PLANT AND EQUIPMENT MANAGEMENT TO MINIMIZE DELAYS IN ROAD CONSTRUCTION PROJECTS

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ABSTRACT

Construction is the ultimate objective of a design, and the transformation of a design by construction into a useful structure which is accomplished through proper management of human, material, machineries and equipment resources. A project manager must insure that these inputs are effectively coordinated to achieve an efficient construction process. "Delay" in construction is a project slipping over the planned schedule and is considered as a common problem in construction projects. Plant and Equipment (P&E) management is a complex procedure in a construction project. Machines are to be selected, arrived on site, are used and, when a project is completed, removed and returned to the company's plant depot or the hire company. Within this cycle various decisions and assessments are required to be made. These are related to above challenges and delays due such could be affected directly or indirectly by poor P&E management. Hence, introduction of proper construction P&E management criteria helps in minimizing the confusion created due to the above problems and further to cut down monetary losses.

Therefore, this research aims to study the effects of improper P&E management on construction delays and to identify proper practices on P&E management to minimize delays. The paper discusses the theoretical background of the issue based on the findings of the comprehensive literature review done through refereeing to the published material. Research will be followed by a questionnaire survey to explore the situation within the Sri Lankan road construction projects as the field study. The data will be analyzed statistically in order to make conclusions and recommendations.

Keywords: *Construction Projects; Delays; Management; Plant and Equipment.*

1. INTRODUCTION

Construction is the ultimate objective of a design, and the transformation of a design by construction into a useful structure which is accomplished by human, material, machineries and equipment and proper management of those resources (Peurifoy, Clifford, and Shapira, 2006). According to Hendrickson (1998), good project management in construction project regularly continues the efficient utilization of labor, material and equipment. A project manager must insure that these inputs are effectively coordinated to achieve an efficient construction process altogether. This coordination involves both strategic decisions and tactical management in the field. Westland (2003) stated that a project has a clearly specified format and end date within which the deliverables must be produced to meet a specified customer requirement. Wherever such coordination is missing, delays in completion of the project can be occurred.

The project manager must also manage the plant and equipment assigned or used in the project (Reh, 2013). The use of new equipment, proper equipment and innovative methods has made possible changes in construction technologies in recent decades (Hendrickson, 1998). Therefore financial planning in construction companies tends to focus on decisions relating purchasing, leasing, depreciating, maintaining, repairing, and replacing equipment. One of the keys in success is the control of time, cost, and quality by the selection and use of the right equipment for the job (Day and Benjamin, 1924). Hence a relationship can be seen between P&E management and project duration.

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Assaf and Hejji (2006) stated, in construction, delay could be defined as the time overrun either beyond completion date specified in a contract, or beyond the date that the parties agreed upon for delivery of a project. Delays are considered as a common problem in construction projects. To the owner, delay means loss of revenue through lack of production facilities and rentable space or a dependence on present facilities. In some cases, to the contractor, delay means higher overhead costs because of longer work period, higher material costs through inflation, and higher labor costs.

The choice of construction equipment is determined on method of doing the work, the time to complete the work, and the cost of construction (Day and Benjamin, 1924). Therefore when there a shortage in selected plant and equipment force is occurred, it may influence on construction duration as well as the cost. Hence poor management of plant and equipment may be a considerable reason behind many of the factors. As Sharma (2007) stated, P&E manager should co-ordinate with various wings of the organization in discharging his job of equipment planning, balancing, selection of equipment, its deployment and its utilization, personnel selection and training, financial planning, preventive maintenance and general supervision. Thus, equipment management integrates and continuously interacts with human, technical, financial, and production system in order to achieve top efficiency and cost effectiveness. Like the other major resources, committed P&E are expected to be fully utilized to complete a project due time (Uher, 2003).

However, there could be number of factors affect to the delays in construction projects. P&E management is a major procedure in a construction project. Because of the complexity of this procedure, project time could be affected by poor plant and equipment management. Therefore this research addresses the issue of effects of poor P&E management on project delays.

