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Operations Scheduling of Sugarcane Production Using Classical Gert Method (Part Ii: Preserve Operations, Harvesting and Ratooning)

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Abstract

Graphical Evaluation and Review Technique (GERT) is a systems analysis technique for project management. GERT provides a visual picture of the system and helps to analyse the system in a less inductive manner. Therefore, the purpose of this paper is studying the application of project scheduling in agriculture, for operations scheduling of sugarcane production (preserve operations, harvesting and rationing) using classical GERT method in Khuzestan province of Iran. Results showed that the network model was able to answer any statistic all the questions concerning the project. GERT networks are increasingly becoming a powerful tool for modelling, scheduling, planning, controlling and analysing of agricultural mechanization projects.

Keywords: Scheduling, GERT network, Agricultural Mechanization, Sugarcane

1. Introduction

Many different techniques and tools have been developed to support better project planning and these tools are used seriously by a large majority of project managers (Fahimifard & Kehkha, 2009; Fox & Spence, 1998; Pollack, 1998). Graphical Evaluation and Review Technique (GERT) is popularly a graphical tool for the analysis of complex systems because GERT can easily analyse stochastic networks with logical node and directed branches (Lin et al, 2011). A GERT network is an activity-on-the-arc network. The network may contain cycles, allowing for the multiple execution of activities during the execution of the project. Each arc (ij) is assigned a weight vector (Pij, Fij). Pij > 0 is the conditional execution probability of the corresponding activity (ij) given that project event i has occurred. Fij is the conditional distribution function of the nonnegative duration dij of activity (ij) given that (ij) is carried out. Pij and Fij are assumed to be independent of the number of times that project event i have occurred or activity (ij) has been executed before, respectively (Neumann, 1999; Neumann, 1990; Neumann, 1984; Neumann & Steinhardt, 1979). Since the efficiency and capabilities of GERT networks for modelling, simulation, planning, scheduling and analysis of the projects in complicated systems had been proved and confirmed in different fields of industry (Matsumoto et al, 2007; Ahcom 2004; Takanobu et al, 2004; Gauri, 2003; Kenzo & Nobuyuki, 2002). Also, the planning and project controlling techniques, especially network models, have been used in agricultural projects (Monjezi et al, 2012a; Monjezi et al, 2012b; Abdi et al, 2009). Therefore, the purpose of this paper is studying the application of project scheduling in agriculture, for operations scheduling of sugarcane production (preserve operations, harvesting and rationing) using classical GERT method.

2. Materials and Methods

The study was carried out in Khuzestan province of Iran in 2015. Data were collected from variety sources such as reports and statistics of meteorological synoptic stations, opinions and

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comments of Khuzestan Sugarcane and by-Product Research and Training Institute experts and reports and statistics of Sugarcane Agro-Industry. All activity times are given in day. For the sake of completion, a brief introduction of GERT (Manju, & Pooja, 2007; Cheng, 1994; Whitehouse, 1973) is given. GERT is a procedure, which combines the disciplines of the flow graph theory, Moment Generating Function (MGF) and Project Evaluation and Review Technique (PERT) for analysing stochastic networks having logical nodes and directed branches. Each branch has a probability that the activity associated with it will be performed. Therefore, GERT provides a visual picture of the system by means of the corresponding graph and makes it possible to analyse the given system in a less inductive manner. The results are obtained based on the MGF using Mason's formula, which takes care of all possible products of transmittances of non-intersecting loops described later.

The following steps are employed, when applying GERT:

1. Convert a qualitative description of a system or problem to a model in a stochastic network form.

2. Collect the necessary data to describe the transmittances of the network.

3. Apply Mason's rule to determine the equivalent function or functions of the network.

4. Convert the equivalent function into the following two performance measures of the network:

(a) The probability that a specific node is realized.

(b) The moment generating function of the time associated with a node, if it is realized.

5. Make inferences concerning the system under study from the information obtained in the Step 4.

GERT is based on the following definitions and rules:

• GERT network:

A GERT network generally contains one of the following two types of logical nodes:

(a) Nodes with Exclusive-Or input function and Deterministic output function.

(b) Nodes with Exclusive-Or input function and Probabilistic output function.

Exclusive-Or input: The node is realized; when any arc leading into it is realized. However, one and only one of the arcs can be realized at a given time.

Deterministic output: All arcs emanating from the node are taken, if the node is realized.

Probabilistic output: Exactly one arc emanating from the node is taken, if the node is realized.

In this paper type (b) nodes are used.

• Path:

A path is a series of branches, which joins two nodes and do not pass through any node more than once. The value of a path is the product of the so-called transmittances along the path.

