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AN IMPACT OF EQUIPMENT SELECTION ON CONSTRUCTION PROJECTS: CASE STUDY OF A ROAD PROJECT IN EGYPT

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The use of equipment in the construction industry has expanded in recent years due to the equipment's ability to complete most work items such as excavation work, casting, and more in a relatively short period of time. However, the real challenge would be selecting the appropriate equipment and accurately predicting the productivity of the equipment. In most projects, the choice of equipment to execute any work is based mainly on the expertise of contractors without taking into account any aspect of equipment's life. Therefore, any insufficient construction equipment planning and management would have a huge undesirable effect on the time and cost of any project. The main aim of this research is to study the impact of equipment selection on the productivity of construction excavation sites and its effect on time and cost through a road project in Egypt as a case study. A highway road excavation project in Egypt with a total length of 7.2 km (4.5 miles). The impact would be determined by monitoring the progress of earthmoving activities and conducting a comparison between the estimated and actual productivity of equipment (long boom backhoe). The progress data was collected over 30 days for eight working hours per day for each piece of equipment. As a result of the poor equipment management, the actual productivity was 50% of the predicted rate, and that impacted the project's cost by a 71.5% increase and by a 72% increase in the duration.

Keywords: construction equipment management, equipment selection, equipment production rate, projects cost and time, excavation activity, backhoe

1 INTRODUCTION

Construction is an industry that is heavily reliant on the efficient use of construction equipment [1]. Thus, equipment is a critical component in increasing capability for executing tasks more successfully and efficiently. The overall progress of the project is contingent upon how quickly the job is completed. As a result, it becomes necessary to pick equipment that takes into account all aspects of the site's working environment. Therefore, it is vital to provide good planning and management of equipment in order to utilize it effectively and efficiently at the lowest possible cost and with the highest possible output production rate [2]. On the other hand, the duration of the majority of projects is limited. A project with a limited duration may have a higher cost. This complicates the process of finding a suitable balance in a real-world context even more.

Additionally, when it comes to picking a contractor for the bulk of jobs, the cost is a critical factor. Contractors' profit margins may have to be reduced in order to remain competitive in the market. Failure to estimate a project's cost accurately may result in a contractor's profit margin being decreased to the point of insolvency [3]. Certain construction contracts require the contractor to complete a job within a certain time range or risk financial penalties. As a result, an accurate time forecasting is crucial for calculating the total cost [4]. According to [5–8], planning a construction project includes figuring out how much of the work will be done by machines, planning the equipment, planning the equipment's management, and planning the execution. Finally, the environment and safety.

Currently, the road-building industry in Egypt plays a significant role in short—and long-term trends, with more frequent development, not only for the sector itself, but also for other economic activities [9]. As a result, it is widely thought that the road-building business requires an efficient resource management strategy in order to maintain profitability and contribute dynamically to the country's progress. Moreover, road projects depend heavily on the construction equipment [10]. However, one of the key reasons for construction project delays in Egypt was considered to be equipment management concerns, organizational deficiencies, a shortage of building supplies, and inefficiency among site staff [11, 12]. Thus, with EGP 53 billion added in 2021, the Egyptian construction sector contributed 7.5 percent of Egypt's GDP, making it a substantial economic contributor. Despite its enormous economic impact, equipment production rate is poor [13].

Therefore, as equipment costs are in a range of 30% of the total construction project cost [14] and its production rate is more variable and changing than the other project cost components, it becomes critical to quantify equipment production rates and understand its influence on the project's cost and duration. Moreover, on average, excavation activities in any project represent about 20% of the overall cost of construction projects [3]. This research will focus on the excavation activity for a road project in Egypt. To complete the excavation activity, a long boom backhoe was selected by project executives and its production rate was estimated to be 200 m3 per hour. The equipment selection and production rate estimation process were done based on project executives experience. This research will examine the effects of excavating with the selected equipment on project cost, time, and the discrepancy between expected and actual excavation quantities, as well as establish a practical approach for selecting appropriate equipment for the construction industry.

2 CONSTRUCTION EQUIPMENT MANAGEMENT (CEM)

2.1 CEM Introduction

CEM is a process that entails the planning, selection, procurement, maintenance, standardization, and quality control of construction equipment [1]. However, in many situations, a large portion of this process is skipped or bypassed entirely. Equipment planning is used to illustrate the distinct sizes and types of equipment necessary for rent, lease, or outright purchase. The term “construction equipment” refers to the tools, instruments, machines, and other mechanical devices necessary to execute construction activity. Additionally, any additional processing units that are constructed on the site are essentially permanent or set in place [15]. Proper equipment selection is critical to the timely and efficient completion of a road construction project. The problem of equipment selection has become more challenging as a result of the wide range of equipment manufactured nowadays.

