Evaluation of the Resource Leveling Techniques Employed by Contractors in the Kenyan Construction Industry

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Abstract: ***The purpose of this research was to identify and evaluate the various resource leveling techniques employed by contractors in the Kenyan construction industry. The researcher adopted a survey research design whereby questionnaires were distributed among contractors. A response rate of 76% was achieved. The three most popular Resource Leveling techniques employed by contractors were found to be fast tracking, Microsoft Project and authorizing overtime. The three least popular Resource Leveling techniques were found to be splitting tasks into non-sequential pieces, delaying critical path tasks and doing nothing. The three most effective Resource Leveling techniques as experienced by contractors were found to be fast tracking, Microsoft Project and substituting resource of equal or greater capability. The three least effective Resource Leveling techniques were found to be extending critical path tasks, delaying critical path tasks and doing nothing. Contractors were generally found to be aware of the different available options for Resource Leveling. The techniques found to be least effective in practice are theoretically known to have the highest negative impact on the project schedule. This reinforces the idea that contractors are not only aware of the various resource leveling techniques existing in theory but also understand their effects on the project performance.***

Index Terms**: Resource Leveling, Construction, Contractors.**

I. INTRODUCTION

The construction industry is also known to make a notable contribution to other sectors of any country's economy. While it produces inputs required to support production process in other sectors, it also creates demand for outputs produced by those sectors of the economy. Sectors known to interact with the construction industry include agriculture, forestry, manufacturing, transport, mining and services. According to Bon & Crosthwaite, (2000b) and as cited by Wibowo, (2009), the construction industry has a significant interaction with other economic sectors as a backward and forward linkage; the forward linkages depict correlations of inter-industry total sales to total output, while the backward linkages depict the relationship of inter-industry purchases to total input. According to Badawiyeh, (2010) resource leveling is a trial and error method where noncritical activities are delayed beyond their early start with the aim of maintaining a a uniform resource requirement levels. Dubey, (2015) sums this up succinctly when he describes resource leveling as the act of taking a project with people assigned to a bunch of tasks and making it so that they do not have to work overtime.

Some of the benefits which can be achieved from Resource Leveling include: reduction of peak demands for resources and creating requirements of the same resources in other off-peak times; there is continuity in the workforce since there is reduced need for the contractor to employ and fire employees at different stages of the project (Mendoza, 1995)

II. LITERATURE REVIEW

2.1. Resource Leveling

Resource leveling is a technique used in project and resource scheduling with the aim of minimizing fluctuations in resource requirement at different stages of the project. It levels the resource usage in a way that we require approximately constant amount of resources on site. It can be seen as a trial and error method, one which should ensure that the overall project duration is not interfered with.

Gido & Clements, (2003) assert that optimization of the use of labour and equipment is significant in the process of resource leveling. The underlying assumption is that continuous and consistent use of the fewest resources is most desirable in construction projects (Badawiyeh, 2010). Verzuh, (2003) states that project managers ought to avoid troughs and peaks in the resource profile. They should use a set of people and equipment on a consistent rate as it is more effective and prevents costs associated with every upswing in the uptake of new members of the workforce or procuring more equipment.

2.2 Significance of Resource Leveling

According to Badawiyeh (2010), the advantages of resource leveling affect the entire organization leading to enhanced overall operations. From a management level, it can be agreed that organizations which practice resource leveling need less management attention on project activities thus giving them time to concentrate on other aspects of the organization. This is because they are not overloaded with the work of tackling daily resource management.

Secondly, resource leveling promotes workers' morale. This is because they have a guaranteed job security without the fear of being fired once there is no work for them. Keeping approximately constant personnel on site reduces labor turnover and consequently reduces the cost of investing in labour training. Human retention in any site results to increased experience thereby reducing costly errors in work execution.

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This reduces the cost of production thus increasing project profitability.

