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Traditional Critical Path Method versus Critical Chain Project Management: A Comparative View

Shurrab M*

Deparment of Mechanical Engineering, Ksyushu University, Japan

Abstract

Critical Chain Project Management (CCPM) provided a tangible progress to the Project Management Body of Knowledge. The Critical Chain Project Management (CCPM) differs from the traditional Critical Path Method (CPM) which includes never changing resource dependencies. CCPM improves the project plan by aggregating uncertainty into buffers at the end of activity paths. In this research, one hundred twenty random projects were generated and analyzed using Microsoft Project software according to the traditional CPM and the CCPM once using the Sum of Squares (SSQ) method and another using the cut and past (C&PM) method. CCPM-SSQ method revealed an average savings of 13% and 43% in duration and cost, with a standard deviation of 21 and 11 for duration and cost respectively. While the CCPM-C&PM method revealed an average overestimation of about 2% in duration and 43% savings in cost, with a standard deviation of 25 and 11 for duration and cost respectively.

Keywords: Project management; Critical path method; Critical chain method; Scheduling; Theory of constraints

Introduction

Creation of reliable and accurate schedules in project management is the first step towards project success. Using the Critical Path Method (CPM) implies calculating Early Start and Finish dates as well as Late Start and Finish dates by forward and backward analysis of the project network diagram paths. Choosing the relevant resources is usually done after identifying the path. Activity owners add buffers (i.e. safety margin) for each activity in order to overcome the uncertainties [1]. Using CPM, if a resource completes an activity before the planned finish date, the time gain is still not propagated to next activity. That is because the early start date of next activity has been not reached yet. However, delays are propagated which may even change the existing critical path [2]. Critical chain project management (CCPM) is the direct application of the theory of constraints (TOC) to project management developed by Goldrate [3-5] which is a technique related to scheduling analysis for network that considers task dependencies, scarcity of resources, and buffers. CCPM has received much attention recently in project management literature. However, there are still arguments over the advantages and difficulties of the CCPM when compared with the traditional CPM [6-10]. The first buffer sizing method reduces the duration of each activity by 50% and lets the buffer size equal to the summation of half of the reduced duration for each activity. This implies about 25% reduction in project duration. Tukel [10] referred to this as the 'Cut and Paste Method' (C&PM). Leach [11] refers to this as the '50% of the Chain' method, and clarifies by stating that one should not count gaps in the chain or path when applying this method. Advantages include, simple to apply method, and it provides a large enough buffer. Disadvantage of this method is not allowing accounting for known variation in the feeding path. The 'square root of the sum of squares' method (SSQ) makes buffer size as the square root of the SSQ of the difference between low risk duration and mean duration for each task. It perhaps a duration with a probability greater than 90% of being achieved. Merit of the SSQ method is that it permits to account for known variation in task duration. Demerit is that it could lead to undersized buffers for long chains [10]. CCPM method's first step is to identify the set of activities that results in critical chains. The resources which are used in the critical chain activities are usually considered as critical resources. Activities that are not included in the critical chain while at the same time converging to critical chain are considered feeders. The following step is to reduce the duration of the activity considering the buffer management. The main focus of CCPM is to eliminate the uncertain delays, task overestimation duration delays, and wasted internal buffers delays [12]. In CCPM, project duration does not change even if all the activity safety margins were eliminated, because of the project buffer [13]. Project buffer protects the project completion on the critical chain path, while feeding buffers protects the critical chain from path merging [14]. Managing the buffer further improve the decision making of project control. In general, using CCPM will further enhance the project schedule, cost, and scope performance. Experience with CCPM projects demonstrates completion with 10% to 50% in cost and duration [15].

Why are Projects Late

In spite of the fact that task durations are often carefully estimated to begin with, the presence of certain behaviors causes them to increase. Four important behaviors make project durations longer than necessary, which are deliberate padding, student syndrome, bad multitasking and Parkinson's law Woeppel [16], following is a description of each.

Deliberate padding

Deliberate padding happens when after the work has been conservatively estimated several layers of management will increase it even more. Managers feel they must protect their own performance, in many organizations task estimates are not treated as "estimates" but rather as "commitments". People don't want to be late on commitments, thus, they "pad" their estimates of how long a given task will take.