A substantial amount of experience operating and maintaining equipment in the field is required for equipment selection. Indeed, equipment selection is a significant choice throughout the planning and execution of a construction project, as it affects the method in which work will be conducted, the length of time necessary to complete the task, and the amount of money expended [16]. It is vital to have sufficient construction equipment on hand in order to create excellent roadways [17]. Additionally, effective planning and management of construction equipment require the ability to differentiate between a losing business and a lucrative and successful one [18]. Construction firms are thriving despite the present economic slump by developing new methods to save operating and maintenance expenses, maximize their use, minimize downtime, and increase profitability.

2.2 Challenges in CEM

Choosing the right equipment for the job is all about meeting the requirements of the job and the contract. The specific construction operation, the job specification requirement, the job site conditions, the job site location, the time allowed to complete the job, the balance of interdependent equipment, the mobility required of the equipment, and the equipment’s versatility are all included in this constraint or factor [19]. Even more so, contractors have numerous challenges while handling construction equipment, including a huge capital expenditure during the acquisition phase, which may be quite costly. Up to a third of a building project’s expenditure can be spent on purchasing huge construction equipment that has a high risk of delaying the project’s completion by months [20].

Contractors commonly encounter issues during the operational phase as a result of the high rate of equipment faults and accidents caused by inexperienced employees [21]. Operator training deficiencies are usually recognized as the leading cause of equipment-related mishaps [22]. Proper equipment maintenance management cannot be stressed during the maintenance phase, since cost and schedule overruns are typically the result of poor equipment maintenance procedures. Excessive equipment maintenance, on the other hand, is detrimental. Finally, determining an asset’s economic life and the proper time to replace it is difficult, as such decisions are impacted by a range of factors, including equipment obsolescence and efficiency [23, 24]. The following section highlights the most common causes of CEM problems as shown in Figure 1:

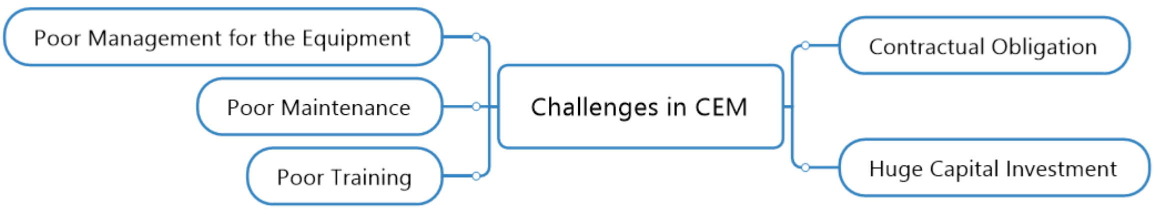

Fig. 1. Issues in Construction Equipment Management

2.2.1 Contractual Obligation

Choosing the right equipment for the job is all about meeting the requirements of the job and the contract. The specific construction operation, the job specification requirement, the job site conditions, the job site location, the time allowed to complete the job, the balance of interdependent equipment, the mobility required of the equipment, and the equipment’s versatility are all included in this constraint or factor [19]. Even more so, contractors have numerous challenges while handling construction equipment, including a huge capital expenditure during the acquisition phase, which may be quite costly. Up to a third of a building project’s expenditure can be spent on purchasing huge construction equipment that has a high risk of delaying the project’s completion by months [20].

2.2.2 Huge Capital Investment

The primary consideration when selecting whether to purchase, lease, or rent is the degree of risk assumed by the contractor. Typically, this danger is accompanied by financial concerns, such as a significant capital expenditure. As a result of this risk assessment, equipment acquisition has developed into a substantial managerial issue. Before making an equipment purchase, it is advisable to consult an accountant to ascertain the cash flow and tax implications. Along with these financial considerations, the single most important element impacting the return on investment is the amount of equipment that will be used [25].

Future work volume, production requirements, project-specific or client requirements, long-term corporate goals, acquisition time, and equipment availability must all be taken into account when developing an equipment utilization plan for a single piece of equipment or a fleet of equipment. Due to the equipment's high initial and ongoing costs, a strategic approach to equipment management is necessary to maximize return on investment, productivity and operating, maintenance, and repair costs [26].

2.2.3 Poor Training

The last shooter is the equipment operator, who decides the machine's production rate. Downtime can become more frequent and cost more money when equipment is mishandled, whether because of operator carelessness or a supervisor's lack of training and expertise in the area [9]. Task efficiency and the operator's ability to perform at a high level are both directly impacted by competency, and as a result, competence is critical [27].

2.2.4 Poor Maintenance

Poor equipment maintenance procedures result in catastrophic failures of equipment replacement parts and increase equipment downtime, which diminishes equipment output and raises project costs. Thus, in order to comprehend efficient CEM, it is necessary to comprehend effective construction equipment maintenance [1]. The specifics of an equipment maintenance program are determined by a variety of criteria, including the size of the fleet, the type of project, the location, and the climatic conditions. However, the absence of an effective maintenance schedule results in early equipment failure, significant cost overruns, and increased worker idle time while equipment is being repaired. Furthermore, as mentioned in [1], the percentage of overall operating costs spent on repairs can reach 25% or more. As a result, the quality of maintenance management has a substantial impact on the actual cost of ownership of construction equipment. Implementing a comprehensive maintenance program can significantly reduce the cost of operating the equipment envisioned in the estimate and save time.

