ia}}^{LS_{ia}} tS_{iamt} + h_{iab} = \sum_{m=1}^{M_b} \sum_{t=ES_{ib}}^{LS_{ib}} tS_{ibmt}$$

6.3) Finish-to-Finish Relationship: the finish time of job b ($\sum_m \sum_t tX_b$) must be greater than the finish time of job a ($\sum_m \sum_t tX_a$); h.brepresents the time difference between the ending of b and ending of a.

$$\sum_{m=1}^{M_a} \sum_{t=EF_{ia}}^{LF_{ia}} tX_{iamt} + h_{iab} = \sum_{m=1}^{M_b} \sum_{t=EF_{ib}}^{LF_{ib}} tX_{ibmt}$$

6.4) Start-to-Finish Relationship: the finish time of job b ($\sum_m \sum_t tX$) must be greater than the start time of job a ($\sum_m \sum_t tS$); h_{iab}, represents the time difference between the ending of b and start of a.

$$\sum_{m=1}^{M_a} \sum_{t=ES_{ia}}^{LS_{ia}} tS_{iamt} + h_{iab} = \sum_{m=1}^{M_b} \sum_{t=EF_{ib}}^{LF_{ib}} tX_{ibmt}$$

6.5) **Composite Start-to-Start and Finish-to-Finish Relationship**: constraints (6.2) and (6.3) are applied to the job simultaneously.

$$\sum_{m=1}^{M_a} \sum_{t=ES_{ia}}^{LS_{ia}} tS_{iamt} + h_{iab} = \sum_{m=1}^{M_b} \sum_{t=ES_{ib}}^{LS_{ib}} tS_{ibmt}$$

And

$$\sum_{m=1}^{M_a} \sum_{t=EF_{ia}}^{LF_{ia}} tX_{iamt} + h_{iab} = \sum_{m=1}^{M_b} \sum_{t=EF_{ib}}^{LF_{ib}} tX_{ibmt}$$

Since the decision variable S_{ijmt} nonsplittable jobs, the term

$$\sum_{m=1}^{M_j} \sum_{t=ES_{ij}}^{LS_{ij}} tS_{ijmt}$$

is replaced by

$$\sum_{m=1}^{M_j} \sum_{t-EF_{ij}}^{LF_{ij}} (t - d_{ijm})X_{ijmt}.$$

7. <u>Constraints for Cost-Related Objective and Time-Cost Tradeoffs Problem</u>

The project must be completed (Z_i) by the due date

$$Z_i \leq G_i$$

For i=,….,I

<u>8. Constraints for Resource Leveling Objective</u>

the objective express the minimization of the absolute deviation between resource consumption and some desired level. The total renewable resource consumption at time period t by all nonsplittable jobs ($\sum_i \sum_j \sum_m \sum_q rX$) and by all splittable jobs ($\sum_i \sum_j \sum_m rY$) must equal the desired level, D_{kt}; v_{kt}^{-} *and* v_{kt}^{+}) represent the under- and over-utilization of resource k at time period t from the desired level.

$$\sum_{i=1}^{I} \sum_{\forall j} \sum_{m=1}^{M_j} \sum_{q=1}^{t+d_{ijm}-1} r_{ijmk} X_{ijq} + \sum_{i=1}^{I} \sum_{\forall j\prime} \sum_{m=1}^{M_j\,\prime} r_{ij\prime mk} Y_{ij'mt} - D_{kt} + v_{kt}^{-} - v_{kt}^{+} = 0$$

Where v_{kt}^{-} , $v_{kt}^{+} \geq 0$

J ϵ {nonsplittable jobs}

J’ ϵ {splittable jobs}

k= 1,...,K

t = 1,...,max G_i

8.1 The objective expresses the minimization of the absolute deviation between resource consumption of consecutive time periods. The total renewable resource consumption at time (t+1) by all nonsplittable jobs ($\sum_i \sum_j \sum_m \sum_{q=t+1} rX_q$) and by all splittable jobs ($\sum_i \sum_j \sum_m rY_{t+1}$).is desired to be equal to the resource level at the previous time period, t. The deviation variablesu_{kt}^{-} and u_{kt}^{+}) represent negative and positive deviations of resource levels from one period to the next.

$$\sum_{i=1}^{I} \sum_{\forall j} \sum_{m=1}^{M_j} \sum_{q=t+1}^{t+d_{ijm}} r_{ijmk} X_{ijmq} + \sum_{i=1}^{I} \sum_{\forall j\prime} \sum_{m=1}^{M_j\,\prime} r_{ij\prime mk} Y_{ij'm(t+1)}$$

$$-\sum_{i=1}^{I} \sum_{\forall j} \sum_{m=1}^{M_j} \sum_{q=t}^{t+d_{ijm}-1} r_{ijmk} X_{ijmq} - \sum_{i=1}^{I} \sum_{\forall j\prime} \sum_{m=1}^{M_j\,\prime} r_{ij\prime mk} Y_{ij'mt} + u_{kt}^{-} - u_{kt}^{+} = 0$$

Where u_{kt}^{-} , $u_{kt}^{+} \geq 0$)

j ϵ {nonsplittable jobs}

j' ϵ {splittable jobs}

k= 1,...,K

t = 1,...,(max G_i) -1

Objective Functions

1. Minimizing Total Project Throughput Time

Since project throughput time is given by the difference between the project completion period (Z_i) and the arrival period (a_i), the objective function can be written as:

$$\text{Minimize} \sum_{i=1}^{I} Z_i$$

If it is desired to start all activities as soon as possible without increasing throughput time, all nonsplittable jobs, j, must be completed as soon as possible ($Min \sum_i \sum_j \sum \quad \sum_t tX$) and all splittable jobs, j', must start as soon as possible ($Min \sum_i \sum_{j\prime} \sum \quad \sum_t tS$)

$$Minimize \sum_{i=1}^{I} \sum_{\forall j} \sum_{m} \sum_{t=EF_{ij}}^{LF_{ij}} tX_{ijmt} + \sum_{i=1}^{I} \sum_{\forall j\prime} \sum_{m=1}^{M_j\,\prime} tS_{ij\prime t}$$

For j ϵ {nonsplittable jobs}

j' ϵ {splittable jobs}

If it is desired to start all jobs as late as possible without increasing throughput time, the difference between the project completion period (Z_i) and the completion period of each job (tX) must be minimized

$$Minimize \sum_{i=1}^{I} \sum_{j=1}^{N_i} \sum_{=1}^{j} \sum_{t=EF_{ij}}^{LF_{ij}} (Z_i - tX_{ijt})$$

2. <u>Minimizing Makespan</u>

The makespan can be minimized when the completion time of all projects (Z) is minimized.

Minimize Z

If it is desired to start all activities as soon as possible without increasing makespan, all nonsplittable jobs (j) must be completed as soon as possible ($Min \sum_i \sum_j \sum_m \sum_t tX$)) and all splittable jobs (j') must start as soon as possible ($Min \sum_i \sum_{j\prime} \sum_m \sum_t tS$)

$$Minimize \sum_{i=1}^{I} \sum_{\forall j} \sum_{m=1}^{M_j} \sum_{t=EF_{ij}}^{LF_{ij}} tX_{ijmt} + \sum_{i=1}^{I} \sum_{\forall j\prime} \sum_{m=1}^{M_j\,\prime} \sum_{t=ES_{ij\prime}}^{LS_{ij\prime}} tS_{ij\prime mt}$$

for j ϵ {nonsplittable jobs}

j' ϵ {splittable jobs}

If it is desired to start all jobs as late as possible without increasing makespan, the difference between the completion period of all projects (Z) and the completion period of each job (tX) must be minimized.

$$Minimize \sum_{i=1}^{I} \sum_{j=1}^{N_i} \sum_{m=1}^{M_j} \sum_{t=EF_{ij}}^{LF_{ij}} (Z - tX_{ijmt})$$

3. Minimizing Total Lateness or Lateness Penalty

A project is late if $Z_i > g_i$The total project lateness can be defined as

$$\sum_{i=1}^{I} (Z_i - g_i)$$

and the total lateness penalty can be defined as

$$\sum_{i=1}^{I} l_i (Z_i - g_i)$$

. The objective function of lateness penalty then becomes:

$$Minimize \sum_{i=1}^{I} l_i (Z_i - g_i)$$

The objective function of lateness penalty can be reduced to the objective function of total project lateness when all l_i, are equal to one.

4. Minimizing Project Overhead Cost (Indirect Cost)

The project overhead cost can be defined as the product of overhead cost per period (c_i) and project completion time (Z_i).

$$Minimize \sum_{i=1}^{I} c_i Z_i$$

5. Minimizing Project Direct Cost

5.1) Direct cost due to renewable resources

$Let\ w_{ijmc}$ Be the total cost (nonrenewable resource type c) associated with all renewable resources used in job j of project i operating in. The objective of minimizing

Project direct cost of all jobs ($\sum_i \sum_j \sum_m \sum_t wX$) can be given by:

$$Minimize \sum_{i=1}^{I} \sum_{j=1}^{N_i} \sum_{m=1}^{M_j} \sum_{t=EF_{ij}}^{LF_{ij}} (w_{ijmc} t X_{ijmt})$$

6. **Resource Leveling Objectives**

6.1) Minimizing the absolute deviation between resource consumption and a desired rate. The total amount of resource underutilized(v_{kt}^{-}) and over utilized (v_{kt}^{+})as given in constraint (11.1) must be minimized,

$$Minimize \sum_{k=1}^{k} \sum_{t=1}^{maxG_i} (v_{kt}^{-} + v_{kt}^{+}) = 0$$

6.2) Minimizing the absolute deviation between resource consumption of consecutive time periods. The total amount of resource underutilized (u_{kt}^{+}) and over utilized (u_{kt}^{-})as given in constraint (11.2) must be minimized,

$$Minimize \sum_{k=1}^{k} \sum_{t=1}^{maxG_i} (u_{kt}^{-} + u_{kt}^{+}) = 0$$

7. Multiple Objective Function

A Preemptive goal programming model can be formulated by adding the goal constraint associated with each goal in addition to the real constraints, and using the deviation variables in the objective functions. Assume that a priority level, P_i (i = 1,...,k), is assigned to goal i, and

$P_i \gg> P_{i+1}$ The target level of goal i, and d is the deviation variable associated with the goal constraint, $G_i()$. The model can be written as:

$$Minimize \sum_{k=1}^{k} P_i(d_{kt}^{+} + d_{kt}^{-}) = 0$$

Subject to:

$$G_i() - d_{kt}^{+} + d_{kt}^{-} = T_i$$

Chapter Five **Data Analysis and Synthesis**

5.1. Introduction

One of the central challenges of computer science is to get a computer to do what needs to be done, without telling it how to do it. MOGA addresses this challenge by providing a method for automatically creating a working computer program from a high-level problem statement of the problem. MoGA achieves this goal of automatic programming (also sometimes called program synthesis or program induction) by genetically breeding a population of computer programs using the Roulette Wheel Selection which, Chromosome with bigger fitness will be selected more times. The steps of genetic optimization programming as defined by Sivanandam and Deepa, (2008), At this chapter, a model development of optimization problem is presented for resource constrained project scheduling problem (RCPSP) including.

