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A SCIENTIFIC STUDY ON A NETWORK WITH ARITHMETIC PROGRESSION ON OPTIMISTIC TIME ESTIMATE

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The present paper targets to analyse whether Arithmetic Progression (A.P) in a peculiar case will affirm a network or not. A big network is constructed in a scientific way with 124 activities which are formed with 94 nodes. A.P is applied on optimistic time estimate (a) among the three time estimates namely optimistic, most likely and pessimistic. A computational study has been done on the network. Some remarkable results are established. All float values are also computed. Critical path is traced and project analysis has been carried out. Periodical analysis is accomplished with standard normal distribution curves.

KEYWORDS: Network, Time estimates, Float, Critical path, Normal distribution.

AMS Classification: 90-08, 90B10, 90C90

INRTRODUCTION

Few decades back, Gantt bar chart was the good planning tool which provided the starting and finishing times for the each activity on horizontal time scale. But the bar chart does not ascertain the interdependency between distinct activities. Modern projects need systematic and effective planning techniques for reaching the necessary objectives. CPM and PERT are two project management tools for planning, scheduling and controlling the projects. The two methods are developed by two eminent groups simultaneously. Walker, E.L. du pont de Nemours Company developed CPM for solving scheduling problems. Mauchly Associates enhanced the quality later. PERT was developed by Engineers of US Navy in the polar's missile programme.

Acharyulu, K.V.L.N. *et. al*. [1-5] obtained some results on Networks which are impacted by various progressions. S.D Sharma [6] mentioned few useful applications in the area of PERT & CPM. PERT algorithm was applied on some real life models by Billy E. Gillett [7] in 1979. Levin and Kirkpatrick [9] discussed about planning and control with PERT and CPM in

1966. Wiest and Levy [8] have given a clear approch to PERT/CPM for beginners of operations research in 1969.

The Paper concerns with the computational study to analyse whether Arithmetic Progression (A.P.) in a case will support a network or not. A huge network is taken in a scientific way with 124 activities and 94 nodes. A.P is employed on a most likely time estimate among the three time estimates namely optimistic, most likely and pessimistic. A computational study has been done on the network. Some remarkable results are established. All float values are also computed. Critical path is traced and project analysis has been carried out. Periodical analysis is accomplished with standard normal distribution curves.