3 POOR MANAGEMENT FOR THE EQUIPMENT

Construction equipment has a three-tiered lifecycle: physical life, economic life, and profit life. Figure 2 depicts the link between these various definitions and the average life expectancy of a piece of equipment. [1]. As seen in the graph, it takes time for a new machine to generate enough revenue to pay its purchase costs. It then enters a phase during which the equipment generates more money than it costs to acquire, run, and maintain, and finally reaches a point where the cost of maintenance surpasses the revenue generated during periods of operation. Physical life is the moment at which a machine has degraded to the point of being unable to produce reliably. At this stage, it is often abandoned or discarded. Costs associated with maintenance and operation grow as construction equipment matures. The term "profit life" refers to the time period during which an item of equipment earns a profit. Beyond that point, retention will result in a loss of operating efficiency [1].

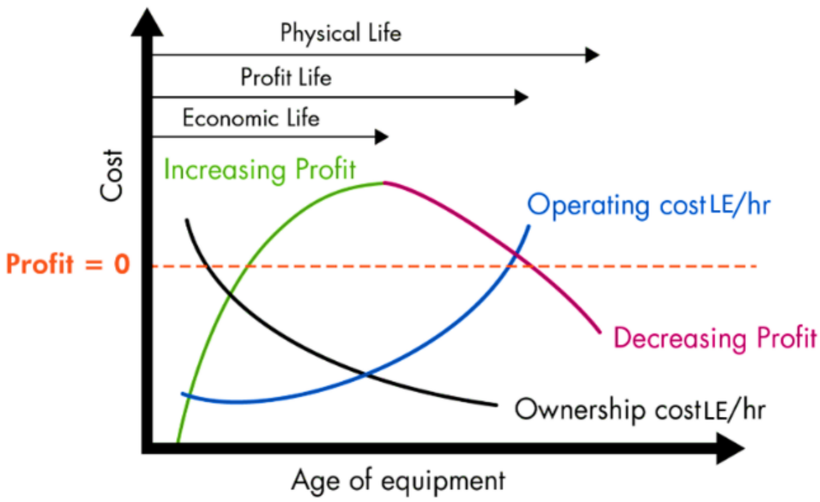

Fig. 2. Equipment Life Cycle—Inspired from [1]

The economic life of the equipment is defined as the time period during which earnings are relative to the usable life of the equipment. Equipment owners are constantly looking for ways to increase production rates while lowering production expenses. Thus, by selecting when to replace equipment based on economic life duration, you are essentially maximizing production in terms of profit. Equipment's economic life is shorter than its physical life and terminates when the profit margin connected with a particular machine reaches its maximum value. Due to increased maintenance and operating costs as equipment reach the end of its economic life, inefficient equipment replacement scheduling results in a loss of profitability. Records of maintenance and repair expenditures can help owners determine the most cost-effective time to replace equipment [1].

3.1 Effects of Poor CEM

3.1.1 Time Overrun

Delay is often regarded as the most frequent, costly, difficult, and lethal issue that emerges during building projects [28]. Time is a frequent cause of contention and claims, which frequently end in litigation, due to the vital significance of time for both the owner (in terms of performance) and the contractor (in terms of financial gain). A construction delay is defined as the period of time between the contract's completion date and the date agreed upon by the parties for project delivery. There are various hypotheses as to why engineering and building projects are delayed. Numerous studies have determined that the majority of delays are caused directly or indirectly by insufficient equipment design and management [29].

3.1.2 Cost Overruns

The project's cost is made up of both cost and resources (labor, equipment, and materials). There are a lot of factors that go into a client's decision to hire a contractor. Project managers must accept or create a cost performance standard [30]. However, numerous characteristics influencing cost overruns in road construction projects have been identified across numerous regions and time periods. Numerous concerns and complications may occur for contractors throughout their work with the equipment, including the machine's lifecycle and other financial hazards that could be exceedingly costly to the company [31]. Numerous contractors would be unable to complete their work without sufficient financial assistance. Equipment costs are estimated to account for 36% of the entire cost of a construction project [20]. As a result, insufficient equipment planning, and control are the leading causes of project cost overruns.

3.1.3 Loss in Production Rate of Equipment

The term "productivity" refers to the ratio of valuable work generated to the time necessary to do it [32]. Current construction equipment production rate has increased in lockstep with technological breakthroughs and modernization, allowing for relatively steady operating costs. Equipment planning and management inefficiencies result in inefficiencies and lost productive time results in cost increases. According to [24, 33], the back points are the key causes contributing to the low equipment production rate in the construction industry.

