Chapter V

Conclusions and Further Research

5.1 Conclusion

This thesis described a comparison buffer sizing approach between C&PM (adjust percent of cutting and pasting) and RSEM under multi project environment.

In experimental design, we divide the level of projects up by using four subproject parameters, namely the number of activities (n), Order Strength (OS), Resource Factor (RF) and Resource Constraintedness (RC), into three levels (Low level, Medium level, High level). Each level, we computed project buffer, feeding buffers and capacity constraint buffer size by using each sizing approaches (C&PM 50%, C&PM 40%, C&PM 30%, C&PM 20%, C&PM 10% and RSEM), then compare project duration of each buffer sizing approach.

We examine master projects which have between 3 and 10 subprojects. Furthermore, we will investigate master project which has 3 subprojects as special case.

In each master project which has subproject form 4 up to 10 subprojects, we could separate into 2 cases, namely: all the subprojects are identical and all the subprojects are different (but in the same level).

For master projects which have 3 subprojects (also called “special case”), the experiment could be separated into two cases, namely, all the subprojects are identical and all the subprojects are different (subprojects might not be the same level)

For each case and each level of subproject, we had done experiment by trying out 100 master projects, so as to observe project duration corresponding to each buffer sizing approach. Because of comparison in each project due date calculated form each buffer sizing approach, so we adopted One-Way Repeated-Measures ANOVA to compare master project due date as experiment result. The experiment result could be summarized as table 5-1, table 5-2, table 5-3 and table 5-4:

According to Table 5-1 (3 subprojects case), we found that RSEM has efficiency (gives little value of project duration) on condition that subproject are in medium or high level (no matter the same or different subprojects), whereas low level subproject give quite inefficient outcome (gives high value of project duration), no matter the same or different subproject.

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With respect to C&PM, if subproject is in medium or high level, higher percent C&PM is inclined to be more efficient (gives little value of project duration) than lower percent C&PM regardless of those subprojects are identical or different, but on the other hand, if subproject is in low level, higher percent C&PM is inclined to be poorer than (gives high value of project duration) lower percent C&PM regardless of those subprojects are identical or different.

Table 5-1: Experiment result conclusion (special case: 3 subprojects)

Characteristic of each subproject	Level of subproject	Comparison of project duration corresponding with each buffer sizing method
Identical	LLL	C50>C40~C30~RSEM>C20>C10
	MMM	C10>C20~C30>C40>C50~RSEM
	HHH	C10>C20>C30>C40>C50>RSEM
Different	LLL	C50>RSEM>C40>C30>C20>C10
	LLM	C50~C30>C40~C20~RSEM>C10
	LML	C50>RSEM~C20~C10>C30~C40
	MLL	C50>RSEM~C10~C40~C30>C20
	LLH	C50>RSEM>C30~C40>C20~C10
	LHL	C10~C20~C30>C40>C50~RSEM
	HLL	C10~C20~C30>C40>C50~RSEM
	MMM	C10~C20>C30>C40~C50~RSEM
	MML	C10~C20>C50~C40~C30~RSEM
	MLM	C10>C30~C20~C40~C50>RSEM
	LMM	C30>C50~C40~C20>C10~RSEM
	MMH	C30~C20>C10>C40~C50~RSEM
	MHM	C10>C20>C30>C40>C50>RSEM
	HMM	C10~C30~C20>C40>C50~RSEM
	LMH	C20~C10~C30>C40>C50>RSEM
	LHM	C10~C20>C30>C40~C50~RSEM
	MLH	C30>C50~C40>C10~C20~RSEM
	MHL	C10>C20>C30~C40>C50>RSEM
	HML	C10>C20>C30>C40>C50~RSEM
	HLM	C10~C20>C30>C40~C50~RSEM
	HHH	C10>C20~C30>C40>C50~RSEM
	HHL	C10>C20~C30>C40>C50>RSEM
	HLH	C10>C20>C30>C40>C50~RSEM
	LHH	C10>C20~C30>C40~C50>RSEM
	HHM	C10>C30~C20>C40>C50>RSEM
	HMH	C20~C10~C30>C40>RSEM~C50
	MHH	C20>C30>C10~C40~RSEM>C50
	Random	C10>C20~C30>C40~C50~RSEM

