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Reducing Maintenance Costs for Government Projects in Iraq Using Performance Indicators

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ABSTRACT

Institutions and companies are looking to reduce spending on buildings and services according to scientific methods, provided they reach the same purpose but at a lower cost. On this basis, this paper proposes a model to measure and reduce maintenance costs in one of the public sector institutions in Iraq by using performance indicators that fit the nature of the work of this institution and the available data. The paper relied on studying the nature of the institution's work in the maintenance field and looking at the type of data available to know the type and number of appropriate indicators to create the model. Maintenance data were collected for the previous six years by reviewing the maintenance and financial department records. On this basis, three performance indicators are proposed in creating the model. The result is a model to reduce maintenance costs based on three indicators; each indicator contains a baseline value and a target value. If this model is applied, it will significantly help measure, track, control, and reduce maintenance costs in government institutions.

Keywords: Maintenance, Mcosts, Performance Indicators, Government projects.

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تخفيض تكاليف الصيانة في المشاريع الحكومية في العراق باستخدام مؤشرات الأداء

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الخلاصة

تتطلع المؤسسات والشركات إلى تقليل الإنفاق على المباني والخدمات وفق الأساليب العلمية بشرط أن تصل إلى نفس الغرض ولكن بتكلفة أقل. وعلى هذا الأساس تقترح هذه الورقة نموذجاً لقياس وتخفيض تكاليف الصيانة في إحدى مؤسسات القطاع العام في العراق ، وذلك باستخدام مؤشرات الأداء التي تتناسب مع طبيعة عمل هذه المؤسسة والبيانات المتوفرة. واعتمدت الورقة على دراسة طبيعة عمل المؤسسة في مجال الصيانة والنظر في نوع البيانات المتوفرة لغرض معرفة نوع وعدد المؤشرات المناسبة التي يمكن استخدامها في إنشاء النموذج. تم جمع بيانات الصيانة للسنوات الست السابقة من خلال مراجعة سجلات الصيانة وسجلات الإدارة المالية. على هذا الأساس ، تم اقتراح ثلاثة مؤشرات أداء في إنشاء النموذج. والنتيجة هي نموذج لتقليل تكاليف الصيانة استنادًا إلى ثلاثة مؤشرات ، يحتوي كل مؤشر على قيمة أساسية وقيمة مستهدفة. إذا تم تطبيق هذا النموذج ، فسيساعد كثيرًا في قياس وتتبع ومراقبة وتقليل تكاليف الصيانة في المؤسسات الحكومية.

الكلمات المفتاحية: الصيانة, كلف الصيانة, مؤشرات الاداء, المشاريع الحكومية.

1. INTRODUCTION

Due to the high costs of establishing projects, it is necessary to preserve them and all their components from damage or misuse, using a clear and correct strategy in conducting maintenance for them, which leads to their sustainability and increases their life span, thus reducing costs. Maintenance in Iraq is essential because buildings and infrastructure have been damaged as a result of the conditions that the country has lived through for decades and the lack of renewal or modernization of infrastructure. Every structure requires care to limit deterioration. Exposure to the elements causes all building materials to wear down eventually. Periodic inspections can help to figure out the problems early, and with regular maintenance, these practices can extend the life of the building **(Reziej and Al-Hilaly, 2017).**

A methodical approach to information management is required for maintenance strategies, effective methods for organizing and scheduling work orders and resources and monitoring maintenance activities **(Rodrigues et al., 2023)**.

The term “maintenance” is explained by many definitions. Throughout an object's full lifespan, a combination of technical, administrative, and managerial actions are conducted to maintain or restore its capacity to execute its fundamental duties **(BSI 13306, 2017)**. By keeping, renovating, or enhancing each component of a structure, its services, and its surroundings to a current acceptable level, the activity is carried out to preserve the utility

and value of a facility **(Hoe, 2009)**. The concept of "maintenance" refers to the administrative, technical, and supervision procedures needed to maintain or repair a product to continue to fulfil its intended function **(Parida and Kumar, 2006)**. Maintenance work is the only method to keep a property in good shape and increase its value **(Ali et al., 2013)**.

Any institution that wants to improve its performance, strategies, and objectives should know its current level of performance to set in mind the objectives it wants to reach. Here, it is necessary to understand how to measure performance.