Student syndrome

Student syndrome is a natural defense mechanism in which the work is put off until the last possible moment. The student syndrome causes longer durations because some of the time needed to complete

***Corresponding author:** Mohammed Shurrab, Deparment of Mechanical Engineering, Kyushu University, Japan, Tel: 81 92-642-2111; E-mail: mshurrab@live.com

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a task is lost when it is started too late or even when it is started "just in time." Then, according to Murphy's Law it takes even longer either due to common cause process variation or special cause process variation.

Bad multitasking

Bad multitasking occurs when an individual is working on more than one task at the same time. Multitasking is divided into two categories which are, good and bad. Good multitasking is moving more than one task together in a smooth way. Bad multitasking is working on a single task before it is finished so as to start another.

Parkinson's Law

Parkinson's Law states that "the amount of work rises to fill the time available to complete it".

Objective

This paper aims at comparing the traditional CPM against CCPM Goldratt, [4] once using SSQ and other using C&PM techniques in terms of duration and cost performance.

This will be done by applying the different methods to the one hundred twenty project networks with the different number of activities in each project and different interconnections with resources.

Methodology

To achieve the research objectives, one hundred and twenty combinations of randomly generated project networks were studied and evaluated once using the traditional CPM and another using CCPM with SSQ and C&PM methods. The project networks comprised of activities ranging from seven up to four hundred fifty activities with four different combinations of resources for each. The resources ranged from two to thirty types [17-20]. The networks were tested once without mixed the resources and another with mixed resources. Microsoft Project (MS Project) Software© (2007) have been customized to accept CCPM networks in addition to traditional scheduling, and was used to schedule and evaluate the one hundred twenty generated networks. Table 2 shows the duration, cost, and percent of savings in both duration and cost for each tested network using the traditional CPM, CCPM with the C&PM and SSQ methods [21]. To demonstrate the procedure followed for the one hundred and twenty networks throughout this research, the first case is explained. Figure 1 depicts the Precedence network diagram (PDM) for the first sample project network of the thirty project networks. Next, the resources are loaded and leveled; Figure 2 depicts the Gantt chart after loading resources and leveling for the first case with seven activities and two resources using traditional CPM, while Figures 3 and 4 depicts scheduling using CCPM using the SSQ and C&PM methods respectively (Figures 1-4).

Table 1 shows the output analysis for the first case with a savings of about 25% in duration and 50% in cost. Summary results for the one hundred twenty cases are shown in Table 2.

Analysis

The one hundred twenty sample projects are analyzed using MS Project using CPM and the two CCPM methods with added feature to accommodate for the CCPM criteria. The CCPM-SSQ method revealed an average savings of 12.72% and 43.08% savings in duration and cost respectively, with a standard deviation of 20.99 and 11.05 for duration and cost respectively. Figures 5 and 6 depict those changes against the traditional CPM method.

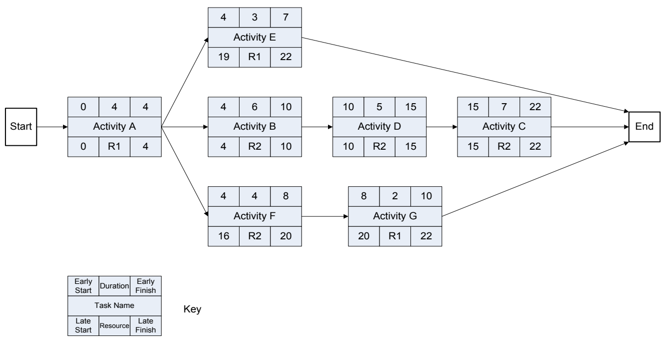

Figure 1: The PDM for the first sample project network.

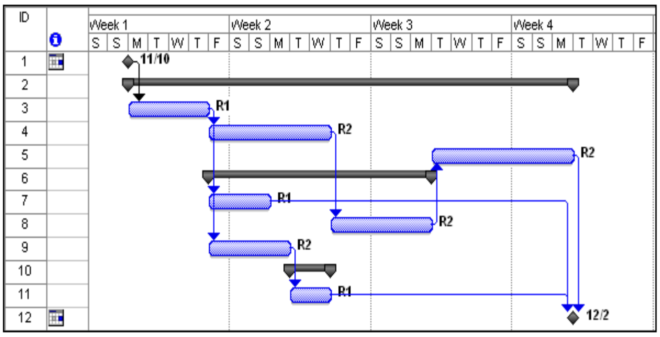

Figure 2: Gantt chart for the traditional CPM.