2. PLANT AND EQUIPMENT MANAGEMENT IN ROAD CONSTRUCTION PROJECTS

Introduction of proper construction P&E management helps in minimizing the confusions created due to logistics management, horizontal/vertical transportation, material handling, execution methods, interruptions, delays, prolonged duration of projects, finishing trades, and infrastructure requirements (Mohideen, 2011). It is difficult to identify the limit to machine usage on construction sites. It is clear, however, that as time goes by more machines will be invented or adapted for use in the construction industry. Therefore management continually has to make decisions about methods of operation and the right mix of human and machines within a working environment. Machines are therefore selected, arrive on site, are used and, when a project is completed, removed and returned to the company's plant depot or the hire company. Within this cycle various decisions and assessments are required to be made (Canter, 1993). Therefore if these assessments and decisions are not made in proper manner, it will be difficult to face the challenges previously stated. That means proper management of P&E is essential for a successive completion.

Further, P&E management can be done in several ways. Various types of construction equipment can be grouped in several ways (Day and Benjamin, 1991). Mainly they could be classified as functionally and operationally.

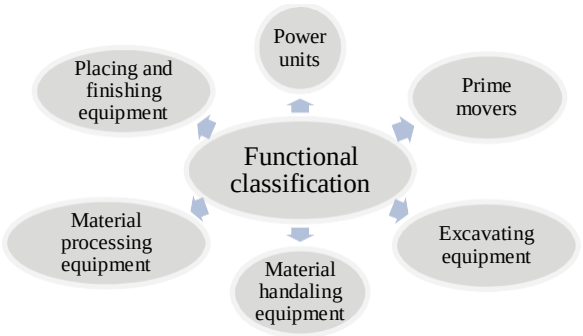

Figure 1: Functional Classification of P&E (Source: Day and Benjamin, 1991)

Operational classification is better in use (Day and Benjamin, 1924). Functional classification is done according to the functional activity of equipments as above.

According to Leuva (2012), to construct perfect roads, it is essential that there is adequate equipment for the construction work. Further, Campbell (2011) states that effective construction equipment management means being able to draw a definitive line between a losing company and one that is profitable and successful. Construction companies that are finding continued success even in the current economy who finds new ways to lower operating and maintenance costs, optimize their utilization, reduce downtime and increase profits. As per to Marvelous (2012) maintenance of construction equipment is crucial as this preserve them for future construction jobs, accident and save contractors from unnecessary expenses. Maintenance is not only thing to be aware of in P&E management. Selecting and planning proper equipments on specific construction tasks also a one of important proportions of that management criteria (Casals, 2005). Therefore management of these P&E is directly affects on project duration. All road construction activities comprised with P&E management part and, included in the critical path of a project mostly. Therefore management of these P&E is directly affects on project duration. Thus, in minimizing construction delays, it is very important to manage P&E in a proper manner.

Further, Edwards and Holt (2009) concludes that construction P&E management is embedded within the broader subject of construction management, representing a vibrant research field from which eight principal research themes have been identified as plant maintenance, downtime and productivity, optimization, robotics and automation, health and safety, operators and competence, machine control and miscellaneous.

3. STRATEGIES AND BEST PRACTICES FOR P&E MANAGEMENT

Construction management is a vast area that considers several components of a project. Direct involvement of P&E management is rare to be seen in these management strategies. However P&E practices can be categories as below.

- **Selection**

Contractors consider selection of equipment fleet a vital factor for any construction project to be successful. The task of the project planner, estimator or the engineer on the job is to select and match the right machine or combination of machines to the job at hand (Peurifoy, Schexnayder and Shapira, 2006).

Table 1: Best Practices for P&E Selection

P&E selection best practices	Reference
Use models based on traditional mass haul diagrams, artificial intelligence and genetic algorithm and geographic information system to crew optimisation	Mawdesley *et al*., 2004)
Mathematics of rough sets and fuzzy sets	Cirovic and Plamenac (2006)
Analytical hierarchy process to take account of qualitative factors	Goldenberg and Shapira (2007)

- **Acquisition**

Contractors have two options in acquiring plant. They may either own their machinery and equipment or hire it. Many contractors prefer to hire only those items of plant, which are required to meet peak demand or specialized activities. The alternative decision to purchase will have important financial consequences for the contractor, since considerable capital sums will be blocked up in the plant, which

must be operated at an economic utilization level to produce a profitable rate of return of investment (Construction information services, 2012).

