Chapter III

Research Methodology

3.1 Research Framework and Model

With regard to this research, we want to investigate two buffer sizing approaches under CCPM multi project management, namely C&PM (by adjusting percent from cut and paste 10% up to 50%) and RSEM, and adjust some subproject parameters in order to examine whether aforementioned factors have made an impact on overall project duration.

In the first step, we set the master project precedence. For instance, we have set the precedence of master project which has three subprojects as figure 3-1.

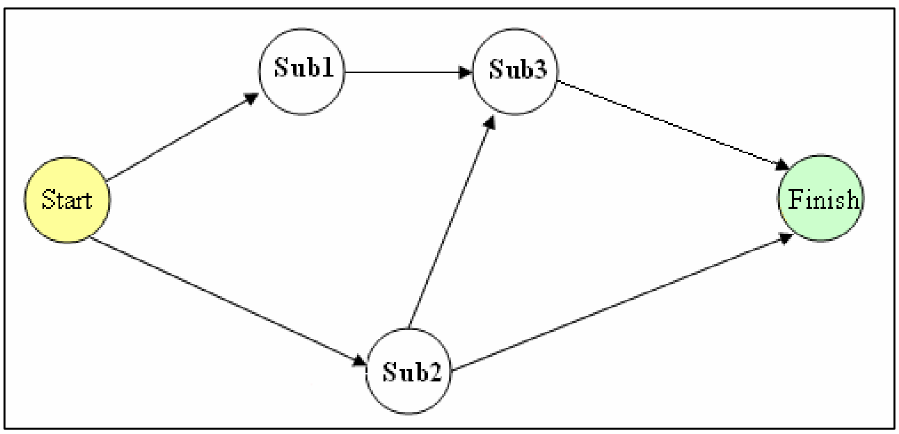

Figure 3-1: The precedence of an example master project

According to CCPM under multi-project environment, the workflow of master project could be summarized as following:

- Plan each subproject as following step:
    - Reduce activity-estimated time by eliminating contingency time.
    - Identify the critical chain.
- Identify the capacity-constraint resource (also called drum resource).
- Add a project buffer (PB), feeding buffer (FB) into each subproject.
- Insert capacity-constraint buffer (CCBs) between the subprojects.
- If insertion of CCBs influences the capacity-constraint resource schedule, resolve contention.

3.2 Research Methodologies and Tools

In this section, we describe our experimental set-up that is used to compare C&PM with RSEM for applying in project buffer, feeding buffer and capacity-constraint buffer sizing. We use the RanGen [1] software developed by Demeulemeester (Demeulemeester, 2003) to generate network instances. Every network is characterized by:

- ***n***: The number of activities in subprojects.
- ***OS***: The order strength; Reyck (Reyck ,1996) defined OS as a the number of precedence relations (including the transitive ones but not including the arcs connecting the dummy start or end activity) divided by the theoretical maximum number of precedence relation n (n-1)/2, where n denotes the number of non-dummy activities in the network. Demeulemeester (Demeulemeester, 2003) conclude that the OS is a measure to describe the density of the network.

In the experiment, the resource usage is defined by two parameters:

- ***RF***: The resource factor reflects the average portion of resource types requested per activity. RF = 1 means that all activities require all resource types in a certain quantity. (Reyck ,1996)
- ***RC***: The resource constrainedness is the average portion of resource availability that used by an activity. RC = 0.5 means that the average usage of an activity that needs a certain resource type, equals half the availability of that type.

The setting for the parameters in this experiment (categorized in three levels) can be found in Table 3-1, and example of using RanGen generating subproject show in figure 3-2 and figure 3-3 (In Patterson format).