Many researchers have defined performance measurement. Assessing the business's performance and efficiency. The states of the properties pertaining to the measuring item are identified **(Neely, 2005).** The value of the output or input, or the degree of activity for a process or event, is used to define it. Enhancing motivation, behaviour, and procedures results from performance measurement, a prerequisite for performance management **(Radnor and Barnes, 2007)**. It is the procedure for determining the state of a measuring object's attributes. The applications of the data obtained from performance measurement are referred to as performance management **(Lönnqvist, 2004)**.

Many researchers have been able to link performance indicators with maintenance. **(Muchiri et al., 2011)** identified maintenance performance indicators and maintenance results for each category according to a conceptual framework. **(Gonçalves et al., 2015)** proposes a novel way for choosing pertinent maintenance KPIs based on the multi-criteria decision-making process of the original ELECTRE I. The suggested methodology, which incorporates the decision maker's preference data, establishes a ranking of potential choices after evaluating them in accordance with crucial criteria. **(Shohet, 2006)** suggested that age and occupancy coefficients are critical factors for determining the requirements of big healthcare facilities, as a useful metric for long-term facility maintenance planning, and for gauging FM efficiency. The study emphasizes integrating quantitative performance, personnel, and maintenance indicators into strategic healthcare facilities management.

The reality of Iraqi construction projects refers to the necessity for performance development to enhance quality, decrease flaws and errors, and regulate time and cost. Therefore, efficient approaches must be applied in this area **(Al-Ajeeli and Mehdi, 2015)**. Across the world, enormous sums of money, time, and effort are invested in building projects. It is not compatible with the current projects, which are characterized by complexity, expansion, dispersion, tighter schedules and standards, more requirements and expectations, and more challenges and problems, that expenses and time are spent in Iraq on developing and improving the performance of project management compared to costs and time spent on projects execution. Construction projects today have many issues, difficulties, flaws, inefficiencies, and inefficacies; as a result, active development and improvement of current performance are needed to support the present level of project management and execution **(Al Saffar et al., 2023)**.

Models linking maintenance choices to building performance have been developed by several authors **(Jones and Sharp, 2007)**. According to these models, maintenance choices ought to be based on assessments of building performance indicators in relation to industry standards **(Hassanain et al., 2003)**. The benchmark models, however, are condition-based and do not address the underlying problems that link building maintenance costs to an organization's commercial performance **(Lee Cooke, 2003)**. In residential, long-term care, and office buildings, the identification of correlations between these maintenance cost

indicators and their pertinent components has been examined and evaluated **(Madritsch et al., 2008**; **Stoy and Kytzia, 2008**; **Lai and Yik, 2008**; **Ottoman et al., 1999)**.
Stakeholders, including building clients, users, and maintenance contractors, must be involved in the upkeep of buildings. Owners of buildings may also be occupants, as well as people who have rented building space **(Goh et al., 2005)**.
The present problem is the lack of a system for tracking and measuring maintenance costs in most government institutions, and it is noted from previous studies that there is a research gap on the use of performance indicators in measuring, controlling, and reducing maintenance costs, which will be covered in this work.