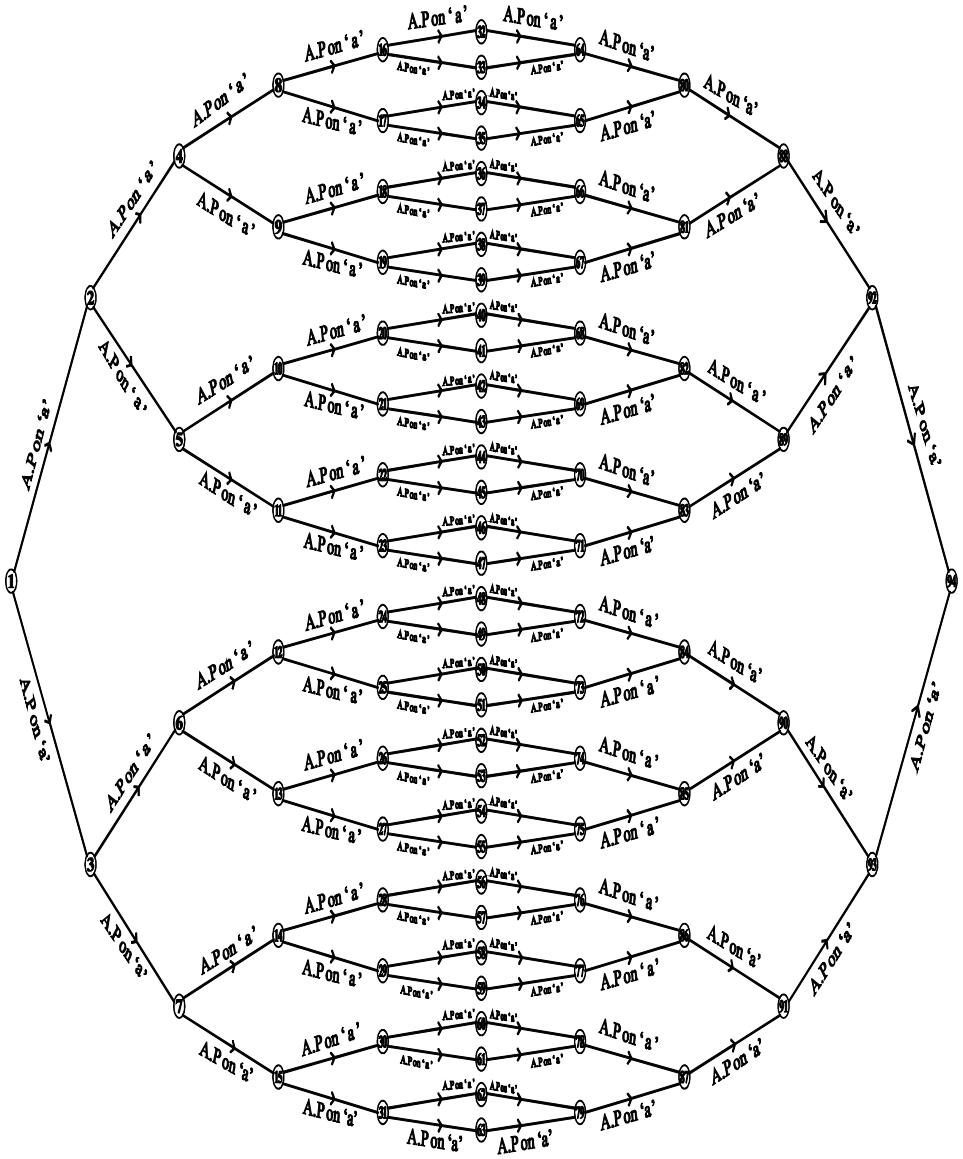


Fig. 1. Network with 124 activities and 94 node

BASIC CONSTRUCTION OF NETWORK

A network is made with 94 nodes and 124 activities in a scientific way for analyzing the influence of **Arithmetic Progression**. A.P. is used on optimistic time estimate (a) in case (II) among the three estimates. No Dummy activity and No error occurred in Network.

PRELIMINARIES AND NOTATIONS

(i) TE = Earliest excepted completion time of event (TE).

Def. For the fixed value of j = TE (j) = Max [TE (i) + ET (i, j)] which ranges over all activities from i - j.

(ii) TL = Latest allowable event completion time (TL)

Def: For the fixed value of i = TL(i) = Min [TL (j) + ET (i, j)] which ranges over all activities from $i - j$.

(iii) ET = Excepted completion time of activity (I, J)

(iv) a = Optimistic time estimate

(v) m = Most likely time estimate

(vi) b = Pessimistic time estimate

(vii) ES = Earliest start of an activity

(viii) EF = Earliest finish of an activity

(ix) LS = Latest start of an activity

(x) LF = Latest finish of an activity

(xi) TF = Total Float

Def: TF of activity $i - j = LF_{i-j} - EF_{i-j}$ (or) $LS_{i-j} - ES_{i-j}$

(xii) FF = Free Float

Def: FF of activity $i - j = TF - (TL - TE)$ of node j

(xiii) IF = Independent Float

Def: IF of activity $i - j = FF - (TL - TE)$ of node i

(xiv) SE = Slack event time

(xv) CPI = Critical Path Indicator

(xvi) SCT = Scheduled Time

(xvii) σ = Standard deviation of project length

MATERIAL AND METHODS:

Step 1: Draw the project network completion time

Step 2: Compute the excepted duration of each activity by using the formula $ET = \frac{a + 4m + b}{6}$.