Table 2: Best Practices for P&E Acquisition

P&E acquisition best practice	Reference
Purchase equipment outright by cash, financing	Tavakoli *et al*. (1989)
Acquiring rental equipment	Tavakoli *et al*. (1989)
Acquiring leased equipment	Tavakoli *et al*. (1989)
P&E acquisition best practice	**Reference**
Purchase equipment in used condition, new condition, based on personal judgments, based on current and future workload, based on life cycle cost (LCC) of equipment, based on company financial status or based on internal rate of return (IRR) of investment	Prasertrungruang and Hadikusumo (2007); Schexnayder and Hancher (1981); Tavakoli *et al*. (1989)
Make decision on acquiring or disposing equipment by president/CEO, by board of directors, by equipment managers or by project managers	Hinze and Ashton (1979); Schexnayder and Hancher (1981); Tavakoli *et al*. (1989)
Purchase equipment based on brand popularity and spare parts availability, functions and its usage	Hinze and Ashton (1979); Prasertrungruang and Hadikusumo (2007)
Purchase the same brand that is being used regularly	Hinze and Ashton (1979)
Purchase equipment from familiar dealers	Prasertrungruang and Hadikusumo (2007)
Purchase equipment based on its price	Hinze and Ashton (1979)
Buy new or used machine based on budget availability	Prasertrungruang and Hadikusumo (2007)
Buy used machines because of cheaper price but still in good condition or need in functions and advanced technology	Prasertrungruang and Hadikusumo (2007)
Buy used machines only the ones that do not have complicated systems, ones that render expensive repair cost once failure, ones that do not have high repair cost once failure, ones that are not frequently utilized or ones that are frequently utilized for a long time	Prasertrungruang and Hadikusumo (2007)
Use rental or leasing strategy for the infrequent utilized equipment, to avoid equipment obsolescence, to avoid uncertainty of spare part cost, to avoid initially financial burden to the company, to test a newly launched machine, to save spare parts cost, to benefit from mechanics' learning curve, to lower operator/labour costs of machines or to enhance safety as operator uses similar machines	Hinze and Ashton (1979), Prasertrungruang and Hadikusumo (2007); Tavakoli *et al*. (1989)
Use standardization policy for better relationship with dealers or for easier equipment administration	Tavakoli *et al*. (1989)

- **Operation**

Stewart (as cited in Prasertrungruang and Hadikusumo, 2007) says an equipment operator is the person in the construction organisation who has the control on equipment costs. Quality output can be partly achieved through skilful operators working with machines that are in good operational condition, thus educating equipment operators is one of the most important policies and thus holds great cost-saving potential.

Table 3: Best Practices for P&E Operation

P&E operational best practice	Reference
Allow an equipment operator to work with more than one machine	Hinze and Ashton (1979); Tavakoli *et al*. (1989)
Provide training by in-house equipment department, equipment dealers or external agencies	Prasertrungruang and Hadikusumo (2007)
Consider poor operating procedures as a main cause of equipment accident	Tavakoli *et al*. (1989)
Consider poor maintenance as a main cause of equipment accident	Prasertrungruang and Hadikusumo (2007)

- **Maintenance**

P&E are exposed to a huge amount of abuse, dirt and various other elements which can cause damage of equipment if they are not cared for in the proper way. Maintenance of construction equipment is crucial as this preserve them for future construction jobs, accident and save contractors from unnecessary expenses and time (Mavelous, 2012).

