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THE BOUNDARY BETWEEN GOOD AND BAD MULTITASKING IN CCPM

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ABSTRACT

Elimination of bad multitasking, as one of the main features of Critical Chain Project Management (CCPM), implies that there is also a good level of multitasking that can be retained in such environment. Although there have been attempts to define good and bad multitasking, the boundary between them is not yet lucid in practical terms. The present study intends to clarify this boundary for multi-project environments with ten different rates of resource availability using Monte Carlo simulations of randomly generated project data. The conclusions drawn from results of simulations of ten portfolios with similar size, variability and complexity levels, each containing four projects, show that while no level of multitasking is good for portfolios with resource availability rates of 170% of all resource requirements or higher, for lower rates, a good multitasking of up to two tasks at the same time can be distinguished from multitasking of 3 tasks and more as bad multitasking. This is a significant contribution to the theory of CCPM because of its implications for the roadrunner mentality recommended by CCPM and the fact that for the first time a boundary is suggested for determination of good and bad multitasking in multi-project environments.

1. Introduction

Goldratt *(1997)* extended application of his Theory of Constraints *(TOC)* to project management in a business novel named "Critical Chain" and advocated it as a new method for scheduling and managing projects. The method was later called Critical Chain Project Management *(CCPM) (Leach, 2000)* and since then, many authors have studied and critically reviewed its fundamentals, principles and literature: e.g. Leach *(1999, 2003, 2014)*, Lechler et al. *(2005)*, Herroelen and Leus *(2001)*, Ghaffari and Emsley *(2015)*, Trietsch *(2005)*, Raz et al. *(2003)*, Steyn *(2001, 2002)*. It is not within the scope of this study to elaborate on CCPM basics. Thus, readers are kindly referred to the noted studies for further information on CCPM fundamentals, principles and literature.

CCPM promotes a specific type of work ethic called relay race *(also called roadrunner in some sources)* for project environments. In the relay race work ethic resources are encouraged to work 100% dedicated to an allocated task and complete it as soon as possible without having a deadline *(just like a relay runner who is not instructed when to finish and is only supposed to do her/his best to finish as soon as possible) (Kendall and Austin, 2013)*. CCPM establishes such work ethic by eliminating task deadlines, using the median value *(with 50% probability of completion)* of task estimates, starting non-critical chains as late as possible, eliminating the blame culture in a project team and forbidding bad multitasking.

Picking up on the last feature of relay race work ethic mentioned above, multitasking generally happens when resources switch among unfinished tasks in one or more projects. Studies conducted on the relationship between the level of multitasking and performance of task owners in fields other than project management *(Buser and Peter, 2012; Coviello et al. 2010; Elfving and Tommelein, 2003)* widely show that multitasking has an adverse effect on level of productivity of subjects due to issues it causes to human brains' functionality *(Edwards and Gronlund, 1998; Foerde et al., 2006; Gladstones et al. 1989; Pashler, 1994; Gorlick, 2009)*. It has also been demonstrated that brain can only handle a maximum of two simultaneous tasks satisfactorily *(Charron and Koechlin, 2010; Clarke and Wheelwright, 1993; McCollum and Sherman, 1991)*.

As mentioned, one eminent feature of a relay race work ethic in CCPM is that it is completely against bad multitasking of resources *(Leach, 2000, 2003, 2014; Herman and Goldratt, 2010; Shurrab, 2015)*. Bad multitasking is defined by TOCICO Dictionary *(Cox et al. 2012) (the most reliable source for definitions of TOC terms and acronyms)* as a situation where "switching tasks does not help any project finish earlier". On the other hand, there is a good type of multitasking when "a resource is forced to stop a task on one project in order to complete a task that is delaying the critical chain or the most penetrating chain on another project, thereby helping that project to finish earlier" *(Cox et al. 2012)*.

There is no consensus among CCPM authors on the above definitions. For example, while Goldratt UK *(2007)* agrees with the definitions provided by TOCICO Dictionary, Whoeppel's *(2009)* and Palmer's *(2013)* definitions of bad multitasking forbids any kind of switching among tasks and considers only non-project work *(e.g. catching up on customer calls or attending training sessions)* as good multitasking. Kerzner *(2006)* mentions that multitasking can be good when a resource is waiting for an approval of his/her task, for instance, and is able to work on another short task before immediately resuming work on the previous one. Moreover, Sproull *(2015)* more generally defines bad multitasking as working on multiple project activities at the same time.