To summarize, previous research has been undertaken to analyze CEM. [34] emphasized the crucial nature of improving production rates in order to optimize construction operations. High equipment availability will be achieved, which is determined by equipment dependability and maintainability. Additionally, [9] investigated the planning and management of construction equipment in road-building projects in Addis Ababa, Ethiopia. He conducted research in which the majority of respondents felt that maintenance is a critical component of equipment management since it directly impacts the cost of operation of any piece of equipment. [35] conducted a case study on road CEM in Malaysia and found that implementing solutions based on cost reduction and profit maximization modules will aid in optimal decision-making.

Therefore, according to the current literature analysis, there is a gap in this area as no substantial research has been conducted to examine the influence of equipment management on the production rate of the Egyptian construction industry. Egypt is a growing country where multimillion-dollar projects are underway concurrently and account for a sizable portion of equipment usage. With these considerations, the research would analyze the impact of equipment selection on a road project in Egypt on its time and cost. Furthermore, suggestions would be made on how to enhance the CEM in order to mitigate the likely negative consequences on time and cost.

4 RESEARCH METHODOLOGY: CASE STUDY OF A ROAD PROJECT IN EGYPT

The research technique entails an initial complete literature search, which was conducted by consulting books, journals, and articles in order to gain exciting knowledge about the many causes of CEM delays. Based on the results of the literature search, this research collects and analyzes data from a case study in Egypt. The data was collected from a construction excavation activity on a highway road in Egypt. The highway road was about 7.2 km (4.5 miles) away. The data was collected from a 30-day observation of long boom backhoe excavation production rate by using Activity Sampling (AS) technique [24, 31]. The daily data collection sheet shown in Table 1 includes information about the estimated and actual quantities, hoe numbers, cumulative quantities, and daily hoe production rate. The working hours were eight hours daily, and there is no night shift in this excavation activity for the project. There are 30 long boom backhoe equipment each with 15-meter-long arms and utilized to cover 30 × 30 m2.

The observation number needed to find the construction equipment production rate was estimated from the next formula [31] that cited from [36–38] Equation 1 and Equation 2. The primary purpose of this research is to draw a methodology for establishing a production rate baseline that reflects an equipment's typical performance. The following steps summarize the research methodology:

- Use equipment production rate values that are related to the disputed actual production rate.
- Consistently apply a process control chart to production rate data in order to remove outliers.
- Calculate baseline equipment production rate as the typical construction equipment production rate, based on quantities, in order to determine a long hoe equipment's normal working performance.

– Calculate the time difference between the cumulative times required to complete the task and the cumulative times required to finish the work.

Calculate the time required to accomplish the assignment. As a result, determine the increase in project costs due to low equipment production rate.

Table 1. Data of daily hoe excavation work production rate

Days	Number of Used Hoes	Working Hours (HR)	Daily Excavation Quantity	Hoe Production rate (M3/HR)		Cumulative Quantities (M3)	
				Actual	Estimated	Actual	Estimated
1	30	240	24,000	100	200	24,000	48,000
2	30	240	25,200	105	200	49,200	96,000
3	30	240	25,680	107	200	74,880	144,000
4	30	240	26,400	110	200	101,280	192,000
5	30	240	28,080	117	200	129,360	240,000
6	30	240	26,880	112	200	156,240	288,000
7	30	240	27,600	115	200	183,840	336,000
8	30	240	28800	120	200	212,640	384,000
9	30	240	24,480	102	200	237,120	432,000
10	30	240	25,200	105	200	262,320	480,000
11	30	240	25,680	107	200	288,000	528,000
12	30	240	25,920	108	200	313,920	576,000
13	30	240	26,640	111	200	340,560	624,000
14	30	240	27,120	113	200	367,680	672,000
15	30	240	26,160	109	200	393,840	720,000
16	30	240	25,200	105	200	419,040	768,000
17	30	240	24,480	102	200	443,520	816,000
18	30	240	28,320	118	200	471,840	864,000
19	30	240	36000	150	200	507,840	912,000
20	30	240	30,000	125	200	537,840	960,000
21	30	240	35,280	147	200	573,120	1,008,000
22	30	240	27,600	115	200	600,720	1,056,000
23	30	240	34,080	142	200	634,800	1,104,000
24	30	240	28,320	118	200	663,120	1,152,000
25	30	240	28800	120	200	691,920	1,200,000
26	30	240	29,040	121	200	720,960	1,248,000
27	30	240	30,720	128	200	751,680	1,296,000
28	30	240	29,760	124	200	781,440	1,344,000
29	30	240	30,960	129	200	812,400	1,392,000
30	30	240	25,920	108	200	838,320	1,440,000

$$N = \frac{Z^2 * P * (1-P)}{L^2} \tag{1}$$

$$\frac{dN}{dP} = \frac{Z^2}{L^2}(1-2P) = 0 \tag{2}$$

Where N is the size of the sample, Z is the value taken from the statistical tables and depends on the level of confidence, P is the activity observed percentage, and L is the accuracy limit, which will be 5%. This research is used (Z=2) for a 95% confidence level. To maximize N, the differentiation of N will be equal to zero. Then, P equal 0.5 [37]. Substituting Z=2, P= 0.5, and L=0.05 into the Equation (1) provides: N equal 400. Thus, if N=400 was applied, all possible values of P would meet the accuracy criteria. The number of observations in this research was taken from 2896 working hours through 30 days.