5.2. Modeling of industry project scheduling

A project such as a construction industry project consists of a network of activities and a node network corresponds to an activity. Each activity in a project has a corresponding duration and also needs certain amount of resources such as labor material to execute itself with them. Activity duration usually measured in integral increments of time called planning units. The normal duration of an activity refers to the time required to complete that activity under normal circumstances. Figure (4.1) shows a typical network of a construction project, and table (4.1) shows the resource usage of the project activities.

Table5. 1 Precedence relations and resources usage of construction project activities

Activity No.	predecessor	Resource Usage			Actual duration(in month)
		Manpower	Machines	Equipment’s	
1	-	-	-	-	-
2	1	100	-	-	13
3	2	6	-	-	1
4	3	5	-	-	54
5	4	45	-	-	3
6	5	53	20	1	18
7	5	72	22	1	18
8	5	83	12	-	18
9	5	6	9	-	18
10	5	65	5	-	18
11	5	12	22	-	9
12	5,6	120	3	-	6
13	5,6	-	-	-	6
14	6,7,8,9,10,11,12,13	5	-	-	22
15	5	91	11	-	12
16	5	117	5	-	3
17	15,16	72	12	1	10
18	17	78	5	1	10
19	15,16,17,18,14	110	12	1	10
20	14,19	120	5	1	4
21	19,20	79	5	2	3
22	21,25,27	79	5	-	1
23	22	79	5	-	1
24	19,20	100	-	-	5
25	3	48	-	-	69

26	4	5	9	-	10
27	26	100	-	-	9
28	23,24	48	-	-	-
29	28	-	-	-	-

5.3. Formulation of RCPSP as a MoGA optimization problem

The first step in the formulation of an optimization problem is to identify the components of the problem, namely, the fixed parameters, design variables, objective function, and constraints. The design variables are determined in such a way that the value of the objective function becomes minimum.

5.3.1. Fixed parameters

The model takes on the following assumptions:

1. Each activity assumed to require a known, deterministic, integer period of time during which it must be in process.
2. For each activity, a known, deterministic level of resource usage is required or (may be zero) for each of the resource classes.
3. Each activity requires a constant level of resource usage for each resource class during the entire interval in which it is in process.
4. The level of availability of each resource class is constant throughout the schedule.
5. Setup times assumed negligible or are included in the processing times.

Termination of the Algorithm

- The proposed algorithm terminates to produce the best solution that contains the starting and finishing time of all the activities in the individual, resource fitness values, the project duration, sequencing date
- Define the project activity number, predecessor activity, resource requirement and Activity duration.
- Get the random sequence of activity number by random number generator operator in C++ program coding.
- Select each activity one by one as per the sequence generated randomly.
- For each selected activity get the predecessor activity, if the predecessor activity is zero it implies that the activity can start at a specific time.

- Based on the predecessor activity number and the binary function it has to check whether the predecessor activity is actually exist or not. If the binary operator is zero the predecessor activity does not exist and in this case the selection will carried forward for next activity to repeat the same, else if it is one then that activity sequence has been selected.
- The start time has been calculated, it is the time greater than the finish date of the predecessor activity.
- Base on the resource availability and available time span (which has to be fit to the activity duration defined in definition phase) the start time and finish time has been calculated.
- The finish time has been calculated for each activity.
- The available resource based on the different activity start and finish interval has been calculated using C++ program coding. The sequenced date is the finish date of some activity and duration is the time span from its previous duration, the available resource is the resource available for the next sequenced activity to perform based on the random sequencing.
- On activating each activity this available resource, time span and sequenced date adjusted based on the start and finishing time of each activity.
- The final fitness value is the maximum fitness value of each population of sequenced activity string.
- The fitness value will be calculated based on each population fitness value.
- Maximum resource level

5.3.2. Design variables

As design variables should be independent of each other, the design variables of resource constrained project scheduling problem (RCPSP) are defined in this study as the starting dates of the project activities. Which define the schedule of the project where the first activity has a starting date of zero. This means that the number of the design variables depends on the project and equals to the number of the activities in the project. Project schedule Where is the starting date of the activity *i*.

5.3.3. Objective function

The key question addressed in RCPSP is to determine the starting date of each activity such that precedence and resource constraints are satisfied while achieving some objectives like shortest project duration or minimum resource investment [86] The objective function is to find the best schedule that gives the minimum total project duration (T) and total cost. Where *T* is the total Duration of the project is the starting date of activity I is the duration of activity I and C total cost of the project starting date of activity I is the cost of activity i.

5.3.4. Constraints

In this research two types of constraints are considered; precedence constraints and resource constraints.

Precedence constrains are where an activity cannot start until all its predecessors have finished for each activity i precede activity j.

Resource constraints Processing every activity in the project requires a predefined amount of resources, which are available in limited quantities in every time unit, where at time (t) the total consumption of the j'th resource cannot exceed the available amount of this resource

5.4 Encoding and Representation of Chromosome"

For many optimization problems, GA don't operate directly on the solution or the problems .instead, they make use of problem-specific representations of the solution by means of a so-called decoding procedure."[44]

First we discuss how to represent the sequence of a set of numbers in the chromosome. Then we discuss how to allocate the resources and start time to each activity. To facilitate the discussion, we use the previous sequence studies as a starting point. During the last decades, there have been two main chromosome encoding methods for representing the sequence of a set of numbers(a) Adjacency, (b) path representation[35].Each of these chromosome-encoding methods has its own" genetic" operator .

- **(a) Ad**jacency representation designed to facilitate the manipulation of edges. the crossover operators based on this representation generate offspring that inherit most of their edges from the parent chromosomes

For the Traveling Salesman Problem, it can be described as follows: city j occupies position I in the chromosome. If there is an edge from city I to city j in the tour, For example, the chromosome [38526417] encodes the tour [13564287]. City 3 occupies position 1 in the chromosome because edge (1,3) in the tour, similarly, city 8 occupies position 2 because edge(2,8) is in the tour ,et(jean1996)

(b) Path representation is a representation of a schedule. For example, a schedule 5-1-7-8-9-4-6-2-3 is represented simply as [5 1 7 8 9 4 6 2 3]. Obviously, if we choose path representation as the encoding and representation of chromosome, we can avoid the unnecessary complexity.

Based on the above discussion, we chose the path representation as the presentation of the chromosome of MOGA. Therefore, we create an activity list that indicates the sequence of activities. After discussing how to represent the sequence of numbers in the chromosome, we need to discuss how to allocate the resources and start time to the each activity. There are two possible schedule generation schemes (SGC): a serial schedule generation scheme and a parallel scheduling generation scheme." The serial SGC contracts schedules from activity lists as follows: the activity 1 started at time 0. Then the activities scheduled in the order that presented by the activity list. There by, each activity assigned the earlier precedence and resource feasible start time. Parallel SGC also begin the activity at time 0. The difference is that it computes a so-called decision point which is the time at which an activity to be scheduled is started. This decision point is determined by the earliest finish time of the activities currently in process. For each decision point, the set eligible activites is computed as the set of those activities that can be feasibly started at the decision point. Then the next decision point and activities are feasibly schedule."(hartmann 2002). He also pointed out that the activity list representation together with the serial SGC as decoding procedure leads to better results than other representations for the RCPP. Based on this research we chose the serial SGC in MOGA.

As a summary, the encoding, and presentation of chromosome of SMMOGA divided into two stages. In the first stage, we generate the chromosomes that do not break the precedence constraints in the form of path representation. Each time when SMMOGA generates an individual allele, it will check whether adding this allele into the chromosome will check whether adding this allele into the chromosome will break the precedence constraints. If using the new allele as the next activity in the schedule will break the precedence constraints, SMMOGA will abort this allele and continue to generate new alleles until using the allele as the next activity in the schedule does not break the precedence constraint.

In the first SMMOGA guarantees the precedence constraint and in the second stage it considers the resources constraints. In fact, we begin from the first activity in the chromosomes, allocate the resource, start, and finish time to each activity in order to complete a feasible schedule and achieve its multiobjective. if the individual activity has enough resources to begin, we let this activity begin as soon as possible. Otherwise, we delay it until some previous activities finish and free enough resources.

5.5. Crossover

For RCPS problem, a simple crossover reproduction scheme does not work since it makes the chromosomes inconsistent(some activities may be repeated while others are missed out and hence solutions cannot meet the precedence constraints).the traditional crossover operators like one point crossover is regarded as inappropriate in the study of scheduling problems. The drawback of the simple crossover mechanism illustrated in figure5. 2.

Parent1=[1 2 3 4 5 11 8 15 18 10 7 6 12 13 25 26| 9 14 27 16 17 19 20 24 21 22 23 28 29] Parent2=[1 2 3 4 26 27 25 5 7 15 6 13 11 8 12 16| 18 17 9 10 14 19 20 24 21 22 23 28 29]
After the one point crossover (with the crossover points marked by "|") Offspring 1 = [1 2 3 4 5 11 8 15 18 10 76 12 13 25 26| 18 17 9 10 14 19 20 24 21 22 23 28 29] Offspring 2 = [1 2 3 4 26 27 25 5 7 15 6 13 11 8 12 16 | 9 14 27 16 17 19 20 24 21 22 23 28 29]

Figure5.1Illegal solution created by crossovers.

A simple crossover operator also cannot guarantee the precedence constraints, even no activity missed out or visited twice. For example, we assume, as the precedence constraint, activity 18 must begin after activity 16 is finished. In this case, after the simple crossover, activity 18 maybe begins before activity16.

Except traditional one or two point crossover, recently two crossover operators developed for the sequence problem: partial-mapped (PMX) and order (OX) crossovers, they only can guarantee no activities missed out or visited twice. Sometimes they still break the precedence constraints. The crossover operator used in this thesis is derived from them inherits their merits. We discuss PMX and OX, then the crossover operator used in SMMOGA.

(1) PMX is developed by david and lingle(1985). This operator first randomly selects two cut points in the first parent and replaces the corresponding subtracting in the second parent.then, inverse replacement is applied outside of the cut points,in order to climinatblicates and recover all activites. In Figure 5.3 the child is created by first replacing the substring (236), I parent 2 by subtracting (564).

Hence, activity 5 represent Partially-mapped, crossover (PMX) Example P1 = (1 2 3 | 4 5 6 7 | 8 9) P2 = (4 5 2 | 1 8 7 6 | 9 3) O1 = (x xx| 1 8 7 6 | x x) O2 = (x x x | 4 5 6 7 | x x) O1 = (x 2 3 | 1 8 7 6 | x 9) O2 = (x x 2 | 4 5 6 7 | 9 3) O1 = (4 2 3 | 1 8 7 6 | 5 9) O2 = (1 8 2 | 4 5 6 7 | 9 3) This swap also defines a series of mappings: 1 ↔ 4, 8 ↔ 5, 7 ↔ 6, and 6 ↔ 7

Fill in additional cities from the original parents for which there's no conflict. The symbol "x" will be interpreted as "at present unknown". The first x in the offspring O1 (which should be 1, but there was a conflict) is replaced by 4 because of the mapping 1 ↔ 4. Similarly for the other x. Alternative crossover operators Order crossover (OX) • This crossover builds offspring by choosing a subsequence of a tour from one parent and preserving the relative order of cities from the other parent.

