Model Development of Rescue Assignment and Scheduling Problem Using Grasp Metaheuristic

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Abstract - **Natural disasters could not be avoided by humans. Indonesia is often facing natural disaster. Natural disasters can cause social, economic, and environmental impacts. This problem encourages researchers to take an active actions in disaster management issues. This research develops Rescue Team Assignment and Scheduling Problem by considering the required capability for the disaster incident locations and capability of rescue teams to handling time and applying fuzzy logic for travel times and severity of incident locations. This research also develops the solution method by applying GRASP Metaheuristics approach to solve this problem in a reasonable computation time.**

Keywords – **assignment and scheduling, rescue team, natural disaster, humanitarian logistics, GRASP metaheuristics**

I. INTRODUCTION

Rossum and Krukkert [1] stated Indonesia has been struck by natural disaster in the past decades, included volcano eruptions. After natural disaster occurred, we can divide the response time become four phases (Rossum and Krukkert [1]). The first phase deal with how to rescue people, the second phase deal with how to supply medical attention, food, water, shelter to the victim. The third and fourth phases deal with the recovery of incident area. This paper focus on how to rescue people (victims).

In order to save the victims of natural disaster, we have to make a plan to manage disaster. According to Altay and Green [2], disaster management consists of four phase: mitigation, preparedness, response and recovery. Rescue planning especially rescue team assignment and scheduling is planned in preparedness phase and is executed in response phase. Wex et al. [3] have developed model rescue team assignment and scheduling (RUASP). The objective of the RUASP model is to minimize the sum of the weighted completion time of all incidents. The model that Wex et al. [3] developed, deal with probabilistic severity level and travel time. But the model did not consider ratio of the required capability at incident area to the capability of available rescue team.

Each rescue team has different capability and each incident area has different level of damaged (severity level) (Chen and Miller-Hooks [4]). For that reason, it is necessary to take account the ratio of the required capability at incident area to the capability of available rescue team into the RUASP model. Therefore, not all rescue team can handle all of incidents. Only a rescue team having a suitable capability can handle an incident area. This proposed RUASP model is developed by dealing with ratio of the required capability at incident area to the capability of available rescue team.

Wex et al [3] assumes severity level of each incident and travel time of each rescue team follow certain probability distribution. In the fact, we only have imperfect information (uncertainty) of the severity level of each incident. The travel time is influenced by the condition of transportation infrastructure after disaster. Therefore, travel time from one incident area to another incident area also have imperfect information. The imperfect information can be caused by lack of information, ambiguity (linguistic) and conflicting evidence [5]

Because the information is imperfect, the certain probability distribution is not an appropriate approach for capturing the data pattern. Sughanti et al. [6] states the fuzzy concept is an appropriate approach for imperfect information. The benefit of applying Fuzzy concept is to capture the uncertainty of demand pattern more detail [5]. Hence, the proposed RUASP model uses the fuzzy concept for severity level and travel time.

II. RESEARCH METHODOLOGY

The research step of the proposed model development can be described as follows: first, based on the previous model developed by Wex et al. [3], we developed Rescue Team Assignment and Scheduling Problem (RUASP) model taking into account the required rescue team capability in each area of incidence and the capability of the available rescue teams related to time required for rescue process. The model also considers transportation time to incident area and damaged level of each incidence area.

RUASP model aimed to decide team assignment and team scheduling, is classified into mixed integer linear programming. Consequently, the RUASP model is categorized as NP-Hard model [7], model that has high complexity is caused by number of decision variable, non-linear variables relationship, etc. It means we need longer time to solve the RUASP model categorized as NP-Hard model. Therefore, we need a metaheuristic procedure such as Greedy Randomized Adaptive Search Procedure (GRASP) as an appropriate approach. GRASP method can be used whether for small scale and large scale problem. Hence, the second step, we developed a metaheuristic procedure, Greedy Randomized Adaptive Search Procedure (GRASP) to solve the proposed RUASP model.

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The third step is to validate the proposed model using numerical example and solved by GRASP metaheuristic. The last step, we draw some conclusions based on the results of the proposed RUASP model.

III. MODEL DEVELOPMENT

The Rescue Team Assignment and Scheduling Problem (RUASP) model has been developed by considering uncertainty factors using fuzzy logic sets for site-specific severity, and the travel time required for rescue teams to reach the incident locations. The ratio of the capabilities of the rescue teams and the capabilities required by each incident location to the handling times.

The proposed RUASP model was developed based on RUASP model developed by Wex et al. [3] with differences as shown in Table 1.

