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Construction Project Monitoring: The Cost and Schedule Control by Earned Value Method (EVM)

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Abstract On account of ever increasing complexities and uncertainties, construction project management has become more and more challenging day by day. As a result, continuous project monitoring emerges as a prime concern for the planned activities to be completed on schedule and within budget. Limitations in traditional time and cost monitoring practices result in time and cost overrun which seriously hinder successful completion of a project. The impact of time and cost at various stages of a construction project is a critical factor in the project's successful completion and management. Most of the construction projects in Bangladesh have completed with extra time which leads the demand of additional cost because of poor project monitoring and controlling system. In these consequences, a widely recognized emerging project monitoring technique, Earned Value Management (EVM) can be introduced to conduct project progress, performance and forecasting. EVM measures the actual work completed on a project at any time with respect to the original cost and schedule by integrating project scope, cost and schedule in order to predict cost and completion timeline. In this study, a three-storied residential building project at Khulna, Bangladesh was considered to perform earned value management for tracking whether the project is either delay or not along with either over budget or under budget at any particular day. The construction operations up to the first six months were assessed using an EVM based on a work-breakdown structure (WBS), in which the real activities and costs were compared to the projected program. The progress of the under constructed project considering cost and schedule were also evaluated through analyzing EVM indexes using Microsoft Project Professional 2019 software. Construction performance was assessed respecting cost variance (CV), schedule variance (SV), cost performance index (CPI) and schedule performance index (SPI). CV and CPI are evidently less than 0 and 1, respectively, indicating that the project was on the verge of cost overrun; on the other hand, SV and SPI are both less than 0 and 1, indicating that the project was running behind budget after six months. As a result, if this project is pursued at its current pace, it will be finished behind schedule and above budget. It will undoubtedly assist project rescheduling to bring the performance back to harmony.

Keywords: Project monitoring, earned value method (EVM), cost performance index (CPI), schedule performance index (SPI).

1. Introduction

Construction is considered as a unique sector and the growth of the construction industry can keep a great contribution to the progress of a society and which leads the progress of a nation (Hillebrandt, 2000). The construction industries of a country have to be more frugal with the increasing infrastructural development, because those

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development are ailing with national development in case of developing countries (Okpala & Aniekwu, 1988). Geographically, Bangladesh is small and over populated and developing country. According to the World Fact book report (2019), the total population was 162.65 million with an annual growth rate of 0.98% (Asia & Asia, 2019). Alone other basic needs this extra population has demanded housing. Government of Bangladesh has been increasing their budget on housing and infrastructural development in every financial year. Compare to other developing countries, such as Nigeria (Elinwa & Buba, 1993; Okpala & Aniekwu, 1988), Malaysia (Young, 1988), and Indonesia (Kaming, Olomolaiye, Holt, & Harris, 1997), the infrastructural progress in Bangladesh is increasing rapidly. The demand of construction project in Bangladesh is increasing and becoming more competitive which leads the construction industry to find talent in completing the tasks. The reputation of the construction industry depends on the ability to complete projects on time, within budget and to the proper quality (Chan & Kumaraswamy, 1982). Projects with good planning, adequate organizational machinery and sufficient flow of resources cannot automatically achieve the desired result. There must be some warning mechanism, which can alert the organization about its possible success and failures, off and on. The success of any project depends on its managerial excellence where needs extra focus on project coordination. Good project coordination depends on proper monitoring and choosing appropriate control functions. Timely completion of projects is the most important success indicator of an efficient construction industry (Office, N. E. D., 1988). Delay of a project causes extra cost and it affects both clients and contractors.

Maximum construction projects in Bangladesh are fallen in financial problem, even both of clients and contractors take pre-estimated program. Those financial losses may occur due to delay and lack of proper midway monitoring. To avoid such losses in the construction industry of Bangladesh, there needs to introduce an efficient and powerful tool with contractors which can be operated easily based on software operation to monitor and control of a construction project. About 38.0% of the construction project control managers wanted 'monitoring and control' activities automated to reduce their workload as well as optimize the waste of time and resources to continuously monitor project productivity (Isaac & Navon, 2014). From this need, this study was performed how the construction industry in Bangladesh can know the updates of their construction project through easy automated monitoring in any phases of the project using software analysis based on EVM.