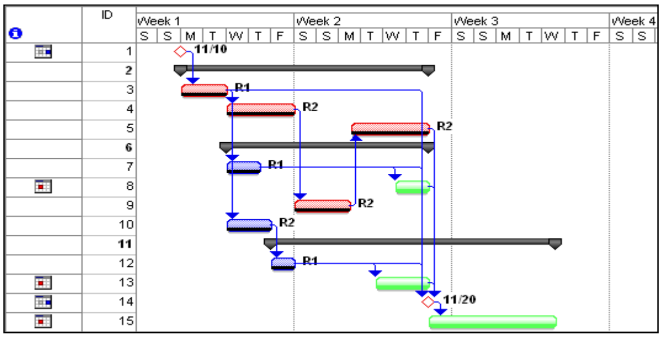

Figure 3: Gantt chart for the CCPM using SSQ method.

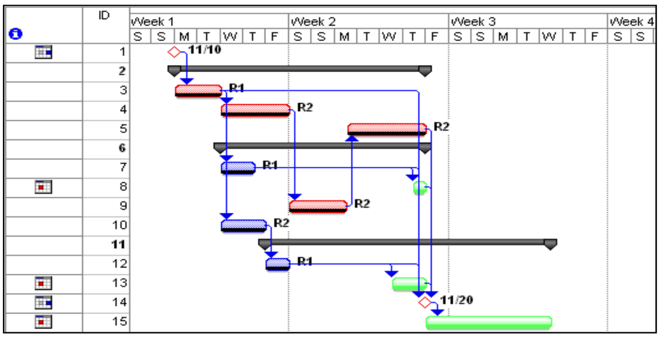

Figure 4: Gantt chart for the CCPM using C&PM method.

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Method	Duration (days)	% Change in Duration	Cost (JD)*	% Change in Cost
CPM	22.00	-	2448	-
CCPM-SSQ	16.61	24.5	1224	50
CCPM-C&PM	16.50	25.0	1224	50

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Table 1: Analysis results of CPM and CCPM method.