5 DATA ANALYSIS AND DISCUSSION

5.1 Control Charts

A control chart is a diagram used to manage a product's quality [39]. It was eventually recognized as applicable to processes involving service transfers and other activities [40]. As shown in Figure 3, the control chart has a predefined shape. The vertical axis shows the process metric values, while the horizontal axis shows the time values. For repetitive samples selected at each of the designated time intervals, an equivalent summary statistic such as a sample average may be used. It shows three horizontal markers: UCL, CL, and ULC (LCL). The metric's mean value is represented by the centerline. The upper control limit is traditionally calculated as mean—standard deviation, and the lower control limit is calculated as mean + standard deviation. The typical range of variation or a typical cause of variation is expected to be plotted within the control limits of the control. Outliers are points that deviate from a control limit. Excessive control limits indicate that a process operating at the typical level of the center line's value terms is unlikely to produce the matched values.

A normal working environment is not required to manufacture it. For the research's main subject, reducing production rate values that are not comparable to equipment performance allows separation of those that are. This necessitates a unique control chart [41]. In this context, a day is the unit of measurement for equipment production rate. The arithmetic mean is used to find the center (equipment production rate values divided by the total number of values). The standard deviation is computed using multiple measurements taken at various times and locations. This research calculates the standard deviation from the range. The range of observed values is the difference between maximum and minimum values. This research typically employs a statistical process control strategy. In order to get the standard deviation, you need to find the range between two ordered values. Control charts can be automatically generated by mathematical software.

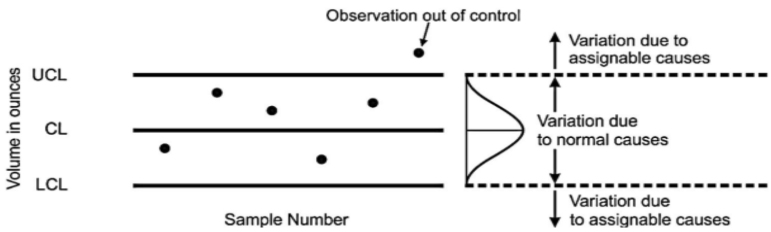

Fig. 3. Control Limit Chart Source; [31]

5.2 Determination of Baseline

The baseline value of construction equipment production rate is calculated using an individual control chart as described previously. For this reason, it is necessary to repeatedly apply the individual's chart to production rate figures until no values are found to be outside of the control limits, using recalculated control limits and the centerline. When out-of-control values are removed from the control chart, the baseline production rate level is the average production rate of the values that remain within the control borders, which corresponds to the final iteration's control chart generated. Underestimating average production and obscuring the range around that average are both problems with this new baseline.

By assessing the daily productivity of excavation activities on a daily basis, as shown in Table 1, the impacted and unimpacted periods of operation are provided to create a baseline, without making any reference to an impacted or unimpacted period. As shown in Figure 4, this is the control chart designated as the first control chart, which was first applied to the production rate points for the 30-working-day record. As seen in the Figure 4, equipment production rate on workdays 19, 20, and 23 surpasses the upper limit of control, while it exceeds the lower limit of control on workdays 1, 9, and 19. As a result, when the control bounds for the next chart Figure 5 is recalculated, these data are excluded. Additional cycles are required to generate a control chart with values within the control borders.