Order crossover (OX) Example, P1 = (1 2 3 | 4 5 6 7 | 8 9) P2 = (4 5 2 | 1 8 7 6 | 9 3) O1 = (x xx| 1 8 7 6 | x x) O2 = (x x x | 4 5 6 7 | x x) 9 -3 -4 -5 -2 -1 -8 -7 -6 9 -3 -2 -1 8 O1 = (2 1 8 | 4 5 6 7 | 9 3) O2 = (3 4 5 | 1 8 7 6 | 9 2)

Sequence of cities in the second parent (from the second cut point), Sequence of cities after removing cities 4, 5, 6, and 7, which are already in the first offspring. The symbol "x" will be interpreted as "at present unknown". This sequence placed in the first offspring (starting from the second cut point). Similarly, we obtain the other offspring. Alternative crossover operators Cycle crossover (OX) • This crossover builds offspring in such a way that each city and its position comes from one of the parents.

Cycle crossover (OX) Example P1 = (1 2 3 4 5 6 7 8 9) P2 = (4 1 2 8 7 6 9 3 5) O1 = (1 x x x x x x x x) O1 = (1 x x 4 x x x x x) O1 = (1 x x 4 x xx8 x) O1 = (1 x 3 4 x xx8 x) O1 = (1 2 3 4 x xx8 x)

The first city from the first parent, the next city to be considered must be city 4, as it's the city from parent P2 that's just "below" the selected city 1. In P1 this city is at position "4". The symbol "x" will be interpreted as "at present unknown". The selection of city 2 requires selecting city 1, which is already on the list. Thus, we have completed a cycle. The remaining cities filled in from the other parent.

Cycle crossover (OX) Example P1 = (1 2 3 4 5 6 7 8 9) P2 = (4 1 2 8 7 6 9 3 5) O1 = (1 2 3 4 7 6 9 8 5) O2 = (4 x x x x x x x x) ... O2 = (4 1 2 8 5 6 7 3 9)

The first city from the first parent Similarly for O2 the symbol "x" will be interpreted as "at present unknown." CX preserves the absolute position of the elements in the parent sequence.

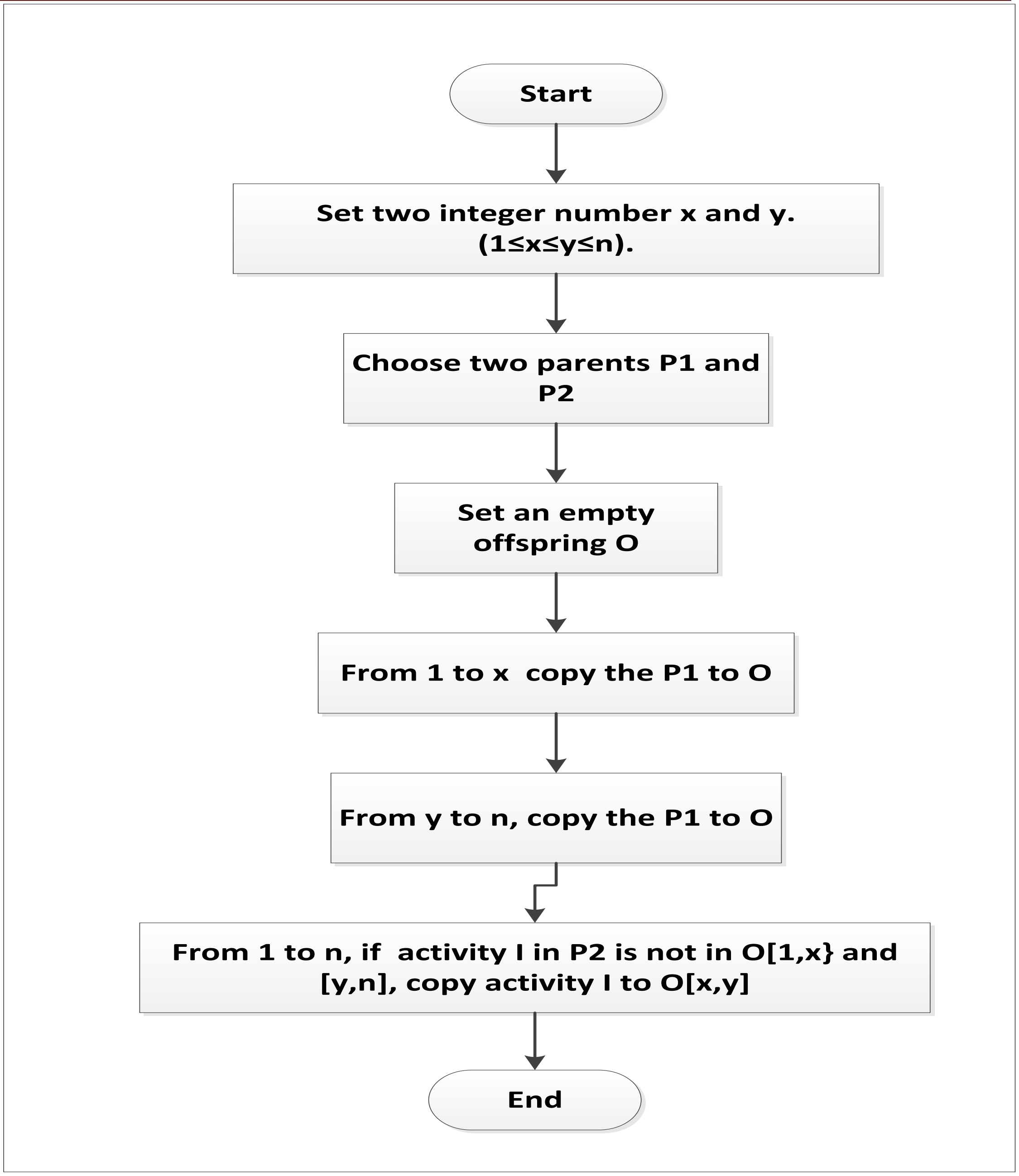

Figure5.2 Procedure of new crossover operator

5.5 Mutation

The classic mutation operator is also inappropriate in scheduling problems in terms of precedence constraints as well as crossover operators. Mutation used in this thesis will first randomly choose 2 activities, and if possible, it swaps them. The reason for using the word "possible "is that the offspring after mutation may be invalid and MOGA checks the precedence constraint and resource constraint. This mean swap breaks the precedence constraints, the procedure abandons this switch flow chart of mutation of SMMOGA is

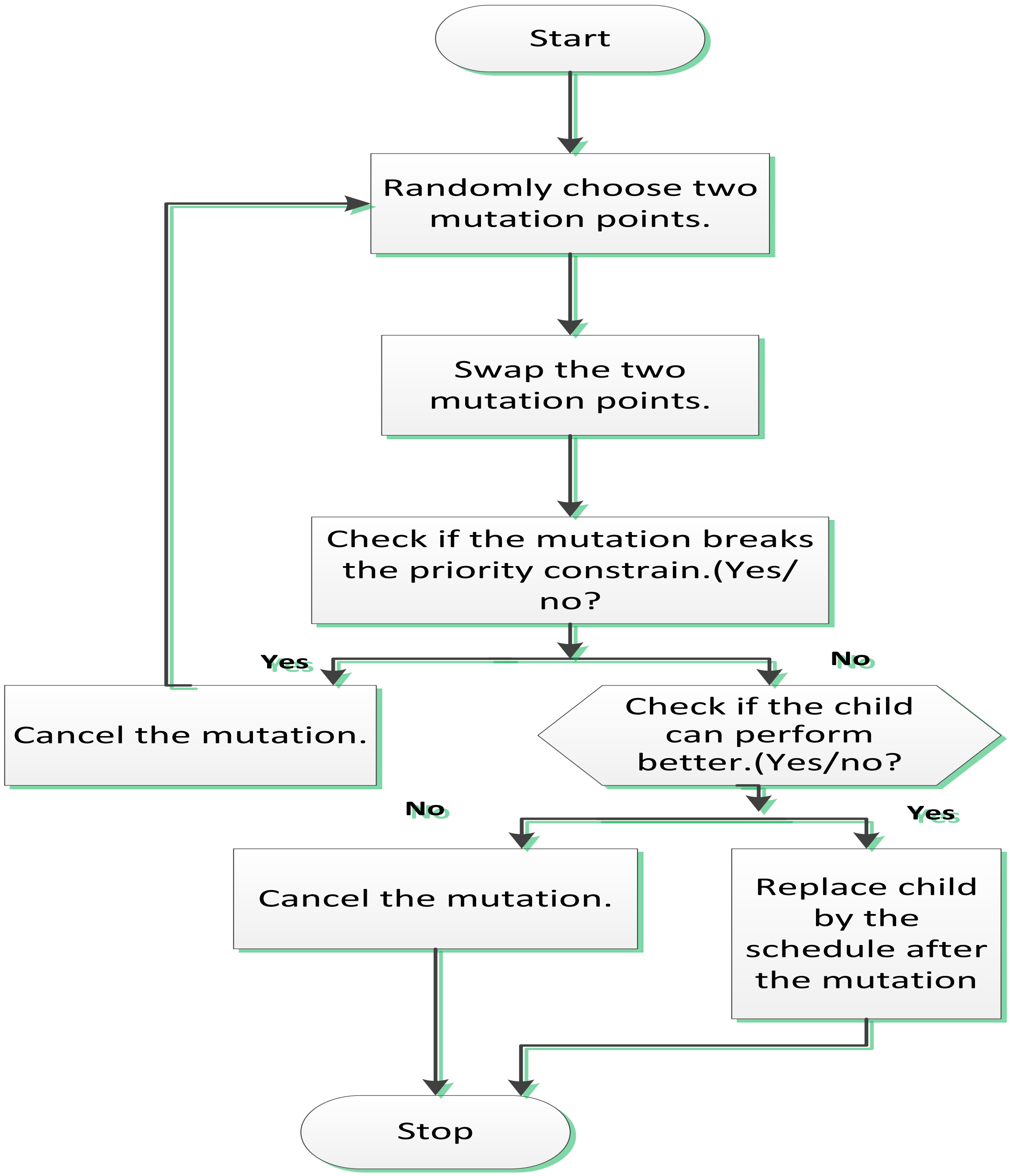

Figure5.3 The mutation operator of SMMOGA

5.6. Selection

The parent selection operator used in SMMOGA randomly choose the parents. From the population to do the crossover and makes the 29 best schedules to enter the next generation. The reason is that the child can inherit the good gene from the good parents. This is shown in Figure5.6