2.3 Structure of Resource Leveling

According to Reddy & Nagaraju, (2015), many organizations carry out resource leveling in a structured manner. A work based structure is prepared giving the scope and how the tasks have been organized and allocated to different members of the team. The structure helps the project team to execute the project tasks effectively, efficiently and on time. Most construction companies are looking for adequate resource optimization with the aim of improving productivity thence resulting to profitable projects (Reddy & Nagaraju, 2015). The key to such would be completing projects on time, within the targeted budget without compromising the quality required of the project. Resource leveling enables the contractor to utilize the available resources at optimum levels without any wastage by avoiding over-allocation and under-allocation of resources to project tasks.

2.4 Types of Resource Leveling

There are two types of resource leveling, "time-constrained" and "resource-constrained" (Nosbisch, Co, Winter, & League, 2005). If the project scheduling is being conducted by the contractor, the technique use in resource leveling should be based on the potentiality of project time adjustment. If the project period cannot be adjusted, then the contractor should adopt time-constrained leveling with the aim of maintaining the scheduled project completion date. Such a scenario would rise if the contractor has not experienced any excusable delays (Nosbisch *et al*., 2005).

However in a case where the contractor has the leeway to adjust the project duration, resource-constrained leveling would be best applicable. This will prevent occurrence of resource over-allocations but might result to a delay in the project duration (Nosbisch *et al*., 2005). This is best applicable if the contractor has experienced excusable delays; reasons beyond his control.

The period of time between the contractual completion date and the delayed completion date will

then be the amount of time extension that the contractor should ultimately seek from the owner (Nosbisch *et al*., 2005).

2.4.1 Time-Constrained Leveling

This type of resource leveling is commonly practiced together with time constrained project scheduling. The project duration is preset using a network analysis of the different logical relationships in project activities. The predetermined project completion date cannot be extended. Alterations affecting activity durations and required resources at any given time interval are adjusted within the available float except those within the critical path (Badawiyeh, 2010).

Time-constrained leveling works under the assumption that the project must be finished by a certain time, using as few resources as possible. Since time (not resource usage), is critical, the project will not be allowed to be delayed.

2.4.2 Resource-Constrained Leveling

Unlike time-constrained leveling, resource-constrained leveling begins at the status date and works forward to project completion, allocating time to activities based on logic and resource availability. This technique recognizes that the project must be completed as soon as possible without exceeding a certain level of resource availability. This technique assumes that the client is willing to let the project delay beyond the early finish date if all required resources are unavailable.

Project duration is considered to be of no importance since project criteria is limited to resources available (Gray & Larson, 2006). Consequently if demand exceeds availability, activities will be delayed till needed resources are made available (Badawiyeh, 2010).

2.5 Resource Leveling Techniques & Their Impacts

2.5.1 Doing nothing

This is possible if the over allocation is within acceptable limits. This technique has no effect on both the schedule/time and the resource/cost.

2.5.2 Delay Non-Critical Tasks within Available Float

When resources are not available for a given activity, the task can be delayed. Tasks which are likely to be postponed are those which do not fall on the critical path. This is to ensure minimal interruption to the project predetermined completion period. While this technique has no effect on the schedule/time or resource/cost under normal circumstances, it would have an effect on the resource/cost in the event of inflation.

2.5.3 Extend non-critical task durations within the available float

This has no effect on both schedule and cost except for situations where there is inflation.

2.5.4 Add resource of equal or greater capability

Addition of more resources has the effect of reducing the project duration. There is likely going to be a cost impact since the additional resource will have a new cost value. The project duration is likely to reduce when resources are added. However, the learning curve of the new resource ought to be considered. Resource-wise, additional resources come at an additional cost.

2.5.5 Substitute resource of equal or greater capability

Substitution of existing resources has the effect of either reducing or increasing the project duration. This depends on the capacity and efficiency of the new resource. However there is need to consider the learning curve for the new resource. There is likely going to be a cost impact since the alternative resource will have a different cost value

2.5.6 Delay critical path tasks

Delay of critical activities should be the considered after all attempts have been made on the non-critical tasks. When there is a common pool of resources, priority for resource allocation should be given to projects with minimum float. The schedule/time impact is equivalent to the delay. There will be a cost impact due to project time extension (delay damages) and inflation costs.