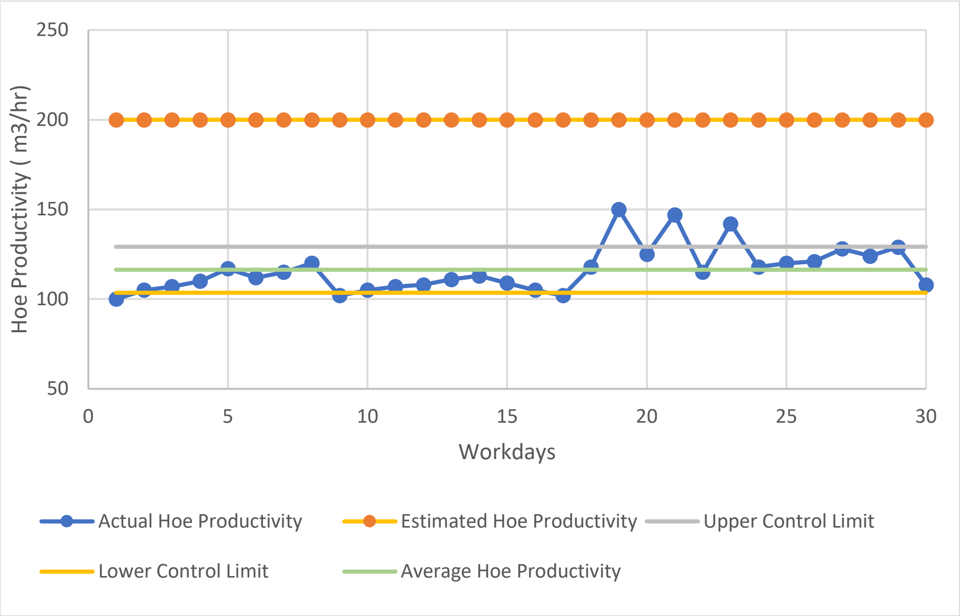

Fig. 4. Control Chart for the project before removing the outsiders

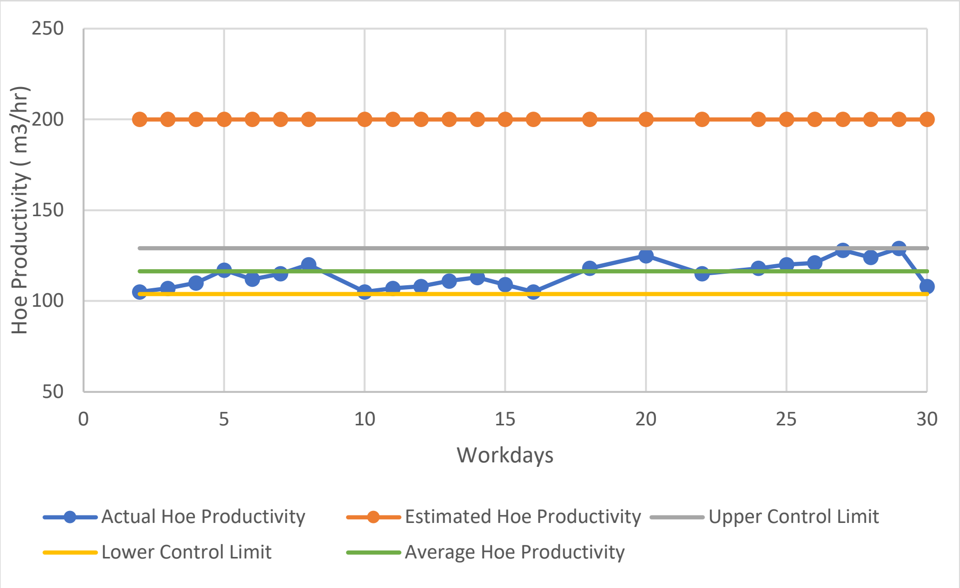

Fig. 5. The control chart for the project after removing the outsiders

5.3 Results and Discussion

According to the estimates, the long boom hoe used to do the excavation work had a production rate of 200 m3 per hour, according to the estimates (caterpillar graphs to estimate the equipment production rate). If each day has eight working hours, then the daily production rate is 8 * 200 = 1600 m3 per day. In order to identify the loss of production due to poor equipment production rate and compression between the cumulative estimated quintets and cumulative actual quintets within 30 days of work, as shown in Figure 6. The cumulative estimated quantity leads to 1,440,000 m3 to finish 100% of the work Table 1.

$$Average\ Daily\ Production = \frac{Total\ Quantity}{Number\ of\ days * \ Number\ of\ Used\ Equipments} \quad (3)$$

$$Average\ Daily\ Production = \frac{838320}{30 * 30} = 931.5\ M^3\ /\ Dayfor\ Each\ Hoe$$

While the actual cumulative quantity of the collected data was 838,320 m3, the loss of production due to poor equipment production equals the cumulative estimated quantity of 1,440,000 m3 minus the actual cumulative quantities of 838,320 m3, which is equal to 601,680 m3. In order to identify the time lost due to poor equipment production rate, the average actual daily production rate was calculated by calculating the summation of the observed daily production rate (838,320 m3) divided by the number of working days.