Remarks:

- L stands for Low level
- M stands for Medium level
- H stands for High level
- A ~ B stands for A is not different form B at significance level of 5%
- A > B stands for A is more than B at significance level of 5%
- In different case and level of subproject is "Random", it means that level of each subproject is selected randomly form Low level, medium level or high level.

Concerning with the comparison between RSEM and C&PM in special case (3 subprojects), the compared result is shown in the following:

- In case subproject are in low level, the project duration corresponding with RSEM is poorer than C&PM 20% and 10%, but better than C&PM 50% regardless of those subprojects are identical or different at significance level of 5%.

- In condition that subprojects are identical, and in the high level, RSEM gives the best result (give the least project duration) at significance level of 5%.
- In condition that subprojects are identical, and in the high level, RSEM and C&PM50% give the best result (give the least project duration) at significance level of 5%.
- In case subprojects are different and in medium level, RSEM, C&PM 40% and C&PM50% give the best result (give the least project duration) at significance level of 5%.
- In case subprojects are different and level of each subproject is selected randomly, RSEM, C&PM 40% and C&PM50% give the best result (give the least project duration) at significance level of 5% and they are not different at significance level of 5%.

Table 5-2: Experiment result conclusion (Identical case)

Level of subproject	Number of subproject	Comparison of project duration corresponding with each buffer sizing method
Low	3	C50>C40~C30~RSEM>C20>C10
	4	C50>C30~RSEM>C20~C40>C10
	5	C50>C40~C30~RSEM>C20>C10
	6	C50>C40~C30>C20~RSEM>C10
	7	C50>C30~C20>C10~C40~ RSEM
	8	C50~C30>C20~C40>C10~RSEM
	9	C50~C30> C20>C10>C40>RSEM
	10	C50>C30~C20~C10>C40>RSEM
Medium	3	C10>C20~C30>C40>C50~RSEM
	4	C10>C20>C30>C40~RSEM>C50
	5	C10~C20~C30>C50~RSEM~C40
	6	C10>C20~C30>C40~C50>RSEM
	7	C10>C20~C30> RSEM~C40~C50
	8	C10>C20~C30>C50~RSEM~C40
	9	C10>C20>C30>RSEM~C50~C40
	10	C10>C20>C30>C40~ RSEM~C50
High	3	C10>C20>C30>C40>C50>RSEM
	4	C10>C20>C30>C40>C50~RSEM
	5	C10>C20>C30>C40>C50~RSEM
	6	C10>C20~C30>C40>RSEM~C50
	7	C10>C20>C30>C40>RSEM~C50
	8	C10>C20>C30>C40>RSEM~C50
	9	C10>C20>C30>C40>C50~RSEM
	10	C10>C20>C30>C40>C50~RSEM

Remarks:

- L stands for Low level
- M stands for Medium level
- H stands for High level
- A ~ B stands for A is not different form B at significance level of 5%
- A > B stands for A is more than B at significance level of 5%

According to table 5-2 which sums up identical case when master projects have between 3 and 10 subprojects.

- **Low level:** RSEM gives quite inefficient outcome (gives high value of project duration) while number of subproject is low, but on the other hand, RSEM improves its efficiency (gives less project duration) when increasing number of subproject. In accordance with table 15-2, it is obviously found that RSEM will give wonderful outcome (give low value of project duration) when the master projects which have number of subproject over 7.With respect to C&PM, higher percent C&PM is inclined to be poorer than (gives high value of project duration) lower percent C&PM. Comparison between RSEM and C&PM is concluded that RSEM give more efficiency (gives little project duration) than all percent C&PM at significance level of 5% when number of subproject is over 7 .