Table 3-1: Parameter setting for experiment

	low	**medium**	**high**
n	10	15	20
OS	0.2	0.3	0.5
RF	0.3	0.5	1
RC	0.3	0.5	0.7

[1] Free download *RanGen* Network Generators: http://www.projectmanagement.ugent.be/rangen.php

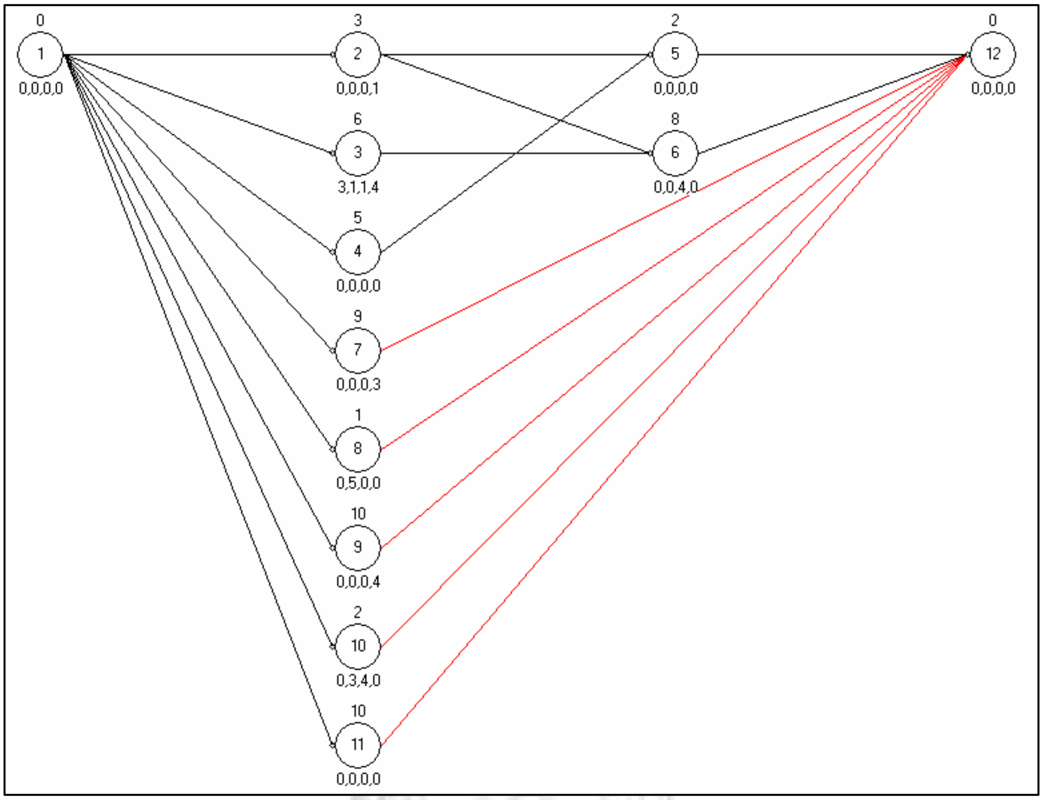

Figure 3-2: Network instance by setting n = 10, OS = 0.2, RF = 0.3 and RC = 0.3. (Low level)

12	4												
10	10	10	10										
0	0	0	0	0	8	2	3	4	7	8	9	10	11
3	0	0	0	1	2	6	5						
6	3	1	1	4	1	6							
5	0	0	0	0	1	5							
2	0	0	0	0	1	12							
8	0	0	4	0	1	12							
9	0	0	0	3	1	12							
1	0	5	0	0	1	12							
10	0	0	0	4	1	12							
2	0	3	4	0	1	12							
10	0	0	0	0	1	12							
0	0	0	0	0	0								

Figure 3-3: Network in Figure 3-2 viewing in Patterson format.

Figure 3-3 shows network of figure 3-2 in form of Patterson format, that format could be explained as follows:

- The first column of the first row denotes how many nodes there are in the entire network including dummy nodes which have zero duration and zero resource consumption. In figure 3-3 have 12 nodes, especially, node 1 and 12 are dummy nodes.
- The second column of the first row shows an amount of resource type in the network. For instance, figure 3-3 has four type resources in the network.

- Each column of the second row shows the amount of each type resource per period. In figure 3-3, each type of resource has 10 units.
- The next row until the last row are the details of each node, those details consist of durations spent on each node, quantity of each resource used per unit time. At the sixth column represents the number of node that connects with considering node. The seventh node till the last column show which node joins with considering node. For example, at the third row, node 1 (dummy node) column 1 = 0 because the duration of dummy activity node is zero; column 2 to column 5 are zero since each resource used on dummy activity node is zero. The sixth column is 8 because there are 8 nodes connect with 0 zero, namely, node 2,3,4,7,8,9,10,11, by showing in column 7 to column 14.