From the time estimates *a*, *m* and *p*, calculate the excepted variance. σ^2 of each activity

Step 3: Calculate *TE*, *TL*.

Step 4: Find Total Float, Free Float and Independent Float

Step 5: Find the critical path and identify the critical activities

Step 6: Compute project length which is a square root to sum of variance of all the critical activities.

Step 7: From the standard normal variable $z = \frac{SCT - ETC}{\sigma}$, where SCT is scheduled Completion time of event, *ETC* is expected completion time of the Project, σ = standard deviation of project length and also by using the standard normal curve, we can estimate the probability of completing project within specified time.

Results

By applying CPM and PERT algorithm on the Network, the critical path is obtained from Table-1 which is built with all Activities, Time estimates, ET, Varience. ES, EF, LS, LF and all Float values. The Critical path indicator furnishes the critical Activities in the following tables from Table (1) to Table (6).

Table 1. The values of TF,FF and IF in first three levels from event(1) to event(7)

Activity	Time Estimates			ET	σ^2	Earliest[E]		Latest[L]		TF	FF	IF	CPI
	a	m	b			ES	EF	LS	LF				
1-2	1.5	1	2	1.25	0.0069	0	1.25	124	125.25	124	0	0	
1-3	3.5	3	4	3.25	0.0069	0	3.25	0	3.25	0	0	0	*
2-4	5.5	5	6	5.25	0.0069	1.25	6.5	185.25	190.5	184	0	-124	
2-5	7.5	7	8	7.25	0.0069	1.25	8.5	125.25	132.5	124	0	-124	
3-6	9.5	9	10	9.25	0.0069	3.25	12.5	63.25	72.5	60	0	0	
3-7	11.5	11	12	11.25	0.0069	3.25	14.5	3.25	14.5	0	0	0	*
4-8	13.5	13	14	13.25	0.0069	6.5	19.75	203.5	216.75	197	0	-184	
4-9	15.5	15	16	15.25	0.0069	6.5	21.75	190.5	205.75	184	0	-184	
5-10	17.5	17	18	17.25	0.0069	8.5	25.75	160.5	177.75	152	0	-124	
5-11	19.5	19	20	19.25	0.0069	8.5	27.75	132.5	151.75	124	0	-124	
6-12	21.5	21	22	21.25	0.0069	12.5	33.75	100.5	121.75	88	0	-60	
6-13	23.5	23	24	23.25	0.0069	12.5	35.75	72.5	95.75	60	0	-60	
7-14	25.5	25	26	25.25	0.0069	14.5	39.75	42.5	67.75	28	0	0	
7-15	27.5	27	28	27.25	0.0069	14.5	41.75	14.5	41.75	0	0	0	*

Table 2. The values of TF, FF and IF in fourth level from event (8) to event (15)

Activity	Time Estimates	ET	σ^2	Earliest [E]	Latest [L]	TF	FF	IF	CPI

	a	m	b			ES	EF	LS	LF				
8-16	29.5	29	30	29.25	0.0069	19.75	49	216.75	246	197	0	– 197	
8-17	31.5	31	32	31.25	0.0069	19.75	51	231.75	263	212	0	– 197	
9-18	33.5	33	34	33.25	0.0069	21.75	55	217.75	251	196	0	– 184	
9-19	35.5	35	36	35.25	0.0069	21.75	57	205.75	241	184	0	– 184	
10-20	37.5	37	38	37.25	0.0069	25.75	63	189.75	227	164	0	– 152	
10-21	39.5	39	40	39.25	0.0069	25.75	65	177.75	217	152	0	– 152	
11-22	41.5	41	42	41.25	0.0069	27.75	69	163.75	205	136	0	– 124	
11-23	43.5	43	44	43.25	0.0069	27.75	71	151.75	195	124	0	– 124	
12-24	45.5	45	46	45.25	0.0069	33.75	79	133.75	179	100	0	– 88	
12-25	47.5	47	48	47.25	0.0069	33.75	81	121.75	169	88	0	– 88	
13-26	49.5	49	50	49.25	0.0069	35.75	85	107.75	157	72	0	– 60	
13-27	51.5	51	52	51.25	0.0069	35.75	87	95.75	147	60	0	– 60	
14-28	53.5	53	54	53.25	0.0069	39.75	93	79.75	133	40	0	– 28	
14-29	55.5	55	56	55.25	0.0069	39.75	95	67.75	123	28	0	– 28	
15-30	57.5	57	58	57.25	0.0069	41.75	99	53.75	111	12	0	0	
15-31	59.5	59	60	59.25	0.0069	41.75	101	41.75	101	0	0	0	*