- **Medium level:** RSEM gives pretty good result (give quite low project duration). Higher percent C&PM is inclined to be more efficient (gives little project duration) than lower percent C&PM. Project duration corresponding with C&PM 50% is not different form project duration corresponding with RSEM at significance level of 5%. In accordance with table 15-2 medium level, the efficiency of RSEM is better than efficiency of C&PM 10%, C&PM20% and C&PM 30% at significance level of 5%.

- **High level:** RSEM gives good result (gives low project duration). With regard to C&PM, higher percent C&PM is inclined to be more efficient (gives little project duration) than lower percent C&PM. Project duration corresponding with C&PM 50% is not different form project duration corresponding with RSEM at significance level of 5%. In accordance with table 15-2 high level, the efficiency of RSEM is better than efficiency of C&PM 10%, C&PM20%, C&PM 30% and C&PM 40% at significance level of 5%.

According to table 5-3 which sums up different case (but in the same level) while master projects have between 3 and 10 subprojects.

- **Low level:** we could not conclude RSEM performance because project duration corresponding with RSEM gives inconstant direction outcome. With respect to C&PM, higher percent C&PM is inclined to be poorer than (gives high value of project duration) lower percent C&PM.

- **Medium level:** RSEM gives pretty good result (give quite low project duration). Higher percent C&PM is inclined to be more efficient (gives little project duration) than lower percent C&PM. Project duration corresponding with C&PM 50% is not different form project duration corresponding with RSEM at significance level of 5%. In accordance with table 15-2 medium level, the efficiency of RSEM is better than efficiency of C&PM 10%, C&PM20% and C&PM 30% at significance level of 5%.

- **High level:** RSEM gives good result (gives low project duration). With regard to C&PM, higher percent C&PM is inclined to be more efficient (gives little project duration) than lower percent C&PM. Project duration corresponding with C&PM 50% is not different form project duration corresponding with RSEM at significance level of 5%. In accordance with table 15-2 high level, the efficiency of RSEM is better than efficiency of C&PM 10%, C&PM20%, C&PM 30% and C&PM 40% at significance level of 5%.

Table 5-3: Experiment result conclusion (different case)

Level of subproject	Number of subproject	Comparison of project duration corresponding with each buffer sizing method
Low	3	C50>RSEM>C40>C30>C20>C10
	4	C50>RSEM>C40~C30>C20>C10
	5	C50>C30~C40~RSEM>C20>C10
	6	C50>C30>C40~C20~RSEM>C10
	7	C50>C40~C30~C20>RSEM~C10
	8	C50~RSEM~C20>C30~C40~C10
	9	C50> C30~C20~C40~RSEM>C10
	10	C50>C30~C40~RSEM~C20>C10
Medium	3	C10~C20>C30>C40~C50~RSEM
	4	C10~C20>C30>C50~C40~RSEM
	5	C10>C20~C30>RSEM~C40>C50
	6	C10>C20>C30> RSEM~C40~C50
	7	C10>C20>C30>C40~RSEM~C50
	8	C10~C20>C30>C40>C50~RSEM
	9	C10>C20>C30>C40~C50>RSEM
	10	C10~C20>C30>C40~RSEM>C50
High	3	C10>C20~C30>C40>C50~RSEM
	4	C10>C20>C30>C40>C50~RSEM
	5	C10>C20>C30>C40>C50~RSEM
	6	C10>C20>C30>C40>C50~RSEM
	7	C10>C20>C30>C40>RSEM~C50
	8	C10>C20>C30>C40>RSEM~C50
	9	C10>C20>C30>C40>RSEM~C50
	10	C10>C20>C30>C40>C50~RSEM

Remarks:

- L stands for Low level
- M stands for Medium level
- H stands for High level
- A ~ B stands for A is not different form B at significance level of 5%
- A > B stands for A is more than B at significance level of 5%