EVM analysis is a powerful control technique which can help project managers to track project cost and schedule, even it tending towards overrun and delay (Chou, Chen, Hou, & Lin, 2010). Using the EVM tool one can know the deviations from plan of any construction project and also can take proper corrective actions which may include a set of policies (Hazır, 2015). Project Management Institute defined EVM as "a methodology that combines scope, schedule, and resource measurements to assess project performance and progress" (PMI, 2013). Naderpour & Mofid (2011) defined EVM as a recognized system that provides measures to project performance and integrates it with cost and schedule. De Marco & Narbaev (2013) have proven that EVM is able to forecast a construction project as early as when the project is 20% completed. The work-breakdown structure (WBS) provides the structure necessary to track project progress specially to assign completion to parts of the project. The ability to correctly determine the percentage of completed activities is fundamental needs for accuracy of the forecasts. From researches it was found three key parameters of EVM required in order to measure project performance namely planned value (PV), actual cost (AC) and earned value (EV) (Vanhoucke, 2012). According to PMI (PMI, 2013), EVM analysis can be performed following the questions:

$$\text{Planned Value(PV)} = \text{Budgeted Cost of Work scheduled(BCWS)} \quad (1)$$
$$\text{Earned Value(EV)} = \text{Budgeted Cost of Work Performed(BCWP)} \quad (2)$$
$$\text{Actual Cost(AC)} = \text{Actual Cost of Work Performed(ACWP)} \quad (3)$$
$$\text{Schedule Variance(SV)} = \text{EV} - \text{PV} \quad (4)$$
$$\text{Cost Variance(CV)} = \text{EV} - \text{AC} \quad (5)$$
$$\text{Schedule Performance Index(SPI)} = \text{EV} \div \text{PV} \quad (6)$$
$$\text{Cost Performance Index(CPI)} = \text{EV} \div \text{AC} \quad (7)$$

Table 1 - Glossary of EVM terms

No.	Term	Acronym	Definition
1	Cost variance	CV	CV is the difference among the actual incurred cost and the earned value
2	Schedule variance	SV	SV is equal to the difference between the planned value and earned value
3	Schedule performance index	SPI	SPI is equal to the earned value over the planned value
4	Cost performance index	CPI	CPI is calculated over the earned value to the actual costs
5	Budget cost of work scheduled	BCWS	BCWS is the budget summation of all scheduled works to be completed in a predetermined time
6	Budget cost of work performed	BCWP	BCWP is the planned cost of the work value which is completed up to the present time

7	Actual cost of work performed	ACWP	ACWP is the recorded cost of completed works within a predetermined time

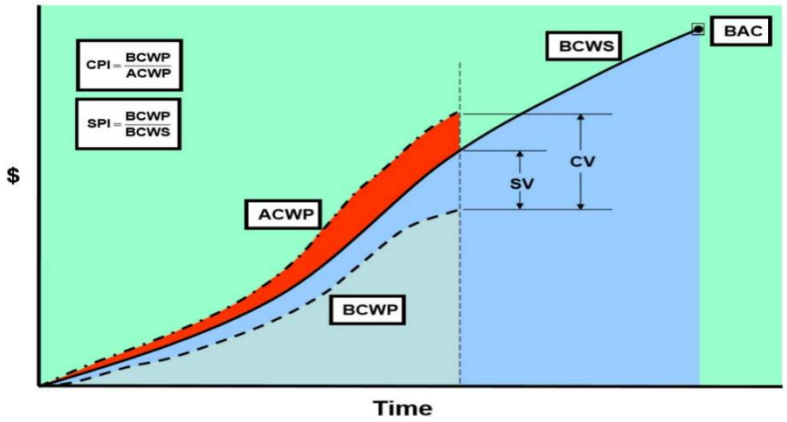


Fig. 1 - Arrangements of ACWP, BCWP, and baseline BCWS resulting with SV and CV (Pajares & Lopez-Paredes, 2011)