Table 3. The values of TF, FF and IF in fifth level from event (16) to event(31)

Activity	Time Estimates			ET	σ^2	Earliest [E]		Latest [L]		TF	FF	IF	CPI
	a	m	b			ES	EF	LS	LF				
16-32	61.5	61	62	61.25	0.0069	49	110.25	250	311.25	201	0	– 197	
16-33	63.5	63	64	63.25	0.0069	49	112.25	246	309.25	197	0	– 197	
14-34	65.5	65	66	65.25	0.0069	51	116.25	267	332.25	216	0	– 212	
17-35	67.5	67	68	67.25	0.0069	51	118.25	263	330.25	212	0	– 212	
18-36	69.5	69	70	69.25	0.0069	55	124.25	255	324.25	200	0	– 196	
18-37	71.5	71	72	71.25	0.0069	55	126.25	251	322.25	196	0	– 196	
19-38	73.5	73	74	73.25	0.0069	57	130.25	245	318.25	188	0	– 184	
19-39	75.5	75	76	75.25	0.0069	57	132.25	241	316.25	184	0	– 184	
20-40	77.5	77	78	77.25	0.0069	63	140.25	231	308.25	168	0	– 164	
20-41	79.5	79	80	79.25	0.0069	63	142.25	227	306.25	164	0	– 164	
21-42	81.5	81	82	81.25	0.0069	65	146.25	221	302.25	156	0	– 152	
21-43	83.5	83	84	83.25	0.0069	65	148.25	217	300.25	152	0	– 152	
22-44	85.5	85	86	85.25	0.0069	69	154.25	209	294.25	140	0	– 136	
22-45	87.5	87	88	87.25	0.0069	69	156.25	205	292.25	136	0	– 136	
23-46	89.5	89	90	89.25	0.0069	71	160.25	199	288.25	128	0	– 124	
23-47	91.5	91	92	91.25	0.0069	71	162.25	195	286.25	124	0	– 124	
24-48	93.5	93	94	93.25	0.0069	79	172.25	183	276.25	104	0	– 100	
24-49	95.5	95	96	95.25	0.0069	79	174.25	179	274.25	100	0	– 100	

25-50	97.5	97	98	97.25	0.0069	81	178.25	173	270.25	92	0	– 88	
25-51	99.5	99	100	99.25	0.0069	81	180.25	169	268.25	88	0	– 88	
26-52	101.5	101	102	101.25	0.0069	85	186.25	161	262.25	76	0	– 72	
26-53	103.5	103	104	103.25	0.0069	85	188.25	157	260.25	72	0	– 72	
27-54	105.5	105	106	105.25	0.0069	87	192.25	151	256.25	64	0	– 60	
27-55	107.5	107	108	107.25	0.0069	87	194.25	147	254.25	60	0	– 60	
28-56	109.5	109	110	109.25	0.0069	93	202.25	137	246.25	44	0	– 40	
28-57	111.5	111	112	111.25	0.0069	93	204.25	133	244.25	40	0	– 40	
29-58	113.5	113	114	113.25	0.0069	95	208.25	127	240.25	32	0	– 28	
29-59	115.5	115	116	115.25	0.0069	95	210.25	123	238.25	28	0	– 28	
30-60	117.5	117	118	117.25	0.0069	99	216.25	115	232.25	16	0	– 12	
30-61	119.5	119	120	119.25	0.0069	99	218.25	111	230.25	12	0	– 12	
31-62	121.5	121	122	121.25	0.0069	101	222.25	105	226.25	4	0	0	
31-63	123.5	123	124	123.25	0.0069	101	224.25	101	224.25	0	0	0	*