A silty clay soil excavation of 1,440,000 m3 requires 30 long boom backhoes working for 30 days, with each day having eight working hours. The total expected working hours will be 7,200 based on Equation 4. The actual time to perform a silty clay soil excavation of 1,440,000 m3 was calculated by dividing the total excavation quantity by the average actual hourly production, which is 51.5 daily based on Equation 5. The loss of time due to poor equipment production rate equals 5160 working hours (about 71.5%). This value defines the difference between the final cumulative average actual production and the cumulative estimated production as shown in Figure 7.

$$\begin{aligned} &Expected\ Working\ Hours \\ &\quad = Number\ of\ days * Number\ of\ Equipments * Working\ hours \end{aligned} \tag{4}$$

$$Expected\ Working\ Hours = 30 * 30 * 8\ = 7200\ Working\ Hours$$

$$Actual\ Time = \frac{Quantity\ of\ the\ work}{Actual\ Quantity * Number\ of\ Equipments} \tag{5}$$

$$Actual\ Time = \frac{1{,}440{,}000}{9315.5 * 30} = 51.5\ Daily\ work$$

$$Actual\ Working\ Hours = Actual\ Time * Number\ of\ Equipments * Working\ hours \tag{6}$$

$$Actual\ Working\ Hours = 51.5 * 30 * 8\ = 12360\ Working\ Hours$$

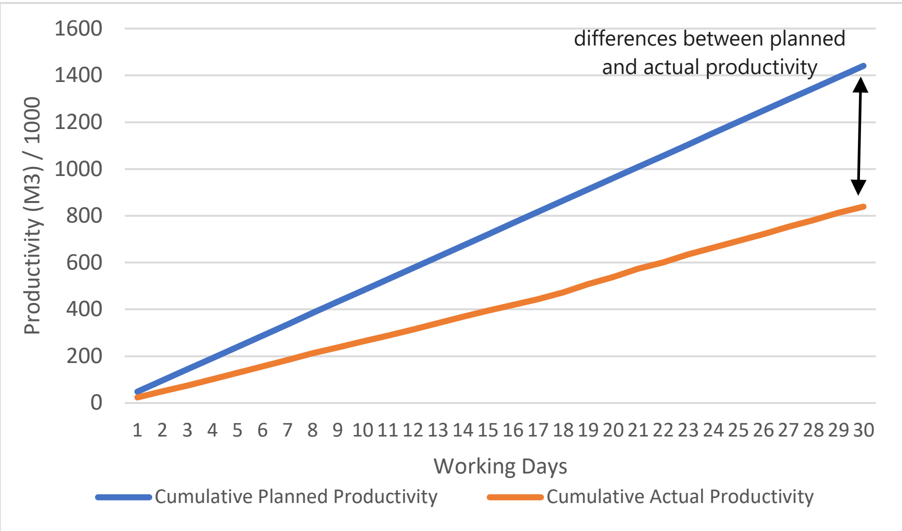

Fig. 6. Time loss due to poor equipment productivity

The baseline equipment production rate of the Egyptian construction sector is determined under normal operating conditions. The total number of hours required to perform the work required to operate normally in the absence of disruption is calculated. To calculate the time lost due to inefficient equipment production rate, utilize the variation between the estimated unaffected times, cumulative baseline production rate, and the actual cumulated times as the number of lost hours. Figure 7 showed the cumulative percent done in volume against the cumulative hours based on everyday data. This shows how long it takes to move through the project's different stages.

The fundamental reason for the variance in ordinary equipment production rate is that equipment will not reach the same level of production rates from time to time, even in the absence of external factors impacting the work process. This volatility cannot be eliminated and should thus be accepted as a component of performance for any collection of repeating jobs. External causes of variance include those that are within the contractor’s control and those that are not. Based on previous information, it is inferred that the reasons for low equipment production rate are ineffective supervisors and a lack of equipment and skills, which affect the time required to perform an activity, necessitating continuous training of them. On the other hand, ineffective interaction as a result of improper instructions results in work slowing down, rework, inability to comprehend the designs and work being refused by consultants [42]. The technique employed in this paper to calculate baseline production rates automatically eliminates the outlier results caused by these reasons [33, 43].

The control chart might be used to examine the values of construction equipment production rate, first to determine if any are anomalous, and then to establish a baseline production rate using our approach. As a result, losses can be computed using these equipment production rate figures about the established baseline. The total estimated loss is then calculated as the difference between the total number of hours spent on an impact and the resultant baseline production rate. The developing value is used to calculate the project’s loss caused as a result of low equipment production rate. Thus, assuming the average daily equipment price in Egypt is approximately LE800 ($35) in 2022, the total cost of the project will be doubled. This cost increase is due to the execution of excavation activity, which accounts for about 30% of the time and cost. This means that the time it takes for a construction equipment to do all the work in typical working conditions makes up about 70% of the total time needed.