Pajares & Lopez-Paredes (2011) showed the evolution of cumulative values of AC, EV and PV over time is shown in Fig. 1. Whenever CV and CPI will be less than zero and one respectively, the project can be termed as cost overrun; whereas, when CV and CPI will be greater than zero and one respectively, the project can be fallen into under budget. Again, when SV and SPI will be less than zero and one respectively, the project will be delayed; otherwise, if SV and SPI will be found greater than zero and one respectively, the project will be considered as ahead of schedule. When CV and SV will be equal to zero and CPI and SPI will be equal to one the project is regarded as on cost and/or timely respectively (Pajares & Lopez-Paredes, 2011). The critical path method (CPM) is the most utilized scheduling tool in the construction industry (Meredith, Shafer, & Mantel Jr, 2017). CPM scheduling is used and accepted on many major projects to plan and coordinate work. CPM works most successfully when the entire organization, from the owner and the general contractor to the subcontractors and suppliers, are involved in the input of information (Horowitz, 1967). CPM scheduling is the development and use of a comprehensive work plan that graphically represents the construction logic of the project. Called network diagrams, these charts represent how the work will be performed. However, for certain types of projects, CPM's usefulness decreases, because it becomes complex and difficult to use and understand (Baki, 1998). Therefore, to exercise this method in the construction industry of Bangladesh, a real time three storied residential building project at Khulna, Bangladesh was investigated to assess the construction performance respecting cost variance (CV), schedule variance (SV), cost performance index (CPI) and schedule performance index (SPI) in this study. It would certainly help with project rescheduling in order to restore the performance's harmony.

2. Methodology

A survey was carried out among fifty under-constructed three to five storied residential building projects at Khulna, Bangladesh to know the status that how the construction project managers manage their construction project, whether they are familiar with any automated system regarding with project monitoring. A real time three storied residential building project having 1280 ft^2 floor area is shown in Fig. 2 was investigated at Khulna, Bangladesh. The estimation summary for relevant drawings is shown in Fig. 3 were collected from project engineer. After that all activities with its precedence activities were listed as WBS. The activities were grouped according to precedence, estimated cost (planned value, PV) and time duration. CPM network was found from the scheduling of the activities through Microsoft Project Professional 2019 software is referred to Fig. 4. The network analysis showed Gantt chart and network diagram, from that critical path was calculated which means the projects expected times to completion is presented in Fig. 5. Actual % of work completion with cost and expected % of work were collected after six months from project started. And from those data CV, SV, CPI and SPI were calculated.

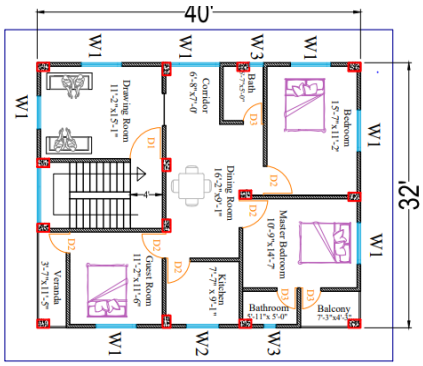
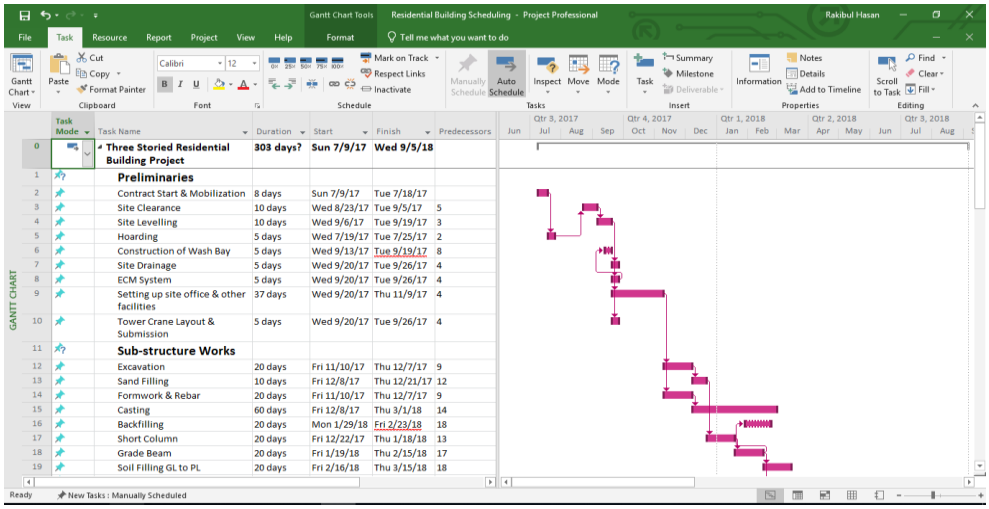


