Combinatorial Optimization in Project Selection Using Genetic Algorithm

Sari Dewi\textsuperscript{1}, Sawaluddin\textsuperscript{2}
\textsuperscript{1,2}Department of Mathematics, Universitas Sumatera Utara, Indonesia

E-mail : 1dewiq.ui@yahoo.com, 2sawal@usu.ac.id

Abstract. This paper discusses the problem of project selection in the presence of two objective functions that maximize profit and minimize cost and the existence of some limitations is limited resources availability and time available so that there is need allocation of resources in each project. These resources are human resources, machine resources, raw material resources. This is treated as a consideration to not exceed the budget that has been determined. So that can be formulated mathematics for objective function (multi-objective) with boundaries that fulfilled. To assist the project selection process, a multi-objective combinatorial optimization approach is used to obtain an optimal solution for the selection of the right project. It then described a multi-objective method of genetic algorithm as one method of multi-objective combinatorial optimization approach to simplify the project selection process in a large scope.

1. Introduction
Project selection is the process of assessing each project idea and selecting the project with the highest priority \cite{1}. The objective of the project selection process is to ensure that the selected project benefits optimally for enterprise resources. It also seeks to ensure that relevant investments are made. One of the project management tasks is to choose from a variety of projects that are better adapted to organizational goals \cite{2}. Project management aims as a powerful tool for improving the ability to plan, execute and control activities and how to utilize resources and performance \cite{3}.

The uniqueness of the project requires different ways of handling so that the study of project selection activities grows as the development of project selection models to the development of decision-making systems to support such activities. Prior research uses the PMB (Packing-Multiple-Boxer) model or multi-knapsacks model to find solutions in the selection and scheduling of R & D projects \cite{4}, based on a simple 0-1 integer programming model, PMB models that can be used to select R & D projects and at the same time can create a selected project schedule. A comprehensive framework is proposed \cite{5} for the project selection problem of uncertainty factors with apparent constraints.

The hybrid approach is used for project selection involving economic procedures and probabilities \cite{6}. Multi objective combinatorial optimization is the process of discovery of one or more optimum solutions as a possible solution for finding the best maximum or minimum value of some conflicting objective (objective) or dual purpose objectives \cite{7}. Techniques for solving multi-objective
combinatorial optimization problems can be classified into appropriate estimation algorithms. Some of the research done in solving the problem of project selection with metaheuristic methods such as doing by means of two objective functions that is maximizing profit and maximizing limited resources using multi objective method Ant Colony [15], also using Genetic Algorithm [16], Multi objective methods of Particel Swarm Optimization [8], and the multi-objective method of Genetic Algorithm [9]. This study considers several objectives of maximizing revenue, minimizing costs and risks that will occur.

2. Problem definition
A project is a complex enterprise with clear objectives, there are schedules, budgets, and consists of interrelated tasks performed by various organizational units [10]. Project selection involves simultaneous comparisons of a number of projects in order to arrive at the project's desired rating [11]. Projects with the lowest criteria are evaluated and then selected with available resources. In some constraints such as models or methods on project selection can be used to increase profits, select investments with limited capital resources, or enhance the competitive position of the organization. The project selection includes a large number of resource allocation methods and techniques [12].

Project management is the application of a set of tools and techniques to direct the use of resources such as time, cost and quality constraints to a unique, complex, and timely outcome [13]. Each job requires a combination of structured tools and techniques to fit the work environment and life cycle from conception to completion. A project is a human activity to achieve clear goals against time scale and achievement [14]. Project management has been developed to plan, coordinate and control complex and diverse project activities with regard to cost, time and quality as the criteria required to measure the project management process [15]. Project management aims as a powerful tool for improving the ability to plan, implement and control activities and how to use resources and performance [3].

3. Mathematical formulation
Suppose that project $i$ ($i = 1, 2, ..., H$) will be selected in the period $t$ ($t = 1, 2, ..., T$) required for the selection of housing construction projects. Housing construction is carried out at several locations in the area. So that the housing construction process at each location in period $t$ is not more than one project $i$ will be implemented. This is considered based on the area of land available. Then the selected project $i$ determination is adjusted to the location within period $t$. The housing development process involves several factors: $b_{it}$ gain (profit), $c_{it}$ cost, $t$ period and limited resources. So the need for an appropriate allocation of resources to meet each project to be selected. The purpose of the allocation of such resources so that the budget or the cost of $c_{it}$ issued in housing construction does not exceed the specified $Q_{o} budget and less than the $b_{it}$ gain gained due to limited resources. So the goals that are considered important for housing development can be realized smoothly that is to maximize profits and minimize costs to be incurred on the project. It is proposed to make it easier in determining the project to be selected.