2. MAINTENANCE AFFECTING FACTORS

(El-Haram and Horner, 2002) identified 24 factors influencing home maintenance costs and surveyed 50 local governments and housing associations to find the most relevant elements. The analysis indicated that the main causes were high tenant expectations, budget restrictions, improper use of property, and right-to-buy policy. A literature review was conducted on the variables impacting building maintenance costs **(Al-Khatam, 2003).** Engineering services, labor, construction materials, environment, management and administration, budgeting and financing, and building consumer behaviours were among the 34 factors the assessment identified, and these were grouped into seven categories.
(Hassanain et al., 2013) identified and classified 33 factors that affect hospital maintenance costs into seven major categories: a lack of regional material standards and requirements, owner concern over the initial cost, poor project management, shoddy scheduling, a lack of system maintenance contracts, and poor building and design. The degree to which a facility is maintained is determined by the requirement to protect building performance, promote productivity, and increase user satisfaction. Businesses should adopt a strategic maintenance program to optimise their facilities' value. Maximizing user performance should be the primary driving force behind the decision to keep. Poor design, shoddy workmanship, subpar materials and components, use and ageing, climatic and environmental factors, and individual behaviour can all lead to maintenance **(Olanrewaju and Abdul-Aziz, 2015)**.
According to **(Waziri, 2016)**, the use of defective construction materials, poor supervision, a failure to follow specifications, lax quality control on the job site, flaws in the architectural design, the use of new and unfamiliar materials, and unqualified labourers were the leading causes of the high level of required maintenance in residential buildings. 31 factors that affect maintenance problems and, eventually, maintenance expenses in academic institutions are categorized **(Okosun and Olagunju, 2017)**. These were divided into seven groups: design factors, human factor/user, environmental factors, age of the building/property, quality and suitability of the materials used, negligent construction, and flawed system.
(Hassanain et al., 2019) directed a comprehensive literature review to identify the factors affecting school building maintenance costs. 54 factors influenced the cost of maintaining school facilities. These factors were divided into nine categories: rules and agreements, the planning and building process, maintenance management, budgeting, operations, user awareness, building components, and the environment. The most significant factors affecting maintenance in Iraq can be identified as Maintenance time (from the time it began), safety and health precautions, time required to complete the work, subpar construction, a

lack of implementation, subpar maintenance work, design issues, a delay in reporting failure, response time for maintenance work, maintenance personnel skill, a shortage of skilled workers, and services. Materials used in construction, material properties, an unqualified contractor, poor financial oversight, a lack of finance, the building's age and condition, and the networks of sewage parts are all factors. Controlling these variables by positively affecting maintenance procedures and schedules can enhance the reality of preserving government buildings in Iraq **(Al-Ajeeli and Jawad, 2021)**.
When making outsourcing decisions, Saudi universities typically recognize the significance of the quality, management, and strategic issues. The increase in the speed of implementation, improvement of the quality requirements, and risk sharing with contractors were the three most crucial reasons affecting the choice to outsource maintenance services in the public universities of Saudi Arabia **(Assaf et al., 2011)**.

3. MAINTENANCE TYPES

Regarding terminology for different types of maintenance, there is still much uncertainty, particularly in the industrial sector. This confusion extends beyond Production and Operations Management to connected literature. This may make it challenging to define a standard nomenclature. According to **(Márquez, 2007),** maintenance has been divided into two main types: preventive maintenance and corrective maintenance, and each type includes two branches of maintenance:

3.1. Preventive Maintenance

Preventive maintenance is defined as maintenance performed at regular intervals or in accordance with established standards to lower the likelihood of failure or degrading the functionality of the equipment. Preventive maintenance can be predetermined or condition-based.

3.1.1. Predetermined maintenance
Preventive maintenance is performed in line with predetermined time intervals or quantities of usage (i.e., planned maintenance) but without first examining the item's state.

3.1.2. Condition-based maintenance
Preventive maintenance is based on monitoring performance and/or parameters and the measures taken afterwards. It is possible to schedule, request-based, or continuous performance and parameter monitoring.

3.2. Corrective Maintenance
Corrective maintenance is done after a defect has been found and is designed to restore the equipment to a condition where it can carry out its intended purpose. Corrective maintenance can be immediate or deferred:

3.2.1. Immediate maintenance

Maintenance is done soon to prevent unacceptable repercussions when a problem is found.

3.2.2. Deferred maintenance

Corrective maintenance that, when a defect is discovered, is delayed in accordance with the maintenance guidelines. **(Doos et al., 2016)** divided maintenance into two main types, corrective maintenance and preventive maintenance, and **Table 1** shows the logic behind each maintenance type.

Table 1. The logic behind maintenance types **(Doos et al., 2016)**

Maintenance type	Logic
Corrective maintenance	Maintain when it failed
Preventive maintenance (Time-based)	Maintain it regularly
Preventative maintenance (condition-based)	Maintain it (just) before it failed
Opportunistic maintenance	Maintain it if it is cost-effective
Proactive maintenance	Maintain the root causes of the failure

When looking at the different types of maintenance, one can see a connection between them and the performance indicators. Consider planned maintenance versus unplanned maintenance; the more planned maintenance there is, the more accurate the work is and the more accurate the budget is. Similar things apply to corrective maintenance, where a faster response results in less expensive maintenance.

