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A Novel Approach for Scheduling Rescue Robot Mission Using Decision Analysis

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Abstract**—**In this paper, a new method for multi criteria decision making is represented whichspecifies a trajectory satisfying desired criteria including minimization of time. A rescue robot is defined to perform certain tasks before the arrival of rescue team, including evaluation of the probability of explosion in the area, detecting human-beings, and providing preliminary aidsin case of identifying signs of life, so that the security of the surroundings will have enhanced significantly for the individuals inside the disaster zone as well as the rescue team. The main idea behind our technique is using the Program Evaluation and Review Technique analysis along with Critical Path Method and use the Multi Criteria Decision Making (MCDM) method to decidewhich set of activities must be performed first. Since the disastrous event in one area may be well contagious to others, it is one of the robot's priorities to evaluate the relative adversity of the situation, using the above methods and prioritize its mission.

Keywords**—**PERT, CPM, MCDM.

I. Introduction

PROJECT management is the process of planning, organizing and controlling resources to achieve specific goals in scientific, industrial or even daily problems. Amond different methods of project management, Critical Path Method (CPM) is one of the most common tools for predicting and managing different short time or long time projects and is used to plan and control most modern projects such as Urban Search and Rescue operations [1]-[6]. A CPM network represents various activities that comprise a project and the precedence relationships between them. It can be analyzed to determine the criticality and float of activities, the level of resources needed during each day of project, and the dates at which important milestones will be achieved. Using CPM method, he constructed network for project management is an aid for control of project implementation with deterministic time durations. However, in real projects and in projects where human is involved, uncertainty is unavoidable due to various circumstances. Consequently, recognizing the uncertainty in the duration of activities helps in evaluating the project more realistically ahead of time. As a result, realization of CPM approach is not realistic in situations where uncertainty is involved. Program Evaluation and Review Technique (PERT) is another method of project management which offers a better solution by defining optimistic, pessimistic and most likely durations for activities instead of constant one value durations. In PERT mean values of durations of activities and their variances are calculated by:

$$\mu_i = \frac{1}{6}\left(a_i + 4m_i + b\right) \tag{1}$$

$$\sigma_i^2 = \frac{1}{36}\left(b_i - a_i\right)^2 \tag{2}$$

where *a*, *m* and *b* are the optimistic, most likely and pessimistic durations of activity *i* respectively [7]-[12]. Based on the Central Limit Theorem, the distribution describing a project'sduration is approximately normal.

Graphical Evaluation and Review Technique (GERT) is another method of project management which addresses the majority of the limitations associated with CPM and PERT since it allows assignment of probabilistic values for estimated durations of activities [13]-[15].

In this paper we have introduced a new method for project management for a scenario of Search and Rescue operations. The main idea behind our technique is using PERT/ MCDM combined analysis three optimistic, most likely and pessimistic values are given to all the factors effecting fulfillment of each activity in the project and degree of maximum fulfillment of criterion through every activity is calculated. Then CPM method is used to find critical path which actually shows best sequence of activities to be done. The remaining of the paper is organized as follows: Methodology is discussed in Section II, in Section III a typical search and rescue operation is discussed in detail as the case study of this paper, Section IV covers the results of applying this method on the project management of a USAR operation and Section V highlights the method and results.

II. Methodology

Given the graph representing the sequence of activities in a disastrous situation, the first step is to obtain necessary information for making decision. The mentioned information consist of: a) parameters affecting the decision making, which are mostly predefined and weighted, and b) estimating approximate durations of the activities which may occur during the mission. To reach a more realistic situation, the given information is provided in three different manners: optimistic, pessimistic and realistic (most likely). The degree of fulfillment of each parameter by each activity is calculated using PERT and the three-valued results of questionnaire of experts.