Project Number	Number of Activities	Number of Resources	CPM		CCPM							
					SSQ				C&PM			
			Duration (Days)	Cost (JD)*	Duration (Days)	Change in	Cost (JD)*	Change in Cost	Duration (Days)	Change in	Cost (JD)*	Change in Cost
1	7	2	22	2448	16.61	24.50	1224	50.00	16.50	25.00	1224	50.00
	7	2(mix)	19	3200	14.48	23.79	1600	50.00	14.25	25.00	1600	50.00
	7	4	42	6320	32.75	22.02	3160	50.00	31.50	25.00	3160	50.00
	7	4(mix)	15	3184	11.53	23.13	1880	40.96	11.00	26.67	1880	40.96
2	17	5	48	3888	37.27	22.35	1944	50.00	40.50	15.63	1944	50.00
	17	5(mix)	41	3776	29.82	27.27	1888	50.00	32.50	20.73	1888	50.00
	17	8	41	3200	29.82	27.27	1600	50.00	32.50	20.73	1600	50.00
	17	8(mix)	35	3512	26.19	25.17	1756	50.00	28.25	19.29	1756	50.00
3	23	6	70	9184	45.14	35.51	4483	51.19	52.00	25.72	4483	51.19
	23	6(mix)	62	8200	46.81	24.50	4100	50.00	50.75	18.15	4100	50.00
	23	10	60	6860	46.91	21.82	3624	47.17	49.75	17.08	3624	47.17
	23	10(mix)	49	8048	39.53	19.33	4025	49.98	41.76	14.78	4025	49.98
4	30	9	88	10264	59.26	32.66	5132	50.00	69.50	21.02	5132	50.00
	30	9(mix)	73	9420	46.43	36.38	4710	50.00	54.75	25.00	4710	50.00
	30	13	88	8168	99.68	-13.28	4084	50.00	110.00	-25.00	4084	50.00
	30	13(mix)	78	6844	49.48	36.56	3422	50.00	58.50	25.00	3422	50.00
5	35	10	199	15603	135.12	32.10	7804	49.98	155.25	21.99	7804	49.99
	35	10(mix)	93.5	8144	109.33	-16.93	4072	50.00	122.38	-30.89	4072	50.00
	35	14	93.5	6684	82.33	11.95	3342	50.00	95.38	-2.01	3342	50.00
	35	14(mix)	83.75	7080	102.47	-22.35	3602	49.12	114.19	-36.35	3602	49.12
6	47	5	98	16644	61.35	37.40	8386	49.62	74.88	23.59	8386	49.62
	47	5(mix)	86	6160	65.15	24.24	3204	47.99	73.00	15.12	3204	47.99
	47	12	111	9304	74.16	33.19	4644	50.06	88.75	20.05	4644	50.09
	47	12(mix)	124	13579	57.23	53.85	6880	49.33	65.01	47.57	6881	49.33
7	55	8	64	21824	47.13	26.36	10912	50.00	57.50	10.16	10912	50.00
	55	8(mix)	57	17880	45.57	20.05	8940	50.00	51.88	08.98	8940	50.00
	55	13	64	16784	49.48	22.69	8892	47.02	57.50	10.16	8892	47.03
	55	13(mix)	55	17260	45.10	18.00	8630	50.00	53.34	03.02	8630	50.00
8	70	9	90	19084	83.06	07.71	9562	49.90	93.63	-04.03	9562	49.90
	70	9(mix)	77	17814	52.64	31.64	8776	50.74	61.5	20.13	8776	50.74
	70	15	93	19088	70.29	24.42	9960	47.82	85.75	07.80	9960	47.82
	70	15(mix)	90	21016	59.29	34.12	10503	50.02	71.25	20.83	10503	50.02
9	98	18	562	115096	329.22	41.42	57548	50.00	404.50	28.03	57548	50.00
	98	18(mix)	464.5	93600	267.74	42.36	50300	46.26	332.38	28.44	50300	46.26
	98	30	818	129024	482.45	41.02	64752	49.81	604.00	26.16	64752	49.81
	98	30(mix)	919.5	157700	533.68	41.96	78850	50.00	666.88	27.47	78850	50.00
10	120	15	161	488408	122.39	23.98	244076	50.02	168.25	-04.50	244076	50.03
	120	15(mix)	131	45292	97.96	25.22	22696	49.89	127.88	02.38	22696	49.89
	120	23	161	79664	121.11	24.78	39892	49.93	164.25	-02.02	39892	49.93
	120	23(mix)	113	44361	96.42	14.67	22181	50.00	136.75	-21.02	22181	50.00
11	150	15	649	164816	701.06	-08.02	134360	18.48	843.00	-29.89	134360	18.48