4. METHOD AND MODEL BUILDING

Initially, a public sector institution was selected that accepted cooperation and provided possible data for the maintenance of projects under its management, but on the condition that its name or address is not published due to the privacy policy. And after reviewing the nature of the institution's work in the maintenance field and the data provided, which are recorded in the maintenance and financial records. A model has been proposed to reduce project maintenance costs based on three performance indicators, as shown in **Fig. 1:**

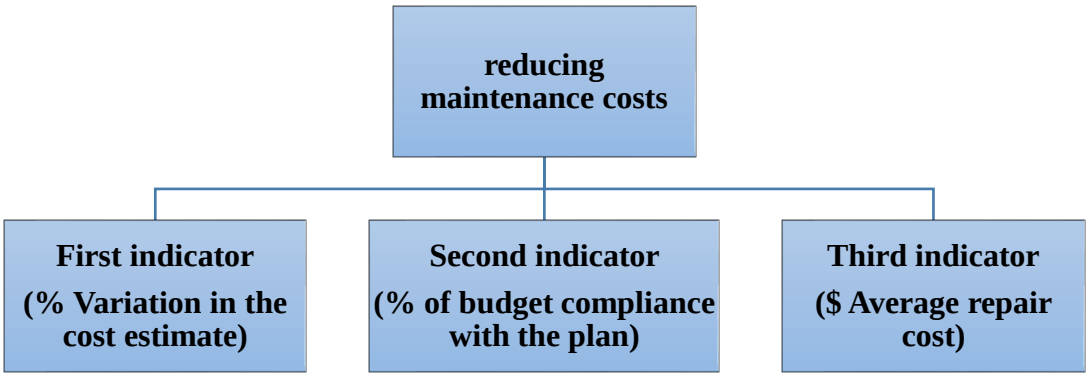

Figure 1. Reducing maintenance costs model

where:
% is the percentage, and $ is the currency
There are many performance indicators related to maintenance costs, but only three indicators were chosen in building the model for two reasons:

- The first reason is the type and size of data available in the institution.
- The second reason is that the employees are unaware of the performance indicators and how they work. Therefore, it is obvious to start with a few indicators until the employees know what the performance indicators are and how to work with them, and then it is possible to ease the number of indicators gra in gradually.

The data for the indicators are collected for the previous six years and entered into the Microsoft Excel program to perform the calculations and show the results in statistical forms. Eq. (1) is used to calculate the first indicator:

$$\%\text{VCE} = \frac{\text{TVC}}{\text{TMC}} * 100 \quad (1)$$

where:
%VCE is the variation cost estimate percentage
TVC is the total variation cost
TMC is the total maintenance cost

Eq. (2) to calculate the second indicator:

$$\%\text{BCWP} = \frac{\text{TAB}}{\text{TEB}} * 100 \quad (2)$$

where:
%BCWP is the budget compliance with the plan percentage
TAB is the total actual budget
TEB is the total estimated budget

and Eq. (3) to calculate the third indicator:

$$ARC = \frac{TRC}{TNRO} \quad (3)$$

where:
ARC is the average repair cost
TRC is the total repair cost
TNRO is the total number of request orders
By understanding the nature of indicators, it is noted that they depend in their work on two values: the baseline value and the target value. The baseline value is determined by choosing the best value for the indicator from the previous data. The target value is estimated to be realistic, achievable, and specific. There are two indicators: one tends to increase to reach the target value, and the second tends to decrease to achieve the target value. In the proposed model in this paper, we note that the first and third indicators tend to decline, and the second indicator tends to increase. **Fig. 2** shows an example of the indicator where an employee monitors the indicator, and a group of employees is assigned to this work.
If the index falls below the baseline value, the management must know the reasons and take processes to raise the index above the baseline. But if the target value is achieved, a new target value will be made, and the previous value will be the new baseline value. If the target

value is not completed on time, the management can adjust it by reducing it gradually and monitoring the results.

5. RESULTS AND DISCUSSION

After all the data has been entered into the Microsoft Excel program and the calculations are performed according to the equations (1, 2, 3), the results will be shown below:

5.1. First Performance Indicator (Variation % in the cost estimate)

This indicator is one of the indicators that need to be reduced, and therefore, it is noted from the results shown in **Fig. 3** that the best value was 1.36% in 2017, and the worst value was 5.32% in 2018. This is possibly due to the lack of experience in the staff or the emergence of unexpected things during the implementation of the work.