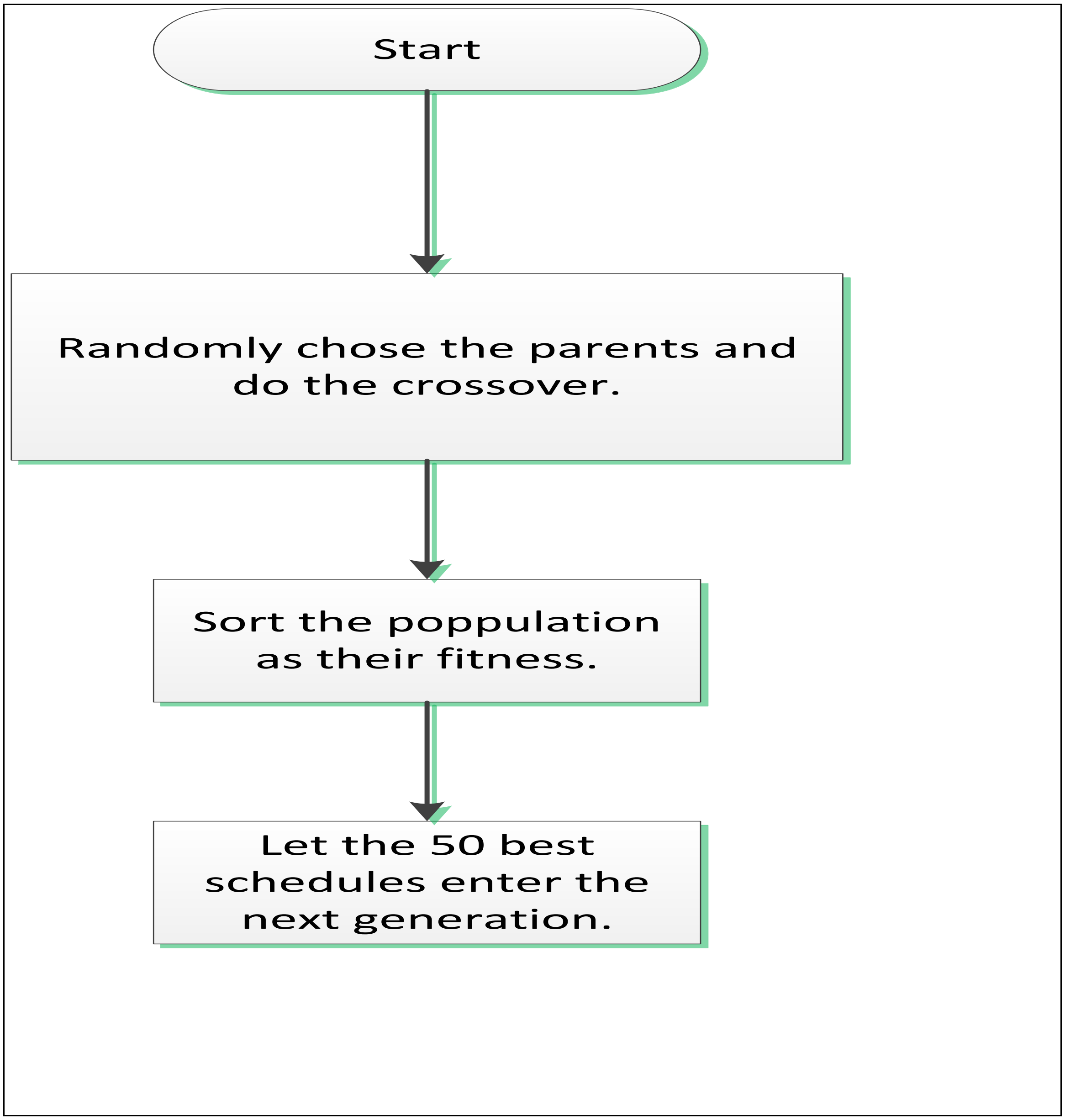

Figure 5. 4 The Selection Operator of MOGA

5.7 control parameter setting

The control parameter setting of MOGA described as follows. The population size of individual generation is 50 generation is 50. So the total population size is 50*50=2500.for each crossover generation, we do the crossover 60 times and mutation 10 times.

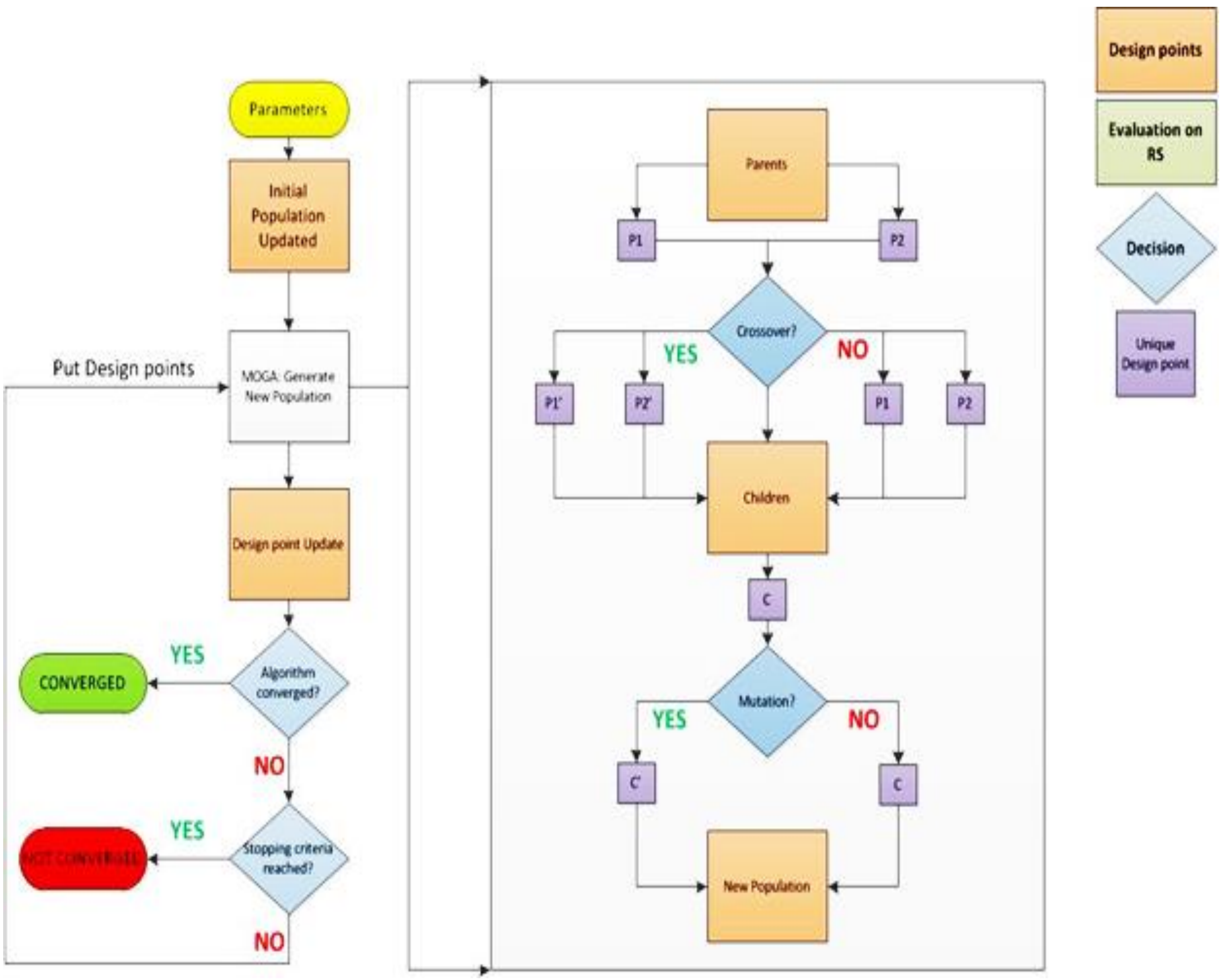

Figure5. 5 Flow Chart of MOGA

Chapter Six **Results and Discussion**

6.1. Introduction

An implementation of the developed SM-MOGA optimization model for resource-constrained project scheduling has resulted in an application program called the code block C++ .This program is to implement genetic algorithm to resource constrained project scheduling problems in order to further investigate the practical benefits to real world projects. To verify and validate the model, a comparison with the solution obtained for scheduling problems solved by Case Company will carried out through this chapter.

6.2. The SM-MOGA Optimizer

We have performed a series of computational experiments using real world data test problems in order to examine and enhance the performance of the MOGA optimization model for resource-constrained project scheduling algorithms.

In this section, we evaluate the performance of MOGA model by considering real project plane data, which got from Habesha cements Share Company. To verify and validate the model, a comparison with the actual and planned Habesha cements construction industry scheduling project data and different model input conditions results will also be compared. Instance ware tested.

A flow chart of the developed MoGA optimization model for the resource constrained project-scheduling problem is shown in figure (5.3) as explained in the chapter (5). The model called Multi-objective Genetic algorithm. The MOGA algorithm modeled to suit the special nature of the studied problem and the type of coding used, that instead of using binary coding, a value encoding was used. It Enables the user to add a new project, the names of the activities, and the duration of each of them. The program creates a table showing the activities and the duration of each activity automatically.

6.3 Case study problem (29 activities project)

The following problem was from Habesha cement construction project. We applied multi-objective genetic algorithms to construction industry scheduling with or without resource, applying it to 29 activities project problem. In the current research, the MM- MoGA Optimizer used to solve the problem, and the result compared with HCSC model results.

6.3.1 Description of the problem

A simplified breakdown of the works necessary for construction of a cement industry considered to yield the activities shown in table (6.1), where the precedence relations and durations presented.

Table 6. 1 The precedence relations and durations of the first problem

Activity No.	Description	precedence	Resource Usage			Actual duration(in month)
			Manpower	Machines	Equipment’s	
1	Starting node	-	-	-	-	-
2	Establishment, Shares Sale, Feasibility Study & Pre production, Tendering, evaluation and award	1	100	-	-	13
3	Contract Signing	2	6	-	-	1
4	Site Acquisition and Loan	3	5	-	-	54

	Process					
5	Design	4	45	-	-	3
6	Mechanical Equipment	5	53	20	1	18
7	General Layout Equipment	5	72	22	1	18
8	Water Supply and drainage	5	83	12	-	18
9	Workshop machines	5	6	9	-	18
10	Erection materials	5	65	5	-	18
11	steel structure	5	12	22	-	9
12	Electrical and automation	5,6	120	3	-	6
13	spare parts	5,6	-	-	-	6
14	Insurance, Transporting and custom clearing	6,7,8,9,10 ,11,12,13	5	-	-	22
15	Construction Inputs supply	5	91	11	-	12
16	Excavation	5	117	5	-	3
17	Concrete	15,16	72	12	1	10

18	Back fill	17	78	5	1	10
19	Mechanical Erection	15,16,17, 18,14	110	12	1	10
20	Electrical Installation	14,19	120	5	1	4
21	No load test	19,20	79	5	2	3
22	load test	21,25,27	79	5	-	1
23	Performance test	22	79	5	-	1
24	Training	19,20	100	-	-	5
25	Availing Utilities (water, power, communication, access road)	3	48	-	-	69
26	Quarry machinery and mine development	4	5	9	-	10
27	Working Capital	26	100	-	-	9
28	Project Completion and Acceptance	23,24	48	-	-	-
29	End of project	28	-	-	-	-

It is assumed that there are ***three resources*** type used in this project, labor (R1), the machine(R2) and Equipment (R3), and that there is different resource for individual..