For this experiment, we use Java language and choose Editplus[2] which is a lightweight Shareware text editor for coding Java. Editplus is developed by ES-Computing. Features include color coding for most programming languages, clip text, built in FTP manager, grouping and calling various external applications from within Editplus interface.

An advantage of using Editplus in this thesis:

- Supporting many program languages such as HTML, ASP, Perl, PHP and Java.
- Editplus could compile Java code within this editor.
- Be easier than other editor.
- Editplus has small size.

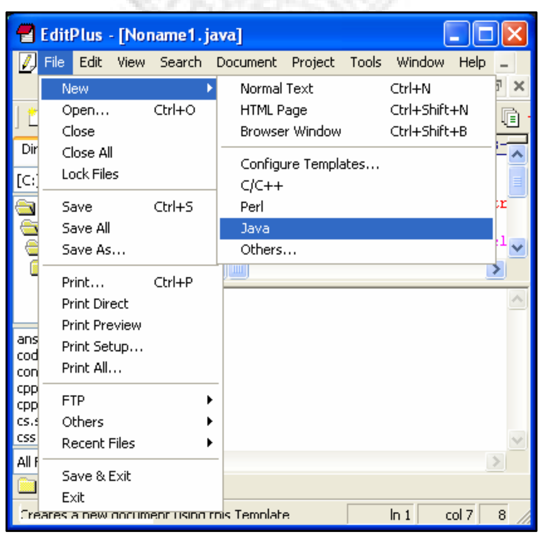

Figure 3-4: Editplus could compile Java code

[2] Free download Editplus: http://www.editplus.com

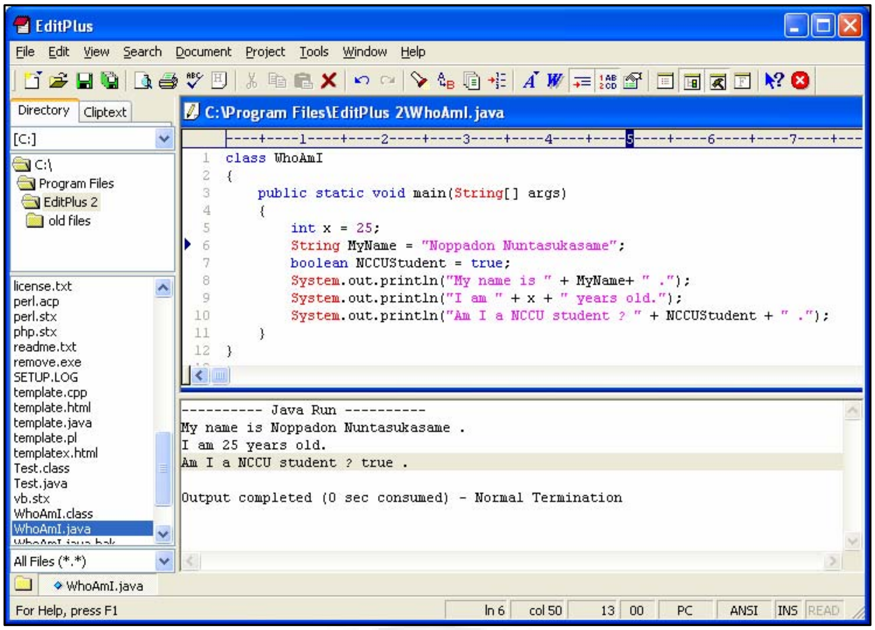

Figure 3-5: Editplus include color coding for most programming languages

In order to analyze comparison result between C&PM and RSEM accurately, we use SPSS for Windows which is a computer application that provides statistical analysis of data. It allows for in-depth data access and preparation, analytical reporting, graphics and modeling. SPSS may be used for many univariate and multivariate statistical analyzes and has facilities for sorting and merging files and manipulating data.