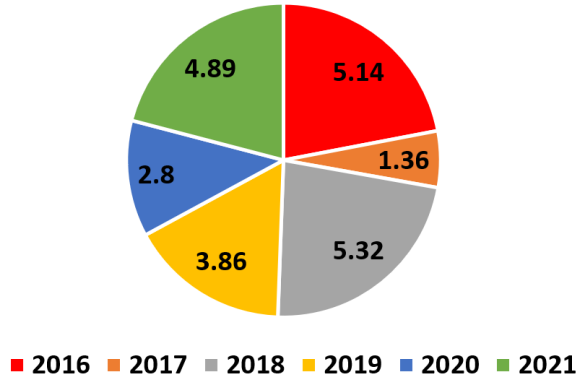

Figure 3. % Variation in the cost estimate

5.2. Second Performance Indicator (budget compliance % with the plan)

Since the value of this indicator needs to be increased, it is noted from the results shown in **Fig. 4** that the best value is 85.86% in the year 2019, and the worst value is 29.36% in the year 2021. This is due to a lack of planning or lack of experience in maintenance management.

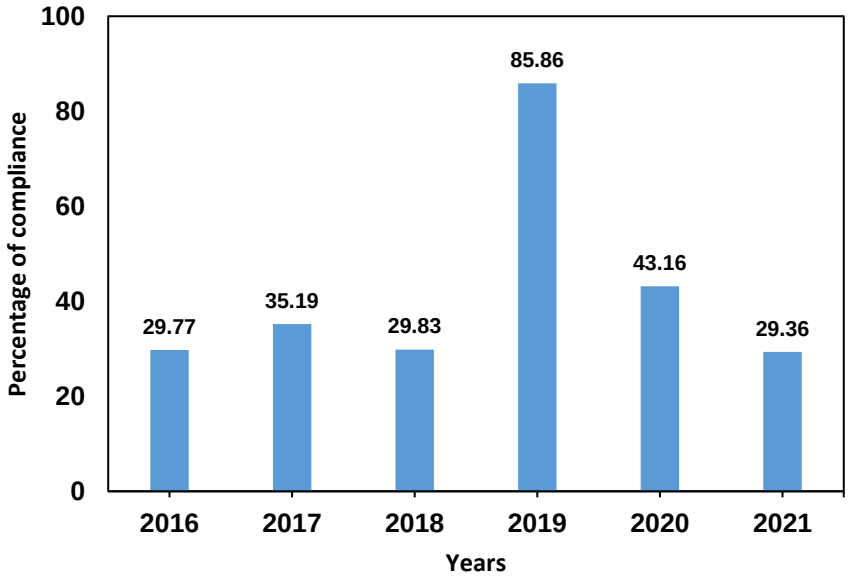

Figure 4. Percentage of budget compliance with the plan

5.3. Third Performance Indicator (Average $ repair cost)

As the value of this indicator needs to be reduced, it is noted from the results shown in **Fig. 5** that the best value was 1,516,844.83 IQD in the year 2017, and the worst value was 12,401,444.44 IQD in the year 2019.