6.3.2 HCSC Solution of the problem

Table6.2 The overall Habesha cement share company project activities information

S. No.	Activity	Duration (in months)	Start	Finish
		Planned	Planned	
		Actual	Actual	
1	Activity start	0	0	
2	Establishment, Shares Sale, Feasibility Study & Pre production, Tendering, evaluation and award	13(0-13)	Sep,2009	Sep,2010
		13	Sep,2009	Sep,2010
3	Contract Signing		Oct, 2010	
		(14-15)	Oct,2010	
4	Site Acquisition and Loan Process	12(16-28)	Nov,2010	Oct,2011
		54	Nov,2010	Apr,2014
5	Design	1(29-30)	Nov, 2011	Dec,2011
		3	May,2014	Jul,2014
6	Mechanical Equipment	8(30-38)	Dec, 2011	Aug,2012
		18	Jul,2014	Dec,2015
7	General Layout Equipment	8(30-38)	Dec, 2011	Aug,2012
		18	Jul,2014	Dec,2015
8	Water Supply and drainage	8(30-38)	Dec, 2011	Aug,2012
		18	Jul,2014	Dec,2015
9	Workshop machines	8(30-38)	Dec, 2011	Aug,2012
		18	Jul,2014	Dec,2015
10	Erection materials	8(30-38)	Dec, 2011	Aug,2012

		18	Jul,2014	Dec,2015
11	steel structure	8(30-38)	Dec, 2011	Aug,2012
		9	Jul,2014	Mzr,2015
12	Electrical and automation	4(39-43)	Sept, 2012	Dec,2012
		6	Jan,2016	Jun,2016
13	spare parts	4(39-43)	Sept, 2012	Dec,2012
		6	Jan,2016	Jun,2016
14	Insurance, Transporting and custom clearing	12(33-45)	Mar,2012	Feb,2013
		22	Jan,2015	Oct,2016
15	Construction Inputs supply	12(31-43)	Jan,2012	Dec,2012
		12	Mar,2015	Feb,2016
16	Excavation	2(31-33)	Jan,2012	Feb,2012
		3	Mar,2015	May,2015
17	Concrete	10((33-43)	Mar,2012	Dec,2012
		10	May,2015	Feb,2016
18	Back fill	10(33-43)	Mar,2012	Dec,2012
		10	Jun,2015	Feb,2016
19	Mechanical Erection	7(41-48)	Oct,2012	Apr,2013
		10	Nov,2015	Aug,2016
20	Electrical Installation	3(49-52)	May,2013	Jul,2013
		4	Sep,2016	Dec,2016
21	No load test	1(53-54)	Aug,2013	
		3	Jan,2017	Mar,2017
22	Load test	1(54-55)	Sep,2013	
		1	Apr,2017	
23	Performance test	1(56-57)	Oct,2013	
		1	May,2017	
24	Training	3(53-56)	Aug,2013	Oct,2013
		5	Jan,2017	May,2017
	Availing Utilities (water, power,	24(27-52)	Aug,2011	Jul,2013

25	communication, access road)	69	Aug,2011	Mar,2017
26	Quarry machinery and mine development	8(44-53)	Jan,2013	Aug,2013
		10	Mar,2016	Dec,2016
27	Working Capital	6(49-57)	May,2013	Oct,2013
		9	Sep,2016	May,2017
28	Project Completion and Acceptance		Oct31,2013	
			May31,2017	
29				
	End of activities	0	0	0

The MPS for this problem indicates that:-

The minimum Total numbers of month estimated/planned to finish project =58 month

Total numbers of month requires to finish actual activities =107 month

Project management, project kick off, consultancy, and local project management should be started at the end of activity (4).

Table6.3 Project plan scheduling without consideration of all available resource type

Activities list	Start time(in month)	End time(in month)
1	0	0
2	0	13
3	13	14
4	14	26
5	26	27
25	26	50

Activities list	Start time(in month)	End time(in month)
26	26	34
27	50	56
8	56	64
7	0	0
10	27	35
9	34	42
16	64	66
6	42	50
13	50	54
12	66	70
11	0	0
15	70	82
18	82	92
14	70	82
17	92	102
19	102	109
20	109	112
24	112	115

Activities list	Start time(in month)	End time(in month)
21	0	0
22	115	116
23	116	117
28	117	
29	0	0

Man power = 120, Machine=20, Equipments =1

Minimum Total numbers of month requires to finish actual project activities =117 month

The result of MOGA model project plan scheduling without consideration of all available resource type

Table6.4 project scheduling for all available resource type with a minimum resource leveling

Activities list	Start time(in month)	End time(in month)
1	0	0
2	0	13
3	13	14
4	14	26
5	26	27
8	27	35
26	26	34

Activities list	Start time(in month)	End time(in month)
25	35	59
7	35	43
15	59	71
6	43	51
12	71	75
13	51	55
9	51	59
10	51	59
11	75	83
16	83	85
17	85	95
14	85	97
27	75	81
18	95	105
19	105	112
20	112	115
24	115	118
21	118	119

Activities list	Start time(in month)	End time(in month)
22	119	120
23	120	121
28	121	
29	0	0

Project plan scheduling with consideration:-

- Man power = 121, Machine=23, Equipments =2
- Minimum Total numbers of month requires to finish actual project activities =121 month
- The total Indirect cost required to finish all projects activity is= $3.60785e+007
- The total cost required to finish all projects activity is= $1.56545e+008
- The total cost deviation b/n MOGA and actual project cost is= $-4.47254e+006

The result of MM_MOGA model project scheduling for this condition with consideration of all available resource types with a minimum resource leveling considered.

Table6.5 all available resource type with a maximum resources leveling.

Activities list	Start time(in month)	End time(in month)
1	0	0
2	0	13
3	13	14
4	14	26
26	26	34
27	34	40

Activities list	Start time(in month)	End time(in month)
5	26	27
9	27	35
16	27	29
6	27	35
11	27	35
10	27	35
12	35	39
13	35	39
7	27	35
15	27	39
17	39	49
18	39	49
8	29	37
14	39	51
19	51	58
20	58	61
25	26	50
24	61	64

Activities list	Start time(in month)	End time(in month)
21	61	62
22	62	63
23	63	64
28	64	
29	0	0

Project scheduling with considering of all available resource type with a maximum resources leveling.

Man power = 621, Machine=110, Equipment's =5

Minimum Total numbers of month requires to finish actual project activities =64 month

The total Indirect cost required to finish all projects activity is= = $1.90828e+007

The total cost required to finish all projects activity is= $1.39549e+008

The total cost deviation b/n MOGA and actual project cost is= $1.25231e+007

Table 6.6 The result of MOGA model project plan scheduling with consideration of all available resource type with a maximum resources leveling.

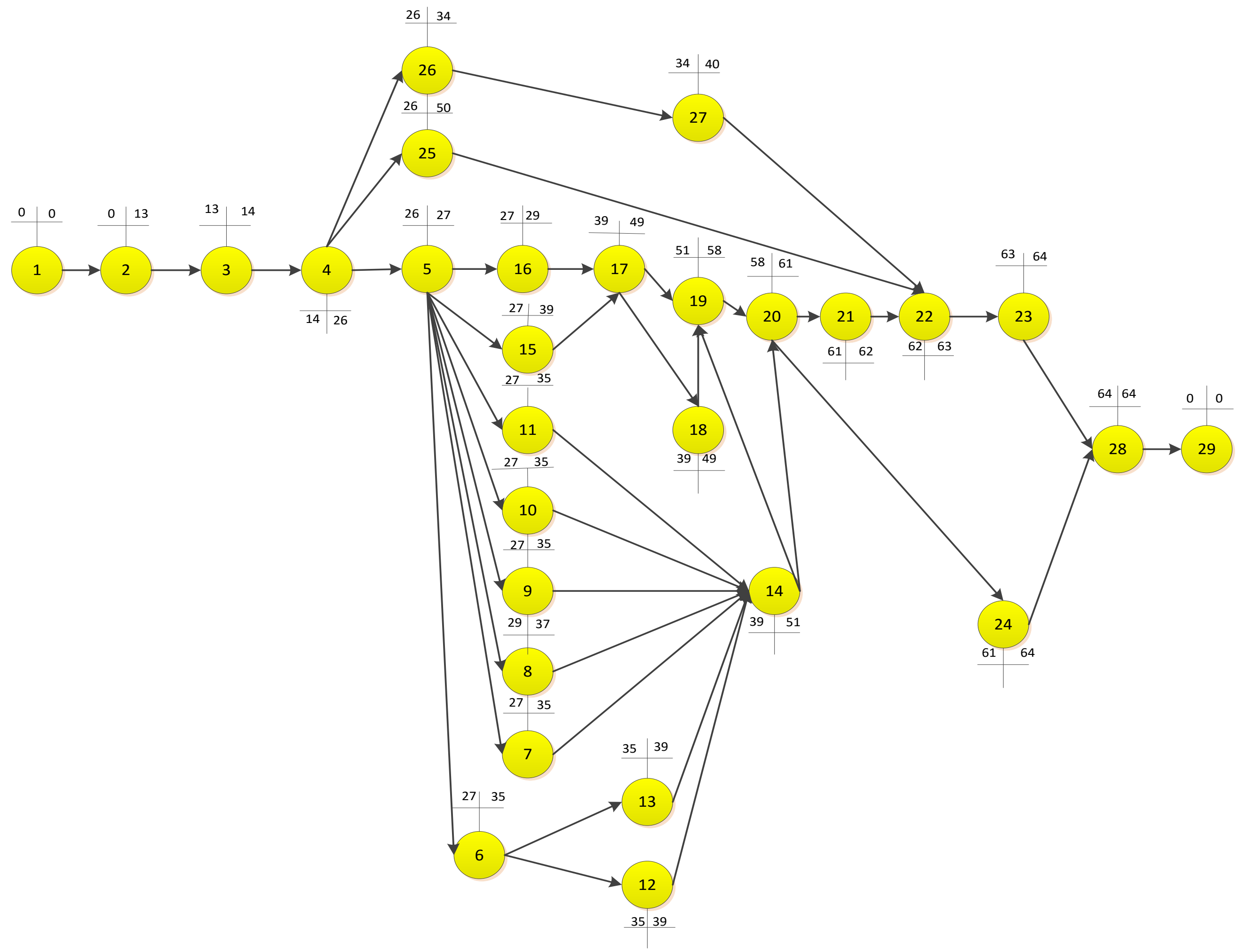

Figure6.1Start-to-Finish Relationship

Table 6.6 Resource Leveling and Allocation

RESOURSE LEVELING AND ALLOCTING		
MANPOWER	MACHINES	EQUIPMENTS
521	110	5
521	110	5
521	110	5
521	110	5
521	110	5
521	110	5
521	110	5