Having gained the necessary data, PERT algorithm is used

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for the process of durations of activities. The resulted output is the data needed for classic MCDM analysis which consists of: standard deviation, free slack and total slack for activities, and the probability of occurrence of activities before a certain time. The outputs of PERT and the criteria are given to classic MCDM algorithm as inputs. Classic MCDM makes a multi criteria decision making and assigns a decision value for each activity. These values are treated as the duration of each activity and are given to CPM. It is obvious that output Es (Earliest Starts representing the decision indexes of missions) of CPM can be interpreted as the degreeoffulfillment of the activities leading to a certain event. So by comparing the Es of the last events of several missions represented by graphs, we can deduce which mission fulfill our criteria more and must be executed. Consequently the most desirable network based on our criteria is chosen.

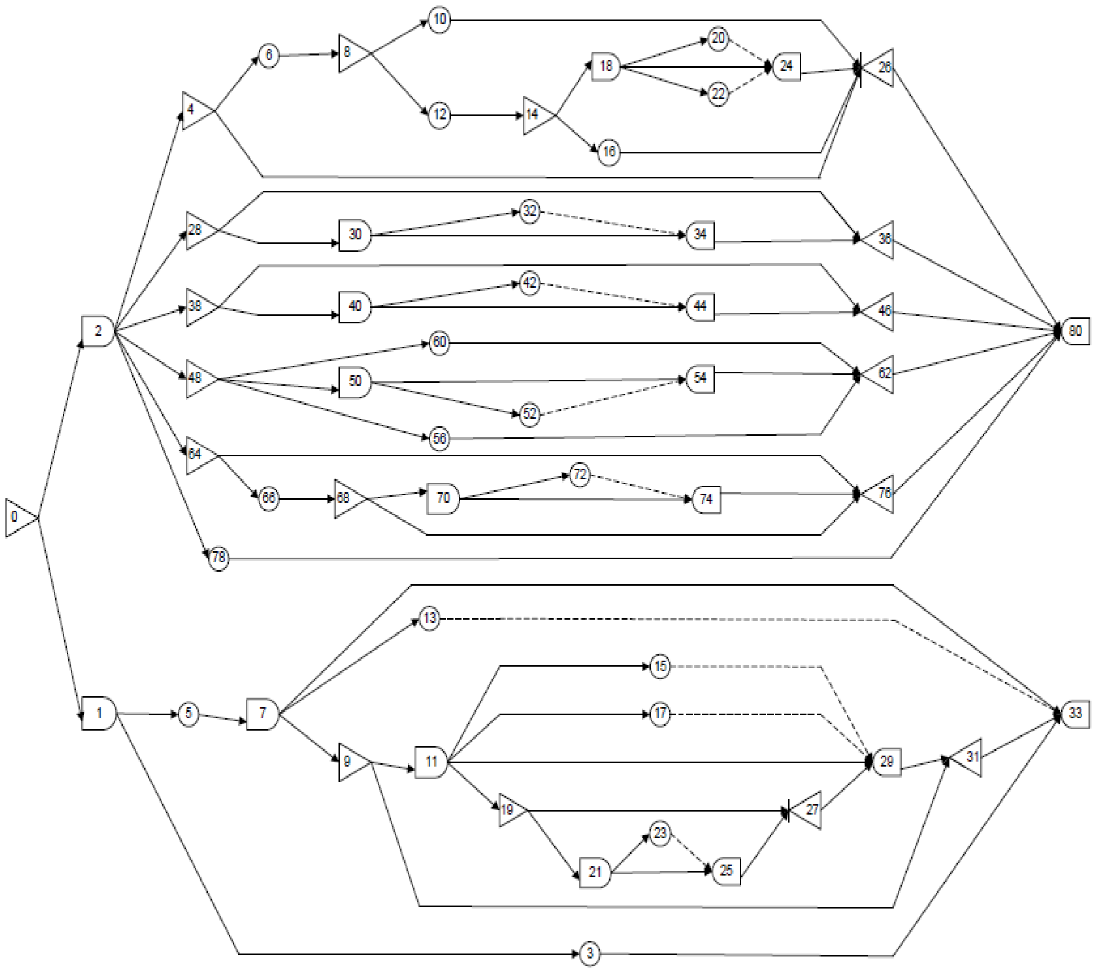

Fig. 1 Different choices for the robot in the form of a graph

III. Case Study

Two case studies are considered: first, a building is collapsed for a certain reason and there are catastrophic consequences including the conflagration and the possibility of explosion and dangers for human-being trapped under the ruins; second, a gas station is destroyed for the same reason and there is the risk of gas or petrol leak, and the explosion hazard. An intelligent robot must be organized to get a decision for its mission. We have plotted the different choices for the robot in the form of a graph shown in Fig. 1. The network is only for one stage of the robot's activities and these activities will be repeated iteratively (as a loop) until the whole network is covered. Since specifying the probabilities for choices in a general form network is practically too complicated, in order to clarify the outlines of our algorithm, we study only one decision part of the network. We have evaluated the durations of activities by means of a questionnaire of experts corresponding to one of the three categories optimistic, realistic and pessimistic. To include all other parameters effective in optimizing the trajectory, the criteria for choosing the path are tabulated andelaborated on. Afterwards, we define how important each parameter is. To define the main criteria for activities and their levels of importance, we have questioned a group of experts, categorized as before. These parameters include human and environmental indices, those affecting the robot itself, and

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those effective in the cost value. For the network of each case study, the parameters together with the resultsobtained by performing PERT algorithm for durations of activities are inputted to a function named “mcdm” which gives us the decision values for each activity based on the MCDM algorithm. Then, the obtained results are given to “cpm” function. Comparing the two Es of networks (Evaluation indexes of missions), it will be apparent whichnetwork the robot should decide to go first.