According to table 5-4 which sums up mix case (each level of subproject, number of subprojects is selected randomly form 3 up to 10 by equal probability)

Considering identical case:

- RSEM give good result (gives low project duration) in all level. With respect to C&PM low level, C&PM 10%, C&PM 20%, C&PM 30%, and C&PM 40% are not different at significance level of 5%.
- In medium level and high level, higher percent C&PM is inclined to be more efficient (gives little project duration) than lower percent C&PM.
- In medium level, project duration corresponding with C&PM 50%, C&PM 40% and RSEM are not different at significance level of 5%.
- In high level, Project duration corresponding with C&PM 50% is not different form project duration corresponding with RSEM at significance level of 5%.

Considering different case:

- In low level, RSEM give moderate efficiency (project duration neither very great nor very small project duration).With respect to C&PM, higher percent C&PM is inclined to be poorer than (gives high value of project duration) lower percent C&PM.
- In medium – high level, RSEM gives good result (gives low project duration). With regard to C&PM, higher percent C&PM is inclined to be more efficient (gives little project duration) than lower percent C&PM.
- In medium level, project duration corresponding with C&PM 50%, C&PM 40% and RSEM are not different at significance level of 5%
- In high level, Project duration corresponding with C&PM 50% is not different form project duration corresponding with RSEM at significance level of 5%.

Table 5-4: Experiment result conclusion (mix case)

Characteristic of each subproject	Level of subproject	Comparison of project duration corresponding with each buffer sizing method
Identical	Low	C50>C20~C30~C10~C40~RSEM
	Medium	C10>C20~C30>C40~RSEM~C50
	High	C10>C20>C30>C40>C50~RSEM
Different	Low	C50>C40~RSEM~C30~C20>C10
	Medium	C10~C20>C30>C40~RSEM~C50
	High	C10>C20>C30>C40>RSEM~C50
Remarks:	A ~ B stands for A is not different form B at significance level of 5% A > B stands for A is more than B at significance level of 5% Each level of subproject, number of subprojects is selected randomly from 3 up to 10 (equal probabilities)	

Table 5-5 and Table 5-6 show mean value of master project duration corresponding to each buffer sizing method, and display minimum mean value of each level, each situation by shading that cell.

5.2 Further Research

Even if this thesis has not mentioned to search optimal solution and pre-determined due date scheduling problem, these topic are very interesting in project scheduling field.

For this research, we found that RSEM and C&PM buffer sizing method are under the control of activity duration, but they are irrelevant to other factor (such as network complexity , number of resource type etc.).

Further research is recommended for:

- Finding out optimal solution of scheduling when pre-determined project due date under critical chain project management
- Researching a new buffer sizing method which considers other factor, in order to calculate buffer size more efficiently and practically.
- Find relationship between each subproject factor (n,OS,RF,RC) and master project duration.

Table 5-5: Identical case (Mean of master project duration corresponding to each buffer sizing method)