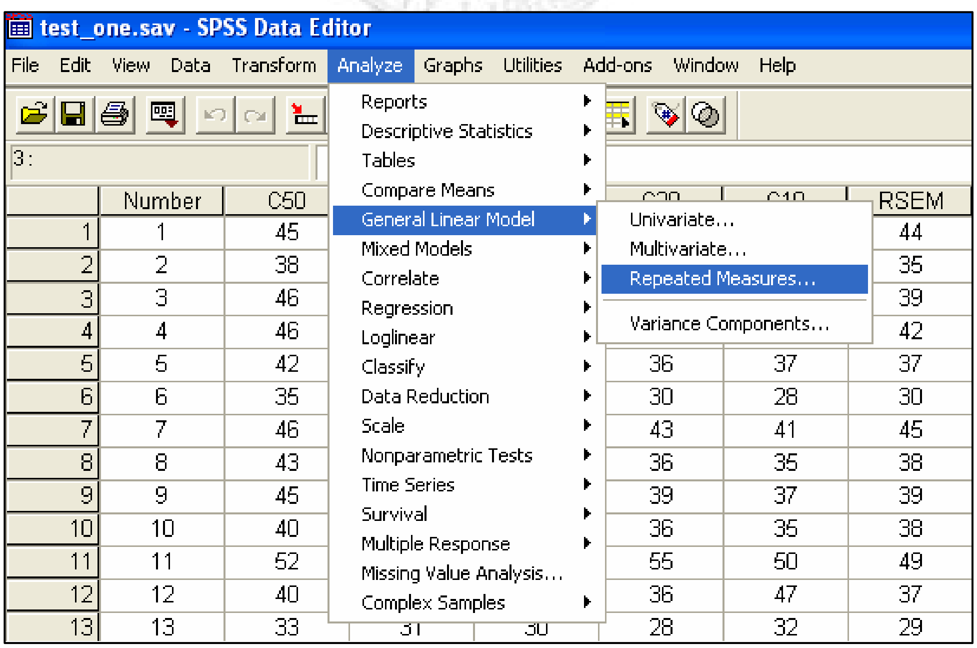

Figure 3-6: SPSS for Windows: A software system for data management and analysis

3.3 Steps of the Research Process

3.3.1 Set-up of the computational experiment

In this section, we describe our experimental set-up which used to compare master project duration corresponding with buffer sizing method by examining 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:

- **Case 1**: all the subprojects are identical
  - Case 1.1 all parameters are low value.
  - Case 1.2 all parameters are medium value.
  - Case 1.3 all parameters are high value.
- **Case 2**: all the subprojects are different (but in the same level)
  - Case 2.1 all parameters are low value.
  - Case 2.2 all parameters are medium value.
  - Case 2.3 all parameters are high value.

For master projects which have 3 subprojects (in this place called "special case"), the experiment could be separated into two cases:

- **Case S1**: all the subprojects are identical
  - Case 1.1 all parameters are low value.
  - Case 1.2 all parameters are medium value.
  - Case 1.3 all parameters are high value.
- **Case S2**: all the subprojects are different (subprojects might not be the same level)

For case S2 of special case, all the subprojects are different, we could separate into 3 groups 27 sub cases, shown as figure 3-7.

According to each level of subproject, RanGen could generate the number of resource type from one type to 30 types:

- Low level (n =10;OS=0.2;RF=0.3;RC=0.3): In each number of resource type, RanGen can generate 613 network instances; therefore, the number of low level project network instance would be $613 \times 30 = 18390$ network instances

- Medium level (n =15;OS=0.3;RF=0.5;RC=0.5): In each number of resource type, RanGen can generate 1000 network instances; therefore, the number of medium level project network instance would be 1000 × 30 = 30000 network instances
- High level (n =20;OS=0.5;RF=1.0;RC=0.7): In each number of resource type, RanGen can generate 1000 network instances; therefore, the number of high level project network instance would be 1000 × 30 = 30000 network instances