If the probability of finishing the task is low, it is preferred that the robot not chooses the defined network and tries other activities with higher prospect of accomplishment.

IV. Analysis of the Results

With the purpose of evaluating the results, we first explain the network of our case studies in detail. The list of activities for the network represented in Fig. 1, are shown in Table I. As it was mentioned before, in order to clarify the outlines ofour algorithm, we study only one decision part of the network.The related graph is represented by Fig. 2.

TABLE I
List of Activities for Network of Fig. 1

Activity	Description
0-2	Building
2-4	Applying the sensor to detect poisonous gas
4-6	Gas detected
6-8	Evaluating the probability of explosion by means of thermal sensors
8-10	Possibility of explosion present
10-26	Signaling warning to the rescue team for possibility of explosion
8-12	No Possibility for explosion
12-14	Considering the data of the sensor for CO2 and respiration
14-18	Human life detected
18-20	Providing the living person with oxygen
20-24	Dummy activity
18-24	Signaling assistance message to the rescue team
18-22	Signaling warning to the rescue team to wear gas masks
22-24	Dummy activity
24-26	--
14-16	No Human lifedetected
16-26	Signaling warning to the rescue team to wear gas masks
4-26	No dangerous gas detected
26-80	--
2-28	Applying the sensor to detect CO2
28-36	No CO2 detected
28-30	CO2 detected
30-32	Signaling assistance message to the rescue team
32-34	Dummy activity
30-34	Providing the living person with oxygen
34-36	--
36-80	--
2-38	Noise detection
38-46	No Noise detected
38-40	Noise detected
40-42	Providing the living person with oxygen
42-44	Dummy activity
40-44	Signaling assistance message to the rescue team
44-46	---
46-80	---
2-48	Applying the sensor to measure temperature
48-60	Low temperature
60-62	Signaling message to the rescue team to evaluate the place for possible conflagration
48-50	High temperature
50-54	Signaling assistance message to the rescue team
50-52	Applying the extinguisher
52-54	Dummy activity
54-62	--
48-56	Extremely high temperature
56-62	Applying the extinguisher
62-80	--
2-64	Detecting bumpy plains
64-76	No Roughnessdetected
64-66	Roughness detected
66-68	Considering the data of the sensor of CO2 and respiration
68-70	No Human lifedetected
70-72	Leveling the path
72-74	Dummy activity
70-74	Signaling message to the rescue team responsible for leveling the path
74-76	--
68-76	Human life detected
76-80	--
2-78	Taking photos of the surroundings
78-80	Sending the photos
0-1	Gas Station
1-5	Detecting the temperature of the surroundings with sensor
5-7	Moving to the point with highest temperature
7-33	Using nitrogen to cool down the surroundings
7-13	Applying the extinguisher
13-33	Dummy activity
7-9	Applying the sensor to detect gas leakage
9-11	gas leakage detected
11-15	Signaling warning to the rescue team
15-29	Dummy activity
11-17	Using nitrogen to cool down the surroundings
17-29	Dummy activity
11-29	Applying the extinguisher
11-19	Applying the sensor to detect CO2
19-27	No CO2 detected
19-21	CO2 detected
21-23	Providing the living person with oxygen
23-25	Dummy activity
21-25	Signaling assistance message to the rescue team
25-27	---
27-29	---
29-31	---
31-33	---
9-31	---
1-3	Taking photos of the surroundings
3-33	Sending the photos