• Loop:

A loop is a series of branches, which emerges from a node, and eventually returns to that node without passing through any node more than once. The value of a loop is equal to the product of the transmittances around the loop. A first order loop can be viewed as a loop having a consecutive path of arrows emerging from a node and returning to the same node. A self-loop can be viewed as a degenerated first order loop.

A Loop of order n is represented by a set of n disjoint first order loops.

• Mason's Rule:

In an open flow graph, write down the product of the transmittances along each path from the independent to the dependent variable. Multiply its transmittance by the sum of the non-touching loops to that path. Sum these modified path transmittances and divide by the sum of all the loops in the open flow graph yielding the transmittance T:

$$T = \frac{\sum(path \sum nontouching\ loops)}{\sum loops} \tag{1}$$

Where:

$$\sum nontouching\ loops = 1 - \sum first\ order\ nontouching\ loops + \sum second\ order\ nontouching\ loops - \sum third\ order\ nontouching\ loops + \cdots$$

$$\sum loops = 1 - \sum first\ oeder\ loops + \sum second\ order\ loops - \cdots$$

W-function for GERT:

In a network G with only GERT nodes, let the random variable Y_{ij} be the duration of the activity (i, j) and f (y_{ij}) be the conditional probability of the duration y_{ij} of the activity (i, j).

The conditional MGF of the random variable Y_{ij} is given as:

$$M_{ij}(s) = E[e^{sY_{ij}}] = \sum e^{sY_{ij}} f(Y_{ij}) \tag{2}$$

The conditional probability p_{ij} that the activity (i, j) will be undertaken, given that node i is realized, is multiplied by the MGF to yield a W-function:

$$W_{ij}(s) = p_{ij}M_{ij}(s) \tag{3}$$

The W-function is used to obtain the information about a relationship between the nodes.

3. Results and Discussion

GERT network model resulted from sugarcane production (preserve operations, harvesting and rationing) as follows (Fig. 1). Parameters of sugarcane production classical GERT network are presented in Table 1. Due to the nature of the data, the distribution density function of time for each activity, the constant function with zero variance. According to the Materials and Methods, the probability, mean and variance of the completion time of sugarcane production obtained. The worth of different parts of the network is calculated. The relationship 4 shows the worth of equivalent branch that connect the starting node to node 86.

$$W_{(t)_{start-86}} = \left[\left(W_{(t)_{121}} * W_{(t)_{122}}\right) + W_{(t)_{120}}\right] * W_{(t)_{119}} = e^{2t}\left(0.9e^{4t} + 0.1\right) \tag{4}$$

By placing t = 0 in function $W_{(t)_{start-86}}$, probability of Equivalent branch was calculated (according to relationship 5.

$$P_{start-86} = W_{(0)_{83-86}} = e^{0}\left(0.9e^{0} + 0.1\right) = 1 \tag{5}$$

To calculate the mean time from starting node to node 86, the first derivative of the function $W_{(t)_{start-86}}$ was taken and the answer was 5.6 days. And by using the relationships 3 and taking second derivative of function $W_{(t)_{start-86}}$, the variance was obtained 1.44. Also worth of network loops was calculated as follow:

1. The worth of the loop N. 1 with track start-86:

$$W_{(t)_{L_{11}}} = 0.7 * e^{68t} = 0.7e^{68t}$$

2. The worth of the loop N. 2 with track 86-87-88-89-90-start:

$$W_{(t)_{L_{12}}} = 0.1e^{7t}\left(0.9e^{4t} + 0.1\right)$$

3. The worth of the loop N. 3 with track 86-91-start:

$$W_{(t)_{L_{13}}} = 0.1e^{5t}$$

4. The worth of the loop N. 4 with track 86-92-93-94-95-96-97-98-99-100-101-102-103-104-105-106-107-108-109-start:

$$W_{(t)_{L_{14}}} = 0.05e^{41t} * \frac{e^t}{1-0.5e^t}$$

A prerequisite for completing operation is that each loops in the network be done one time and with significant order (in the case of first loop, Activity No. 123, was repeated 17 times). So the worth of equivalent branch between starting node and node No. 109 was obtained as follows:

$$\begin{aligned} W_{(t)_{start-109}} &= W_{(t)_{start-86}} * W_{(t)_{L_{11}}} * W_{(t)_{L_{12}}} * W_{(t)_{L_{13}}} * W_{(t)_{L_{14}}} \\ &= e^{2t}(0.9e^{4t}+0.1) * e^{68t} * e^{7t}(0.9e^{4t}+0.1) * e^{5t} * 0.5 * e^{41t} \\ &* \frac{e^t}{1-0.5e^t} = e^{123t} * (0.9e^{4t}+0.1)^2 * \frac{e^t}{1-0.5e^t} * 0.5 \end{aligned} \tag{6}$$

By placing t = 0 in the function $W_{(t)_{start-86}}$, the probability of starting node to node 109 was obtained a hundred percent.

