A Brief Discussion on Metrics

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ABSTRACT:

Metrics are essential to system engineering because they provide quantitative metrics to evaluate and enhance the functionality, dependability, and standard of complex systems. This abstract provides a thorough analysis of system engineering metrics, emphasising their use in the formulation and assessment of system designs, requirements, and overall system performance. The core idea of metrics and their importance in system engineering are introduced in the abstract's first paragraph. It emphasises that in order to accurately assess system performance, metrics must be well-defined, quantifiable, and in line with system goals. The abstract then discusses the many uses and advantages of several metrics categories, such as process metrics, product metrics, and resource metrics. The abstract also discusses system architecture metrics including modularity, coupling, and cohesion metrics that are used to evaluate the complexity, design quality, and maintainability of system components. The abstract also looks at metrics for requirements engineering, such as those for completeness, consistency, and traceability, which help to guarantee accurate and trustworthy system specifications.

KEYWORDS:

Interoperability, Management Metrics, Metrics, Product Affordability, Process Metrics.

INTRODUCTION

Metrics are essential for monitoring and evaluating the efficiency, effectiveness, and quality of systems and processes in system engineering. Metrics provide unbiased, quantitative statistics that aid in assessing and tracking many facets of a system's performance, facilitating wise decision-making and ongoing development. A broad variety of system engineering tasks, including as requirements analysis, design, implementation, testing, and maintenance, are evaluated using metrics. They indicate areas that need improvement and possible dangers while offering insightful information on the efficacy, dependability, and efficiency of various activities. Metrics usage in system engineering has a number of advantages. First and foremost, metrics provide a standardised and reliable method for assessing system performance. Organisations may set benchmarks and measure progress over time by setting precise and quantifiable metrics, enabling useful comparisons and analyses [1], [2].

Organisations may discover and rank areas for improvement using metrics. Organisations may identify inefficiencies, bottlenecks, or quality problems by tracking key performance indicators (KPIs), which enables focused interventions and process optimisation. Metrics also support the development of well-informed decisions. They provide unbiased information to enable the assessment of various possibilities, trade-offs, and design decisions. Metrics make it easier to evaluate how various options may affect system performance, cost, schedule, and other important considerations [3], [4].

The management of risk is aided by metrics. Organisations may detect risks, deviations, or abnormalities early on by monitoring the right metrics, which enables proactive action to lessen or avert negative repercussions. Metrics help risk assessment and mitigation techniques and act as early warning indications. Metrics also make it easier for stakeholders to collaborate and communicate effectively. In order to effectively convey system performance and development to many stakeholders, such as management, clients, and project teams, they provide a consistent language and unbiased statistics. Metrics provide objective and quantitative measures for assessing the performance, quality, and effectiveness of systems, making them a crucial tool in system engineering. They facilitate stakeholder communication, process improvement, risk management, and decision-making. Organisations may improve their capacity to create, deploy, and manage dependable systems by using metrics [5], [6].

DISCUSSION

Management metrics

Metrics are measures that are taken in order to assess the overall state of a project and its development by tracking how the quantity being measured changes over time. Three fundamental metrics must be used for technical activity management:

1. Product metrics that monitor a product's evolution,
2. Earned Value, which monitors adherence to the budgeted timeline and cost;
3. Metrics for the management process that monitor managerial actions.

A system of periodic reporting must be developed, implemented, and maintained to ensure that metrics are correctly measured, assessed, and the resultant data is distributed. Metrics measurement, assessment, and control are performed via this system.

Metrics for Products

Product metrics are those that measure important design elements to monitor advancements towards fulfilling client needs. Three fundamental categories of needs are reflected in product metrics: operational performance, life-cycle appropriateness, and affordability. The Technical Performance Measurements (TPM) are the most important collection of systems engineering measurements. TPMs are product metrics that monitor how well a design is approaching the needs of the consumer. They are strongly related to the system engineering methodology because they enable the direct connection between operational demands and design efforts. Measures of Performance (MOPs), which represent system requirements, are used to produce TPMs. Measures of Effectiveness (MOEs), which represent operational performance criteria, are the source of MOPs [7], [8].

The word "metric" suggests data that may be measured quantitatively. Metric data is more valuable in design if it can be measured at the configuration item level. For instance, weight estimates are possible at every level of the WBS. Even though speed is a crucial operational element, it cannot be distributed via the WBS. It cannot be quantified until an integrated product is ready, except via analysis and simulation. Weight may be a preferable metric option since it plays a significant role in reaching speed targets and may be assessed at different levels as the system is improved. It directly affects speed, therefore it relates to the operational need, but most significantly, it can be distributed throughout the WBS, making it possible to assess progress towards meeting weight targets from development to production [9], [10].

Measures of Suitability and Effectiveness

Operational effectiveness and appropriateness in terms of operational outcomes are measured by Measures of Effectiveness (MOEs) and Measures of appropriateness (MOSs). In the operational requirements document, they will represent the most important operational demands and define the performance criteria that must be met in order to achieve system-level mission goals. Operational effectiveness measures a system's overall capacity to complete a mission successfully while taking into account the whole operational environment. For instance, the efficacy of a weapon system would take into account threat characteristics, operator organisation, doctrine, and tactics, as well as environmental aspects like survivability and vulnerability. On the other hand, MOSs would assess how effectively the system fits into the operational environment while taking supportability, human interface compatibility, and maintainability into account.