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	150	15(mix)	609.5	171304	645.8	-05.96	133748	21.92	739.63	-21.35	133748	21.92
	150	30	657	145958	715.63	-08.92	110907	24.01	791.63	-20.49	110907	24.02
	150	30(mix)	689.5	224560	717.7	-04.09	141751	36.88	812.13	-17.79	141752	36.88
12	170	15	480.5	209712	427.96	10.93	129136	38.42	491.13	-02.21	129137	38.42
	170	15(mix)	428	260158	319.28	25.40	130081	50.00	413.63	03.36	130081	50.00
	170	30	1028	254774	884.36	13.97	127388	50.00	921.95	10.32	127388	50.00
	170	30(mix)	2254.86	1140853	2080.94	07.71	570441	50.00	2237.84	00.76	570442	50.00
13	190	15	649	210208	705.15	-08.65	165344	21.34	891.00	-37.29	165344	21.34
	190	15(mix)	609.5	216928	644.37	-05.72	162666	25.01	729.75	-19.73	162666	25.01
	190	30	715	181457	785.88	-09.91	135735	25.20	892.88	-24.88	135736	25.20
	190	30(mix)	715	235785	775.37	-08.44	174380	26.04	851.88	-19.14	174380	26.04
14	200	8	480.5	249585	425.98	11.35	189011	24.27	489.13	-01.80	189012	24.27
	200	8(mix)	448.5	232743	407.4	09.16	158763	31.79	505.25	-12.65	158764	31.79
	200	15	688	430667	535.86	22.11	215333	50.00	626.00	09.01	215333	50.00
	200	15(mix)	656.25	499651	489.17	25.46	249493	50.07	652.63	00.55	249494	50.07
15	220	15	649	239096	705.15	-08.65	189568	20.72	891.00	-37.29	189568	20.72
	220	15(mix)	609.5	231820	649	-06.48	187736	19.01	730.31	-19.82	187736	19.02
	220	30	715	211461	788.68	-10.30	154617	26.88	899.25	-25.77	154618	26.89
	220	30(mix)	715	91846	787.48	-10.13	204104	48.60	906.25	-26.75	204104	48.60
16	235	10	618	228540	616.11	00.31	156465	31.54	726.5	-17.56	156466	31.54
	235	10(mix)	483	234460	390.71	19.12	157442	32.85	500.61	-03.65	157442	32.85
	235	30	649	257456	425.93	34.37	128728	50.00	567.75	12.52	128728	50.00
	235	30(mix)	602.5	320536	407.03	32.44	160268	50.00	525.75	12.74	160268	50.00
17	250	15	649	268976	704.41	-08.54	213430	20.65	849.5	-30.89	213430	20.65
	250	15(mix)	609.5	264152	636.84	-04.49	212095	19.71	694.18	-13.89	212095	19.71
	250	30	787	231041	859.79	-09.25	167437	27.53	984.63	-25.11	167437	27.53
18	260	15	648	326592	426.93	34.12	163296	50.00	567.75	12.38	163296	50.00
	260	15(mix)	588	358362	392.61	33.23	179182	50.00	509.00	13.44	179182	50.00
	260	30	756	582188	498.84	34.02	310964	46.59	696.75	07.84	310965	46.59
	260	30(mix)	623.33	487629	420.12	32.60	247302	49.28	586.33	05.94	247302	49.29
19	280	10	1166	451272	1580	-35.51	307367	31.89	1861.76	-59.67	307368	31.89
	280	10(mix)	1295.5	703230	1600	-23.50	431187	38.69	1954.00	-50.83	431188	38.69
	280	30	1061	469304	659.32	37.86	313444	33.21	866.00	18.38	313444	33.21
	280	30(mix)	1061	455288	1105.3	-04.18	228508	49.81	1268.25	-19.53	228508	49.81
20	285	15	875	513404	841.38	03.84	258652	49.62	1031.25	-17.86	258652	49.62
	285	15(mix)	868	507860	930.12	-07.16	253940	50.00	1088.69	-25.43	253940	50.00
	285	30	814	405240	885.12	-08.74	202621	50.00	1015.25	-24.72	202622	50.00
	285	30(mix)	894	616462	1109.46	-24.10	308234	50.00	1084.00	-21.25	308234	50.00
21	300	10	649	427052	450.82	30.54	217568	49.05	585.50	09.78	221878	49.05
	300	10(mix)	486	440152	346.81	28.64	220080	50.00	451.25	07.15	220080	50.00
	300	30	810	406388	787.08	02.83	330430	18.69	902.50	-11.42	330430	18.69
	300	30(mix)	602	440872	402.95	33.07	222124	49.62	568.63	05.54	222124	49.62
22	320	15	718.5	341052	821.43	-14.33	308686	09.49	982.00	-36.67	308686	09.49
	320	15(mix)	868	341622	933.81	-07.58	248631	27.22	137.06	84.21	248632	27.22
	320	30	915	273144	999.69	-09.25	236379	13.46	1152.75	-25.98	236380	13.46
	320	30(mix)	984	387640	1193	-21.24	344618	11.10	1170.00	-18.90	344618	11.10
23	335	15	717.5	526824	463	35.47	263412	50.00	622.38	13.26	263572	50.00
	335	15(mix)	678	530756	443.17	34.64	265114	50.05	582.63	14.07	265114	50.05
	335	30	717.5	635268	709.19	01.16	362184	42.99	818.88	-14.13	362184	42.99
	335	30(mix)	813.5	627040	722.36	11.20	313520	50.00	849.63	-04.44	313520	50.00
24	350	20	1468	778825	1572.05	-07.09	389413	50.00	1946.5	-32.60	389414	50.00
	350	20(mix)	1050.5	690739	953.29	09.25	345371	50.00	1165.25	-10.92	345371	50.00
	350	30	915	541605	1346.42	-47.15	270805	50.00	1507.25	-64.73	270806	50.00
	350	30(mix)	872.25	339762	969.7	-11.17	155986	54.09	1083.54	-24.22	155986	54.09