Fig. 2 - Floor Plan of invesigated project

Name of Work	Totall Cost (Tk.)
Excavation	4628.81
Brick Work (First Class Brick)	192529.50
Sand Filling	64525.88
Brick Flat Soling	26581.06
CC Work of Foundation	175020.60
CC Work of Grade Beam	92154.26
CC Work of Columns	58754.90
CC Work of Beam	184308.51
Slab Casting	279248.49
Stair Casting	189477.02
Plastering	215879.65
Colorings & Paintings	16770.21
Tiles & Mosaic	499918.34
Doors	219285.00
Windows	528854.99
Reinforcement	543626.56
Grand Total Cost	3091562.96
Cost of Profit & Overhead Vat	417361.00
Cost of VAT	204219.37
Final Cost ofPlan	3713143.34

Fig. 3 - Estimated cost against major activities



	Task Mode	Task Name	Duration	Start	Finish	Predecessors
0		**Three Storied Residential Building Project**	**303 days?**	**Sun 7/9/17**	**Wed 9/5/18**	
1		**Preliminaries**				
2		Contract Start & Mobilization	8 days	Sun 7/9/17	Tue 7/18/17	
3		Site Clearance	10 days	Wed 8/23/17	Tue 9/5/17	5
4		Site Levelling	10 days	Wed 9/6/17	Tue 9/19/17	3
5		Hoarding	5 days	Wed 7/19/17	Tue 7/25/17	2
6		Construction of Wash Bay	5 days	Wed 9/13/17	Tue 9/19/17	8
7		Site Drainage	5 days	Wed 9/20/17	Tue 9/26/17	4
8		ECM System	5 days	Wed 9/20/17	Tue 9/26/17	4
9		Setting up site office & other facilities	37 days	Wed 9/20/17	Thu 11/9/17	4
10		Tower Crane Layout & Submission	5 days	Wed 9/20/17	Tue 9/26/17	4
11		**Sub-structure Works**				
12		Excavation	20 days	Fri 11/10/17	Thu 12/7/17	9
13		Sand Filling	10 days	Fri 12/8/17	Thu 12/21/17	12
14		Formwork & Rebar	20 days	Fri 11/10/17	Thu 12/7/17	9
15		Casting	60 days	Fri 12/8/17	Thu 3/1/18	14
16		Backfilling	20 days	Mon 1/29/18	Fri 2/23/18	18
17		Short Column	20 days	Fri 12/22/17	Thu 1/18/18	13
18		Grade Beam	20 days	Fri 1/19/18	Thu 2/15/18	17
19		Soil Filling GL to PL	20 days	Fri 2/16/18	Thu 3/15/18	18