2.5.7 Extend critical path task durations

The impact on the schedule is equal to the amount of delay. The cost impact will be influenced by the level of inflation. Delay damages will also affect the project completion cost.

2.5.8 Splitting tasks into non sequential pieces

Certain types of work may be interrupted in between execution. Rather than carrying out an activity sequentially, it is split into smaller activities which are not sequential (Dubey, 2015). The weakness with this approach however is that resources tend to lose time as they re-adapt themselves to previous tasks.

The schedule/time impact is equivalent to the part of the task that extends beyond activity float. The cost impact is due to delay damages as a result of project time extension, inefficiencies in splitting tasks and inflation costs.

2.5.9 Authorize Overtime

Resources may be required to work overtime if they are to complete their assigned work. This would mean that they will have to be paid more wages as compensation over and above what they earn during normal standard working hours. However this strategy can only level resources up to a certain limit (Dubey, 2015).

This method has the likelihood of reducing the project schedule time while increasing the project cost due to premium cost rates associated with working beyond the normal working calendar.

2.5.10 Crashing

This involves assigning of extra resources to critical path tasks in addition to the existing resources with the aim of getting the work done faster. This however has a short term negative effect of additional labour and equipment costs (Hegazy, 2010).

2.5.11 Fast tracking

This involves performance of tasks within the critical path in parallel instead of sequentially as previously planned. This helps the planner buy time. The prominent feature of this technique is that although the work is completed for the moment, possibility of rework is higher (Dominguez, 2010). There is also an increased risk within the project schedule.

2.5.12 Microsoft Project

Microsoft Project has the ability to automatically level resources based on the resource calendar, task types, their dependencies and constraints set up by the programmer. This can also be achieved by leveling the resources manually via the resource usage view option.

In case of resource conflicts such as under or over allocations, the following options are available; delay of certain tasks, assigning different resources to activities, review of task dependencies (logic relationships), remove certain tasks or add tasks to the programme (Dominguez, 2010).

2.5.13 Modify the scope

This involves restructuring the project brief to either increase or reduce the amount of work to be executed. If the project can function satisfactorily without some of the sections, the client may opt to exclude such tasks from the contract.

The schedule/time and resource/cost could increase or decrease depending on the nature and volume of the new work compared to the original scope. The schedule/time could shorten due to less work or work of less quality being accomplished. The vice versa is true. The same logic could be applied for resource/time impact

There

III. METHODOLOGY

The researcher distributed the questionnaires to respective respondents with the help of assistants. The purpose of personally administering questionnaires to respondents was to establish rapport with the respondents while introducing the research, providing any clarifications sought by respondents and collecting the questionnaires soon after they were completed (Juma, 2015).

An appendix was provided to the questionnaire explaining all the terminologies which were deemed technical. It is also important to note that majority of the questionnaires were administered by the researcher personally. This helped ensure that any questions regarding the technical terms were addressed by the researcher himself. As for the questionnaires delivered by the research assistants, the researcher's contacts were provided in the letter of introduction. This allowed the respondents to reach out to the researcher for any clarifications regarding the questions.

IV. DATA ANALYSIS AND DISCUSSION

The personnel in contracting firms is categorised into full time staff and part time labourers. This means that the contractor employs on permanent basis those professionals who will be required in majority of future projects and those required to run and maintain the head office operations. Those that are employed on part time basis are usually engaged per-project basis or even in sections of the project and are released whenever they are no longer required.

The graph below illustrates the frequencies of the number of full time staff engaged by contractors in their firms and projects.