25	365	12	891	792576	633.12	28.94	396288	50.00	797.25	10.52	396288	50.00
	365	12(mix)	660	622692	614.11	06.95	311346	50.00	704.00	-06.67	311346	50.00
	365	30	648	621340	612.45	05.49	310670	50.00	701.00	-08.18	310670	50.00
	365	30(mix)	837	803596	628.41	24.92	401798	50.00	748.25	10.60	401798	50.00
26	385	20	1775.67	945374	1163.81	34.46	542851	42.58	1482.95	16.49	542852	42.58
	385	20(mix)	1216	859831	1302.78	-07.14	474179	44.85	1510.75	-24.23	474179	44.85
	385	30	927.5	632662	782.7	15.61	332025	47.52	979.25	-05.58	332026	47.52
	385	30(mix)	900.5	748249	975.47	-08.33	373962	50.02	1114.8	-23.80	373962	50.02
27	400	20	1678	975604	1837.21	-09.49	487802	50.00	1835.38	-09.38	487802	50.00
	400	20(mix)	1678	1019685	1714.03	-02.15	511626	49.83	1779.17	-06.02	511627	49.83
	400	30	1370	841826	631.64	53.90	441349	47.57	843.00	38.47	441350	47.57
	400	30(mix)	1370	845137	1470.21	-07.32	422569	50.00	1610.5	-17.56	422569	50.00
28	415	20	1147	1143971	1232.18	-07.43	618648	45.92	1532.88	-33.64	618649	45.92
	415	20(mix)	1332.5	932113	1372.38	-3.00	526195	43.55	1639.38	-23.03	531879	43.55
	415	30	982	686558	812.74	17.23	358658	47.76	1033.00	-5.19	358658	47.76
	415	30(mix)	949.67	818709	981.79	-03.38	409239	50.01	1185.00	-24.78	409240	50.01
29	430	20	1605	1540505	993.4	38.11	872045	43.39	1262.63	21.33	872045	43.39
	430	20(mix)	1301	1229093	795.34	38.87	653806	46.81	1030.50	20.79	653807	46.81
	430	30	902	903482	615.13	31.80	469630	48.02	877.88	02.67	485297	48.02
	430	30(mix)	2149	2677032	1465.72	31.80	2045635	23.59	1649.00	23.27	2045636	23.59
30	450	20	1605	1581337	1097	31.65	856731	45.82	1498.00	06.67	856731	45.82
	450	20(mix)	1268.5	1284861	775.03	38.90	647000	49.64	976.13	23.05	647001	49.64
	450	30	902	923990	1217.75	-35.01	458962	50.33	1743.25	-93.27	458962	50.33
	450	30(mix)	1234.5	932583	1339.6	-08.51	466294	50.00	1490.00	-20.70	466294	50.00

*Jordanian Dinar

Table 2: Microsoft Project Sample Results.

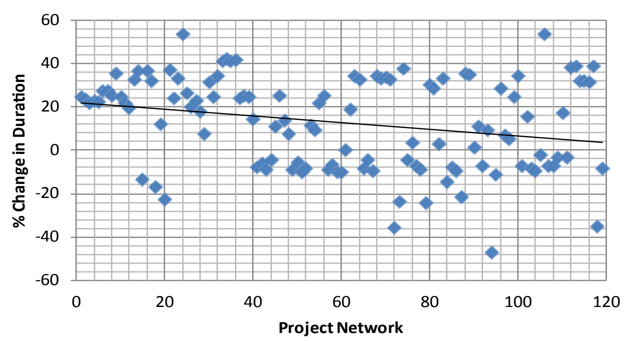

Figure 5: Changes in duration using CCPM-SSQ method.

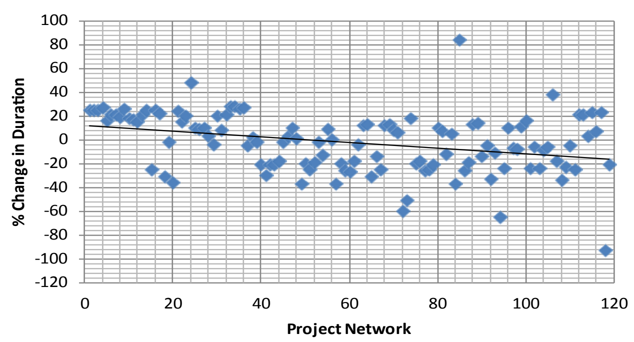

Figure 7: Changes in duration using CCPM-C&PM method.