TABLE 1.
COMPARISON BETWEEN PREVIOUS AND PROPOSED RUASP MODEL

	Previous RUASP Model (Wex *et al.*, 2014)	**Proposed model**
Objective function	To minimize the sum of the weighted completion time of all of incidents	To minimize the sum of the weighted completion time of all of incidents
Solution method	Multi heuristic	GRASP Metaheuristics
Severity level	Probabilistic	*Fuzzy*
travel time required by rescue teams	Probabilistic	*Fuzzy*
Ratio of the required capability at incident area to the capability of available rescue team related to processing time	Not taking account into the model	Taking account into the model

A. Mathematic Notations

The mathematic notations are used in this proposed RUASP model included sets, variables, parameters, and decision variables, as follows:

Sets

n	Total number of incidents, with *set* $I = (1,\ldots,n)$
m	Total number of rescue teams, with *set* $K = (1,\ldots,m)$

Parameters

$w_j \in R^{\geq 0}$	Factor of damaged (severity level) of incident j
$p_j^k \in R^{\geq 0}$	Time required by rescue team k to process incident j; ∞ if rescue team k is incapable of coping incident j.
$s_{ij}^k \in R^{\geq 0}$	Travel time required by rescue team k to move from incident i to incident j; if i=0 then rescue team k start from its initial location before moving to incident j.
$cap_{ki} \in \{0,1\}$	1 if rescue team k is capable to cope incident i; 0 otherwise.
C_j^k	Ratio of required capability at incident j to the capability of rescue team k

Decision Variables

$X_{ij}^k \in \{0,1\}$	1 if incident i is processed by rescue team k immediately before processing incident j; 0 otherwise.
$Y_{ij}^k \in \{0,1\}$	1 if incident i is processed by rescue team k at any time before incident j; 0 otherwise.

B. Mathematical Formulation

Similar with Wex et al. [3], the objective of proposed RUASP model is minimizing the sum of weighted completion times over all incidents that consists of processing time for rescuing the victims and traveling time. Nevertheless, the processing time in this proposed RUASP model depends on ratio of required capability at area of incident to the capability of available rescue team. In addition, the proposed RUASP model use the fuzzy concepts for weight of completion time and for traveling time. The sum of weighted completion times (WCT) is formulated as follows:

$$\begin{aligned}\min \quad WTC = X_{ij}^k, Y_{ij}^k \sum_{j=1}^{n} \Bigg(& (0.3lw_j + 0.4mw_j \\ & + 0.3uw_j) \sum_{i=0}^{n} \sum_{k=1}^{m} \Big[p_j^k Y_{ij}^k + C_j^k p_j^k Y_{ij}^k \\ & + \left(p_j^k + C_j^k p_j^k + (0.3ls_{ij}^k + 0.5ms_{ij}^k \right. \\ & \left. + 0.2us_{ij}^k)\right) X_{ij}^k \\ & + Y_{ij}^k \Bigg(\sum_{l=0}^{n} X_{li}^k (0.3ls_{li}^k + 0.5ms_{li}^k \\ & + 0.2us_{li}^k) \Bigg) \Big] \Bigg) \end{aligned} \tag{1}$$

Several constraints are considered in this proposed RUASP model. Constraint (2) ensures there is exactly one incident is processed immediately before an incident. There is exactly one incident is processed immediately after an incident, is ensured by Constraint (3).

$$\sum_{i=0}^{n} \sum_{k=1}^{m} X_{ij}^k = 1, j = 1, \ldots, n \tag{2}$$

$$\sum_{j=1}^{n+1} \sum_{k=1}^{m} X_{ij}^k = 1, i = 1, \ldots, n \tag{3}$$

Constraint (4) and (5) guarantee each rescue team starts from fictitious incident 0 as the initial location and each rescue team ends at the fictitious incident n+1 as the ending location.

$$\sum_{j=1}^{n+1} X_{0j}^{k} = 1, \qquad k = 1,\ldots, m \qquad (4)$$

$$\sum_{i=0}^{n} X_{i,n+1}^{k} = 1, \qquad k = 1,\ldots, m \qquad (5)$$

Constraint (6) ensures the transitivity in predecessor relationships. If there exists an immediate predecessor for a specific incident, there is a successor that is guaranteed by Constraint (7). Constraint (8) ensured an incident that is immediately processed by rescue team *k*, is considered as general predecessor.

$$Y_{il}^{k} + Y_{ij}^{k} - 1 \leq Y_{ij}^{k}, \quad i = 0,\ldots,n; j = 1,\ldots,n+1; \; k = 1,\ldots,m; l = 1,\ldots,n \qquad (6)$$

$$\sum_{i=0}^{n} X_{il}^{k} = \sum_{j=1}^{n+1} X_{ij}^{k}, \quad l = 1,\ldots,n; k = 1,\ldots,m \qquad (7)$$

$$X_{ij}^{k} \leq Y_{ij}^{k}, \quad i = 0,\ldots,n; j = 1,\ldots,n+1; \; k = 1,\ldots,m \qquad (8)$$