By using Equation 3, the moment generating function $W_{(t)_{start-86}}$ is:

$$M_{(t)_{start-109}} = e^{123t} * (0.9e^{4t}+0.1)^2 * \frac{e^t}{1-0.5e^t} * 0.5 \tag{7}$$

Average time between starting node and node N.109, by deriving from the moment generating function $W_{(t)_{start-86}}$ and placing t = 0 was obtained as follows:

$$\begin{aligned} \mu(t) = 123e^{123t}[(0.9e^{4t}+0.1)^2 * \frac{e^t}{1-0.5e^t} * 0.5] + [7.2e^{4t}(0.9e^{4t}+0.1)] * [e^{123t} \\ * \frac{e^t}{1-0.5e^t} * 0.5] + [\frac{e^t}{(1-0.5e^t)^2} * 0.5] * [e^{123t} * (0.9e^{4t}+0.1)^2] \end{aligned}$$

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$$\mu(0) = 132.2 = \mu$$

The second derivative of the moment generating function $W_{(t)_{start-86}}$ and placing t = 0, the variance between the two nodes was obtained as follows:

$$\begin{aligned}\frac{\partial^2 M_{(t)_{start-109}}}{\partial t^2} = {} & [123 * 123e^{123t} * \left(0.9e^{4t} + 0.1\right)^2 * \left(\frac{e^t}{1-0.5e^t} * 0.5\right)] + [7.2e^{4t} \\ & * \left(0.9e^{4t} + 0.1\right) * 123e^{123t} * \left(\frac{e^t}{1-0.5e^t} * 0.5\right)] + [\frac{e^t}{(1-0.5e^t)^2} * 0.5 \\ & * 123e^{123t} * \left(0.9e^{4t} + 0.1\right)^2] + [25.92e^{131t} * \left(\frac{e^t}{1-0.5e^t} * 0.5\right)] \\ & + [127e^{127t} * 7.2\left(0.9e^{4t} + 0.1\right) * \left(\frac{e^t}{1-0.5e^t} * 0.5\right)] + [\left(\frac{e^t}{(1-0.5e^t)^2} \right. \\ & \left. * 0.5\right) * 7.2e^{127t}\left(0.9e^{4t} + 0.1\right)] + [\frac{e^t(1+0.5e^t)}{(1-0.5e^t)^3} * 0.5 * e^{123t} \\ & * \left(0.9e^{4t} + 0.1\right)^2] + [123e^{123t} * \frac{e^t}{(1-0.5e^t)^2} * 0.5 * \left(0.9e^{4t} + 0.1\right)^2] \\ & + [7.2e^{4t} * \left(0.9e^{4t} + 0.1\right) * e^{123t} * \frac{e^t}{(1-0.5e^t)^2} * 0.5]\end{aligned}$$

$$\frac{\partial^2 M_{(0)_{start-109}}}{\partial t^2} = 17496.12$$

$$Var_{start-109} = 17496.12 - (132.2)^2 = 19.28$$

For each node, to conclude about the probability, mean and variance can use the above procedure and predict various events during operations.so with due attention to certain events that are occurring in the tracks of operation, good decisions can be adopted.

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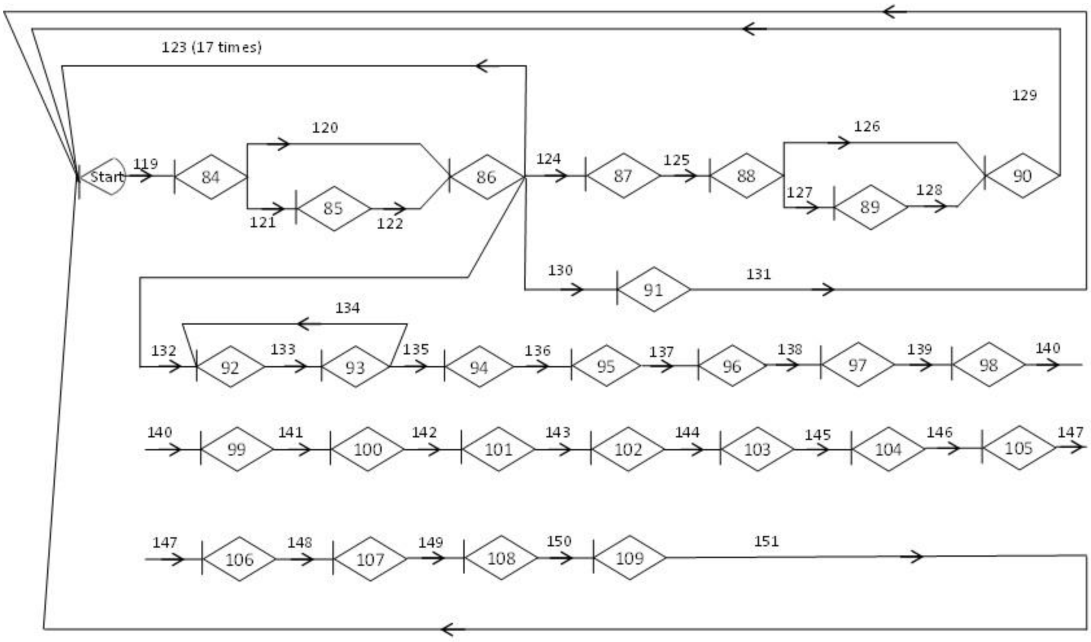