Level of subproject	Number of subproject	C&PM 50 %	C&PM 40 %	C&PM 30 %	C&PM 20 %	C&PM 10 %	RSEM
Low	3	59.15	53.08	53.05	51.24	47.25	53.07
	4	83.40	73.70	78.94	73.71	70.47	78.71
	5	101.67	93.55	93.29	89.98	86.65	93.90
	6	105.32	97.08	98.30	91.21	84.23	89.46
	7	131.41	113.87	125.25	122.46	115.60	113.77
	8	142.86	133.44	139.59	134.31	124.43	123.38
	9	695.35	607.85	682.45	660.13	640.29	578.25
	10	1080.74	952.42	1027.15	1030.58	1009.99	919.69
	Mix	396.20	357.49	365.64	369.80	363.73	355.18
Medium	3	151.63	163.79	180.32	182.67	199.97	150.54
	4	168.90	180.98	195.86	215.66	232.11	177.79
	5	256.11	251.67	294.40	317.51	329.50	252.92
	6	290.30	301.57	376.71	386.00	420.22	279.52
	7	309.18	309.80	362.19	382.85	403.87	309.47
	8	397.16	372.12	451.06	457.86	503.09	392.04
	9	1756.23	1735.61	2013.79	2270.34	2489.01	1772.91
	10	3084.34	3248.98	3634.43	3968.99	4293.10	3136.18
	Mix	878.52	915.92	1043.20	1103.17	1210.84	888.72
High	3	417.20	448.28	526.48	559.40	604.73	410.46
	4	505.95	536.66	657.12	696.68	777.90	505.82
	5	831.24	900.64	1061.24	1128.17	1267.18	829.63
	6	828.74	892.76	1112.65	1165.67	1328.09	835.07
	7	3063.80	3263.12	4044.03	4301.06	5080.12	3066.98
	8	3737.42	3929.71	4645.84	4867.32	5690.10	3744.15
	9	3748.26	4256.59	4860.70	5057.89	5662.06	3817.00
	10	4016.38	4271.16	5105.37	5318.33	5824.93	3999.78
	Mix	1873.52	1971.66	2467.30	2608.97	2956.72	1865.18

Remark:
- When number of subproject is "Mix" , it means that each level of subproject, number of subprojects is selected randomly form 3 up to 10 by equal probability.
- The shaded cell stands for that mean value is minimum.

Table 5-6: Different case (Mean of master project duration corresponding to each buffer sizing method)

Level of subproject	Number of subproject	C&PM 50 %	C&PM 40 %	C&PM 30 %	C&PM 20 %	C&PM 10 %	RSEM
Low	3	57.04	51.84	50.21	47.81	45.06	53.94
	4	128.84	116.66	115.21	112.15	106.70	125.49
	5	181.34	162.70	164.45	152.54	146.16	161.98
	6	257.81	236.88	247.39	236.81	221.72	235.07
	7	258.02	243.84	243.09	237.88	223.18	224.32
	8	277.32	254.51	256.40	269.83	250.76	273.34
	9	498.93	472.04	476.43	474.28	451.48	468.69
	10	505.15	480.92	481.87	478.57	450.70	479.01
	Mix	274.76	257.82	253.51	249.54	232.39	256.39
Medium	3	122.84	124.94	132.17	138.34	142.74	122.05
	4	271.28	268.71	287.34	313.26	323.92	265.43
	5	391.92	432.77	505.26	523.56	557.83	438.01
	6	386.73	403.07	565.09	635.65	649.09	406.60
	7	511.43	531.55	599.73	625.82	647.62	520.25
	8	636.19	689.88	785.26	848.60	868.81	624.94
	9	854.19	871.99	937.22	1001.08	1068.17	808.05
	10	1026.69	1065.03	1188.20	1332.72	1353.23	1062.89
	Mix	690.99	707.56	816.70	867.38	881.50	659.34
High	3	360.63	377.33	426.40	450.00	479.99	355.32
	4	658.06	719.48	853.46	885.76	979.92	656.49
	5	1372.35	1478.40	1838.94	1925.02	2100.88	1364.74
	6	1511.22	1590.56	1956.99	2061.16	2631.09	1500.32
	7	1709.39	1833.02	2138.19	2227.43	2497.86	1710.06
	8	2394.12	2607.17	3080.21	3366.40	3810.14	2397.22
	9	3117.62	3376.22	3748.80	4281.49	4842.95	3131.51
	10	5535.50	6055.25	7048.85	7451.98	8304.35	5509.74
	Mix	2359.18	2538.87	2953.38	3204.01	3561.52	2367.20

Remark:

- When number of subproject is “Mix” , it means that each level of subproject, number of subprojects is selected randomly form 3 up to 10 by equal probability.
- The shaded cell stands for mean value is minimum.