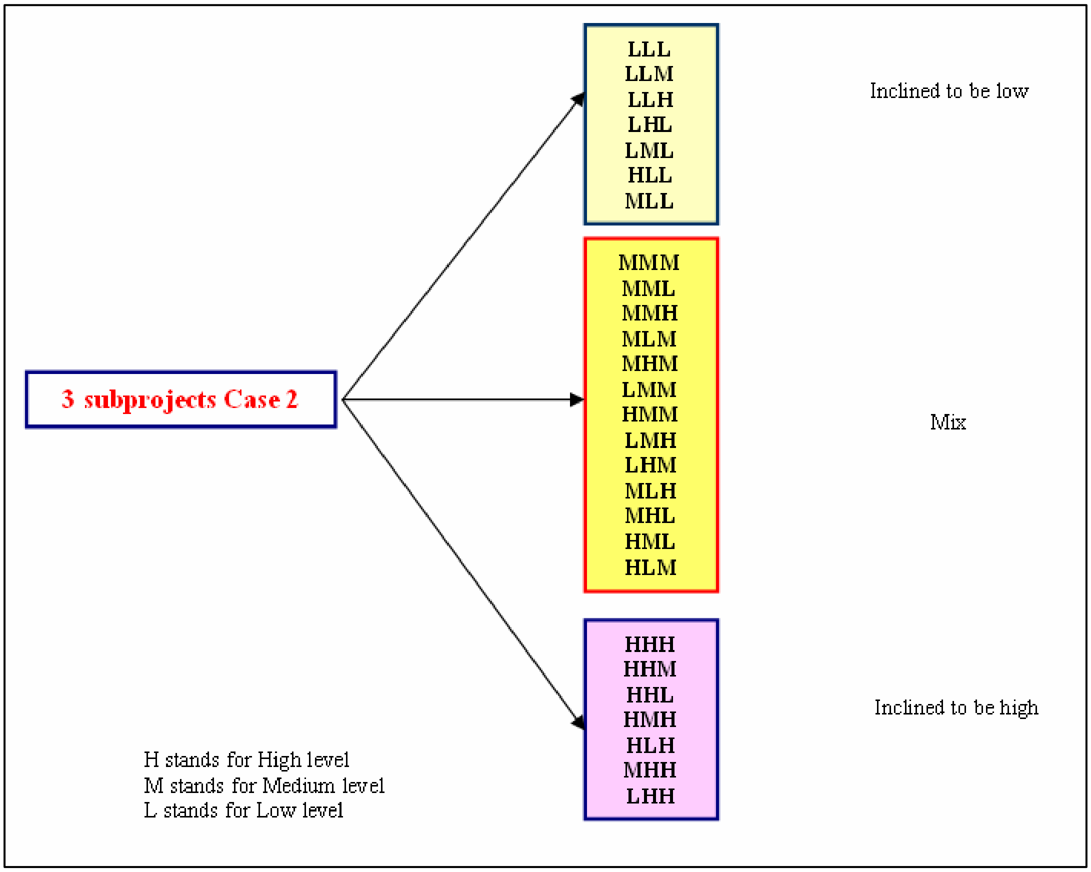

Figure 3-7: Three subprojects case II (all the subprojects are different.)

While sizing buffer in each case, 100 network instances are selected randomly for testing. Besides, computing project buffer , feeding buffers and capacity-constraint buffers size used 6 buffer sizing approaches, namely C&PM 50%, C&PM 40%, C&PM 30%, C&PM 20%, C&PM 10% and RSEM, in order to compare master project due date.

3.3.2 Random Sampling

For example, a random sampling of low level instance, RANGEN could generate resource from one type up to thirty types.

According to table 3-1, Low level; n = 10; OS = 0.2; RF = 0.3 and RC = 0.3

RanGen can generate 613 network instances (for low level), the number of population will be 613×30 = 18390, Then, assign number to all population by assuming the first using of network instance for two type of resource as 614, and the first using of network instance for three type of resource as 1227 and so on.

For example, if we want to examine the case of 3 subproject (by assuming that each subproject is different and all these 3 subprojects are low level; LLL, Different Case). A method of Random Sampling has been used for each subproject by random 100 network instances for each subproject. (Total number of population is 18390) as shown in table 3-2.