Figure 1. Operations of sugarcane production GERT network

4. Conclusion

The purpose of this paper is studying the application of project scheduling in agriculture, for operations scheduling of sugarcane production (preserve operations, harvesting and rationing) using classical GERT method in Khuzestan province of Iran. Results showed that the network model was able to answer any statistic all the questions concerning the project. GERT networks are increasingly becoming a powerful tool for modelling, scheduling, planning, controlling and analysing of agricultural mechanization projects.

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Table 1. Parameters of sugarcane production classical GERT network

Activity code	Activity description	Activity time	Repetition (times)	Moment Generating Function $M_{ij}(t)$	Probability P_{ij}	Worth of activity $W_{ij}(t)$
119	Sampling and determination of crop water requirement	2	1	Exp(2t)	1	Exp(2t)
120	Decide to non- irrigation	0	1	1	0.1	0.1
121	Decide to irrigation	0	1	1	0.9	0.9
122	Irrigation	4	1	Exp(4t)	1	Exp(4t)
123	Irrigation (The number of repeat 17 times)	4	17	Exp(68t)	0.7	0.7× Exp(68t)
124	Biological pest control- parasitoid wasps (second stage)	1	1	Exp(1t)	0.1	0.1× Exp(1t)
125	Sampling and determination of crop fertilizer requirement	2	1	Exp(2t)	1	Exp(2t)
126	Decide to non- top dressing	0	1	1	0.1	0.1
127	Decide to top-dressing	0	1	1	0.9	0.9
128	Irrigation and top-dressing	4	1	Exp(4t)	1	Exp(4t)
129	Irrigation	4	1	Exp(4t)	1	Exp(4t)
130	Biological pest control- parasitoid wasps (third stage)	1	1	Exp(1t)	0.1	0.1× Exp(1t)
131	Irrigation	4	1	Exp(4t)	1	Exp(4t)
132	Biological pest control- parasitoid wasps (fourth stage)	1	1	Exp(1t)	0.1	0.1× Exp(1t)
133	Sugarcane sap test determine the time of harvesting	1	1	Exp(1t)	1	Exp(1t)
134	Diagnosis of product prematurity	0	1	1	0.5	0.5
135	Diagnosis of product ripe	0	1	1	0.5	0.5
136	Cut off irrigation and collecting pipes	1	1	Exp(1t)	1	Exp(1t)

Activity code	Activity description	Activity time	Repetition (times)	Moment Generating Function $M_{1j}(t)$	Probability P_{1j}	Worth of activity $W_{1j}(t)$
137	Leveling of marginal lands and filling the beginning of furrows	1	1	Exp(1t)	1	Exp(1t)
138	The spunk supply and fire field	1	1	Exp(1t)	1	Exp(1t)
139	Harvester, tractor and transporter supply	2	1	Exp(2t)	1	Exp(2t)
140	Oil and fuel for harvesting	1	1	Exp(1t)	1	Exp(1t)
141	Harvesting and carrying cane to the factory	8	1	Exp(8t)	1	Exp(8t)
142	Tractor, trailer and grap loader supply	2	1	Exp(2t)	1	Exp(2t)
143	Liliko	2	1	Exp(2t)	1	Exp(2t)
144	Oil and fuel for ratooning	1	1	Exp(1t)	1	Exp(1t)
145	Subsoiling	5	1	Exp(5t)	1	Exp(5t)
146	Reshaper supply	1	1	Exp(1t)	1	Exp(1t)
147	Ratoon and reshape	4	1	Exp(4t)	1	Exp(4t)
148	Ratoon fertilizering	4	1	Exp(4t)	1	Exp(4t)
149	Ratoon spray	2	1	Exp(2t)	1	Exp(2t)
150	Piping for irrigation	1	1	Exp(1t)	1	Exp(1t)
151	Primary irrigation	4	1	Exp(4t)	1	Exp(4t)

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