One shortage of all the above definitions is that they suggest no practical boundary between good and bad multitasking, i.e. whereas they define the meanings of each concept, they do not clarify when one level of multitasking in a multi-project environment with a specific rate of resource availability should be considered good and when it should be considered bad multitasking. The aim of this study is to clarify such boundary, if it exists, through answering the following question:

What is the boundary between good and bad multitasking in CCPM multi-project environments with different rates of resource availability?

2. Methodology

The research design for this study has been chosen to be experimental *(Matthews and Ross, 2010)*. As Saunders et al. *(2009)* write, experiments are usually conducted using simulated environments in laboratories. This is also true in the context of this research since it is not possible or practical to undertake projects in reality in order to answer the research questions. Therefore, computer simulations are deployed for simulating the implementation of portfolios with a quantitative approach for data collection and analysis has been used. The simulations facilitate testing the following hypothesis:

- A boundary can be established between good and bad multitasking with regard to the rate of resource availability.

The independent and dependent variables of the simulations are depicted in **Figure 1**.

Two software packages were used for the simulations:

- RanGen: a random project network generator that allows manipulation of more topological measures and resource characteristics compared to other alternatives such as ProGen, ProGen/Max and DAGEN.
- Primavera Risk Analysis (PRA): a risk analysis software product that simulates project schedules, using the Monte Carlo method, in order to evaluate the level of confidence a project or a portfolio of projects can meet its obligations. Contrary to other alternatives such as @Risk and Crystal Ball that are spreadsheet based, it can model projects as activity-on-node networks.

Ten portfolios *(ten different rates of resource availability)*, each containing four projects with 30 activities *(each task requires a minimum of 2 types of resources (resource use (RU)* = 2) and 4 resource types, are generated using the characteristics mentioned in Tables 1 and 2 *(refer to Demeulemeester et al., (2003)* for definition of jargon used in these tables). The aim has been to generate projects and portfolios that represent a wide variety of project types.

It has been concluded that the two factors shared by the studies on projects' typology *(Youker, 1999; Shenhar et al. 2002; Wheelwright and Clark, 1992; Shenhar and Dvir, 1996; Pinto and Covin, 1989)*, that are also consistent with the capabilities of the software used by this study, are levels of complexity *(in terms of tasks' interconnectedness)* and uncertainty. Therefore, every project of a portfolio will have different levels of complexity *(determined by order strength (OS)* and complexity index *(CI)* parameters in RanGen) and uncertainty *(determined by the coefficient of variation (CV)* for all tasks in PRA).

A distribution with a higher value of CV has more relative variation *(uncertainty)*. Considering the fact that about 90% of values in any type of distribution lie within three standard deviations on either side of the mean *(Chebyshev's theorem) (Levine, 1984)*, CV values of 0.2, 0.4, 0.6 and 0.8 have been chosen, meaning that a maximum increase or decrease of 60% in the most certain tasks and 240% for the most uncertain tasks are expected. The distribution of all activities' duration was assumed to be lognormal *(characterised by mean values equal to the task durations obtained from RanGen and standard deviations obtained from the CV values mentioned above)*, as suggested by most CCPM authors *(e.g. Goldratt, 1997; Newbold, 1998)*.

The values of OS, CI and CV considered for each project of a portfolio are depicted in **Table 1** in which the complexity and uncertainty of projects increases from Project 1 to Project 4. From the range of CI values that RanGen generates for every value of OS *(Demeulemeester et al., 2003)*, lowest *(8)* and highest *(24)* were selected for the first and fourth projects respectively and middle values *(15 and 19)* were selected for the other two projects.