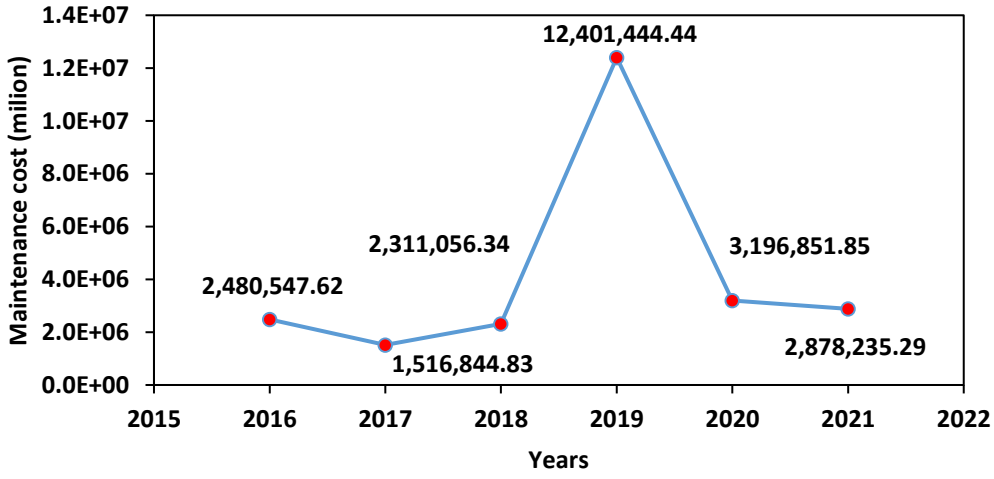

Figure 5. The Average $ repair cost

This may be due to the increase in the number of maintenance requests and their differences from year to year, the failure to analyze prices well, the increase in the amount of maintenance due to the rise in maintenance items, or the use of low-quality materials or poor implementation which causes re-work and the disbursement of additional amounts or the emergence of unexpected things during the work.

After reviewing the previous results, the best value for each indicator was chosen, making it the baseline value, estimating a target value for each indicator, and using Microsoft Excel to make interactive indicators. **Fig. 6** shows the first indicator, while **Fig. 7** shows the second indicator, and **Fig. 8** shows the third indicator:

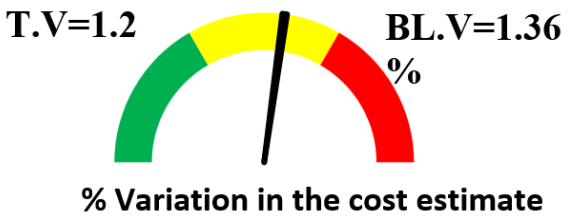

Figure 6. First indicator

Figure 7. Second indicator

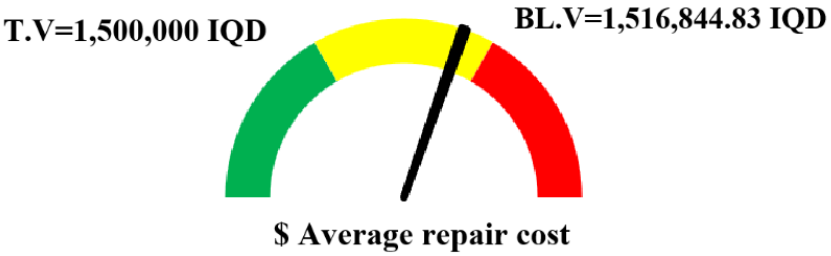

Figure 8. Third indicator

The mechanism of performance indicators depends on competition and challenge. Once start working on the model, especially if it is linked to administrative or financial incentives, competition and challenge will increase among the maintenance staff, and maintenance costs will be reduced through:

- Very accurate cost analysis.
- Accuracy in diagnosing maintenance items.
- Reliance on a staff that works with high efficiency to increase productivity and avoid costly mistakes.
- Reducing wasted time in maintenance work.
- Use of high-quality materials to avoid re-work.
- Increase the percentage of planned maintenance.
- Reduce response time as much as possible in corrective maintenance.
- Accurately plan for all maintenance work.

6. CONCLUSIONS

After applying the above methodology and obtaining the results, the following conclusions can be extracted:

- If this model is applied, it will significantly help measure, track, control, and reduce maintenance costs in government institutions.
- The model helps to improve and maintain the data documentation system.
- The model exposes weaknesses in the institution, such as:

  a. The institution does not use computers to document maintenance data and relies only on records, which may cause their loss due to damage to records paper.
  b. Adopting an old method of documenting maintenance data and the inexperience of the specialized staff in reporting data caused several data to be neglected due to the incompleteness of the required information.
  c. The institution depends on a considerable percentage of corrective maintenance and ignores other types of care, which may significantly increase maintenance costs and reduce the facility's or machine's life span.
  d. There is no planning for maintenance management for the near or far future.
  e. The lack of a system to monitor maintenance costs is one of the reasons for the proposed model.

NOMENCLATURE

Symbol	Description	Symbol	Description
ARC	Average repair cost	TNRO	Total number of request orders
BL.V	Baseline value	TRC	Total repair cost
TAB	Total actual budget	TVC	Total variation cost
TEB	Total estimated budget	$	the currency
T.V	Target value	%VCE	Variation cost estimate percentage
TMC	Total maintenance cost	%BCWP	Budget compliance with the plan percentage

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