Table 4: Best practices for P&E Maintenance

P&E maintenance best practice	Reference
Provide maintenance by equipment operators	Hinze and Ashton (1979); Tavakoli *et al*. (1989)
Provide maintenance by in-house equipment department	Hinze and Ashton (1979); Tavakoli *et al*. (1989)
Provide maintenance by equipment dealers	Hinze and Ashton (1979)
Provide maintenance by other external mechanics	Hinze and Ashton (1979)
Provide preventive maintenance programs to equipment	Tavakoli *et al*. (1989)
Seek for substitute equipment once machine suddenly breakdowns	Tavakoli *et al*. (1989)
Wait until the failed machine is completely repaired and ready for use	Hinze and Ashton (1979); Tavakoli *et al*. (1989)
Transfer crews to other works once machine suddenly breakdowns	Tavakoli *et al*. (1989)
Accelerate speed of works once machine suddenly breakdowns	Hinze and Ashton (1979); Tavakoli *et al*. (1989)
Modify project activity and schedule once machine suddenly breakdowns	Hinze and Ashton (1979); Tavakoli *et al*. (1989)
Consider poor operating procedures as a main cause of machine failure	Hinze and Ashton (1979); Tavakoli *et al*. (1989)
Consider poor maintenance and use of non-original parts as a main cause of machine failure during use	Tavakoli *et al*. (1989)

- **Disposal**

Douglas (as cited in Prasertrungruang and Hadikusumo, 2007) reports the last stage of machine lifecycle is disposal stage, in which two major decisions concerning equipment have to be made as timing of replacement and equipment economic life expectancy. Further Hinze and Ashton (1979) state that there are various factors affecting the timing of replacement as follows, machine efficiency, capital availability, investment costs, commencement of new projects, profits accrued from use, tax expense, depreciation, economic analysis, obsolescence costs, and downtime cost.

Table 5: Best Practices for P&E Disposal

P&E disposal practice	References
Dispose or replace equipment based on intuition and rules of thumb	Schexnayder and Hancher (1981);
Dispose or replace equipment based on equipment economic analysis	Hinze and Ashton (1979); Schexnayder and Hancher (1981); Tavakoli *et al*. (1989)
Dispose or replace equipment when it becomes technologically obsolete	Hinze and Ashton (1979);
Dispose or replace equipment when it becomes inefficient	Hinze and Ashton (1979);
P&E disposal practice	**References**
Dispose or replace equipment when the company financial status is good	Hinze and Ashton (1979);
Dispose or replace equipment before commencing a new job or project	Hinze and Ashton (1979);
Dispose or replace equipment before major overhaul with high repair cost	Hinze and Ashton (1979); Tavakoli *et al*. (1989)
Determine equipment economic life based on investment cost	Hinze and Ashton (1979);
Determine equipment economic life based on downtime cost	Hinze and Ashton (1979); Tavakoli *et al*. (1989)
Determine equipment economic life based on obsolescence cost	Hinze and Ashton (1979); Tavakoli *et al*. (1989)
Determine equipment economic life based on tax advantage	Hinze and Ashton (1979); Tavakoli *et al*. (1989)
Determine equipment economic life based on depreciation cost	Hinze and Ashton (1979); Tavakoli *et al*. (1989)
Determine equipment economic life based on maintenance and repair cost	Hinze and Ashton (1979);
Determine equipment economic life based on profit accrued from use	Hinze and Ashton (1979);

4. PROBLEMS IN P&E MANAGEMENT

When selecting equipment for a given job, the major challenge to be faced is to satisfying several constraints imposed by the job and the contractual obligations. These constraints or factors include, specific construction operation, job specification requirements, conditions of the job site, location of the job site, time allowed to do the job, balance of interdependent equipment, mobility required of the equipment and versatility of the equipment (Day and Benjamin, 1991). Further, in managing construction equipment, contractors are invariably plagued with several difficulties such as huge capital investment in the acquisition phase, which usually constitutes a major financial burden. Procurement of major construction equipment not only costs as high as 36 percent of the total construction project cost, but also causes a high delivery time uncertainty, which may disrupt the construction schedule (Yeo and Ning, 2006).

According to Stewart (as cited in Prasertrungruang and Hadikusumo, 2007), in the operational phase, contractors are often faced with problems relating to high rate of equipment breakdown and accident resulting from unskilled operator abuse. Poor training of equipment operators is often claimed as a major cause of equipment-related accidents (Gann and Senkar, 1998). In the maintenance phase,

proper maintenance management of construction equipment is never over-emphasized since the cost and time that exceed the designated budget or schedule on projects are often resulted from poor machine maintenance practices. However, over-maintenance of equipment is undesirable as well (Vorster and De La Garza, 1990). Finally at the disposal phase, determining equipment economic life and timing for replacement is often problematic because such decision is influenced by various factors such as machine obsolescence and efficiency (Vorster and Garza, 1990).