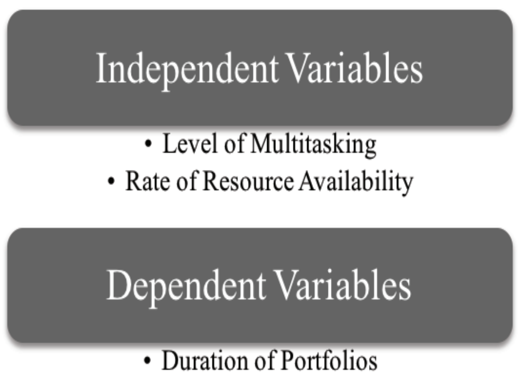


FIGURE 1. *Dependent and independent variables of simulations*

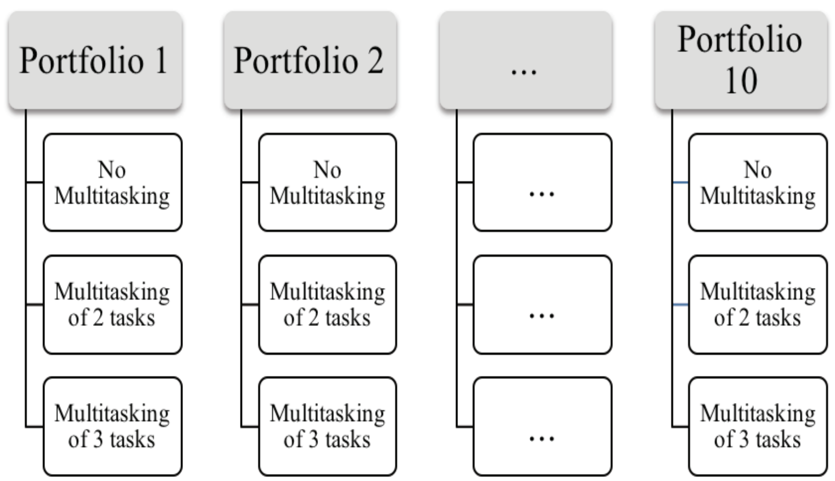


FIGURE 2. *Thirty simulation scenarios*

Project 1	Project 2	Project 3	Project 4
OS1 = 0.2 CI2 = 8 CV3 = 0.2	OS = 0.4 CI = 15 CV = 0.4	OS = 0.6 CI = 19 CV = 0.6	OS = 0.8 CI = 24 CV = 0.8

1. Order Strength, 2. Complexity Index, 3. Coefficient of Variation

TABLE 1. *Complexity and uncertainty levels considered for each project in on of the portfolios*

	Resource Types	Resource Use (RU)	Resource Constrainedness (RC)
Portfolio 1	4	2	0.1
Portfolio 2	4	2	0.2
Portfolio 3	4	2	0.3
Portfolio 4	4	2	0.4
Portfolio 5	4	2	0.5
Portfolio 6	4	2	0.6
Portfolio 7	4	2	0.7
Portfolio 8	4	2	0.8
Portfolio 9	4	2	0.9
Portfolio 10	4	2	1.0

TABLE 2. *Resource characteristics of each portfolio*

Based on the above characteristics, ten portfolios, each containing four projects, have been generated using RanGen and modelled in PRA. The models were developed in accordance to CCPM rules for multi-project management through using the prioritising feature of PRA and sequencing the projects of each portfolio based on the same constraining resource for all portfolios, as described by Leach *(2014)*.

Taking into account the other independent variable *(**Figure 1**) (level of multitasking)*, each of the ten portfolios are simulated in presence of one of these three scenarios using PRA: no multitasking, multitasking of two tasks for each resource at a time and multitasking of three tasks for each resource at a time *(**Figure 2**)*. As a result, a total of thirty simulation scenarios need to be undertaken.

The dependent and independent variables of simulations *(**Figure 1**)* are operationally defined to facilitate analysis as follows:

- Level of multitasking: different levels of multitasking were simulated using the work suspension function of PRA by allowing no suspension (no multitasking), one suspension for each task (multitasking of 2) and two suspensions for each task (multitasking of 3).
- Rate of resource availability: the maximum resource capacity available to each portfolio compared to its requirements. For example, a portfolio with resource constrainedness (RC) of 0.5 has 150% rate of resource availability meaning that 50% of total resource capacity remains unallocated.
- Duration of portfolios: final duration values with 90% probability of happening (that is the probability of finishing CCPM projects on time (Goldratt, 1997)) were obtained from simulations and used throughout the rest of this study.

The modelled portfolios were simulated using PRA for 1000 iterations and results were statistically analysed using the Mann-Whitney-Wilcoxon *(MWW)* nonparametric test before discussing their implications for the research aim, hypothesis and question in the following sections.

3. Results and Analysis

Results obtained from 1000 iterations of portfolio models are shown in **Table 3** below.

*All numbers are in days (unit of time) *1000 iterations were conducted for each condition		No Multitasking	Multitasking of 2	Multitasking of 3
Portfolio 1 (RC0.1)	Duration with 90% Probability	137	137	137
Portfolio 2 (RC0.2)	Duration with 90% Probability	144	144	144
Portfolio 3 (RC0.3)	Duration with 90% Probability	155	155	155
Portfolio 4 (RC0.4)	Duration with 90% Probability	168	164	162
Portfolio 5 (RC0.5)	Duration with 90% Probability	174	170	168
Portfolio 6 (RC0.6)	Duration with 90% Probability	203	194	190
Portfolio 7 (RC0.7)	Duration with 90% Probability	223	211	209
Portfolio 8 (RC0.8)	Duration with 90% Probability	224	212	209
Portfolio 9 (RC0.9)	Duration with 90% Probability	257	242	237
Portfolio 10 (RC1.0)	Duration with 90% Probability	262	243	240