Fig. 4 - Scheduling through Microsoft Project Professional 2019 software

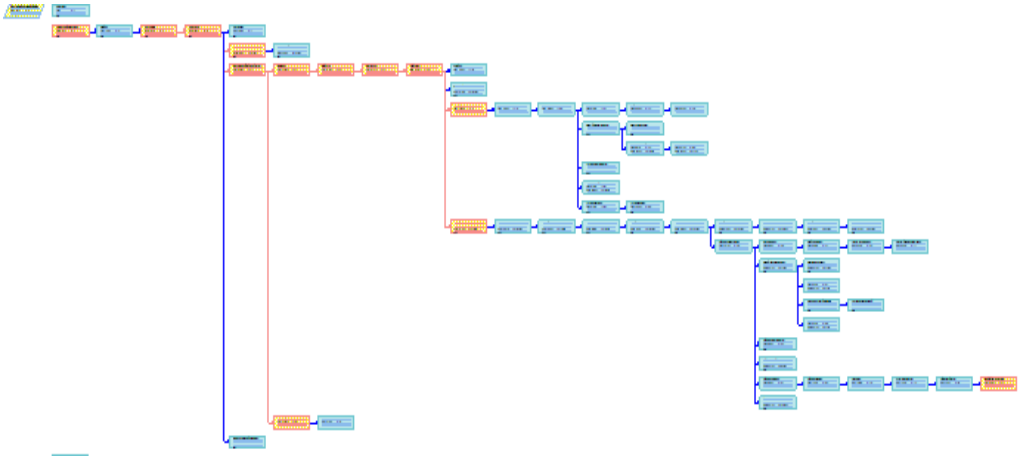


Fig. 5 - Critical path analysis through network diagram

3. Results and Discussion

The survey result of construction project monitoring in Bangladesh is shown in Fig. 6. From this Graph it can be found the almost 63% of residential construction within three to five storied in Bangladesh don't follow any tools to monitor their construction project during construction. There also found that about 12% constructions are completed with only field supervision with following manual recorded format. The description of activities with indication number is shown in Table 2 where the activities are listed up to first six months based on continuation or completion of the project's activities during these periods. Fig. 7 explains the updated information as of first six months after starting construction of this project including actual % of completion compare with PV and EV. From Fig. 7, it is also found that maximum activities were completed with extra cost which was the main cause of time overrun against activities. Fig. 8 shows the EVM analysis; from this analysis it is found that the differences among AC, EV and PV became larger after second months from starting of construction. Fig. 9 and 10 shows the CV, SV and CPI, SPI respectively. Using regression analysis from Fig. 9, it is found that the SV is linearly related with times. Since coefficient of determination, $R^2 = 0.999$ in case of SV, authors can definitely predict that the project's schedule overrun would be continued linearly which associate huge amount of extra cost, if not project manager takes strong necessary actions against delay.

Table 2 - List of activities for first six months of the project

Task Name	Indication Number	Task Name	Indication Number
Contract Start & Mobilization	1	Tower Crane Layout & Submission	10
Site Security	2	Machineries Mobilization	11
Site Clearance	3	Excavation	12
Site Leveling	4	Sand Filling	13
Hoarding	5	Formwork & Rebar	14
Construction of Wash Bay	6	Casting of Footing	15
Site Drainage	7	Short Column	16
ECM System	8	Grade Beam	17
Setting up site office & other facilities	9		