Table 3-2: The order number of 100 networks instance which obtained from random sampling

	Subproject 1	Subproject 2	Subproject 3
1	6804	15885	13186
2	1023	14408	24
3	9283	9057	252
4	17958	9285	220
5	15875	240	11272
6	7055	10358	16704
7	980	17885	5166
8	14561	16961	15501
9	3446	16863	6234
10	16775	16827	16433
11	3503	1573	9491
12	15587	825	3204
13	8021	10205	9154
14	15262	8803	15887
15	2133	6003	17123
16	9973	11454	10339
17	8455	11518	11317
18	5967	10994	16943
19	6181	6954	10132
20	726	2582	2330
21	9697	4138	16370
22	1946	1272	6086
23	9096	16088	14892
24	13262	4072	4044
25	17623	18236	9655
26	10830	10818	9928
27	5807	6346	18172
28	15854	2362	14321
29	13083	12803	14060
30	12316	13368	14879
31	17140	15683	11515
32	5101	4043	15506
33	16794	5096	92
34	8715	8795	4700
35	11958	12650	5412

36	16179	9388	8608
37	5232	728	12180
38	657	11345	534
39	1702	17881	12204
40	14701	10803	3910
41	3163	1962	5143
42	13091	15211	4332
43	9844	14867	2295
44	16145	8972	10284
45	9614	9247	9506
46	9722	1790	9849
47	18067	771	2101
48	10331	7641	7935
49	8776	5466	4324
50	8974	889	6774
51	12607	12700	15726
52	8921	15092	8104
53	4994	10232	17617
54	5395	1219	155
55	6766	6483	633
56	17327	15032	526
57	1224	1504	17259
58	8335	10377	17940
59	1522	6742	689
60	6951	6046	10407
61	12325	13305	7119
62	12057	15447	15632
63	807	10545	9102
64	3585	6099	2229
65	4276	5824	13270
66	11869	2963	796
67	3254	5068	5657
68	2025	17648	5901
69	3493	6707	2353
70	9502	9133	6619
71	9970	941	933
72	2565	10346	1534
73	12651	1724	16688
74	1773	6187	12082
75	16342	4512	3160
76	11742	7392	10220
77	3786	7813	713
78	7909	9838	13282
79	6011	10506	4696
80	4435	17826	13215
81	12806	5458	8024
82	3598	16770	2778
83	16822	17804	2334

84	11908	16947	13062
85	2340	1684	10959
86	17773	3199	4856
87	2354	7722	2210
88	11893	12526	15337
89	11880	14809	9383
90	6659	14145	4660
91	1144	13933	437
92	3850	10964	4567
93	9350	8357	8718
94	10728	10361	6063
95	8791	10909	6205
96	15062	5123	2029
97	18034	1376	12905
98	6091	12068	5431
99	18351	9541	3688
100	2061	5418	15565

3.3.3 Data Analysis

An investigation comparing master project duration form six different buffer sizing approaches (C&PM which not only 50% but also adjust percent to be 40%, 30%, 20% and 10% were applied in calculating and use RSEM to compute the buffer so as to contrast its result with C&PM) was set up for each sub case which was specified in section 3.3.1.

Under each case, and each level of subproject, we want to know whether there is a difference among buffer sizing approaches. To answer this question, we need to use One-Way Repeated-Measures ANOVA. The same sample of master projects used all buffer sizing approaches, that is, there are repeated measures on buffer sizing approaches. An example results are shown in Table 3-3.

Table 3-3: Example results of a one-factor within subject experiment

	Capacity-constraint buffer sizing approaches.					
	C&PM_50%	**C&PM_40%**	**C&PM_30%**	**C&PM_20%**	**C&PM_10%**	**RSEM**
1	45	43	42	40	39	44
2	38	37	36	35	38	35
3	46	44	41	39	37	39
4	46	44	43	40	38	42
5	42	40	39	36	37	37
6	35	33	32	30	28	30
7	46	43	44	43	41	45
8	43	41	38	36	35	38
9	45	43	41	39	37	39
10	40	38	36	36	35	38
⋮	⋮	⋮	⋮	⋮	⋮	⋮

The dependent variable was the project duration received from coding program in experiment. The Repeated-measures factor (also called a within-subjects factor) was buffer sizing approaches.

The null hypothesis of the equality of project duration means can be written as:

$$\boldsymbol{H_0}: \mu_{\text{C\&PM 50\%}} = \mu_{\text{C\&PM 40\%}} = \mu_{\text{C\&PM 30\%}} = \ldots = \mu_{\text{RSEM}}$$

The alternative hypothesis is the opposite of this null hypothesis. The opposite of saying that at least one of them is different.