TABLE 3. *Results of simulations run by PRA*

It can be said from the data shown in **Table 3** that changing the level of multitasking only makes a difference in duration of portfolios where the rate of resource availability is between 100% *(RC 1.0)* and 160% *(RC 0.4)* of the total resource requirements. These differences show that in all cases, shorter durations can be obtained by increasing the level of multitasking. In other occasions, the duration stayed the same for the three levels of multitasking considered in this study meaning that the amount of extra resource capacity in those conditions offsets the extra resource requirements of having a no multitasking policy. Another observation is that regardless of level of multitasking, a rising trend can be seen for duration values when moving from high resource availability *(RC 0.1)* to low resource availability *(RC 1.0)*. Moreover, the amount of duration variation for different levels of multitasking in each degree of resource availability decreases when moving to the opposite direction. The implications of these will be discussed in the next section.

As distribution of duration values are expected not to be normal due to lognormal distribution of all tasks, MWW nonparametric test is conducted using 1000 samples obtained for each condition and the SPSS software to establish whether the difference among results *(for RCs of 0.4 to 1.0)* shown in **Table 3** are statistically significant. Assuming a significance level of $\alpha = 0.05$, a null *(H0: samples of two populations are identical)* and an alternative *(Ha: samples of two populations are not identical)* hypotheses, the results of MWW test for each pair of conditions are demonstrated in **Table 4**.

*All values are level of significance (p-value)	No Multitasking & Multitasking of 2 MWW Test	No Multitasking & Multitasking of 3 MWW Test	Multitasking of 2 & 3 MWW Test
RC 0.4	.000	.000	.006
RC 0.5	.000	.000	.006
RC 0.6	.000	.000	.003
RC 0.7	.000	.000	.008
RC 0.8	.006	.000	.000
RC 0.9	.000	.000	.028
RC 1.0	.000	.000	.007

TABLE 4. *Level of significance (p-value) from the Mann-Whitney-Wilcoxon (MWW) test for the portfolios with different duration values*

According to **Table 4**, there is strong evidence against the null hypothesis for all tests *(p-value < α = 0.05)*. This is consistent with portfolio duration values demonstrated in **Table 3** where all portfolios *(RC 0.4 to 1.0)* have different duration values for various multitasking levels of none, 2 and 3. Therefore, it can be concluded from the MWW tests that discrepancies among duration values in **Table 3** are statistically significant and thus, are valid for comparisons to be drawn among them in the discussion section below and for the purpose of addressing the aim and question of this research.

4. Discussion

Implications of results for the research aim, question and hypothesis are discussed here. The aim of this study was to clarify the boundary between good and bad multitasking in multi-project environments with different rates of resource availability. This aim invoked one research question and one hypothesis that are hereby addressed using the achieved results.

What is the boundary between good and bad multitasking in CCPM multi-project environments with different rates of resource availability?

According to **Table 3**, different levels of multitasking do not affect duration of portfolios with RC of 0.3 or lower while a decrease in duration values can be seen for other portfolios in tandem with higher levels of multitasking. Based on this, it can be said that the level of multitasking is not important when the rate of resource availability is higher than 170% of all resource requirements although higher levels of multitasking are favourable for lower rates of resource availability.

To explain the resemblance of duration values for portfolios with RC of 0.3 and lower, it could be said that the abundance of resources in portfolios with RC of 0.3 and lower where there is no multitasking is to an extent that outweighs the opened-up capacity for the same portfolios where certain levels of multitasking are allowed. Nevertheless, this is not the case for portfolios with RC of 0.4 and higher where resource capacity is overwhelmed by business of resources on only one task at a time compared with the situation where resources are allowed to work on two or three tasks at the same time.

Something that must be taken into account is that it is not only the mechanical effects of multitasking that should be considered but also the human side of it. The literature of multitasking would facilitate a more comprehensive interpretation of these results as follows. It should also be noted that although portfolios are different in two controlled attributes of level of multitasking and resource constrainedness, their results are considered as comparable across portfolios other than these two attributes because of sharing many other similar specifications such as variability, size and complexity of their networks.

Considering the literature of multitasking that was reviewed in the introduction, most researchers *(e.g. Clarke and Wheelwright, 1993; McCollum and Sherman, 1991; Charron and koechlin, 2010; Buser and Peter, 2012; Coviello et al., 2010; Gorlick, 2009)* have come to the conclusion that multitasking *(specially on 3 or more tasks)* has detrimental effects on human health and productivity. Having these in mind, the unchanged duration for portfolios with RC of 0.3 and lower suggests that a policy of no multitasking with presence of the relay race mentality is more preferable in such environments in order to avoid damaging consequences of multitasking.

