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Operations Scheduling of Sugarcane Production Using Classical GERT Method (Part I: Land Preparation, Planting and Preserve Operations)

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Abstract

Analysis and evaluation of agricultural systems use these criteria: energy, economic, agronomy, environmental conservation and time. Because of time importance indicator for reducing timeliness cost, project scheduling techniques are used. Graphical Evaluation and Review Technique (GERT) is widely used as a tool for managing projects. In this research GERT Networks were used and operations scheduling of sugarcane production (land preparation, planting and preserve operations) in Khuzestan province of Iran as a case study was analysed, by using WinQsb software. Critical activities, events and path were determined. The earliest project completion time is 214.03 days. The results show a high potential for operations scheduling of sugarcane production.

Keywords: Scheduling, GERT network, Agricultural Mechanization, Sugarcane

1. Introduction

Analysis and evaluation of agricultural systems use these criteria: energy, economic, agronomy, environmental conservation and time. Because of time importance indicator for reducing timeliness cost and work breakdown, project scheduling techniques and work study especially network models are used. Such a network would as a powerful tool available a farm manager to plan, schedule, monitor, and control a project (Monjezi et al, 2012a). Since GERT (Graphical Evaluation and Review Technique) Networks have most of the advantages associated with networks and enables system analyst in exact evaluation of certain types of networks, in this research GERT Networks were used and operations scheduling of sugarcane production in Khuzestan province of Iran as a case study was analysed. Manju and Pooja (2007) GERT technique was applied to model and analyse the reliability of the above system. One of the strengths of the GERT network is the graphical representation, which is intuitive and easy to understand (Manju & Pooja, 2007). Abdi et al. performed Modeling and Analysis of Mechanization Projects of Wheat Production by GERT Networks. Results showed that the network model was able to answer any statistic questions concerning with the project (Abdi et al, 2010 and Abdi et al, 2009).

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 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. Having known perform once probability (p_{ij}) and three time estimates for an activity: optimistic time (t_o), most likely time (t_m) and pessimistic time (t_p), then expected time (t_e) and variance (v_{te}) was calculated for an activity from formulas (1) and (2):

$$t_e = \mu = \frac{t_o + 4t_m + t_p}{6} \quad (1)$$

$$v_{t_e} = \left(\frac{t_p - t_o}{6}\right)^2 \quad (2)$$

The leading route calculation (the first node of the last node in the network starts to go) as soon as the expected (mean) and its variance of the occurrence of any event, relations (3) and (4) are calculated, respectively.

$$\mu^j_{T_E} = \max\left\{\mu^j_{T_E} + t^{ij}_e, \ldots\right\} \quad (3)$$

$$\delta^{2j}_{T_E} = \delta^{2i}_{T_E} + v^{ij}_{t_e} \quad (4)$$

Where:

$\mu^j_{T_E}$: Expected earliest occurrence time

T_E: Earliest time of occurrence of a random variable

$\delta^{2j}_{T_E}$: Earliest time the event variance

And in computing the backward direction (from the last node to the first node in the network has begun and will continue) latest times the expected (mean) and variance of the occurrence of any event that the relations (5) and (6) are obtained.

$$\mu^i_{T_L} = \min\left\{\mu^j_{T_L} - t^{ij}_e, \ldots\right\} \quad (5)$$

$$\delta^{2i}_{T_L} = \delta^{2j}_{T_L} + v^{ij}_{t_e} \quad (6)$$

Where:

$\mu^i_{T_L}$: Expected latest occurrence time

T_L: Latest time of occurrence of a random variable

$\delta^{2i}_{T_L}$: Latest time the event variance

Events in GERT slack for calculating network, since the slack for the event is the general latest time minus the earliest time of occurrence of the event and also the network and the earliest time of occurrence of GERT latest both random variables are defined, So the slack (S) is also a random variable from equation (7) is calculated.

$$S = T_L - T_E \tag{7}$$

The slack is obtained by subtracting two independent random variables with a normal distribution and to calculate the mean and variance of the relations (8) and (9) are used, respectively.