Table-4: The values of TF, FF and IF in sixth level from event(32) to event(63)

Activity	Time Estimates			ET	σ^2	Earliest [E]		Latest [L]		TF	FF	IF	CPI
	a	m	b			ES	EF	LS	LF				
32-64	125.5	125	126	125.25	0.0069	110.25	235.5	311.25	436.5	201	4	– 197	
33-64	127.5	127	128	127.25	0.0069	112.25	239.5	309.25	436.5	197	0	– 197	
34-65	129.5	129	130	129.25	0.0069	116.25	245.5	332.25	461.5	216	4	– 212	
35-65	131.5	131	132	131.25	0.0069	118.25	249.5	330.25	461.5	212	0	– 212	
36-66	133.5	133	134	133.25	0.0069	124.25	257.5	324.25	457.5	200	4	– 196	
37-66	135.5	135	136	135.25	0.0069	126.25	261.5	322.25	457.5	196	0	– 196	
38-67	137.5	137	138	137.25	0.0069	130.25	267.5	318.25	455.5	188	4	– 184	
39-67	139.5	139	140	139.25	0.0069	132.25	271.5	316.25	455.5	184	0	– 184	
40-68	141.5	141	142	141.25	0.0069	140.25	281.5	308.25	449.5	168	4	– 164	
41-68	143.5	143	144	143.25	0.0069	142.25	285.5	306.25	449.5	164	0	– 164	
42-69	145.5	145	146	145.25	0.0069	146.25	291.5	302.25	447.5	156	4	– 152	
43-69	147.5	147	148	147.25	0.0069	148.25	295.5	300.25	447.5	152	0	– 152	
44-70	149.5	149	150	149.25	0.0069	153.75	303	294.25	443.5	140.5	4.5	– 135.5	
45-70	151.5	151	152	151.25	0.0069	155.75	307	292.25	443.5	136.5	0.5	– 135.5	
46-71	153.5	153	154	153.25	0.0069	159.75	313	288.25	441.5	128.5	4.5	– 123.5	
47-71	155.5	155	156	155.25	0.0069	161.75	317	286.25	441.5	124.5	0.5	– 123.5	
48-72	157.5	157	158	157.25	0.0069	172.25	329.5	276.25	433.5	104	4	– 100	
49-72	159.5	159	160	159.25	0.0069	174.25	333.5	274.25	433.5	100	0	– 100	
50-73	161.5	161	162	161.25	0.0069	178.25	339.5	270.25	431.5	92	4	– 88	
51-73	163.5	163	164	163.25	0.0069	180.25	343.5	268.25	431.5	88	0	– 88	
52-74	165.5	165	166	165.25	0.0069	186.25	351.5	262.25	427.5	76	4	– 72	

53-74	167.5	167	168	167.25	0.0069	188.25	355.5	260.25	427.5	72	0	– 72	
54-75	169.5	169	170	169.25	0.0069	192.25	361.5	256.25	425.5	64	4	– 60	
55-75	171.5	171	172	171.25	0.0069	194.25	365.5	254.25	425.5	60	0	– 60	
56-76	173.5	173	174	173.25	0.0069	202.25	375.5	246.25	419.5	44	4	– 40	
57-76	175.5	175	176	175.25	0.0069	204.25	379.5	244.25	419.5	40	0	– 40	
58-77	177.5	177	178	177.25	0.0069	208.25	385.5	240.25	417.5	32	4	– 28	
59-77	179.5	179	180	179.25	0.0069	210.25	389.5	238.25	417.5	28	0	– 28	
60-78	181.5	181	182	181.25	0.0069	216.25	397.5	232.25	413.5	16	4	– 12	
61-78	183.5	183	184	183.25	0.0069	218.25	401.5	230.25	413.5	12	0	– 12	
62-79	185.5	185	186	185.25	0.0069	222.25	407.5	226.25	411.5	4	4	0	
63-79	187.5	187	188	187.25	0.0069	224.25	411.5	224.25	411.5	0	0	0	*