With regard to portfolios with RC of 0.4 and higher, although duration values of **Table 3** decline by allowing more multitasking, the extent of this reduction is considerably lower for the change from multitasking of 2 to 3 comparing to the shift from no multitasking to multitasking of 2 for each portfolio. For example, while the duration of portfolio with RC of 1.0 reduces from 262 to 243 days *(a change of 19 days)* by increasing the level of multitasking from none to 2, it further goes down to 240 days *(a change of 3 days)* when this increases to multitasking of 3 indicating that multitasking of 2 is a great deal more beneficial in alleviating resource availability issues than multitasking of 3. This supports the hypothesis of this study that says:

A boundary can be established between good and bad multitasking with regard to the rate of resource availability.

On the one hand, the policy of no multitasking is an important part of the relay race mentality in CCPM; on the other hand, high levels of multitasking *(specifically multitasking of more than 3)* is discouraged by many authors. According to hypothesis A and results of simulations in **Table 3** and considering the literature of multitasking, it can be said that multitasking of 2 is an appropriate boundary between good and bad multitasking for portfolios with resource availability of 160% and lower *(RC of 0.4 and higher)* despite the fact that shorter duration values can still be achieved by increasing the level of multitasking to 3. The reason for this is that multitasking of 2 enables managers to address more critical tasks, which are already eroding buffers in CCPM, by interrupting required resources and switching them to those tasks; and also to refrain from encountering excessive multitasking problems explained earlier.

Thus, the rule of no bad multitasking in relay race work ethic does not always mean no multitasking in all environments. However, higher levels of multitasking *(good multitasking)* should be managed in a way that does not damage other aspects of the relay race mentality *(explained earlier)*. Its control must be in the hands of the management team, not the personnel, and be allowed only in times when a more critical task, that is causing penetration into buffers, requires resources that are involved in another task.

5. Conclusions and Recommendations

This study addressed a lack of evidence and a gap that existed about the boundary between good and bad multitasking in the literature of CCPM. A quantitative research method was used to generate, model and simulate ten portfolios with similar size, variability and complexity levels and interpret results with respect to the aim and question of this research. This study proved that such things as good and bad multitasking exist and identified a practical boundary between these two concepts. According to the findings of this study, while all levels of multitasking is bad in portfolios with resource availability rate of 170% or higher, multitasking of up to two tasks should be considered as good multitasking and multitasking of higher than that as bad multitasking for lower rates of availability. Therefore, good multitasking in an organisation should be considered based on the rate of resource availability in that organisation.

In addition, other aspects of the relay race work ethic must remain in place in order to address identified deficiencies of traditional project management stressed by CCPM such as student syndrome *(procrastination)* and Parkinson's Law. In order to avoid adverse effects of multitasking, a good level of multitasking should only be used when a more critical task is causing red-level penetration into the project buffer while waiting for its required resources. This good level of multitasking should not be in a back-and-forth style and the resource must be allowed to finish its new task before resuming work on the unfinished one.

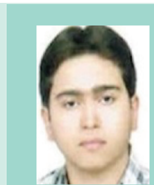
6. Limitations and future research

The validity of results of this study is limited by the extent of effectiveness and capabilities of the software packages that were deployed, namely RanGen and PRA. The available alternatives to these packages and the rationale for choosing them were explained in the methodology section; however, it is certain that their selection over others would have a potential impact on the results. For example, PRA's specific internal resource levelling algorithms and heuristics could be different in any other software. Moreover, there was no recognition of CCPM principles in PRA and they have to be imposed through task and portfolio prioritising function.

Another limitation of this study was the usage of generated data instead of real CCPM projects' data. Although deployment of real data could improve validity of the results through consisting many real-life events such as rework or change of resource capacity throughout portfolios, the controllable topological parameters of generated data enabled a more comprehensive research by including varieties of projects with different variability, complexity and resource availability rates.

Considering what was accomplished in this research, a number of suggestions can be made for future research. Firstly, because of the choices made in selection of software packages, aspects of real environment such as rework and iterative work style were not taken into account in modelling and simulations that could be considered for future studies. Secondly, only human resources were considered in this research. This can be extended to a combination of human and non-human resources in future similar studies. Thirdly, with accumulation of historical data about CCPM projects and portfolios through time, real project data can be deployed in future studies instead of generated data.

authors



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