521	110	5
521	110	5
521	110	5
521	110	5
521	110	5
521	110	5
615	110	5
616	110	5
616	110	5
616	110	5
616	110	5
616	110	5
616	110	5
616	110	5
616	110	5
616	110	5
616	110	5
616	110	5
616	110	5
523	101	5
152	7	3
152	7	3
186	0	3
186	0	3
186	0	3
186	0	3
186	0	3
91	9	3
179	84	5
179	84	5
262	96	5
262	96	5
318	93	3
418	93	3
418	93	3
418	93	3
418	93	3
418	93	3
418	93	3
418	93	3
418	93	3
418	93	3

568	110	5
616	110	5
511	98	4
511	98	4
511	98	4
511	98	4
511	98	4
511	98	4
511	98	4
501	105	4
501	105	4
501	105	4
442	105	3
442	105	5
442	105	5
621	110	5

****************** ********** ********************

AVRGE MANPOWER	AVRGE MACHINE	AVRGE EQUIPMENT
621	110	5

6.4 Test results and comparison

All algorithms were coded using code block software. The experiment ware run on pc Lenovo G50 corei3, processor 1.90 GHz and 4 GB RAM, equipped with windows 10 Ultimate. The experiments made for all of company project activities with population size of individual 50 generation and total 1500 population and different problem.The experiments made for all of company's project activities with population size of individual 50 generation and total 1500 population and different problem instance ware tested. For each generation we do 60 times cross over and 100 times mutation.

The MM_MOGA model results were compared with Habesha cement share company actual project scheduling plan. We set variables project time, resource leveling and cost. The computational test results show that Project Scheduling Plan that is designed based on allocating resources type, resources' leveling and precedence in all project activities can give the **optimum (finishing time and/or resource leveling and/ or total cost)** of overall project activities. This shows that Habesha cement share company actual project was finished with (total project finishing time=107 month & total project cost=$152,072,156.89) whereas by MM-MOGA model project finished with (total project minimum finishing time=64 month & total project cost=$139,549,378.56).The complete test result details are presented in the table 6.3, 6.4 and 6.5.

6.5 Discussions of Result

This research assumes that there were no preferences on project time, cost, and resource leveling in analyzing the process and if the manager has given specific preference on time, cost, and resource fluctuation, it can easily make a decision according to the sorted non-dominated solutions. Table 6.3 shows that the MM-MOGA model results at which project activities scheduling plan without allocating of all resources type and leveling will leads to unexpected(garbage) results as it happens Habesha cement share company estimated /planed project plan. See activity 7, 11, &21 due to scarcity of work force, machine, and equipment respectively give zero value at start and end time, which shows that the activities/s will never start if not availing resource type for each activity. This shows that SM- MOGA model led to the worst result and manger should take care of model inputs.

Table 6.4 shows the minimum available resources required in order to finish activity is (Man power = 121, Machine=23, equipment =3) with finishing time 121 month, this shows overall project cost will increase due to long time span of project finishing time as expected. This shows the reduction in the resource usage fluctuation, the time of the project has been increased which imposes additional cost to the project.

Table 6.5 shows the minimum available resources required in order to finish parallel activities is (Man power = 621, Machine=110, Equipment's =5) with finishing time 64 month, this shows overall project cost will decrease due to short time span of project finishing time as expected. This shows increase in the resource usage fluctuation, the time of the project has been decreased which imposes reduction cost to the project.

It is important to mention the fact that we cannot interpret and conclude the results by considering only time and cost of schedules and ignoring the third aspect, which is resource-leveling parameter.

The findings of this thesis can be summarized as follows .first, this research has shown that the MM_MOGA model of project scheduling gives a promising efficiency for Habesha cement fabrics project scheduling as compared with simple precedence constraint's scheduling model.

The MM-MOGA model developed as follows, first random populations generated and then by selecting two parents from population child generated by using seated parameter. The representation of the chromosome, the crossover and mutation operators in MM-MOGA model can obey the precedence and resource constrains, this means after crossover child solutions can still satisfy precedence constraints. The fore, those child can be selected as a candidate to be parent as it full fill criteria.

Chapter Seven **Conclusion and Recommendation**

7.1 Summary and Conclusion

The multi-objective Resource-Constrained Project Scheduling Problem is an *NP*-hard and complex problem due to its combinatorial aspect. The primary aim of this research is to develop Multi-mode multi-objective genetic algorithm optimization model to schedule project activities in order to minimize the total duration and cost of the project, subjected to both precedence constraints and resources constraints. The main achievements of this project can summarized as follows:

♣ A new approach developed to create the population of the Multi-genetic algorithm individuals that is the *Partial mapped (PMX) and order(X) crossover operator*. That enables the user to create completely feasible solutions that satisfy all constraints, and this helps in getting a quick convergence toward the best solution during MoGA s tags, without losing the MoGA feature of searching global maximum or minimum.

♣ A new crossover operator developed in this study; the procedure of the new crossover operator suit the scheduling problem formulation, and suit the type of the chromosomes encoding used.

♣ An implementation of the MM-MOGA developed model for resource-constrained project scheduling has resulted in application program called the MOGA "Multi-objective genetic algorithm for RCPSP.

♣ The MM-MOGA Optimizer treats the deficiencies of traditional scheduling systems such as CPM that do not take resource constraints in consideration, it has an interface which is easy to use, it contains many tabs, and each tab acts as a sheet of inputs. Tabs enable user to add different categories of project information ranging from activities durations, activities relationships, resources, and MOGA parameters. It is time saving program because it uses the feasible solutions developer operator.

♣ Test and validation of the developed program applied. A comparison with the results of HCSC scheduling plan and with the feature of “resource leveling” The **main conclusions** drawn from the current research can be summarized as follows: Multiple *objective* concurrent projects involves sharing and competing for limited resources such as machine, equipment, manpower and other resources among different projects, which increases the complexity of the scheduling process. As a result, it was motivated in this research to present the development of a MM-multiobjective Genetic Algorithm scheduling optimization model for multiple objectives construction industry project. The model arises throughout considering time/cost tradeoff and resource aspects under a muliti platform. Such aspects considered by integrating the concept of project scheduling together with resource leveling and allocation for concurrent multiple objectives project. The model enables construction companies in solving the problems of how to prioritize the projects with resource conflicts, how to allocate reasonably the limited resources among multiple objectives to meet the resource requirements of different activities, and to optimize project multi-objectives under resource limit. The multi-objectives included in this optimization model were the total duration, total cost, resource fluctuations, models developed to adapt for construction *industry* projects, namely resource model. The main aim of these models is to evaluate the projects’ different multi-objectives values. The scheduling model establishes optimal/near optimal schedules for construction industry projects to determine the projects’ total duration and identify the activities’ start and finish times, the direct total cost and indirect cost of multiple activities based on the schedules obtained from the scheduling model. Finally, *n* the resource model determines the resource fluctuations and monthly maximum resource demand for multiple projects based also on the schedules obtained from the scheduling model. Consequently, a complete optimization model formulation established to identify the model’s decision variables, formulate the optimization objectives, and model the optimization constraints. The decision variables comprised both the start times and resource utilization modes of the projects’ activities. On the other hand, the model formulated under the constraints of preserving the logical relationship between activities while keeping the maximum required resource demand below pre-defined limits. Accordingly, a multi-objective scheduling optimization model developed for construction industry projects using single-mode activities with multi-resources. The developed model was linked with the management models (scheduling, time/cost and resource) to search for schedules that optimize the project' desired objectives using the MOGA technique. The model performed the genetic algorithm operations in three main phases: (1) population initialization; (2) fitness evaluation; and (3) generation evolution,(selection initial generate population,(crossover) and mute the crossover The model was tested to solve a time/cost tradeoff problem, integrated time/cost tradeoff and resource constrained problem.

In order to further, investigate the practical benefits to real world projects. The developed model verified by real world data. Moreover, the model applied on, errors identified, and corrections made to encountered errors. This took a long period of time, and a huge effort by the researcher to get a high degree of certainty about the model verification. Validation developed MOGA Optimizer done. One real case applied and the results are studied and compared with the results of previous studies and with the

Finally, real case data to demonstrate its capabilities to solve integrated resource leveling, resource allocation, scheduling problems for single project under unconstrained and constrained resource limits.

7.2. Recommended

The model should cover all other types of precedence relationships (i.e. finish-to-finish, start-to-start, and start-to-finish) and should consider the time lag between activities. Considering such relationships is essential to develop schedules that are more practical by overlapping the activities of a network to accelerate the execution of a project.

- The optimization model can consider allocating a priority weight for each concurrent project to assign efficiently the available resources and cash among different projects.
- Using a certain Genetic algorithm technique to efficiently solve a specific problem, may not adequately solve other optimization problems. Similarly, a problem solved differently by various algorithms. As a result, other promising meta-heuristics

techniques such as ant colony or particle swarm optimization can be experimented to solve the currently developed model.

- For more practical scheduling, activities' interruption, or splitting caused by different parties considered. Moreover, uncertainties in the activities' duration and cost considered while scheduling the projects.
- Also the project manager must take action during pre-scheduling time not be forgot to be consider resource with the given activities
- Heavy construction industry projects such as manufacturing industry, cement, & chemical usually age and deteriorate at a fast rate requiring immediate rehabilitation efforts to enhance their quality. Therefore, other objectives such as the "construction industry project scheduling method
- Quality and service can be added to be optimized together with the identified multi-objectives

7.3 Research Limitation

The research has some limitations, which summarized as follows:

1. The developed model considers only the finish-to-start precedence relationship between the projects' activities.

2. The developed automated tool requires the user to enter the activities' time, cost, and resource data one by one, which consumes more time than simply importing such data in a tabulated form.

7.4. Recommendation for Future Work

The current research study has been able to accomplish its main objectives. Yet, several points recommended enhancing and extending the current research for future work.