$\boldsymbol{H_1}$: At least one of them is different.

In SPSS, three types of the null hypothesis test are conducted if the within-subjects factor has more than two levels: the standard univariate F test, alternative univariate tests and multivariate tests. All three types of tests evaluate the same hypothesis – the population means are equal for all levels of the factor.

The standard univariate ANOVA F test is not recommended when the within-subjects factor has more than two levels because one of its assumptions , the sphericity assumption, is commonly violated, and the ANOVA F test yields inaccurate p-values to the extent that is assumption is violated (Green, S.B.,2000).

The alternative univariate tests take into account violations of sphericity assumption. These tests employ the same calculated F statistic as the standard univariate test, but its associated p-value potentially differs. In determining the p-value, an epsilon statistic is calculated base on the sample data to assess to degree that the sphericity assumption is violates. The numerator and denominator degrees of freedom of the standard test are multiplied by epsilon to obtain a corrected set of degrees of freedom for the tabled F value and to determine its p-value.

The multivariate test does not require the sphericity assumption. Difference scores are computed by comparing scores from different levels of the within-subject factor. Applied statisticians tend to prefer the multivariate test to the standard or alternative univariate test because the multivariate test and follow-up tests have a close conceptual link to each other. (Landau, S.,2004) . If the initial hypothesis that the project duration means corresponding to sizing approaches are equal is rejected and there are more than project duration means, then follow-up tests are conducted to determine which of project duration means corresponding to buffer sizing approach differs significantly form each other. Although more complex comparisons can be performed, most researchers choose to conduct pairwise comparisons. These comparisons may be evaluated with SPSS using the paired-samples t test procedure, and a *Bonferroni approach*, can be control for Type I error across the multiple pairwise tests.

3.3.4 Running a One-way Repeated-Measures ANOVA in SPSS

In SPSS, One-way Repeated-Measures ANOVA is selected by choosing:

- Analyze>General Linear Model>Repeated Measure…(Figure 3-8)
- Name the within-subject factor: Method (Figure 3-9)
- Identify the number of levels of the within-subject factor: 6 (because we have six buffer sizing approaches)
- Identify the variable which makes up the within-subject factor. (Figure 3-10)
- Request a table of means and graph of estimated marginal.(Figure 3-11)