* Activities with the dashed lines in the description do not signify any specific activity. Theyrepresent the priority considered in making decision

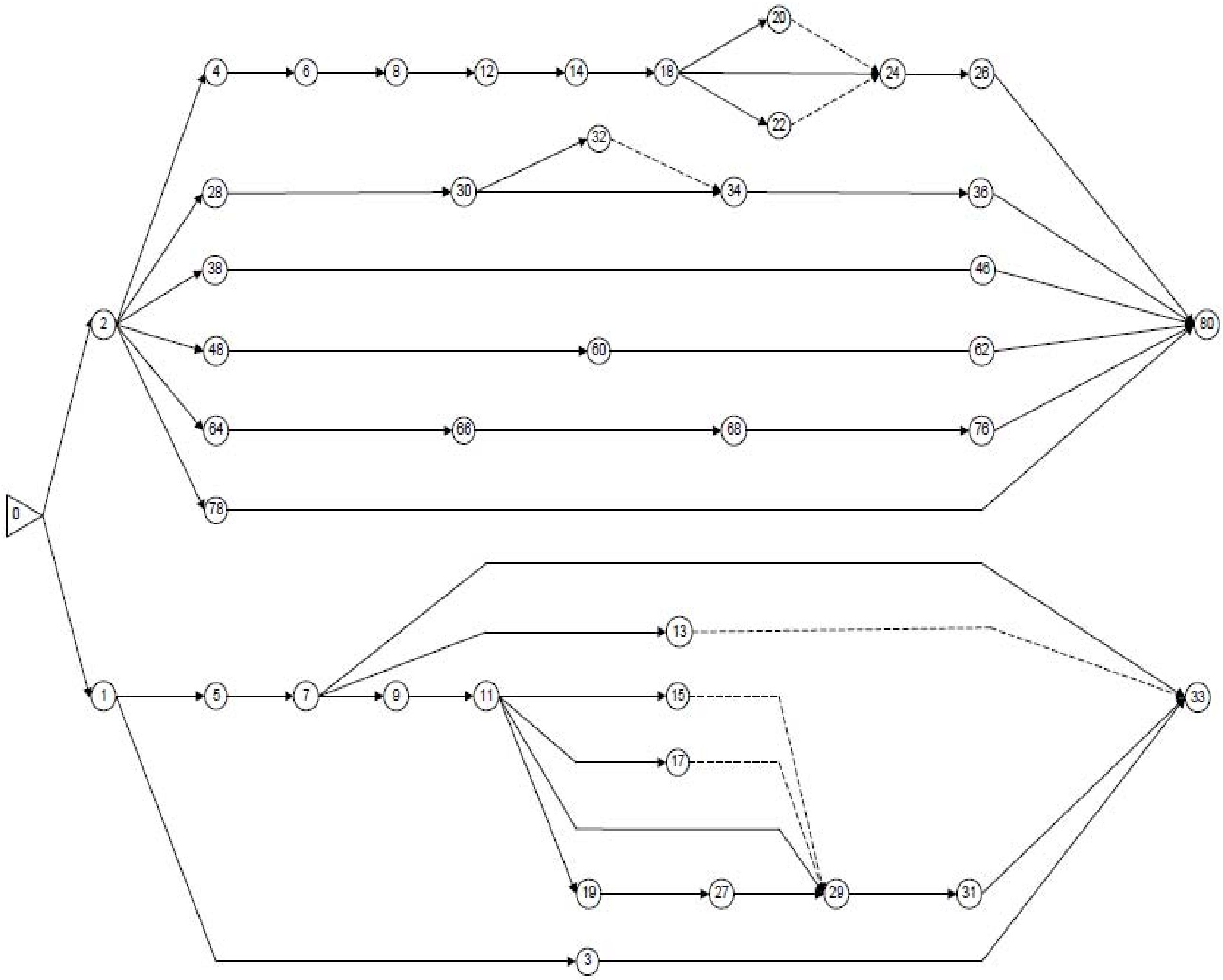

Fig. 2 Graph of activities for the mentioned case study

The main criteria for choosing the path are listed in Table II. Tables III and IV represent the criteria of Table II accompanied by the degree of realization for each activity of gas station and building sub-graphs, respectively, where for each criterion three optimistic, realistic and pessimistic values are defined by means of a questionnaire of experts. In these tables H, E and R indicate parameters concerning human, environment and the robot, respectively.

TABLE II
MAIN CRITERIA FOR CHOOSING THE PATH

Human parameters	Environmental parameters	Parameters concerning the robot
Capacity for reducing the life risk of the rescue team Rescuing and preventing personal damage to the injured person	Prevention of air poisoning in the surroundings Prevention destruction of path for the rescue team Prevention of fire danger in the peripheries	Destruction of accessories Annihilation of the robot Repairable damage to the robot Damage negligible for the robot to be able to continue its task

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TABLE III
DEGREE OF FULFILLMENT OF THE MAIN CRITERIA BY EACH ACTIVITIES OF BUILDING

Activity	Duration			H1			H2			E1			E2			E3			R1			R2			R3			R4		
Numbers	**a**	**m**	**b**	**a**	**m**	**b**	**a**	**m**	**b**	**a**	**m**	**b**	**a**	**m**	**b**	**a**	**m**	**b**	**a**	**m**	**b**	**a**	**m**	**b**	**a**	**m**	**b**	**a**	**m**	**b**
0-2	0	0	0	0.75	0.8	0.95	0.75	0.8	0.95	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2-4	2	5	8	0	0	0	0.75	0.8	0.95	0.5	0.6	0.7	0	0	0	0.5	0.6	0.7	0	0	0	0	0	0	0	0	0	0	0	0
2-28	2	6	10	0	0	0	0.75	0.9	0.95	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2-38	2	6	10	0	0	0	0.8	0.9	0.95	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2-48	2	6	8	0.65	0.8	0.85	0.65	0.8	0.85	0.3	0.5	0.6	0.2	0.4	0.5	0.5	0.6	0.8	0	0	0	0	0	0	0.4	0.25	0.1	0.5	0.3	0.2