$$\mu_S = E(S) = \mu_{T_L} - \mu_{T_E} \tag{8}$$

$$\delta^2_S = \mathrm{var}(S) = \delta^2_{T_L} + \delta^2_{T_E} \tag{9}$$

All calculations were performed using the software Win QSB (Windows Quantitative System for Business)**.**

3. Results and Discussion

Time estimates (optimistic time, most likely time and pessimistic time), probability and Variance for each activity of sugarcane production (land preparation, planting and preserve operations) were calculated (Table 1). The results of Activity Analysis for project scheduling (project completion time, critical activities, earliest and latest start time, earliest and latest finish time and slack time) of sugarcane production, by using WinQsb software, have been shown in Table 1. The Table 1 shows that the earliest project completion time is 214.03 days. Some activities have a positive slack and some may have zero slack. Positive slack for each activity, showing the progress of the project ahead of schedule. In fact, there are many sources for that activity. Zero slack means being critical of the activity, the activity must occur at a specific time; otherwise they will schedule the project. Zero slack in progress, indicates the progress of the project schedule and resources are appropriately allocated. Critical activities, events (event, the result of completing one or more activities), or paths, if they delayed, will delay completion of the project. A project's critical path is understood to mean that sequence of critical activities (and critical events) which connects the project's start event to its end event cannot be delayed without delaying the project [5]. In other words, a critical path defines a chain of critical activities which connects start and end events of the directed network. The method of determining such a path includes two phases: The first phase is called the forward pass where calculations begin from the 'start' node to the 'end'

node. The objective of this phase is computation of the earliest start time (T_E) of all events. The second phase called the backward pass begins calculation from the 'end' node and moves to the 'start' node. The objective of this phase is computation of the latest completion time (T_L) for all events. Slack times is the difference between the latest completion time and the earliest start time ($Si=T_Li-T_Ei$). S, T_L and T_E for each event and the results of computations are presented in Table 1:

(1) T_EEND= 214.03 (day) is the earliest completion time for event END and whole project;

(2) T_LEND=214.03 (day) is the latest completion time for event END and whole project (The researcher assumed that T_L of project equal to T_E one);

(3) S=0 presents that this activity is critical. Project's progress is according to the scheduling and the resource allocation is proper;

(4) S = n, n > 0. Project progress is foregoing than scheduling and resources are surplus;

(5) S=m, m<0. Project progress is lag behind than scheduling and resources are lack;

(6) Critical path, events and activities are known. The critical path is of great interest for project managers. The activities on the critical path are ones which absolutely must be done on time in order to complete the whole project on time. If any activity on the critical

(7) Given the critical path, the earliest expected time for completion of the first part of sugarcane production operations shall be to:

$$\mu_{T_E}^{118} = 0 + 3.16 + 0.1 + 0.1 + 5 + 0 + 8.16 + 0 + 1 + 4 + 1 + 4 + 1.83 + 8 + 1 + 8 + 1.83 + 8 + 1 + 7 + 4 + 1 + 4 + 1.83 + 4 + 1.83 + 2 + 1.83 + 1 + 9 + 1 + 9 + 1.83 + 2.08 + 1 + 4.25 + 3 + 4.25 + 1 + 0 + 1.83 + 4.16 + 0 + 4.25 + 1 + 0 + 2 + 7.16 + 0 + 4.25 + 1.83 + 4 + 4.25 + 5 + 1 + 7.17 + 1 + 1 + 0 + 1.83 + 3 + 0 + 4.25 + 1 + 0 + 1.83 + 2.08 + 0 + 4.25 + 1.83 + 1 + 13.83 + 2 + 0 + 1.83 + 4.25 + 0 = 214.03$$

And also taking into consideration the critical path, the variance of the end activity will be as follows:

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$$\delta_{T_E}^{2^{118}} = 0.250 + 0 + 0 + 0.111 + 0 + 0.250 + 0 + 0 + 0.111 + 0 + 0.111 + 0.027 + 0.111 + 0 + 0.111 + 0.027 + 0.111 + 0 + 0.111 + 0.111 + 0 + 0.111 + 0.027 + 0.111 + 0.027 + 0.111 + 0.027 + 0 + 0.111 + 0 + 0.111 + 0.027 + 0.062 + 0 + 0.174 + 0.111 + 0.174 + 0 + 0 + 0.027 + 0.694 + 0 + 0.174 + 0 + 0 + 0.111 + 0.694 + 0 + 0.174 + 0.027 + 0.111 + 0.174 + 0.444 + 0 + 0694 + 0 + 0 + 0 + 0.027 + 0.111 + 0 + 0.174 + 0 + 0 + 0.027 + 0.062 + 0 + 0.174 + 0.027 + 0 + 4.694 + 0 + 0 + 0.027 + 0.174 + 0 = 11.41$$

This course may be taken with respect to the probability of finding the directories in the path that is provided in Table 1, as follows:

$$P_{critical\,path} = 0.25 \times 0.2 \times 0.25 \times 0.25 \times 0.5 \times 0.9 = 0.0014$$

4. Conclusion

In this research GERT Networks were used and operations scheduling of sugarcane production (land preparation, planting and preserve operations) in Khuzestan province of Iran as a case study was analysed, by using WinQsb software. Critical activities, events and path were determined. The earliest project completion time is 214.03 days. The results show a high potential for operations scheduling of sugarcane production.

Table 1. Computation results and analysis of sugarcane production classical GERT network

Activity code	Activity description	Immediate predecessor	t_o	t_m	t_p	t_e	v_{t_e}	p_{ij}	Start time		Finish time		Start time variance		Finish time variance		Slack (LS-ES)	Variance slack
									ES	LS	EF	LF	VES	VLS	VEF	VLF		
S	START	-	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
001	Sampling of soil	S	1	1	1	1	0	1	0	4.36	1	5.36	0	0.25	0	0.25	4.36	0.25
002	Test results of soil	001	2	3	4	3	0.111	1	1	5.36	4	8.36	0	0.25	0.11	0.36	4.36	0.25
003	Bordering map supply	S	2	3	3	2.83	0.027	1	0	0.53	2.83	3.36	0	0.22	0.03	0.25	0.53	0.22
004	Tractors, border and grader supply	S	1	2	2	1.83	0.027	1	0	1.53	1.83	3.36	0	0.22	0.03	0.25	1.53	0.22
005	Operators employ	S	1	2	3	2	0.111	1	0	1.36	2	3.36	0	0.14	0.11	0.25	1.36	0.14
006	Oil and fuel supply	S	2	3	5	3.16	0.250	1	0	0	3.16	3.16	0	0	0.25	0.25	0	0
007	Oil and fuel for land preparation	006	0.1	0.1	0.1	0.1	0	1	3.16	3.16	3.26	3.26	0.25	0.25	0.25	0.25	0	0
008	Oil and fuel for bordering	007	0.1	0.1	0.1	0.1	0	1	3.26	3.26	3.36	3.36	0.25	0.25	0.25	0.25	0	0
009	Bordering	003,004,005,008	4	5	6	5	0.111	1	3.36	3.36	8.36	8.36	0.25	0.25	0.36	0.36	0	0
010	Decide to leaching	002,009	0	0	0	0	0	0.25	8.36	8.36	8.36	8.36	0.36	0.36	0.36	0.36	0	0
011	Decide to non- leaching	002,009	0	0	0	0	0	0.75	8.36	11.53	8.36	11.53	0.36	0.5	0.36	0.5	3.16	0.14
012	Leaching	010	7	8	10	8.16	0.250	1	8.36	8.36	16.53	16.53	0.36	0.36	0.61	0.61	0	0
013	Pre-irrigation	011	4	5	6	5	0.111	1	8.36	11.53	13.36	16.53	0.36	0.5	0.47	0.61	3.16	0.14
014	Decide to disc harrowing	012	0	0	0	0	0	1	16.53	16.53	16.53	16.53	0.61	0.61	0.61	0.61	0	0
015	Decide to non- disc harrowing	013	0	0	0	0	0	1	13.36	16.53	13.36	16.53	0.47	0.61	0.47	0.61	3.16	0.14
016	Disc harrow supply	014,015	1	1	1	1	0	1	16.53	16.53	17.53	17.53	0.61	0.61	0.61	0.61	0	0
017	Oil and fuel for disc harrowing	007	0.1	0.1	0.1	0.1	0	1	3.26	17.43	3.36	17.53	0.25	0.61	0.25	0.61	14.16	0.36
018	Primary disc harrowing	016,017	3	4	5	4	0.111	1	17.53	17.53	21.53	21.53	0.61	0.61	0.72	0.72	0	0
019	Leveler provide	018	1	1	1	1	0	1	21.53	21.53	22.53	22.53	0.72	0.72	0.72	0.72	0	0