Table-5: The values of TF, FF and IF in seventh level from event(64) to event(79)

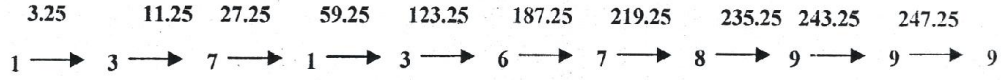
Activity	Time Estimates			ET	σ^2	Earliest [E]		Latest [L]		TF	FF	IF	CPI
	a	m	b			ES	EF	LS	LF				
64-80	189.5	189	190	189.25	0.0069	239.5	428.75	463.5	652.75	224	12	– 185	
65-80	191.5	191	192	191.25	0.0069	249.5	440.75	461.5	652.75	212	0	– 212	
66-81	193.5	193	194	193.25	0.0069	261.5	454.75	457.5	650.75	196	12	– 184	
67-81	195.5	195	196	195.25	0.0069	271.5	466.75	455.5	650.75	184	0	– 184	
68-82	197.5	197	198	197.25	0.0069	285.5	482.75	449.5	646.75	164	12	– 152	
69-82	199.5	199	200	199.25	0.0069	295.5	494.75	447.5	646.75	152	0	– 152	
70-83	201.5	201	202	201.25	0.0069	307.5	508.75	443.5	644.75	136	12	– 124	
71-83	203.5	203	204	203.25	0.0069	317.5	520.75	441.5	644.75	124	0	– 124	
72-84	205.5	205	206	205.25	0.0069	333.5	538.75	433.5	638.75	100	12	– 88	
73-84	207.5	207	208	207.25	0.0069	343.5	550.75	431.5	638.75	88	0	– 88	
74-85	209.5	209	210	209.25	0.0069	355.5	564.75	427.5	636.75	72	12	– 60	
75-85	211.5	211	212	211.25	0.0069	365.5	576.75	425.5	636.75	60	0	– 60	
76-86	213.5	213	214	213.25	0.0069	379.5	592.75	419.5	632.75	40	12	– 28	
77-86	215.5	215	216	215.25	0.0069	389.5	604.75	417.5	632.75	28	0	– 28	
78-87	217.5	217	218	217.25	0.0069	401.5	618.75	413.5	630.75	12	12	0	
79-87	219.5	219	220	219.25	0.0069	411.5	630.75	411.5	630.75	0	0	0	*

Table-6: The values of TF,FF & IF in eighth, ninth and tenth levels from event(80) to event(93)

Activity	Time Estimates			ET	σ^2	Earliest [E]		Latest [L]		TF	FF	IF	CPI
	a	m	b			ES	EF	LS	LF				
80-88	221.5	221	222	221.25	0.0069	440.75	662	652.75	874	212	28	– 184	
81-88	223.5	223	224	223.25	0.0069	466.75	690	650.75	874	184	0	– 184	
82-89	225.5	225	226	225.25	0.0069	494.75	720	646.75	872	152	28	– 124	
83-89	227.5	227	228	227.25	0.0069	520.75	748	644.75	872	124	0	– 124	