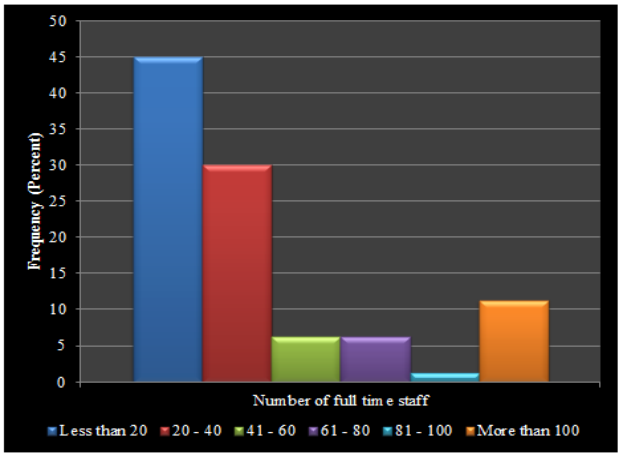

Figure 4.1: Number of full Time Staff
Source: (Author, 2016)

This study established that in majority (44.4%) of the contracting firms, the number of full time staff is less than 20.

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Other results were: 20-40 full time staff, 29.6%; more than 100 full time staff, 11.1%; 41-60 full time staff, 6.2%; 61-80 full time staff, 6.2% and 81-100 full time staff, 1.2%. This means that more than 74% of the contractors engaged in this study maintain a permanent workforce of less than 40 employees. It is clear from these results that majority of contractors maintain a lean permanent workforce. Labour is one of the most critical resources required in any construction project. The concept of resource leveling advocates for maintaining the lowest possible amount of resources in contractors' workplaces. While this will be confirmed or contradicted later in this study, but there seems to be signs of possible application of resource leveling concept.

4.1 Resource Leveling Techniques Employed by Contractors.

Respondents were asked to indicate the extent to which various Resource Leveling techniques were used in their firms based on a likert scale (5-Very High; 4- High; 3-Moderate; 2-Low; 1-None). The results were tabulated below.

Table 4.1: Resource Leveling Techniques (Comparison of Means)

S/ No		Mean	Std. Deviation	N	Rank
1	Doing nothing	1.66	0.996	64	13
2	Delay non-critical tasks within available float	3.03	1.038	64	9
3	Extend non-critical task durations within the available float	3.13	1.062	64	7
4	Add resource of equal or greater capability	3.34	0.963	64	6
5	Substitute resource of equal or greater capability	3.44	0.974	64	4
6	Delay critical path tasks	2.17	1.047	64	12
7	Extend critical path task durations	2.77	1.065	64	10
8	Splitting tasks into non sequential pieces	2.73	0.996	64	11
9	Authorize Overtime	3.45	1.068	64	3
10	Crashing	3.36	1.226	64	5
11	Fast tracking	3.78	0.917	64	1
12	Microsoft Project	3.59	1.205	64	2
13	Modify the scope	3.13	1.148	64	7

Source: (Author, 2016)

The most popular Resource Leveling Technique employed by contractors was found to be "Fast tracking" with a mean of 3.78. The second and third most popular techniques were "Microsoft Project" and "Authorize overtime" with means of 3.59 and 3.45 respectively. "Substitute resource of equal or greater capability", "Crashing" and "Add resource of equal or greater capability" were the fourth, fifth and sixth with means of 3.44, 3.36 and 3.34. The seventh most popular techniques were "Modify the scope" and "Extend non-critical task durations within the available float" with a mean of 3.13. "Delay non-critical tasks within available float" and "Extend critical path task durations" were the ninth and tenth in the ranking with means of 3.03 and 2.77 respectively. The last three techniques were "Splitting tasks into non sequential pieces", "Splitting tasks into non sequential pieces" and "Doing nothing" with means of 2.73, 2.17 and 1.66.

While the first six techniques (fast tracking , Microsoft project, authorizing overtime, substituting resources of equal or greater capability, crashing, and addition of resource of equal or greater capability") in the ranking could be said to be highly used in the Kenyan construction industry due to their high means (3.78, 3.59, 3.45, 3.44, 3.36 and 3.34), the last seven techniques (Modify the scope, Extend non-critical task durations within the available float, Delay non-critical tasks within available float, Extend critical path task durations, Splitting tasks into non sequential pieces, Splitting tasks into non sequential pieces and Doing nothing) were found to be rarely used by a majority of the contractors due to their low means (3.13, 3.13, 3.03, 2.77, 2.73, 2.17 and 1.66).