Activity code	Activity description	Immediate predecessor	t_o	t_m	t_p	t_e	v_{t_e}	p_{ij}	Start time		Finish time		Start time variance		Finish time variance		Slack (LS-ES)	Variance slack
									ES	LS	EF	LF	VES	VLS	VEF	VLF		
020	Oil and fuel for leveling	007	0.1	0.1	0.1	0.1	0	1	3.26	22.43	3.36	22.53	0.25	0.72	0.25	0.72	19.16	0.47
021	Primary leveling	019,020	3	4	5	4	0.111	1	22.53	22.53	26.53	26.53	0.72	0.72	0.83	0.83	0	0
022	Scraper provide	021	1	2	2	1.83	0.027	1	26.53	26.53	28.36	28.36	0.83	0.83	0.86	0.86	0	0
023	Oil and fuel for scrapering	007	0.1	0.1	0.1	0.1	0	1	3.26	28.26	3.36	28.36	0.25	0.86	0.25	0.86	25	0.61
024	Scrapering	022,023	7	8	9	8	0.111	1	28.36	28.36	36.36	36.36	0.86	0.86	0.97	0.97	0	0
025	Mold board plow provide	024	1	1	1	1	0	1	36.36	36.36	37.36	37.36	0.97	0.97	0.97	0.97	0	0
026	Oil and fuel for plowing	007	0.1	0.1	0.1	0.1	0	1	3.26	37.26	3.36	37.36	0.25	0.97	0.25	0.97	34	0.72
027	Plowing	025,026	7	8	9	8	0.111	1	37.36	37.36	45.36	45.36	0.97	0.97	1.08	1.08	0	0
028	Bulldozer and subsoiler supply	027	1	2	2	1.83	0.027	1	45.36	45.36	47.2	47.2	1.08	1.08	1.11	1.11	0	0
029	Oil and fuel for subsoiling	007	0.1	0.1	0.1	0.1	0	1	3.26	47.1	3.36	47.2	0.25	1.11	0.25	1.11	43.83	0.86
030	Subsoiling	028,029	7	8	9	8	0.111	1	47.2	47.2	55.2	55.2	1.11	1.11	1.22	1.22	0	0
031	Tractors and disc harrow supply	030	1	1	1	1	0	1	55.2	55.2	56.2	56.2	1.22	1.22	1.22	1.22	0	0
032	Oil and fuel for second disc harrowing	007	0.1	0.1	0.1	0.1	0	1	3.26	56.1	3.36	56.2	0.25	1.22	0.25	1.22	52.83	0.97
033	Second disc harrowing	031,032	6	7	8	7	0.111	1	56.2	56.2	63.2	63.2	1.22	1.22	1.33	1.33	0	0
034	Second leveling	033	3	4	5	4	0.111	1	63.2	63.2	67.2	67.2	1.33	1.33	1.44	1.44	0	0
035	Furrower supply	034	1	1	1	1	0	1	67.2	67.2	68.2	68.2	1.44	1.44	1.44	1.44	0	0
036	Oil and fuel for furrowing	007	0.1	0.1	0.1	0.1	0	1	3.26	68.1	3.36	68.2	0.25	1.44	0.25	1.44	64.83	1.19
037	Furrowing	035,036	3	4	5	4	0.111	1	68.2	68.2	72.2	72.2	1.44	1.44	1.55	1.55	0	0
038	Chemical fertilizer and fertilizer attachments supply	037	1	2	2	1.83	0.027	1	72.2	72.2	74.03	74.03	1.55	1.55	1.58	1.58	0	0
039	Oil and fuel for fertilizering	007	0.1	0.1	0.1	0.1	0	1	3.26	73.93	3.36	74.03	0.25	1.58	0.25	1.58	70.66	1.33