84-90	229.5	229	230	229.25	0.0069	550.75	780	638.75	868	88	28	– 60	
85-90	231.5	231	232	231.25	0.0069	576.75	808	636.75	868	60	0	– 60	
86-91	233.5	233	234	233.25	0.0069	604.75	838	632.75	866	28	28	0	
87-91	235.5	235	236	235.25	0.0069	630.75	866	630.75	866	0	0	0	*
88-92	237.5	237	238	237.25	0.0069	690	927.25	874	1111.25	184	60	– 124	
89-92	239.5	239	240	239.25	0.0069	748	987.25	872	1111.25	124	0	– 124	
90-93	241.5	241	242	241.25	0.0069	808	1049.25	868	1109.25	60	60	0	
91-93	243.5	243	244	243.25	0.0069	866	1109.25	866	1109.25	0	0	0	*
92-94	245.5	245	246	245.25	0.0069	987.25	1232.5	1111.25	1356.5	124	124	0	
93-94	247.5	247	248	247.25	0.0069	1109.25	1356.5	1109.25	1356.5	0	0	0	*

Critical path is traced as below



Project Length is defined as $\sqrt{\text{Sum of Variances of each Critical activity}}$

i.e. Project Length $= \sqrt{0.0069 + 0.0069 + 0.0069 + 0.0069 + 0.0069 + 0.0069 + 0.0069 + 0.0069 + 0.0069 + 0.0069}$

= 0.2626

The values of TE, TL and SE corresponding to every node are given in Table (7).

The slack event time may be positive, negative or zero.

It is also observed that the values of slack event time vanish at each critical activity.

Slack event time is defined as the amount of time in which the event can be retarded with out involving the scheduled completion time for the project.Any activity on the critical path necessitates time in excess of its expected completion time and detains the project completion consequently.

Table-7

Nodes	**TE**	**TL**	**SE**	**Nodes**	**TE**	**TL**	**SE**
1	0	0	0	48	173.5	277.5	104
2	1.5	197.5	196	49	175.5	275.5	100
3	3.5	3.5	0	50	179.5	271.5	92
4	7	203	196	51	181.5	269.5	88
5	9	333	324	52	187.5	263.5	76
6	13	73	60	53	189.5	261.5	72
7	15	15	0	54	193.5	257.5	64
8	20.5	232.5	212	55	195.5	255.5	60
9	22.5	218.5	196	56	203.5	247.5	44
10	26.5	378.5	352	57	205.5	245.5	40
11	28.5	352.5	324	58	209.5	241.5	32

12	34.5	122.5	88	59	211.5	239.5	28
13	36.5	96.5	60	60	217.5	233.5	16
14	40.5	68.5	28	61	219.5	231.5	12
15	42.5	42.5	0	62	223.5	227.5	4
16	50	274	224	63	225.5	225.5	0
17	52	264	212	64	241	465	224
18	56	252	196	65	251	463	212
19	58	442	384	66	263	459	196
20	64	428	364	67	275	457	182
21	66	418	352	68	287	651	364
22	70	406	336	69	297	649	352
23	72	396	324	70	309	645	336
24	80	180	100	71	319	643	324
25	82	170	88	72	335	435	100
26	86	158	72	73	345	433	88
27	88	148	60	74	357	429	72
28	94	134	40	75	367	427	60
29	96	124	28	76	381	421	40
30	100	112	12	77	391	419	28
31	102	102	0	78	403	415	12
32	111.5	339.5	228	79	413	413	0
33	113.5	337.5	224	80	442.5	654.5	212
34	117.5	333.5	216	81	470.5	652.5	182
35	119.5	331.5	212	82	496.5	848.5	352
36	125.5	325.5	200	83	522.5	846.5	324
37	127.5	323.5	196	84	552.5	640.5	88
38	131.5	519.5	388	85	578.5	638.5	60
39	135.5	517.5	382	86	606.5	634.5	28
40	141.5	509.5	368	87	632.5	632.5	0
41	143.5	507.5	364	88	694	876	182
42	147.5	503.5	356	89	750	874	124
43	149.5	501.5	352	90	810	870	60
44	155.5	495.5	340	91	868	868	0
45	157.5	493.5	336	92	989.5	1113.5	124
46	161.5	489.5	328	93	1111.5	1111.5	0
47	163.5	487.5	324	94	1359	1359	0

Periodical ananlysis

Periodical analysis is done with specific schedule times and the standard normal variables are distinguished in the entire possibelility of probability from zero to one. The percentage of probabilities of completion of the Project are obtained and specified in the following Table-8.