2-64	3	7	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2-78	3	6	10	0	0	0	0.25	0.35	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6-8	6	9	15	0.75	0.9	0.95	0.35	0.5	0.6	0	0	0	0	0	0	0	0	0	0.6	0.5	0.3	0.6	0.4	0.3	0.7	0.5	0.3	0.7	0.6	0.4
8-12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12-14	3	4	7	0	0	0	0.5	0.7	0.85	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14-18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18-20	20	35	45	0	0	0	0.65	0.8	0.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18-22	2	4	8	0.65	0.8	0.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18-24	2	4	8	0	0	0	0.65	0.8	0.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20-24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22-24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24-26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26-80	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28-30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30-32	2	3	7	0	0	0	0.75	0.9	0.95	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30-34	15	25	40	0	0	0	0.75	0.85	0.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32-34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
34-36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36-80	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38-46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
46-80	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
48-60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
60-62	2	4	7	0	0	0	0.65	0.8	0.9	0.6	0.8	0.95	0.6	0.8	0.9	0.8	0.9	0.95	0	0	0	0	0	0	0	0	0	0	0	0
62-80	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
64-66	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
66-68	3	4	7	00	0	0	0.5	0.6	0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
68-76	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
76-80	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
78-80	2	4	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE IV
DEGREE OF FULFILLMENT OF THE MAIN CRITERIA BY EACH ACTIVITIES OF GAS STATION