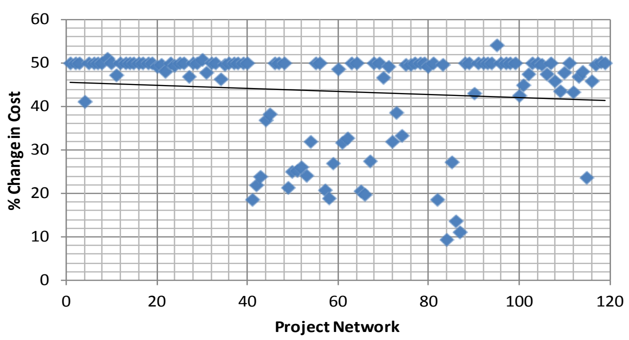

Figure 6: Changes in cost using CCPM-SSQ method.

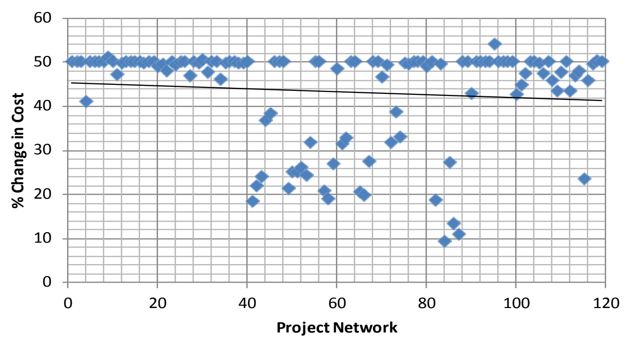

Figure 8: Changes in cost using CCPM-C&PM method.

Using the CCPM-C&PM method revealed an average overestimation of 2% in duration and 43% savings in cost, with a standard deviation of 24.69 and 11.05 for duration and cost respectively. Figures 7 and 8 depict those changes against the traditional CPM method.

In both CCPM methods there was an obvious average savings in cost of about 43%, as for the duration SSQ method resulted in an average savings of about 13% while the C&PM method resulted in an overestimation of about 2%.

Discussion and Conclusions

The traditional CPM technique faces a number of problems such as bad multitasking, Parkinson's Law, student's syndrome and deliberate padding [22-24]. CCPM provides a substantial step in continuous improvement to the project management body of knowledge; however, more research is still required in this direction.

CCPM focus for the whole project, the "Buffers" provide focus and obvious decision for the Project Manager. The essential changes introduced by CCPM relative to the current CPM practices are development of the critical chain using both activity logic and resource constraints, reduction of activity estimated duration and costs in some cases, using buffer management as the primary tool for project management and control.

In this research CCPM technique reduced the duration for some projects, while in others it gave an overestimation in duration. For the projects that CCPM was effective in reducing their durations, there was no particular trend for percentage of reduction, the points are scattered randomly. Looking at the two buffer sizing methods, it appears that each method has its own advantage and disadvantage [25]. A reduction in duration for some projects was obtained using SSQ method while an overestimation occurred using the C&PM method. As for the "time" performance, CCPM-SSQ method changed the project's duration from an overestimation of 47% to a saving of 50%, with an average savings of about 13% and a standard deviation of about 25%, which is consistent to a certain level with the literature that SSQ method provides a reduction in duration between 10% to 50%. For the CCPM-C&PM method, the project's duration changed from an overestimation of 93% to a saving of 84%, with an average overestimation of 2% and a standard deviation of about 25%. Hence, this method resulted in longer project duration than CPM. As for the "cost" performance and looking at the data, we can conclude that CCPM was always an effective approach to reduce the cost for projects. The reduction in cost was the same for both CCPM methods; this can be explained by that the two methods have the same resource leveling. The percentage of savings in cost ranged from 10% to 54% with average savings of 43% and a standard deviation of 11%, which is consistent with the literature which states that the reduction in cost falls between 10% to 50%.

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