Activity code	Activity description	Immediate predecessor	t_o	t_m	t_p	t_e	v_{t_e}	p_{ij}	Start time		Finish time		Start time variance		Finish time variance		Slack (LS-ES)	Variance slack
									ES	LS	EF	LF	VES	VLS	VEF	VLF		
040	Fertilizering	038,039	3	4	5	4	0.111	1	74.03	74.03	78.03	78.03	1.58	1.58	1.69	1.69	0	0
041	Oil and fuel for planting stage	006	1	2	2	1.83	0.027	1	3.16	77.93	5	79.76	0.25	1.69	0.28	1.72	74.76	1.44
042	harvester for Cane cuttings supply	040	1	2	2	1.83	0.027	1	78.03	78.03	79.86	79.86	1.69	1.69	1.72	1.72	0	0
043	Oil and fuel for cane cuttings supply	041	0.1	0.1	0.1	0.1	0	1	5	79.76	5.1	79.86	0.28	1.72	0.28	1.72	74.76	1.44
044	Preparation of cane cuttings	042,043	1	2	3	2	0.111	1	79.86	79.86	81.86	81.86	1.72	1.72	1.83	1.83	0	0
045	Tractor and trailer for carry cuttings supply	044	1	2	2	1.83	0.027	1	81.86	81.86	83.7	83.7	1.83	1.83	1.86	1.86	0	0
046	Oil and fuel for carry cuttings	041	0.1	0.1	0.1	0.1	0	1	5	83.6	5.1	83.7	0.28	1.86	0.28	1.86	78.6	1.58
047	Carry cuttings	045,046	1	1	1	1	0	1	83.7	83.7	84.7	84.7	1.86	1.86	1.86	1.86	0	0
048	Oil and fuel for planting	041	0.1	0.1	0.1	0.1	0	1	5	84.6	5.1	84.7	0.28	1.86	0.28	1.86	79.6	1.58
049	Plant	047,048	8	9	10	9	0.111	1	84.7	84.7	93.7	93.7	1.86	1.86	1.97	1.97	0	0
050	Disc cover and shovel supply	049	1	1	1	1	0	1	93.7	93.7	94.7	94.7	1.97	1.97	1.97	1.97	0	0
051	Oil and fuel for covering	041	0.1	0.1	0.1	0.1	0	1	5	94.6	5.1	94.7	0.28	1.97	0.28	1.97	89.6	1.69
052	Covering (Disc covering and Hand covering)	050,051	8	9	10	9	0.111	1	94.7	94.7	103.7	103.7	1.97	1.97	2.08	2.08	0	0
053	Pesticide supply	052	1	1	1	1	0	1	103.7	104.53	104.7	105.53	2.08	2.11	2.08	2.11	0.83	0.03
054	Sprayer supply	052	1	2	2	1.83	0.027	1	103.7	103.7	105.53	105.53	2.08	2.08	2.11	2.11	0	0
055	Oil and fuel for Pre-emergence spraying	041	0.1	0.1	0.1	0.1	0	1	5	105.43	5.1	105.53	0.28	2.11	0.28	2.11	100.43	1.83
056	Pre-emergence spraying	053,054,055	1.5	2	3	2.08	0.062	1	105.53	105.53	107.61	107.61	2.11	2.11	2.17	2.17	0	0
057	Piping for irrigation	056	1	1	1	1	0	1	107.61	107.61	108.61	108.61	2.17	2.17	2.17	2.17	0	0
058	Primary irrigation	057	3.5	4	6	4.25	0.174	1	108.61	108.61	112.86	112.86	2.17	2.17	2.34	2.34	0	0
059	Recovering	058	2	3	4	3	0.111	1	112.86	112.86	115.86	115.86	2.34	2.34	2.45	2.45	0	0
060	Oil and fuel for preserve operations	006	0.1	0.1	0.1	0.1	0	1	3.16	122.75	3.26	122.85	0.25	2.65	0.25	2.65	119.58	2.4