In the project selection process with the planning horizon (period of planning) in period $t$ means that each project has determined the allocation of available resources to meet the needs of each project with a predetermined range of time $d_{i}$. So it does not exceed the predetermined time limit because if a project $i$ in period $t$ is delayed or exceeds the time limit set then it will impact on all subsequent projects. The allocation of the cost of resources into consideration is the first human resource needs of the project $i$ in which $j = 1, 2, ..., e$ both the needs of machine resources $m_{k}$ on project $i$ where $k = 1, 2, ..., s$ and third requirement of raw material $r_{o}$ at project $i$ where $o = 1, 2, .., v$. So that limited resources can be overcome. The gain on project $i$ in period $t$ is denoted by bits.

3.1 Maximize profits
Benefits are a basic form of need that is useful to facilitate the process of activity. Because the benefits in a project have a positive impact on project selection involves the goal of maximizing profits. Then the total profit gained on project $i$ to be implemented is defined in the following equation:
3.2. Minimize profits
Cost is the fund used for the project to be implemented. Funds spent on project execution involve many criteria so that the need for handling capable of solving funding problems so that the project implementation process can run in accordance with the plan. In this case the cost used in the form of cost on the resources that must be fulfilled the cost of human resource needs symbolized test, the cost of machine resource needs symbolized and cost of raw materials demand expressed as \( r_{ol} \). Cost on project \( i \) in period \( t \) is denoted by \( c_{it} \). Then the total cost obtained in the project \( i \) to be implemented is defined in the following equation:

\[
\min z_2(x) = \sum_{t=1}^{T} \sum_{i=1}^{H} b_{it} x_{it} + \sum_{t=1}^{T} \sum_{i=1}^{H} b_{it} x_{it} + \sum_{t=1}^{T} \sum_{i=1}^{H} m_{kt} c_{kt} + \sum_{t=1}^{T} \sum_{i=1}^{H} r_{ol} c_{ot}
\]

s.t.

\[
\sum_{t=1}^{T} x_{it} \leq 1 \quad i = 1, 2, ..., H
\]

\[
\sum_{t=1}^{T} (t + d_{it}) x_{it} \leq T + 1 \quad i = 1, 2, ..., H
\]

\[
\sum_{i=1}^{H} u_{ji} x_{it} \leq U_{jt} \quad i = 1, 2, ..., e; t = 1, 2, ..., T
\]

\[
\sum_{i=1}^{H} m_{kt} x_{it} \leq M_{kt} \quad i = 1, 2, ..., s; t = 1, 2, ..., T
\]

\[
\left( \sum_{j=1}^{e} u_{ji} + \sum_{k=1}^{s} m_{kt} + \sum_{o=1}^{v} r_{ol} \right) x_{it} \leq Q_{it} \quad i = 1, 2, ..., s; t = 1, 2, ..., T
\]

\[
\left( \sum_{j=1}^{e} u_{ji} + \sum_{k=1}^{s} m_{kt} + \sum_{o=1}^{v} r_{ol} \right) x_{it} \leq b_{it} \quad i = 1, 2, ..., s; t = 1, 2, ..., T
\]

\[
x_{it} \in \{0, 1\} \quad i = 1, 2, ..., s; t = 1, 2, ..., T
\]

The objective function (1) is the equation formed for the purpose of maximizing profits by summing the total gains in project \( i \) period \( t \). The objective function (2) is the equation formed for the purpose of minimizing the cost by summing all the total cost (total cost of human resource requirements of \( u_i \), total cost of machine needs \( m_k \) and total cost of raw materials \( r_o \)) on project \( i \) period \( t \). Limitation (3) ensures that all selected projects are exercised no later than one in period \( t \). Limitation
(3) guarantees that all projects proposed to be selected have clear planning horizon (horizon planning). Limitation (4) guarantees that all human resource availability of the test on the project \( i \) is met according to the allocations established during the project selection process.

Limitation (5) guarantees that all available \( m_k \) machine resources on project \( i \) are met according to the allocations established during the project selection process. Limitation (6) guarantees that all available raw materials of \( r_c \) at project \( i \) are met according to the allocation established during the project selection process. Limitation (7) guarantees that all resource allocation of resources in project selection does not exceed the predetermined \( Q_{it} \) budget. Limitation (8) ensures that all availability of the required cost does not exceed the profit to be earned 10. The decision variable (9) where 1 is the selected project \( i \) and 0 for the unelected project \( i \).

4. Computational Analysis

This section will explain the technicalities of the problem to be solved by discussing a case. The parameters used for this example are presented in Table 1 with the size of the problem that is the problem of project selection on housing construction.

| Table 1. Project costs and benefits (amounts in billions of Rupiah) |
|-----------------------------|-----------------|-----------------|-----------------|-----------------|
| Alternative Project        | Stage 1 Cost   | Stage 1 Benefit | Stage 2 Cost   | Stage 2 Benefit | Stage 3 Cost   | Stage 3 Benefit | Stage 4 Cost   | Stage 4 Benefit |
| 1                          | 2              | 3               | 1              | 4               | 7              | 8               | 4              | 6               |
| 2                          | 5              | 6               | 3              | 5               | 8              | 10              | 7              | 10              |
| 3                          | 6              | 8               | 8              | 10              | 10             | 12              | 8              | 12              |
| 4                          | 8              | 10              | 10             | 12              | 0              | 0               | 9              | 14              |
| 5                          | 10             | 13              | 12             | 14              | 0              | 0               | 10             | 15              |
| 6                          | 13             | 15              | 0              | 0               | 0              | 0               | 0              | 0               |