Activity Numbers	Duration			H1			H2			E1			E2			E3			R1			R2			R3			R4		
	a	m	b	a	m	b	a	m	b	a	m	b	a	m	b	a	m	b	a	m	b	a	m	b	a	m	b	a	m	b
0-1	0	0	0	0.6	0.8	0.9	0.65	0.8	0.9	0.7	0.85	0.95	0.5	0.6	0.8	0.7	0.85	0.95	0.9	0.85	0.75	0.95	0.9	0.75	0.95	0.9	0.75	0.65	0.5	0.4
1-3	6	15	25	0.1	0.15	0.4	0.1	0.15	0.25	0	0.05	0.15	0	0.05	0.15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1-5	5	6	10	0	0.05	0.2	0.1	0.15	0.25	0.15	0.25	0.3	0.1	0.15	0.3	0.15	0.25	0.3	0	0	0	0	0	0	0	0	0	0	0	0
3-33	1	3	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5-7	3	10	20	0.05	0.1	0.25	0.1	0.25	0.4	0.15	0.25	0.3	0.05	0.15	0.2	0.2	0.25	0.35	0.95	0.8	0.7	0.9	0.8	0.75	0.95	0.9	0.8	0.9	0.8	0.75
7-9	3	8	12	0.6	0.8	0.95	0.75	0.9	0.95	0.65	0.8	0.85	0.6	0.75	0.85	0.6	0.75	0.85	0.4	0.3	0.1	0.4	0.2	0.1	0.4	0.3	0.25	0.6	0.5	0.3
7-13	18	24	40	0.25	0.4	0.6	0.6	0.8	0.9	0.65	0.8	0.9	0.7	0.75	0.85	0.65	0.8	0.9	0.8	0.6	0.5	0.8	0.6	0.5	0.9	0.7	0.6	0.95	0.9	0.75
7-33	20	28	40	0.4	0.6	0.75	0.75	0.9	0.95	0.75	0.9	0.95	0.75	0.9	0.95	0.75	0.9	0.95	0.6	0.4	0.3	0.7	0.5	0.4	0.95	0.8	0.65	0.95	0.9	0.75
9-11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11-15	2	3	6	0.75	0.9	0.95	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11-17	20	25	35	0.65	0.8	0.9	0.65	0.8	0.9	0.7	0.85	0.95	0.7	0.85	0.95	0.6	0.75	0.8	0.5	0.3	0.15	0.5	0.3	0.25	0.6	0.5	0.3	0.65	0.5	0.3
11-19	3	8	12	0	0	0	0.75	0.9	0.95	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11-29	14	20	30	0.4	0.6	0.75	0.6	0.75	0.8	0.65	0.8	0.9	0.1	0.25	0.4	0.6	0.7	0.85	0.5	0.4	0.25	0.4	0.25	0.1	0.65	0.5	0.35	0.8	0.75	0.55
13-33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15-29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17-29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19-27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27-29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29-31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31-33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