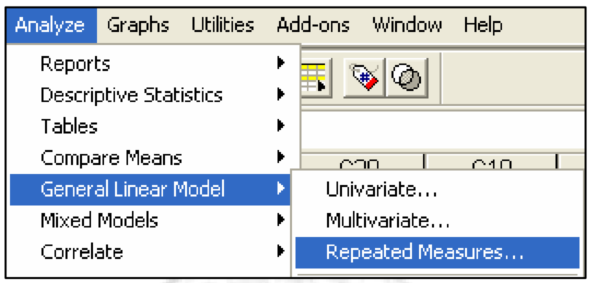

Figure 3-8: Analyze>General Linear Model>Repeated Measure

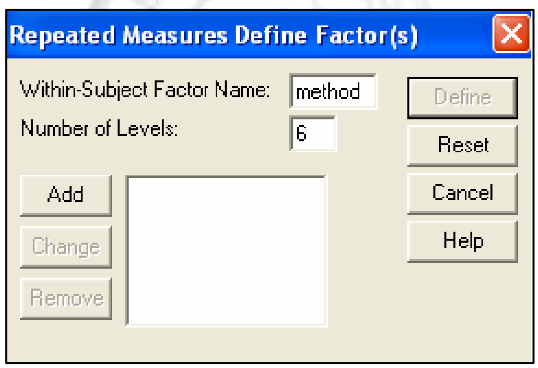

Figure 3-9: Name the within-subject factor

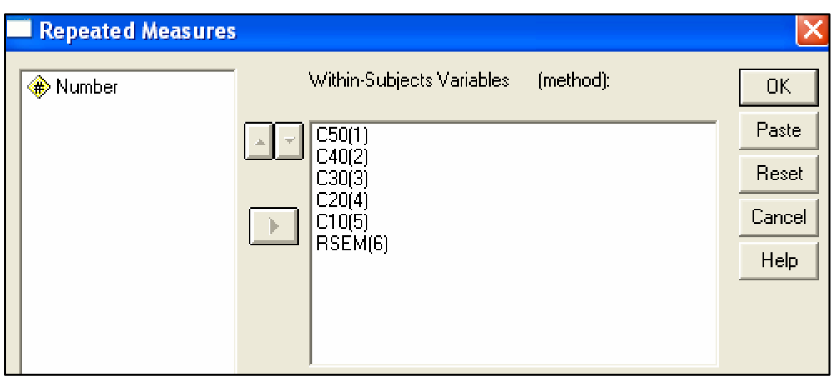

Figure 3-10: Identify the variable which makes up the within-subject factor

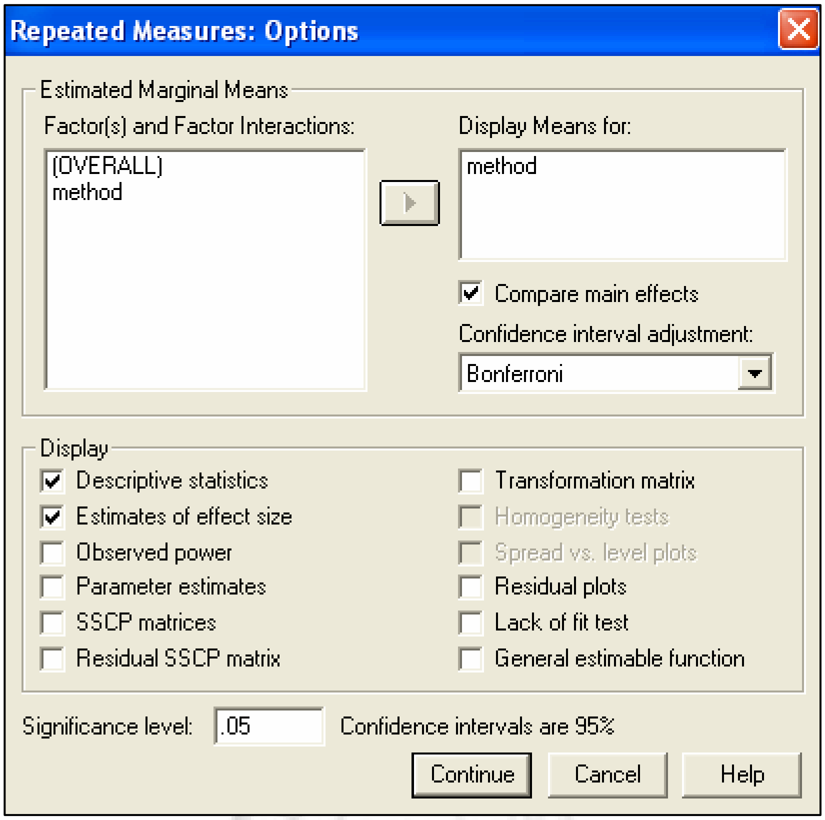

Figure 3-11: Request a table of means and graph of estimated marginal

3.4 Expected Research Outcomes

In single project environment, RSEM has efficiency (gives little value of project duration) on condition that project are in medium or high level, whereas low level project give inefficient outcome (gives high value of project duration).With respect to C&PM, if project 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, 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.

Concerning with the comparison between RSEM and C&PM in single project environment, the compared result is shown in the following:

- In case project are in low level, the project duration corresponding with RSEM is poorer than C&PM 40%, 30%, 20% and 10%, but has not difference statistical significantly at level of 5%.
- In condition that projects are high level, RSEM gives the best result (give the least project duration) at significance level of 5%.

For this experiment, we consider RSEM and C&PM computing buffer size under multi-project environment, we expect that experiment result will be the same as single project environment too.

3.5 Research Limitations

- In case 2 (master project which has subproject form 4 up to 10 subprojects), the subprojects, however, are different, they must be in the same level.
- The priority of capacity-constraint resource, we assume that resource 1 > resource 2 > resource 3 > resource 4.
- No due date constraint.