5. POOR P&E MANAGEMENT AND CONSTRUCTION DELAYS

According to Alaghbari (2007), delay is generally acknowledged as the most common, costly, complex and risky problem encountered in construction projects. Because of the overriding importance of time for both the owner (in terms of performance) and the contractor (in terms of money), it is the source of frequent disputes and claims leading to lawsuits. In construction, delay could be defined as the time overrun either beyond completion date specified in a contract, or beyond the date that the parties agreed upon for delivery of a project. Hancher and Rowings (as cited in Alaghbari, 2007) stated that there is a wide range of views on the causes of time delays for engineering and construction projects. Some are attributed to a single party, others can be ascribed to several quarters, and many relate more to systemic faults or deficiencies rather than to a group or groups.

Generally, delays can be divided into three major types namely, excusable and non-excusable, compensable and non-compensable and concurrent (Alaghbari, 2007). According to Alaghbari (2007), compensable delays are those that are generally caused by the owner or its agents. Basically, non-excusable delays are caused by contractors or subcontractors or materials suppliers, through no fault of the owner. Excusable delays, also known as "force majeure" delays, are the third general category of delay. These delays are commonly called "acts of god" because they are not the responsibility or fault of any particular party. Most contracts allow for the contractor to obtain an extension of time for excusable delays, but not additional money. If only one factor is delaying construction, it is usually fairly easy to calculate both the time and money resulting from that single issue. A more complicated, but also more typical, situation is one in which more than one factor delays the project at the same time or in overlapping periods of time, these are called concurrent delays.

There are various causes for delay on above all categories. Therefore it is important to study causes for delays.

5.1. CAUSES FOR DELAYS

Many of researchers have considered causes for delay in every way can be. Among them, some delay causes can be identified directly and indirectly related to poor P&E practices. Some causes have been severely identified by more than one researcher as tabulated follow.

Table 6: Causes for Delays in Road Construction

Causes for delay	References
Poor site management and supervision	Chan and Kumaraswami (1997); Alaghbari *et al.* (2007); Assaf and Al-Hejji (2005); Ramanathan, Narayanan and Idrus (2012)
Improper control over site resource allocation	Chan and Kumaraswami (1997)
Shortage of material availability	Alaghbari *et al.* (2007); Ramanathan, Narayanan and Idrus (2012)
Shortage material supply	Ramanathan, Narayanan and Idrus (2012)
Shortage of plant/equipment	Chan and Kumaraswami (1997); Assaf and Al-Hejji (2005)
Delay in delivery of materials to site	Alaghbari *et al.* (2007); Assaf and Al-Hejji (2005); Ramanathan, Narayanan and Idrus (2012)

Causes for delay	References
Delays in sub-contractors work	Chan and Kumaraswami (1997); Assaf and Al-Hejji (2005); Ramanathan, Narayanan and Idrus (2012)
Delay in site mobilization	Assaf and Al-Hejji (2005);
Construction mistakes and defective work	Alaghbari *et al.* (2007);
Improper construction methods implemented by contractor	Assaf and Al-Hejji (2005);
Damage of sorted material while they are needed urgently	Assaf and Al-Hejji (2005);
Equipment breakdowns	Assaf and Al-Hejji (2005);
Low productivity and efficiency of equipment	Assaf and Al-Hejji (2005); Ramanathan, Narayanan and Idrus (2012)
Lack of high-technology mechanical	Assaf and Al-Hejji (2005); Ramanathan, Narayanan and Idrus (2012)
Low level of equipment-operators skill	Assaf and Al-Hejji (2005); Ramanathan, Narayanan and Idrus (2012)
Poor judgment and experience of involved people in estimating time and resources	Ramanathan, Narayanan and Idrus (2012)
Ineffective planning and scheduling of project by contractor	Chan and Kumaraswami (1997); Assaf and Al-Hejji (2005); Ramanathan, Narayanan and Idrus (2012)
Accident during construction	Assaf and Al-Hejji (2005)