By applying (1) and (2) to each column of tables, we've got a mean value and variance (standard deviation) for each activity in each network, which can be used to be applied to the "mcdm" function. This function uses the weights defined for each criterion accompanied by the values mentioned above- which represents the degree of satisfaction of each criterion by each activity – to produce decision values as outputs. Since the importance given to some parameters are considerable compared to the others, and these important parameters have negative effect on our decision, the decisions values for these parameters would be negative values and we cannot use them as inputs to the CPM (because the durations should be non-negative).So we have normalized the values in the range [1 10] which are given to CPM as inputs, afterward. The third column of the cpmout (Es) represents the degree of satisfaction of each activity in each network (mission index). We have got 52.9434and 27.0122for the networks of the gas station and building, respectively. Comparing the results, the robot will obviously perform the set of activities defined for the gas station first.

V. CONCLUSION

A new method for multi criteria decision making problem is introduced and formulated by the CPM & PERT method and solved using MCDM algorithm. Our case study was a rescue robot which is designed to perform certain tasks including evaluation of the probability of explosion in the area and etc., before the arrival of rescue teams. Applying desired criteria to the problem and using the mentioned algorithm an optimal decision is made and a certain mission that satisfies the desired parameters most is chosen among others.

REFERENCES

[1] Julio C. Martinez, Photios G. Ioannou2, "State-Based Probabilistic Scheduling Using STROBOSCOPE'sCPM Add-On" , *Proceedings, Construction Congress V, ASCEStuart D. Anderson,ed*

[2] Sohrab Khanmohammadi, "A New Approach for Predicting Project Duration Using Beta Shape Membership Functions and Simulation." *Proc. of The 40th International Conference on Computers & Industrial Engineering*, pp. 1179-1183, July 2010.

[3] S. Mubarak, "The Critical Path Method (CPM) in Construction Project Scheduling and Control", 2nd Edition, *John Wiley & Sons, Inc.*, Hoboken, NJ, 2010, Chapter 4.

[4] M. Lu, H. Li, " Resource-Activity Critical-Path Method for ConstructionPlanning", *Journal of Construction Engineering And Management*, pp. 412- 420, 2003.

[5] M. Sniedovich, "Towards an AoA-Free Courseware forthe Critical Path Method", *INFORMS Transactions on Education*, Vol. 5, No. 2, pp. 47–63, January 2005.

[6] B. Nagy, "Using the Critical Task Method with the Critical Path Method", *Proc. of the 30th Annual Project Management Institute 1999 Seminars & Symposium,* Philadelphia, 1999.

[7] W. Cass, J. McElroy, "The use of Program Evaluation and Review Technique (PERT) in the design and control of a medical research project, *Journal of Computers and Biomedical Research*, Vol. 2, No. 2, PP. 176- 186. October 1968.

[8] W. Power,"Program evaluation and review technique", University of Mississippi Digital Accounting Collection, 1962.

[9] J. Pfeiffer, J. Jones, "An Introduction to PERT", *The 1972 Annual Handbook for Group Facilitator, San Diego, CA: Pfeiffer & Company, 1972.*

[10] "Practical Optimization: a Gentle Introduction", John W. Chinneck, Ch. 11, 2009.

[11] T. Healy, "Activity Subdivision and PERT Probability Statements", *Journal of Operations Research*, Vol. 9, No. 3, pp. 341-348, June 1961.

[12] C. Xiang, W. Yue, "Program Evaluation and Review Technique Based on Moment Generating Function and its Application in Software Engineering", *Proc. of IEEE World Congress on Software Engineering*, pp. 49-52, 2009.

[13] P. Randolph, R. Ringeisen, "A network learning model with GERT analysis", *Journal of Mathematical Psychology*, Vol. 11, No. 1, pp. 59-70, Feb 1974.

[14] G. Cates, “Improving Project Management with Simulation and Completion Distribution Functions”, PhD dissertation, University of Central Florida, Orlando, 2004.
[15] M. Li, “A Robust Planning and Control Methodology for Design-Build Fast-Track Civil Engineering and Architectural Projects”, Master of Science thesis, Massachusetts Institute of Technology, Feb 1999.