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APPENDIX

Algorithms codded in C++ code Block

```
#include <iostream>

#include<cstdlib>

#include<iomanip>

#include"windows.h"

#include<conio.h>

#include<string.h>

using namespace std;

  int va[31][9],vb[31][9],sc[31],k,bn[31],elit[31],pool[200][33],gen[200][33];

   /*int pr[200][3]={{0,1},{1,2},{2,3},{3,4},{4,5},{5,6},{5,7},{5,8},

   {5,9},{5,10},{5,11},{5,12},{6,12},{5,13},{6,13},{6,14},{7,14},

   {8,14},{9,14},{10,14},{11,14},{12,14},{13,14},{5,15},{5,16},{15,17},

   {16,17},{15,18},{15,19},{16,19},{17,19},{18,19},{14,19},{14,20},{19,20},

   {19,21},{20,21},{21,22},{25,28},{27,22},{22,23},{19,24},{20,24},{4,25},{4,26},

   {26,27},{23,28},{24,28},{28,29}};

    int nodtme1[31]={0,390,30,360,30,240,240,240,240,240,240,120,120,360,360,

   60,300,300,210,90,30,30,30,90,60,240,180,0,0};

   int nodtme2[31]={0,390,30,1620,90,540,540,540,540,540,270,180,180,660,360,90,

   300,300,300,120,90,30,30,150,2070,300,270,1,0};
```

```
*/

int pr[200][3]={{1,2},{2,3},{3,4},{4,5},{4,25},{4,26},{5,6},{5,7},{5,8},

        {5,9},{5,10},{5,11},{5,12},{5,13},{5,15},{5,16},{6,12},{6,13},{6,14},{7,14},

{8,14},{9,14},{10,14},{11,14},{12,14},{13,14},{14,19},{14,20},{15,17},{15,19},

{16,17},{16,19},{15,18},{17,19},{18,19},{19,20},{19,21},{19,24},{20,21},{20,24},

        {21,22},{22,23},{23,28},{24,28},{25,22},{26,27},{27,22},{28,29}};

int nodtme[31]={0,13,1,12,1,8,8,8,8,

        8,8,4,4,12,12,2,10,10,

        7,3,1,1,1,3,24,8,6,0,0};

int nodtme1[31]={0,13,1,54,3,18,18,18,18,18,

         9,6,6,22,12,3,10,10,10,4,3,

         1,1,5,69,10,9,0,0};

double cost[31]={0,634161.23,0,1711040.45,1069200.00,26828932.68,346500.00,

684090.00,495000.00,3161367.00,1287000.00,3960000.00,1782000.00,5427267.41,

11286000.00,1915650.00,9578250.00,1277100.00,8331709.24,1766290.76,142560.00,

427680.00,855360.00,495000.00,4343604.71,1508124.91,5975668.20,495000.00,0};
```

```
    int
reso1[10000]={0,100,6,5,45,53,72,83,6,65,12,120,0,5,91,117,72,78,110,120,79,79,79,100,48,
                5,100,48,0};
    int  reso2[10000]={0,0,0,0,0,20,22,12,9,5,22,3,0,0,11,5,12,5,12,5,5,5,5,0,0,9,0,0,0};
    int reso3[10000]={0,0,0,0,0,1,1,0,0,0,0,0,0,0,0,0,1,1,1,1,2,0,0,0,0,0,0,0,0};
   int child[31],pr1[31],pr2[31];
   int avreso1[10000],avreso2[10000],avreso3[10000];
   int resor1,resor2,resor3,c=0,pd1,p,pd2,q=0,o=0,a=0,b=0;
   int stod[50][50],ent[100];
   int pn=50,pz=50;
int eldu=99999,st[200][3],totalactulamoth=106,totalpalnmonth=53;
double
costhb[31],total=0,avindirct_cost=298169.14,totalprojectcost=152072156.89,totalacual_cost=
120466228.08,others_cost=13098671.51;
int total_population()
{
   int p=0;
   int z=0;
   int s=0;
   int d=0;
for(v1=0;v1<n;v1++)
```

```
{
    va[v1][0]=vb[v1][0];
    va[v1][1]=vb[v1][1];
    va[v1][2]=vb[v1][2];
    va[v1][3]=vb[v1][3];
    va[v1][4]=vb[v1][4];
    va[v1][5]=vb[v1][5];
    va[v1][6]=vb[v1][6];
    va[v1][7]=vb[v1][7];
    va[v1][8]=vb[v1][8];
}
for(p=0;p<ps;p++)
{
    pr[p][2]=0;
}
for(k=1;k<n-1;k++)
{
    for(p=0;p<n-1;p++)
    {
        bn[p]=0;
```

```
    }
    p=0;
   for(i=0;i<=k-1;i++)
   {
for(j=0;j<=ps-1;j++)
   {
if(pr[j][0]==sc[i]&&pr[j][2]==0)

{
    bn[p]=pr[j][1];
    p++;
}
   }
   }
d=0;
if(p==0)
{
    sc[k]=0;
}
else
```

```
{
 do
 {
      rd=rand()%p;
      z=bn[rd];
     d=0;
for(s=0;s<9;s++)
{
    if(va[z-1][s]!=0)
    {
        d=1;
    }
}
 }while(d==1);
}
 sc[k]=bn[rd];


for(i=0;i<=ps-1;i++)
{
if(pr[i][1]==bn[rd])
```

```
{
    pr[i][2]=1;
}
}
for(d=0;d<n;d++)
{
    for(s=0;s<9;s++)
    {
        if(va[d][s]==sc[k])
        {
            va[d][s]=0;
        }
    }
}
}
    return 0;
}
int childern_formation()
{
    int x=0,y=0,g=0,a=0,b=0;
```

```
int cp1,cp2;

cp1=1+rand()%(13+1-1);

cp2=15+rand()%(27+1-15);

for(i=0;i<=cp1;i++)

{

   g=pr1[i];

   child[i]=g;

}

for(i=cp2;i<=n-1;i++)

{

   g=pr1[i];

   child[i]=g;

}

k=cp1+1;

do

{

   for(j=0;j<=n-1;j++)

   {

      for(i=0;i<=cp1;i++)

      {
```

```
            a=pr2[j];

            b=child[i];

            if(a==b)

            {

               x=1;

            }

         }

      for(i=cp2;i<=n-1;i++)

         {

            a=pr2[j];

            b=child[i];

            if(a==b)

            {

               y=1;

            }

         }

if((x==0)&&(y==0))

{

   g=pr2[j];

   child[k]=g;
```

```
   k++;

   x=0;

   y=0;

}

x=0;

y=0;

}



}while(k<=(cp2-1));



   return 0;

}

int mututaion()

{

  int  a=0,b=0,c=0,d=0,e=0;

   for(i=0;i<ps;i++)

   {

       pr[i][2]=0;

   }

       rd=rand()%n;
```

```
    a=child[rd];

    b=child[rd+1];

    c=b;

    d=a;

  for(i=0;i<=ps-1;i++)

  {

    if((c==pr[i][0])&&(d==pr[i][1]))

    {

      child[rd]=c;

      child[rd+1]=d;


    }

  }

  return 0;

}

int minimumtime_selection()

{

int s,f,j;

minispan=0;

int previous=0;
```

```
int next=0;

int prevpoint=0;

int a=0,b=0,c=0,d=0,e=0;

for(s=0;s<n;s++)

{

    st[s][1]=0;

}

for(s=0;s<1000;s++)

{

avreso1[s]=resor1;

avreso2[s]=resor2;

avreso3[s]=resor3;



}

for(f=1;f<n;f++)

{

    if(sc[f]==0)

        continue;

         next=sc[f];

    if(sc[f]==n)
```

```
    {

    minispan=0;

    for(s=0;s<n;s++)

    {

        if(st[s][1]+nodtme[s]>minispan)

        {

            minispan=st[s][1]+nodtme[s];

        }

    }

     st[n-1][1]=minispan;

     break;

    }

prevpoint=0;

for(d=0;d<ps;d++)

{

  for(e=0;e<f;e++)

  {

    if(pr[d][1]==next&&pr[d][0]==sc[e]&&st[sc[e]-1][1]+nodtme[sc[e]-1]>=prevpoint)

    {

        previous=sc[e];
```

```
      prevpoint=st[sc[e]-1][1]+nodtme[sc[e]-1];

   }

   }

  }

  for(d=st[previous-1][1]+nodtme[previous-1];d<1000;d++)

  {

     j=0;

     for(s=d;s<d+nodtme[next-1];s++)

     {

if((avreso1[s]<reso1[next-1])||(avreso2[s]<reso2[next-1])||(avreso3[s]<reso3[next-1]))

   {

   j=1;

      }

     }



   if(j!=1)

     {

      st[next-1][1]=d;



      for(a=d;a<d+nodtme[next-1];a++)
```

```
        {
            avreso1[a]=avreso1[a]-reso1[next-1];
            avreso2[a]=avreso2[a]-reso2[next-1];
            avreso3[a]=avreso3[a]-reso3[next-1];
        }
        break;
      }
  }

}

return 0;
}
int starttoend()
{
int s,f,j;
minispan=0;
int previous=0;
int next=0;
int prevpoint=0;
```

```
int a=0,b=0,c=0,d=0,e=0;

for(s=0;s<n;s++)

{

    st[s][1]=0;

}

for(s=0;s<1000;s++)

{

avreso1[s]=resor1;

avreso2[s]=resor2;

avreso3[s]=resor3;

}

for(f=1;f<n;f++)

{

    if(sc[f]==0)

        continue;

         next=sc[f];

         stod[f][0]=next;

    if(sc[f]==n)

    {

    minispan=0;
```

```
   for(s=0;s<n;s++)
   {
       if(st[s][1]+nodtme[s]>minispan)
       {
           minispan=st[s][1]+nodtme[s];
       }
   }
    st[n-1][1]=minispan;
    break;
   }
prevpoint=0;
for(d=0;d<ps;d++)
{
  for(e=0;e<f;e++)
  {
   if(pr[d][1]==next&&pr[d][0]==sc[e]&&st[sc[e]-1][1]+nodtme[sc[e]-1]>=prevpoint)
   {
       previous=sc[e];
       prevpoint=st[sc[e]-1][1]+nodtme[sc[e]-1];
   }
```

```
   }

  }

  for(d=st[previous-1][1]+nodtme[previous-1];d<1000;d++)

  {

     j=0;

     for(s=d;s<d+nodtme[next-1];s++)

     {

if((avreso1[s]<reso1[next-1])||(avreso2[s]<reso2[next-1])||(avreso3[s]<reso3[next-1]))

    {

    j=1;

      }

     }



    if(j!=1)

     {

       st[next-1][1]=d;

       stod[f][1]=d;

        ent[f]=d+(nodtme[next-1]-1);



       for(a=d;a<d+nodtme[next-1];a++)
```

```
        {
            avreso1[a]=avreso1[a]-reso1[next-1];
            avreso2[a]=avreso2[a]-reso2[next-1];
            avreso3[a]=avreso3[a]-reso3[next-1];
        }
        break;
      }
  }
}
stod[0][0]=1;
return 0;
}
int elitime()
{
   for(i=0;i<=n-1;i++)
   {
       g=sc[i];
    elit[i]=g;
   }
```

```
    return 0;

}



int totalsorted_poulation(int bb)

{

int mn,mnd,tep;

for(o=1;o<=bb;o++)

{

    mn=pool[o][n];

    mnd=o;

    for(p=o+1;p<=bb;p++)

    {

        if(pool[p][n]<mn)

        {

            mn=pool[p][n];

            mnd=p;

        }

    }



    if(mn<pool[o][n])
```

```
   {
 for(q=0;q<=n;q++)
   {

        tep=pool[o][q];
        pool[o][q]=pool[mnd][q];
        pool[mnd][q]=tep;
   }
}

}
   return 0;
}
int main()
{
   int eldu=99999,u=0,bb=0;
   char yes;
   system("mode 140");
     //system("color 0");
     system("color a");
```

```
   cout<<"\t