4.2 Effectiveness of various Resource Leveling Techniques

Respondents were asked to indicate the effectiveness of various Resource Leveling techniques as used in their firms based on a likert scale (5-Very Effective; 4- Effective; 3-Fairly Effective; 2-Least Effective; 1-Not Effective). The results were tabulated below.

Table 4.2: Effectiveness of Various RL Techniques (Comparison of Means)

S/ No		Mean	Std. Deviation	N	Rank
1	Doing nothing	1.84	1.319	61	13
2	Delay non-critical tasks within available float	3.15	1.123	61	10
3	Extend non-critical task durations within the available float	3.23	1.055	61	9
4	Add resource of equal or greater capability	3.93	0.910	61	4
5	Substitute resource of equal or greater capability	4.00	0.775	61	3
6	Delay critical path tasks	2.69	1.218	61	12
7	Extend critical path task durations	2.92	1.159	61	11
8	Splitting tasks into non sequential pieces	3.34	0.964	61	8
9	Authorize Overtime	3.87	0.974	61	5
10	Crashing	3.77	1.023	61	6
11	Fast tracking	4.21	0.777	61	1

S/ No		Mean	Std. Deviation	N	Rank
12	Microsoft Project	4.08	1.038	61	2
13	Modify the scope	3.43	1.056	61	7

Source: (Author, 2016)

The top 3 most effective techniques were: "Fast tracking", "Microsoft Project" and "Substitute resource of equal or greater capability" with means of 4.21, 4.08 and 4.00 respectively. "Add resource of equal or greater capability", "Authorize Overtime" and "Crashing" were the fourth, fifth and sixth most effective techniques with means of 3.93, 3.87 and 3.77. The seventh, eighth and ninth techniques in the ranking were: "Modify the scope", "Splitting tasks into non sequential pieces" and "Extend non-critical task durations within the available float" with means of 3.43, 3.34 and 3.23 respectively. "Delay non-critical tasks within available float", "Extend critical path task" and "Delay critical path tasks" were the tenth, eleventh and twelfth most effective techniques with means of 3.15, 2.92 and 2.69 respectively. The least effective techniques was found to be "Doing nothing" with a mean of 1.84.

When a comparison was done based on the rankings in tables 4.1 and 4.2, only five techniques retained similar positions (Fast tracking, 1; Microsoft Project, 2; Modify the scope, 7; Delay critical path tasks, 12; and Doing nothing, 13) in both analyses meaning that the degree to which they were employed by the contractors depended on their effectiveness as experienced by the contractors. Other methods were found to be more popular but less effective based on the same comparison. These were: Authorize Overtime (Positions 3 and 5); Crashing (Positions 5 and 6); Extend non-critical task durations within the available float (Positions 7 and 9); Delay non-critical tasks within available float (Positions 9 and 10); and Extend critical path tasks (Positions 10 and 11). Techniques found to be less popular but more effective were: Substitute resource of equal or greater capability (Positions 4 and 3); Add resource of equal or greater capability (Positions 6 and 4); and Splitting tasks into non sequential pieces (Positions 11 and 8).

It is interesting to note that fast tracking and Microsoft project were found to be the most popular and most effective techniques while delaying critical path tasks and doing nothing were found to be the least popular and the least effective techniques by the contractors.

V. CONCLUSIONS

The three most popular Resource Leveling techniques employed by contractors were found to be fast tracking, Microsoft Project and authorizing overtime.

The three least popular Resource Leveling techniques were found to be splitting tasks into non sequential pieces, delaying critical path tasks and doing nothing.

The three most effective Resource Leveling techniques as experienced by contractors were found to be fast tracking, Microsoft Project and substituting resource of equal or greater capability.

The three least effective Resource Leveling techniques were found to be extending critical path tasks, delaying critical path tasks and doing nothing.

Contractors were generally found to be aware of the different available options for Resource Leveling. The techniques found to be least effective in practice are theoretically known to have the highest negative impact on the project schedule. This reinforces the idea that contractors are not only aware of the various resource leveling techniques existing in theory but also understand their effects on the project performance.

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