Activity code	Activity description	Immediate predecessor	t_o	t_m	t_p	t_e	v_{t_e}	p_{ij}	Start time		Finish time		Start time variance		Finish time variance		Slack (LS-ES)	Variance slack
									ES	LS	EF	LF	VES	VLS	VEF	VLF		
061	Irrigation	059	3.5	4	6	4.25	0.174	1	115.86	115.86	120.11	120.11	2.45	2.45	2.62	2.62	0	0
062	Visit the farm (Evaluation of green field)	061	1	1	1	1	0	1	120.11	120.11	121.11	121.11	2.62	2.62	2.62	2.62	0	0
063	Decide to non- replant	062	0	0	0	0	0	0.8	121.11	127.11	121.11	127.11	2.62	3.34	2.62	3.34	6	0.72
064	Decide to replant	062	0	0	0	0	0	0.2	121.11	121.11	121.11	121.11	2.62	2.62	2.62	2.62	0	0
065	Oil and fuel for replant	060	0.1	0.1	0.1	0.1	0	1	3.26	122.85	3.36	122.95	0.25	2.65	0.25	2.65	119.58	2.4
066	Tractors, trailer, cane cutter and shovel supply	064	1	2	2	1.83	0.027	1	121.11	121.11	122.95	122.95	2.62	2.62	2.65	2.65	0	0
067	Preparation of cane cuttings	064	1	1	1	1	0	1	121.11	121.95	122.11	122.95	2.62	2.65	2.62	2.65	0.83	0.03
068	Replant	065,066,067	2	4	7	4.16	0.694	1	122.95	122.95	127.11	127.11	2.65	2.65	3.34	3.34	0	0
069	Decide to irrigation	068	0	0	0	0	0	1	127.11	127.11	127.11	127.11	3.34	3.34	3.34	3.34	0	0
070	Decide to irrigation	063	0	0	0	0	0	1	121.11	127.11	121.11	127.11	2.62	3.34	2.62	3.34	6	0.72
071	Irrigation	069,070	3.5	4	6	4.25	0.174	1	127.11	127.11	131.36	131.36	3.34	3.34	3.51	3.51	0	0
072	Visit the farm (weed infestation)	071	1	1	1	1	0	1	131.36	131.36	132.36	132.36	3.51	3.51	3.51	3.51	0	0
073	Decide to non- mechanical weed control	072	0	0	0	0	0	0.75	132.36	141.53	132.36	141.53	3.51	4.31	3.51	4.31	9.16	0.8
074	Decide to mechanical weed control	072	0	0	0	0	0	0.25	132.36	132.36	132.36	132.36	3.51	3.51	3.51	3.51	0	0
075	Labor, shovel and sickle supply	074	1	2	3	2	0.111	1	132.36	132.36	134.36	134.36	3.51	3.51	3.62	3.62	0	0
076	mechanical weed control	075	5	7	10	7.16	0.694	1	134.36	134.36	141.53	141.53	3.62	3.62	4.31	4.31	0	0
077	Decide to irrigation	076	0	0	0	0	0	1	141.53	141.53	141.53	141.53	4.31	4.31	4.31	4.31	0	0
078	Decide to irrigation	073	0	0	0	0	0	1	132.36	141.53	132.36	141.53	3.51	4.31	3.51	4.31	9.16	0.8
079	Irrigation	077,078	3.5	4	6	4.25	0.174	1	141.53	141.53	145.78	145.78	4.31	4.31	4.48	4.48	0	0
080	Oil and fuel for hilling up	060	0.1	0.1	0.1	0.1	0	1	3.26	147.51	3.36	147.61	0.25	4.51	0.25	4.51	144.25	4.26