*********************************************************"<<endl;

        cout<<" "<<endl;

        cout<<"\t\t     ADDIS ABABA, INSTITUTE OF TECHNOLOGY SCHOOL OF
MECHANICAL&INDUSTURIAL ENGINEERING   "<<endl;

   cout<<"                                        "<<endl;

        cout<<"\t\t              THESIS  TITLE  :MULTI  OBJECTIVE  RESOURCE
CONSTRAINED,PROJECT SCHEDULING PROBLEM "<<endl;

   cout<<"                                        "<<endl;

   cout<<"\t            PRESENTER :HIWOT WUBISHET  "<<endl;

   cout<<endl;

        cout<<"\t
*********************************************************"<<endl;

   getch();

        system("cls");

        //system("color a");

        system("color 0");

        cout<<"\t
*********************************************************"<<endl;

        cout<<" "<<endl;

        cout<<"\t\t        RESEARCH  AREA:HABESHA  CEMENT  SHARE  COMPANY
"<<endl;
```

```
   cout<<"                                        "<<endl;

   cout<<"\t           HOLETA ,ETHIOPIA  "<<endl;

   cout<<endl;

        cout<<"\t
*********************************************************"<<endl;

   getch();

        system("cls");

        cout<<"please enter average daily/monthly available resource in the projects:\n";

        cout<<"
*********************************************************"<<endl;

   cout<<"enter average daily/monthly available  Man power resources  \n";

   cin>>resor1;

   cout<<endl;

    cout<<"enter average daily/monthly available Machines resources \n";

   cin>>resor2;

   cout<<endl;

   cout<<"enter average daily/monthly available Equipments resources  \n";

   cin>>resor3;

   cout<<endl;

/*

for(i=0;i<n;i++)
```

```
{

  cout<<"enter activity"<<" "<<i+1<<" "<<"node time"<<endl;

  cin>>nodtme[i];

  cout<<endl;

  cout<<"enter activity"<<" "<<i+1<<" "<<"required Man power resources"<<endl;

  cin>>reso1[i];

  cout<<endl;

  cout<<"enter activity"<<" "<<i+1<<" "<<"required Machines resources"<<endl;

  cin>>reso2[i];

  cout<<endl;

  cout<<"enter activity"<<" "<<i+1<<" "<<"required Equipments resources"<<endl;

  cin>>reso3[i];

  cout<<endl;
```

```
}

  /*

  cout<<"Do you want continue to next step:\n";

   getch();

          system("cls");

   cout<<"please enter average required cost of an activity:\n";

   cout<<"  ************************************"<<endl;




for(i=0;i<n;i++)

{

   cout<<"enter activity"<<" "<<i+1<<" "<<"required cost"<<endl;

   cin>>cost[i];

   cout<<endl;

}

*/

for(i=0;i<n;i++)

{

      total=total+cost[i];

}
```

```
do

{



   eldu=99999,u=0,bb=0;

cout<<"Do you want continue to next step:\n";

   getch();

         system("cls");

         //system("color 0");

   cout<<"This is the over all activity precedence list:\n";

   cout<<"\t *************************************"<<endl;

   cout<<"\t"<<"PREDECESSOR"<<"\t"<<"SUCCESSOR"<<endl;

for(i=0;i<ps;i++)

{

for(j=0;j<2;j++)

{

cout<<"\t"<<pr[i][j]<<" \t";

}

pr[i][2]=0;

cout<<endl;

}
```

```
cout<<endl;

cout<<"Do you want continue to next step:\n";

    getch();

            system("cls");

    cout<<"This is the over all information:\n";

    cout<<"\t ******************"<<endl;



cout<<"ACTVTY"<<"\t"<<"RESO1"<<"\t"<<"RESO2"<<"\t"<<"RESO3"<<"\t"<<"NODTI
M"<<"\t"<<"D.COST"<<endl;

for(i=0;i<n;i++)

{



cout<<"___________________________________________________________________________
___\n";

cout<<i+1<<"\t"<<reso1[i]<<"\t"<<reso2[i]<<"\t"<<reso3[i]<<"\t"<<nodtme[i]<<"\t"<<cost[
i]<<endl;

}

cout<<"___________________________________________________________________________
___\n";



for( v1=0;v1<n;v1++)

{
```

```
    va[v1][0]=0;

    va[v1][1]=0;

    va[v1][2]=0;

    va[v1][3]=0;

    va[v1][4]=0;

    va[v1][5]=0;

    va[v1][6]=0;

    va[v1][7]=0;

    va[v1][8]=0;

}

for(v1=2;v1<=n;v1++)

{

for(v2=0;v2<ps;v2++)

{



   if(pr[v2][1]==v1)

   {

          ck=0;

       cd=pr[v2][0];

       if(cd==1)
```

```
      {
          cd=0;
      }
for( v3=0;v3<9;v3++)
  {
if(va[v1-1][v3]==cd)
{
    ck=1;
}


  }
  if(ck==0)
  {
  for( v3=0;v3<9;v3++)
  {
if(va[v1-1][v3]==0)
{
va[v1-1][v3]=cd;
break;
}
```

```
  }

  }

   }

}

}

for(v1=0;v1<n;v1++)

{

    vb[v1][0]=va[v1][0];

    vb[v1][1]=va[v1][1];

    vb[v1][2]=va[v1][2];

    vb[v1][3]=va[v1][3];

    vb[v1][4]=va[v1][4];

    vb[v1][5]=va[v1][5];

    vb[v1][6]=va[v1][6];

    vb[v1][7]=va[v1][7];

    vb[v1][8]=va[v1][8];

}

/*
```

```
cout<<"this is final data\n";

for(i=0;i<n;i++)

{

for(j=0;j<=8;j++)

{

cout<<vb[i][j]<<" ";

}

cout<<endl;

}

cout<<endl;

*/

for(z=1;z<=50;z++)

{

total_population();

minimumtime_selection();

if(minispan<=eldu)

{

  elitime();

    u++;

    eldu=minispan;
```

```
for(i=0;i<n;i++)

{

    h=elit[i];

    pool[u][i]=h;

}

pool[u][n]=minispan;



}



minispan=0;

}



cout<<endl;

cout<<"this is first selected activity\n";

for(z=1;z<=u;z++)

{

    for(i=0;i<=n;i++)

{

    cout<<pool[z][i]<<" ";

}
```

```
cout<<endl;

}

cout<<endl;



for(h=1;h<=25;h++)

{

   bb=u;

for(z=1;z<=60;z++)

   {

      pd1=1+rand()%u;

      pd2=1+rand()%u;

      for(p=0;p<n;p++)

      {

      q=pool[pd1][p];

      pr1[p]=q;

      q=pool[pd2][p];

      pr2[p]=q;

      }

      childern_formation();

      for(p=0;p<n;p++)
```

```
        {
        q=child[p];
        sc[p]=q;
        }
    minimumtime_selection();
if(minispan<=eldu)
{
  elitime();
    bb++;
    eldu=minispan;
for(i=0;i<n;i++)
{
    h=elit[i];
    pool[bb][i]=h;
}
pool[bb][n]=minispan;


}
minispan=0;
```

```
}



for(z=1;z<=1000;z++)

    {

        pd1=1+rand()%(bb);

        for(p=0;p<n;p++)

        {

        q=pool[pd1][p];

        child[p]=q;

        }

        mututaion();

        for(p=0;p<n;p++)

        {

        q=child[p];

        sc[p]=q;

        }

     minimumtime_selection();

if(minispan<eldu)

{

  elitime();
```

```
    eldu=minispan;
for(i=0;i<n;i++)
{
    h=elit[i];
    pool[pd1][i]=h;
}
pool[pd1][n]=minispan;


}
minispan=0;
    }
totalsorted_poulation(bb);
}


cout<<endl;
cout<<"this is over all selected  sorted activity\n";
for(z=1;z<=bb;z++)
{
    for(i=0;i<=n;i++)
{
```

```
    cout<<pool[z][i]<<" ";
}
cout<<endl;
}
for(i=0;i<n;i++)
{
    h=elit[i];
    sc[i]=h;
}
cout<<endl;
cout<<endl;
cout<<"this is best selected  activity sequence \n";
for(i=0;i<n;i++)
{
    cout<<sc[i]<<"->";
}
 starttoend();
 cout<<" with minimum time:=";
 cout<<st[n-1][1]<<endl;
 cout<<"_____________________________________________________________\n";
```

```
cout<<endl;

cout<<"the total Indirect cost required to finish all projects activity is=  $"<<(st[n-1][1]*avindirct_cost);

cout<<endl;

cout<<"________________________________________________________\n";

cout<<endl;

cout<<"the total cost required to finish all projects activity is=  $"<<((st[n-1][1]*avindirct_cost)+totalacual_cost);

cout<<endl;

cout<<"_______________________________________________________________\n";

cout<<endl;

cout<<endl;

cout<<"the total cost deviation b/n my project and actual project cost is= $"<<(totalprojectcost-((st[n-1][1]*avindirct_cost)+totalacual_cost));

cout<<endl;

cout<<"_______________________________________________________________\n";

cout<<endl;

cout<<"\t"<<"ACTIVITY"<<"\t"<<"STARTIME"<<"\t"<<"ENDTME"<<endl;

cout<<"_______________________________________________\n";

ent[0]=-1;

ent[28]=-1;
```

```
for(f=0;f<n;f++)

{

  cout<<"\t"<<stod[f][0]<<"\t\t"<<stod[f][1]<<"\t\t"<<(ent[f]+1)<<endl;

  cout<<"______________________________________________\n";

}

cout<<endl;

cout<<" ************************************************************"<<endl;

   cout<<"\t"<<"AVRGE MAN POWER"<<"\t"<<" AVRGE MACHINE "<<"\t"<<"AVRGE EQUIPMENT"<<endl;

   cout<<"______________________________________________________\n";

   cout<<"\t\t"<<resor1<<"\t\t"<<resor2<<"\t\t"<<resor3<<endl;

   cout<<endl;

cout<<"if you want to repeat the same action Press Y:\n";

cin>>yes;

system("cls");



}while(yes=='y');

        cout<<endl;

        cout<<"AS YOU HAVE SEEN FROM THE ABOVE ANALYSIS DECRIPTION MOGA ANALYSIS IS\n";
```

```
        cout<<"AN ESSEINTIAL TOOLS TO DEVELOPE OPTIMAMUM COST,TIME WITH RESOURCE LEVLING PROJECT SCHEDULING MANGMENT :\n";

    cout<<endl;

        cout<<"THANK YOU :\n";



return 0;

}
```