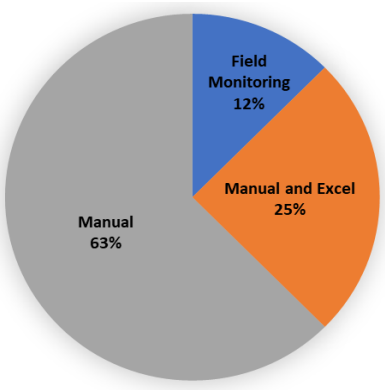


Fig. 6 - Survey result of construction project monitoring in Bangladesh

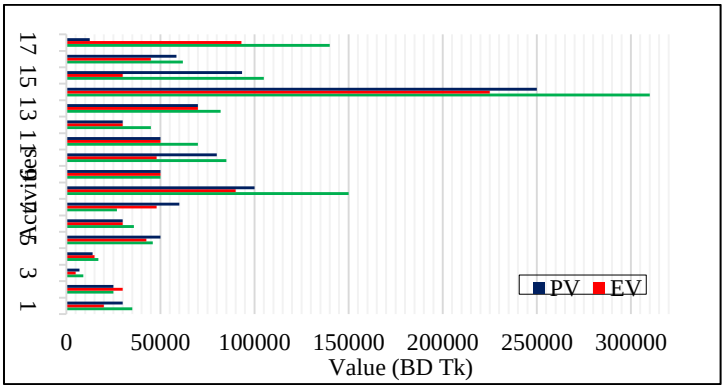


Fig. 7 - Flow of values against activities

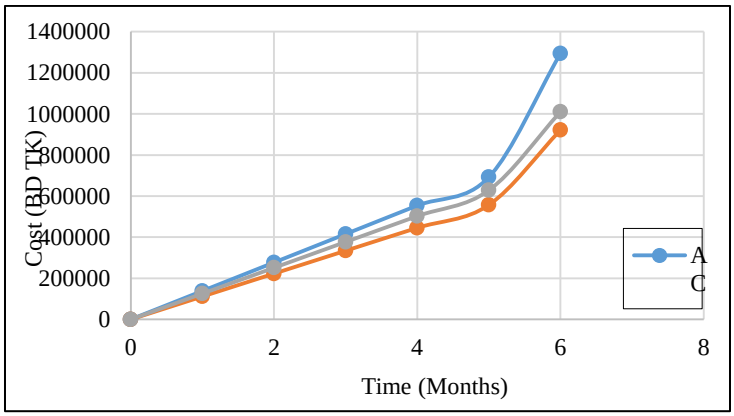


Fig. 8 - Earned value analysis

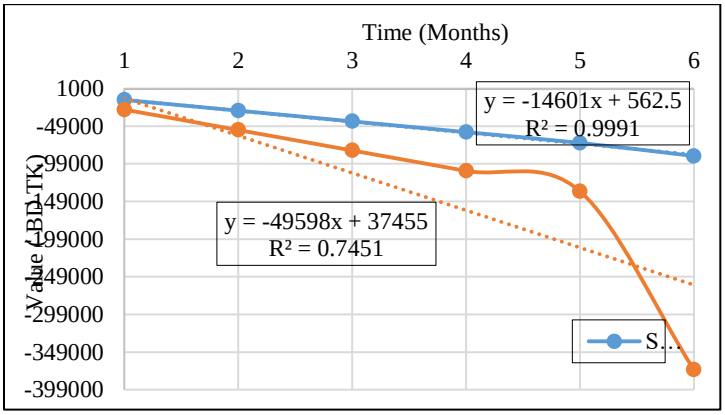


Fig. 9 - Cost and schedule variances

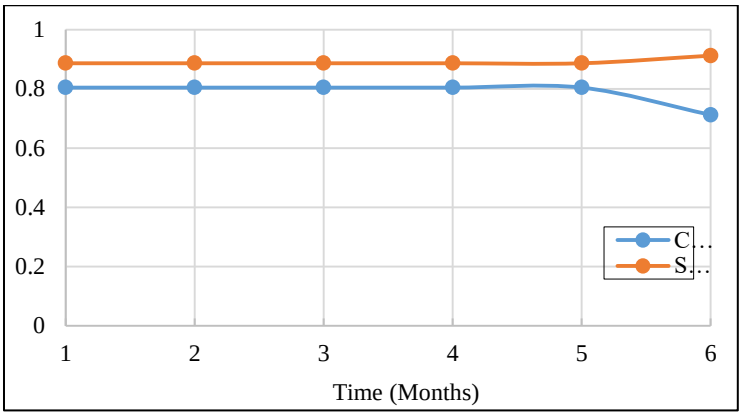


Fig. 10 - EVM performance indexes

From analysis of EVM performance indexes is presented in Fig. 10, it is clearly found that CV and CPI are less than zero and one respectively which indicates the project was tending to cost overrun; on the other hand, and also SV and SPI are found less than zero and one respectively that means the project was backward of planned schedule after six months. Hence, if this project was continued at this rate, the project will be completed behind of schedule and cost over budget. According this way of through analyzing EVM indexes during the execution phase of a project, managers can detect the deviations from planned program and if find any uncertainty this way will help them to take early corrective actions. (Keng & Shahdan, 2015; Ziółkowska & Połoński, 2015) had been also explored that EVM is an effective construction project monitoring tool in the field of construction industries in Malaysia and Poland. Their findings of awareness about EVM and its wide application with construction automation system were merged with the findings of this study in Khulna, Bangladesh.

4. Conclusion

The challenges that initiates in construction industries are maintaining the quality, cost and time of any construction project. Project's activities are greatly influenced by project costs and durations. Most of the construction projects in developing country like Bangladesh is not complete at due cost and time. It may take over budget and time for completion the project than estimated due to lack of proper way in project monitoring. Through tradition project monitoring system project manager or responsible authority cannot determine the project position after some times (quarter, half or more times of estimated schedules) from beginning of construction. For tracking project's status, EVM is more effective and precious method to finding the project position i.e., it may or not remain in budget or in estimated time schedule, if the project's scopes are defined very well. This study focused on EVM through which one can measure the progress of any kind of construction project against the plan and analyze it do or not stick to plan at midway of construction which leads the automation in construction project monitoring. Therefore, EVM analysis enables building construction engineers as well as project managers to monitoring and evaluating of a project at midway of construction and if any deviations from plan are found can take early and time preparing action to solve it.

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