Table-8

SCT	ETC	Z	PROBABILITY	PERCENT OF POSSIBILITY (%)
1355	1356.5	-5.7121	0	0
1356	1356.5	-1.904	0.0287	2.87
1357	1356.5	1.904	0.9713	97.13
1358	1356.5	5.7121	1	100

The Standard Normal Curves are illustrated from Fig. 2-Fig. 4.

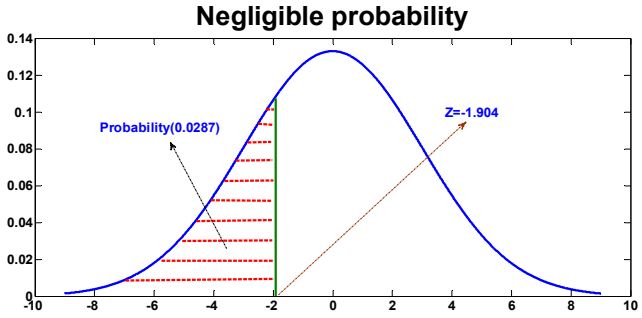


Fig. 2

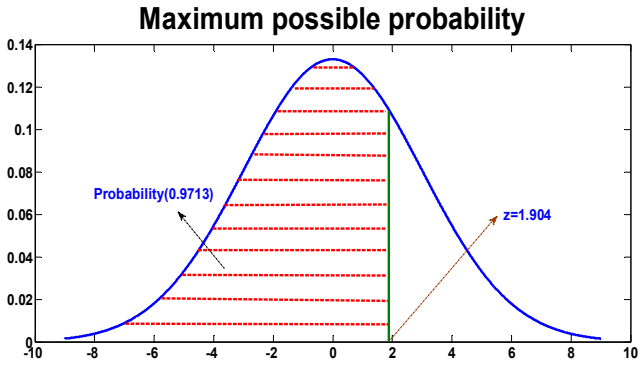


Fig. 3

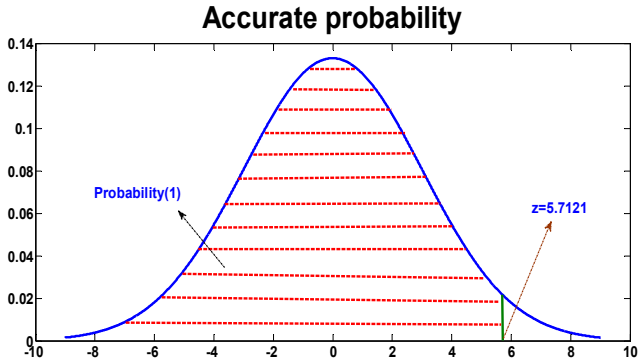


Fig. 4

Conclusions

The conclusions are listed below from the scientific investigation.

(i) The influence of A.P in accordance with SCT and ETC is established as below

  (a) A.P backs up precisely only when SCT is greater than ETC.

  (b) A.P does not backs up efficaciously when SCT is less than or equal to ETC.

  (c) Standard Normal Distribution curves furnish the percentage of possibilities of the Project.

(ii) Constant Variances are identified in any activity of the Network.

(iii) In Critical Path

  (a) All Total Float values of Critical activities are zeros.

  (b) The value of Slack event of each node in critical path has vanished.

  (c) TE and TL are same at each node in critical path.

(iv) In the data of Net work, A.P is considered on optimistic time estimate, the expected completion time of successive activity increased step by step.

(v) A.P affirms conditionally the Network even though the network has big size.

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