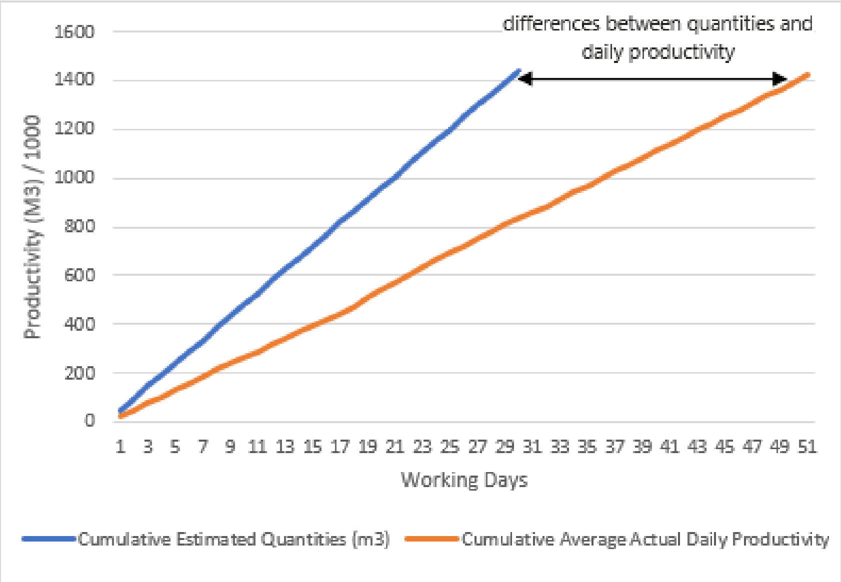

Fig. 7. Time loss due to poor equipment productivity

6 CONCLUSION

The selection of construction equipment has a huge impact on the time and cost, especially excavation activities in a road project as it is considered as a mass excavation process. Furthermore, the cost for construction equipment accounts for approximately a third of the total cost of the road project. The primary objective of this research was to determine the influence of equipment selection based on experience without utilizing CEM concepts on the construction industry in Egypt. Moreover, to draw a technique for determining the baseline estimate of construction equipment production rate that can be applied to find the impact of the inappropriate equipment selection and neglecting CEM processes on construction project time and cost. When the analysis was performed due to the on-site measures, it found out how much time was lost, and cost overrun because of inefficient equipment production rate.

As a case study, this research examined excavation activities for a road project in the Alexandria government. The excavation was 7.2 kilometers (4.5 miles) in length, and the equipment used to complete this task was a 15-meter-long boom backhoe. For a period of 30 days, the backhoe's real production was tracked and measured. The data was used to calculate the cumulative actual excavated quantities with the long boom backhoe and compare them to the cumulative expected excavated quantities in order to calculate the time lost due to inefficient equipment production rate and the cost overrun, which was determined by comparing the cumulative actual excavated quantities to the cumulative expected quantities.

The research findings demonstrated an inadvertent selection of equipment to execute the activity, as its actual production rate was nearly 50 percent that is expected, resulting in an increase of 27.8 percent in the estimated activity's time and 28.5 percent in the estimated activity's cost. Moreover, the research draws a method to calculate the baseline equipment production rate, based on quantities, in order to determine a long hoe equipment’s normal working performance by using the control chart method. Therefore, this method can be used in the future to measure and evaluate equipment selection at any phase of construction projects. The findings revealed that factors such as a lack of knowledge about equipment selection, equipment downtime, poor equipment maintenance practices, improper replacement timing determination, insufficient training of equipment operators, equipment breakdown, ignorance about equipment maintenance, a large capital investment during acquisition, misunderstanding the scope of work performed, unit cost of production, and equipment suitability for job conditions, or neglected the implementation of any CEM procedures could impact time and cost.

reasonable manuscript structure would be: Introduction with research objectives/questions, Materials and Methods, Results and Discussion, Conclusions, Acknowledgement and References. This may vary based on your research. Have in mind that conclusions section should present one or more conclusions drawn from the results and subsequent discussion and should not duplicate the Abstract.

Acknowledgement (optional) of collaboration or preparation assistance should be included. Please note the source of funding for the research.

6.1 Recommendation

Following a thorough assessment of construction equipment planning and management issues, as well as their causes and consequences, suggestions to construction industry decision maker maybe drawn. The idea was aimed at alleviating planning and administration issues associated with road development projects in Egypt. At the management level, a policy should be created for construction equipment planning and management practices that will serve as a guideline for effective equipment use. A plan for maintenance programs should be established to minimize equipment downtime. The present state of any construction equipment and its efficiency must be gathered at the project level.

Moreover, on the labor level, providing training for the equipment workers is the first priority, followed by hiring highly skilled equipment workers. A safety and health plan must be created. Finally, at the lifecycle level, implement a program of preventive, corrective, and unscheduled maintenance on leading construction equipment. Maintenance is also provided by highly skilled equipment maintainers.

6.2 Limitations of This Study

Despite the huge importance of the data collected in the case study, it has some limitations. This research is based on excavation work in only Egypt using a long boom backhoe to cover a large zone. The excavation soil must consist of clay, soft clay, or dirt.

6.3 Future Areas

The continuous research is required to ensure that construction equipment on-site operates at its maximum capability. As a result, the following recommendations are made for future researchers.

- Develop a computer model for managing construction equipment in projects.
- Develop a computer model based on CEM concepts for predicting the production rate of construction equipment.

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