Constraint (9) prohibits a rescue team stop in an incident and ensures a rescue team always move to the other incident. Nevertheless, only a rescue team having capability can process an incident (Constraint 10).

$$Y_{ii}^{k} = 0, \quad i = 0,\ldots,n+1; k = 1,\ldots,m \qquad (9)$$

$$Y_{ij}^{k} \leq cap_{ki}, \quad i = 1,\ldots,n; j = 1,\ldots,n+1; \; k = 1,\ldots,m \qquad (10)$$

Constraint (11) and (12) guarantee $Y_{ijk} = 0$ if rescue team *k* does not process incident *i* before incident *j*. Constraint (13) deals with the binary decision variables.

$$\sum_{l=1}^{n+1} X_{il}^{k} \geq Y_{ij}^{k}, \quad i = 0,\ldots,n; j = 1,\ldots,n+1; \; k = 1,\ldots,m \qquad (11)$$

$$\sum_{l=0}^{n} X_{lj}^{k} \geq Y_{ij}^{k}, \quad i = 0,\ldots,n; j = 1,\ldots,n+1; \; k = 1,\ldots,m \qquad (12)$$

$$X_{ij}^{k}, Y_{ij}^{k} \in \{0,1\}, \quad i = 0,\ldots,n; j = 1,\ldots,n+1; \; k = 1,\ldots,m \qquad (13)$$

IV. GRASP METAHEURISTICS

Development of GRASP metaheuristics algorithm has the following steps:

1. Initialize the number of available rescue team, $K \leftarrow (1,..,k)$
2. Initialize the schedule which is a blank set, $S \leftarrow \emptyset$
3. Initialize initial location of each rescue team, completion time for each rescue team, and list of incident locations assigned to each rescue team, namely: $c_k \leftarrow 0$; $\alpha_k \leftarrow 0$; $\sigma_k \leftarrow \emptyset \;\; \forall k \in K$
4. Initialize the existing incident location list, $I \leftarrow (1,\ldots,n)$.
5. Search for completion time (C) according to the used construction heuristic
6. Calculate $c_{min} \leftarrow \min\{c|c \in C\}$ and $c_{max} \leftarrow \max\{c|c \in C\}$
7. Checking RCL $\leftarrow \{c \in C | c \leq c_{min} + \alpha\,(c_{max} - c_{min})\}$
8. Randomly select one of the values included in the RCL and the incident location that has the value
9. Perform the steps within the construction heuristic algorithm loop that is used.
10. Updating $C \leftarrow C \backslash \{i\}$.
11. Save all selected incident locations into the list (σk)
12. Doing local searches on the incident location list using the selected improvement heuristics and converted into. Update the schedule where $S \leftarrow S \cup \{\sigma'\}$
13. Calculate the total time using the mathematical model that has been developed.
14. Perform steps 1-13 to a desired number of iterations.
15. Save the total time of best iteration result and schedule of each team from the total selected time

This method was applied to numerical experiments as discussed in the Section V.

V. RESULTS AND DISCUSSION

The Rescue Team Assignment and Scheduling Problem (RUASP) Model has been developed by considering uncertainty factors using fuzzy logic sets for site-specific severity, and the travel time required for rescue teams to reach the incident locations. The ratio of the capabilities of the rescue teams and the capabilities required by each incident location to the handling times. Proposed model of RUASP has been applied to numerical example, 13 incident locations that can have different severity level and 5 rescue teams that have travel time to go to each incident location and process time in each incident location. The example is solved by using exact method and GRASP metaheuristics. We compared two methods are exact method and GRASP metaheuristics. The developed GRASP Metaheuristics has near optimal with an average gaps of 1.75% compare to the results of exact method and reduce computation time from 71.28 hours to 20 seconds.

Sensitivity analysis has been conducted to determine the effect of parameter changing to the objective function values. The parameters used in this sensitivity analysis are process times and severity level of each incident location. Based on the sensitivity analysis results, minimum completion time is not sensitive to process time parameters but it is sensitive to severity level of incident locations.

VI. CONCLUSION

This study has developed a RUASP model by considering the ratio of capabilities requirements of incident locations and capabilities of the rescue teams to the handling time and fuzzy logic for the travel times and

the severity of the incident locations. This proposed model has been solved by using the GRASP metaheuristics approach. This solution method could obtain near optimal results in reasonable computation time.

For further research, we might develop a more efficient solution method and consider the uncertainty factors of travel times to the incident locations and the severity level of the disaster impact of each incident location.

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