In Table 1 can be seen about the objective function that becomes the reference that is the cost and profit for each project to be selected (calculated in billions of rupiah) with 4 stages and 6 alternative proposed project. The proposed budget is 20 billion rupiahs. In the table presented has assumed the total cost of the total cost of resources to be used (human resources, raw material resources, and engine resources). The experiments were performed in 4 variations of iterations, ie 50, 100, 150 and 200 iterations.

| Table 2. Projects selected with Genetic Algorithm |
|-----------------------------|-----------------|-----------------|-----------------|
| Generation     | Vector | Cost | Result |
| 20             | 1 2 2 2 | 20 | 28 |
| 100            | 2 2 2 1 | 20 | 27 |
| 150            | 1 1 3 2 | 20 | 29 |
| 200            | 1 1 3 2 | 20 | 29 |

For 50 Iteration experiments, 20 billion rupiahs were obtained and 28 billion rupiahs profit with alternative project ie location 1 project 1 (c11 = 2, b11 = 3), location 2 project 2 (c22 = 3, b22 = 5), location 3 project 2 (c23 = 8, b23 = 10), and location 4 project 2 (c24 = 7, b24 = 10). For the 100 Iteration experiments, 20 billion rupiahs and 27 billion rupiahs were earned with alternative project sites (location 1 project 2 (c21 = 5, b21 = 6), location 2 project 2 (c22 = 3, b22 = 5), location 3 project 2 (c23 = 8, b23 = 10), and location 4 project 1 (c14 = 4, b14 = 6).

For the Iteration 150 experiment, the cost of 20 billion rupiahs and profit 29 billion rupiahs with the alternative of location 1 project 1 (c11 = 2, b11 = 3), location 2 project 1 (c12 = 1, b12 = 4),
References:

[1] Momanyi, D. 2013. Effects of capital budgets on cash flow: a case study of Kenya power and lighting company limited. Institutional Repository of KCA University, Kenya.

[2] Meredith, J.R. dan Samuel, S.J. 2009. Project Management: A managerial Approach, 3rd edn. Willey & Sons, New York.

[3] Ghasemzadeh, F., Archer, N. dan Iyogun, P. 1999. A Zero-one model for project portfolio selection and scheduling. Operational Research Society. Vol 50, No 7, 745-755.

[4] Sun, H. dan Ma, T. 2005. A Packing-multiple-boxes model for R&D Project selection and scheduling. Technovation. Vol 25, No 11, 1355-1361.

[5] Shakhshi, N.M., Torabi, S.H., Iranmaresh. 2011. A Comprehensive framework for project selection problem under uncertainty and real-world Constraints. Computation. Vol 61, No 1, 226-237.

[6] Dutra, C.C., Ribeiro, J.L.D. dan Carvalho, M.M. 2014. An Economic-probabilistic model for project selection and prioritization. Project Management. Vol 32, No 6, 1042-1055.

[7] Bassuer, M., Talbi, E., Nerbo, A. dan Alba E. 2006. Metaheuristics for Multiobjective Combinatorial Optimization Problem. Rapport De Recherche, French.

[8] Rabbani, M., Bajestani, M.A. dan Khoshkhou, B.G. 2010. A Multiobjective Particle Swarm Optimization for Project Selection Problem. Expert System with Application. Vol 37, No 1, 315-321.

[9] Bhattacharyya, R., Kumar, P. dan Kar S. 2011. Fuzzy R&D Portfolio Selection of Interdependent Projects. Computers and Mathemathic with Application. Vol 62, No 10, 3857-3870.

[10] Archibald, R.D. 1992. Managing high technology programs and projects (2nd). Wiley & Sons, NewYork.

[11] Archer, N.P. dan Ghasemzadeh, F. 1999. An integrated framework for project portfolio selection. Project Management. Vol 17, No 4, 207-216.

[12] Dobrovolskiena, N. dan Tamusiuniene, R. 2014. Resource Allocation in project port-folio management-practice in the Baltic states. KSI Transactions on Knowledge Society. Vol 7, No 1, 28-31.

[13] Oisen, P.R. 1971. Can project management be defined?. Project Management quarterly. Vol 2, No 1, 12-14.

[14] Reiss, B. 1993. Project Management. E and FN, London.

[15] Atkinson, R.W. 1997. Effective Organisation, Re-Framing the Thinking for information System Project Success. Cassell, London.

[16] Gorbani, S. dan Rabbani. M. 2009. A New Multiobjective Algorithm For A Project Selection Problem. Advances in Engineering Software. Vol 40, No 1, 9-14.