5.2 RELATIONSHIP BETWEEN DELAY CAUSES AND POOR P&E MANAGEMENT

When considering the above studies, although authors have identified P&E related delay causes separately, also they have identified more causes under another categories where the causes are indirectly influenced by poor P&E management. For example, in Assaf's (2005) research, although P&E has been taken as a separate causes category, there are some causes identified in other categories also related to P&E. In material category, "Delay in material delivery" can be caused by poor management of transportation equipment. Also in contractor category, "Delay in site mobilization" is also related to transportation equipment. In same category "Delays in sub-contractors work", "Ineffective planning and scheduling of project by contractor" are also influenced by poor P&E management. Because, subcontractors also use P&E for their work component, and if P&E selection is not up to level needed, planning and scheduling goes wrong. Therefore by considering these facts, it is important to identify relationships between all causes imported in to table and poor P&E management.

In the table, according to 1st and 2nd causes, those can be related respectively to poor P&E allocation at the site and their poor operational management. 3rd and 4th causes can be influenced by poor transportation equipment management. "Shortage of P&E" (5) is identified as a direct cause for construction delay by Chan and Kumaraswami (1997) and Assaf and Al-Hejji (2005). According to above paragraph, 6th, 8th, 9th and 22nd causes are related to poor P&E management and, in 7th cause, it means that it is a delay in payment of rental of P&E. That may forms absence of P&E at such construction sites. Poor techniques and tasks of relevant P&E also can affect on 10th, 11th and 12th causes. Also 13th cause can be occurred due to use of non- suited P&E in transporting and handling material. "Equipment breakdowns" (14), "Low productivity and efficiency of equipment" (15), "Lack of high-technology mechanical" (16) and "Low level of equipment-operators skill" (17) are delay causes directly related to poor P&E management. In "Poor judgment and experience of involved people in estimating time and resources" (18), these resources may include P&E. Both "Poor economic conditions (currency, inflation rate, etc.)" (19) and "Difficulties in financing project by contractor" (20) can be affect on acquisition of P&E. "Conflicts in sub-contractors schedule in execution of project" (21) also can include poor P&E allocation of sub-contractors. 23rd cause

("Inadequate early planning of project") is formed by consultant's mistake. Due to that problem, contractor won't be able to plan their P&E appropriately. The last (24th) delay cause ("Accident during construction") identified by Assaf and Al-Hejji (2005) and Ramanathan, Narayanan & Idrus (2012) is frequently happening in construction sites due to poor maintenance and operational management practices.

6. SUMMARY AND WAY FORWARD

Construction industry is a rapidly developing industry in Sri Lanka with the many projects which are currently on progress. At the same time, delays in completions can be seen frequently. There could be number of factors affect to the delays in construction projects. Plant and equipment management is a major procedure in a construction project. Because of the complexity of this procedure, project time could be affected by poor plant and equipment management. This research addresses the issue of poor plant and equipment management is effect on project delays.

Therefore this research aims to identify proper practices for plant and equipment management to minimize construction delays by studying the effect of improper plant and equipment management on those delays. In achieving this aim the objectives were set as below;

- Study the major causes for delays in construction projects and to identify the relationship between plant and equipment management and causes of delays.
- Identify proper practices to manage plant and equipment.
- Prepare a guideline to manage plant and equipment in a way of minimizing project delays.

The method for the research comprises an initial comprehensive literature survey which has been carried out through referring to books, journals and articles to obtain existing knowledge on various causes for delays related to plant and equipment management. Based on the findings of the literature survey, a questionnaire survey will be carried out to obtain views upon the factors affecting construction delays, their relationship with plant and equipment management and practices used to prevent each factor. Then statistical analysis will be carried out to rank the causes for delays most related to plant and equipment management according to the level of importance. Also proper plant and equipment management practices used to minimize delays will be ranked. Conclusions and recommendations will be carried out based on findings.

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