Activity code	Activity description	Immediate predecessor	t_o	t_m	t_p	t_e	v_{t_e}	p_{ij}	Start time		Finish time		Start time variance		Finish time variance		Slack (LS-ES)	Variance slack
									ES	LS	EF	LF	VES	VLS	VEF	VLF		
081	Hilling up implement supply	079	1	2	2	1.83	0.027	1	145.78	145.78	147.61	147.61	4.48	4.48	4.51	4.51	0	0
082	Hilling up	080,081	3	4	5	4	0.111	1	147.61	147.61	151.61	151.61	4.51	4.51	4.62	4.62	0	0
083	Irrigation	082	3.5	4	6	4.25	0.174	1	151.61	151.61	155.86	155.86	4.62	4.62	4.79	4.79	0	0
084	Optical trap provide	083	3	5	7	5	0.444	1	155.86	155.86	160.86	160.86	4.79	4.79	5.23	5.23	0	0
085	Mechanical pest control (optical trap)	084	1	1	1	1	0	1	160.86	160.86	161.86	161.86	5.23	5.23	5.23	5.23	0	0
086	Parasitoid wasps supply	085	5	7	10	7.17	0.694	1	161.86	161.86	169.03	169.03	5.23	5.23	5.92	5.92	0	0
087	Biological pest control- parasitoid wasps (first stage)	086	1	1	1	1	0	1	169.03	169.03	170.03	170.03	5.92	5.92	5.92	5.92	0	0
088	Visit the farm (weed infestation)	087	1	1	1	1	0	1	170.03	170.03	171.03	171.03	5.92	5.92	5.92	5.92	0	0
089	Decide to non- mechanical weed control (cultivator)	088	0	0	0	0	0	0.75	171.03	175.86	171.03	175.86	5.92	6.06	5.92	6.06	4.83	0.14
090	Decide to mechanical weed control (cultivator)	088	0	0	0	0	0	0.25	171.03	171.03	171.03	171.03	5.92	5.92	5.92	5.92	0	0
091	Oil and fuel for cultivator	060	0.1	0.1	0.1	0.1	0	1	3.26	172.86	3.36	172.86	0.25	5.95	0.25	5.95	169.5	5.7
092	Tractors and cultivator supply	090	1	2	2	1.83	0.027	1	171.03	171.03	172.86	172.86	5.92	5.92	5.95	5.95	0	0
093	mechanical weed control (cultivator)	091,092	2	3	4	3	0.111	1	172.86	172.86	175.86	175.86	5.95	5.95	6.06	6.06	0	0
094	Decide to irrigation	093	0	0	0	0	0	1	175.86	175.86	175.86	175.86	6.06	6.06	6.06	6.06	0	0
095	Decide to irrigation	089	0	0	0	0	0	1	171.03	175.86	171.03	175.86	5.92	6.06	5.92	6.06	4.83	0.14
096	Irrigation	094,095	3.5	4	6	4.25	0.174	1	175.86	175.86	180.11	180.11	6.06	6.06	6.23	6.23	0	0
097	Visit the farm (weed infestation)	096	1	1	1	1	0	1	180.11	180.11	181.11	181.11	6.23	6.23	6.23	6.23	0	0
098	Decide to non- herbicide spraying	097	0	0	0	0	0	0.5	181.11	185.03	181.11	185.03	6.23	6.32	6.23	6.32	3.91	0.09

Activity code	Activity description	Immediate predecessor	t_o	t_m	t_p	t_e	v_{t_e}	p_{ij}	Start time		Finish time		Start time variance		Finish time variance		Slack (LS-ES)	Variance slack
									ES	LS	EF	LF	VES	VLS	VEF	VLF		
099	Decide to herbicide spraying	097	0	0	0	0	0	0.5	181.11	181.11	181.11	181.11	6.23	6.23	6.23	6.23	0	0
100	Oil and fuel for herbicide spraying	060	0.1	0.1	0.1	0.1	0	1	3.26	182.85	3.36	182.95	0.25	6.26	0.25	6.26	179.58	6.01
101	Herbicide supply	099	1	1	1	1	0	1	181.11	181.95	182.11	182.95	6.23	6.26	6.23	6.26	0.83	0.03
102	Sprayer supply	099	1	2	2	1.83	0.027	1	181.11	181.11	182.95	182.95	6.23	6.23	6.26	6.26	0	0
103	Chemical control of post-emergence weed	100,101,102	1.5	2	3	2.08	0.062	1	182.95	182.95	185.03	185.03	6.26	6.26	6.32	6.32	0	0
104	Decide to irrigation	103	0	0	0	0	0	1	185.03	185.03	185.03	185.03	6.32	6.32	6.32	6.32	0	0
105	Decide to irrigation	098	0	0	0	0	0	1	181.11	185.03	181.11	185.03	6.23	6.32	6.32	6.32	3.91	0.09
106	Irrigation	104,105	3.5	4	6	4.25	0.174	1	185.03	185.03	189.28	189.28	6.32	6.32	6.49	6.49	0	0
107	Oil and fuel for cropping of green trap	060	0.1	0.1	0.1	0.1	0	1	3.26	191.01	3.36	191.11	0.25	6.52	0.25	6.52	187.75	6.27
108	Seed of corn and sorghum supply	106	1	1	1	1	0	1	189.28	189.28	190.28	191.11	6.49	6.52	6.49	6.52	0.83	0.03
109	Tractors and row planter supply	106	1	2	2	1.83	0.027	1	189.28	189.28	191.11	191.11	6.49	6.49	6.52	6.52	0	0
110	mechanical pest control-green trap	107,108,109	1	1	1	1	0	1	191.11	191.11	191.11	191.11	6.52	6.52	6.52	6.52	0	0
111	Crop logging equipment supply	110	7	14	20	13.83	4.694	1	192.11	192.11	205.95	205.95	6.52	6.52	11.21	11.21	0	0
112	Install crop logging equipment	110	1	2	2	1.83	0.027	1	192.11	204.11	193.95	205.95	6.52	11.18	6.55	11.21	12	4.66
113	Sampling and determining the need for fertilizer plant	111,112	2	2	2	2	0	1	205.95	205.95	207.95	207.95	11.21	11.21	11.21	11.21	0	0
114	Decide to non- top dressing	113	0	0	0	0	0	0.1	207.95	214.03	207.95	214.03	11.21	11.41	11.21	11.41	6.08	0.2
115	Decide to top-dressing	113	0	0	0	0	0	0.9	207.95	207.95	207.95	207.95	11.21	11.21	11.21	11.21	0	0
116	Fertilizer drum and fertilizer solution device supply	115	1	1	1	1	0	1	207.95	208.78	208.95	209.78	11.21	11.24	11.21	11.24	0.83	0.03
117	Chemical fertilizer supply	115	1	2	2	1.83	0.027	1	207.95	207.95	209.78	209.78	11.21	11.21	11.24	11.24	0	0

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									ES	LS	EF	LF	VES	VLS	VEF	VLF		
118	Irrigation and top-dressing	116,117	3.5	4	6	4.25	0.174	1	209.78	209.78	214.03	214.03	11.24	11.24	11.41	11.41	0	0
E	END (first part of operation)	114,118	0	0	0	0	0	1	214.03	214.03	214.03	214.03	11.41	11.41	11.41	11.41	0	0

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