Performance Metrics

MOPs describe the physical or functional characteristics related to carrying out the mission or function. A technical or performance requirement that directly derives from MOEs and MOSs is quantified. In order for a change in MOP to be correlated with a change in MOE or MOS, MOPs need be connected to these measurements. Key performance criteria from the system specification should also be reflected in MOPs. The performance requirements that will serve as the foundation for design activities and process development are derived, developed, supported, and documented using MOPs. Additionally, they specify the crucial technical characteristics that will be monitored by TPMs.

Measures of Technical Performance

TPMs are directly developed from MOPs and are chosen as being essential from a perspective of periodic assessment and control. TPMs aid in monitoring and tracking technical risk as well as evaluating design progress and WBS requirement compliance. They may indicate when shortfall recovery is necessary and provide data to enable cost-performance sensitivity analyses. Range, accuracy, weight, size, availability, power output, power needed, process time, and other product attributes that are directly related to the operational needs of the system may be included in TPMs.

TPMs traceable to WBS components are desired so that both the components of the system and the system as a whole can be monitored. Some essential TPMs, nevertheless, will only be available at the system or subsystem level. For instance, tracking the precise fuel usage of an engine throughout engine development would be a TPM, but it is not distributed across the WBS. It is presented as a solitary data point that summarises the functionality of the engine as a whole. In this situation, the measure will show that the design strategy is in line with the expected performance, but it may not serve as a helpful early warning system to show progress towards achieving the design objective.

Example of Measures

1. MOE: One tank of gasoline must be sufficient for the car to go fully loaded from Washington, DC, to Tampa.
2. MOP: The vehicle's range must be at least 1,000 kilometres.
3. TPM: Fuel use, vehicle weight, tank capacity, drag, friction in the powertrain, etc.

Metrics for Suitability

To track progress towards an integrated design, tracking metrics pertaining to operational appropriateness and other life cycle issues may be relevant. The degree to which a system can be used successfully in the field while taking into account factors such as accessibility, compatibility, transportability, interoperability, reliability, usage rates, maintainability, safety, human factors, documentation, training, manpower, supportability, logistics, and environmental effects is known as operational suitability. These suitability criteria may provide product metrics that show development towards a system that is operationally appropriate. For instance, indicators indicating the extent of automation in the design would show development in meeting the demands for quantity and quality of people. TPMs and metrics for acceptability of products often overlap. Mean Time Between Failure (MBTF), for instance, might indicate both efficacy and appropriateness criteria. Measuring improvements in producibility, testability, degree of design simplicity, and design robustness would all be considered suitable measures. An indication of producibility, maintainability, and design simplicity, for instance, may be found in the monitoring of the quantity of components, the quantity of similar parts, and the quantity of worn parts.

Metrics for Product Affordability

Similar to the TPM technique, estimated unit production costs may be monitored throughout the design process with each CI element producing an estimate based on the current design. At higher WBS levels, these estimates are merged to provide subsystem and system cost estimates. This offers a means to identify design issues that might affect production costs, a running engineering estimate of unit production cost, and monitoring of conformity to Design-to-Cost (DTC) targets. Through parameters that are relevant in parametric life cycle cost estimates for the specific system, life cycle affordability may be monitored. For example, fuel consumption and weight, both of which can be monitored as metrics, are two elements that indicate life cycle cost for the majority of transportation systems.

Timing

Metrics for the product are intimately related to the design process. In the idea exploration phase, early preparation is done for metric identification, reporting, and analysis. The management strategy, the performance or characteristics to be monitored and tracked, the predicted values for those performances or characteristics, the timing of assessments, and the assessment goals should all be defined in the early systems engineering planning.

The creation of the functional baseline marks the start of implementation. Systems engineering planning will define crucial technical parameters, time phase planned profiles with tolerance bands and thresholds, reviews or audits or events that are necessary or essential for achieving planned profiles, and the estimating technique throughout this time. The systems engineering method will be used to carry out the plan's implementation and ongoing revisions throughout the design effort, from functional to product baseline. Contracts should provide that contractors must offer measurement, analysis, and reporting in order to assist implementation. In the production phase, often concomitant with the creation of the product (as built) baseline, the necessity to measure product metrics is eliminated.

Policy on Product Metrics from the DoD and Industry

Performance indicators for technical development and design, actual vs planned, and the degree to which systems satisfy criteria must be included in analysis and control operations. DoD 5000.2-R. The performing activity creates and implements TPM to assess the effectiveness of developing solutions and find flaws that affect the system's capacity to achieve a specified value for a technical parameter. Section 3 of EIA IS-632. The performing activity determines the technical performance metrics that are important predictors of system performance should be restricted to crucial MOPs that, if not satisfied, place the project at risk for cost, schedule, or performance. Section 6 of IEEE 1220.

EARNED VALUE

Earned Value is a metric reporting method that compares the cost and schedule progress of system development to an anticipated baseline using cost-performance indicators. It incorporates performance, cost, and scheduling considerations in a "big picture" manner. If we consider the line marked BCWP (budgeted cost of work accomplished) in Figure 1 to reflect the value that the contractor has "earned," then departures from this baseline indicate issues with either cost or schedule. We have a cost variation, for instance, when actual costs differ from projected expenses, and a schedule variance when real work is executed differently from what was originally intended.

The anticipated performance is based on projections of a suitable budget and timetable for completing the work needed by each WBS element. The system engineer may identify WBS items with possible technical development issues when a deviation develops. Earned value is a potent technical management method for identifying and comprehending development issues when used in conjunction with product measurements.

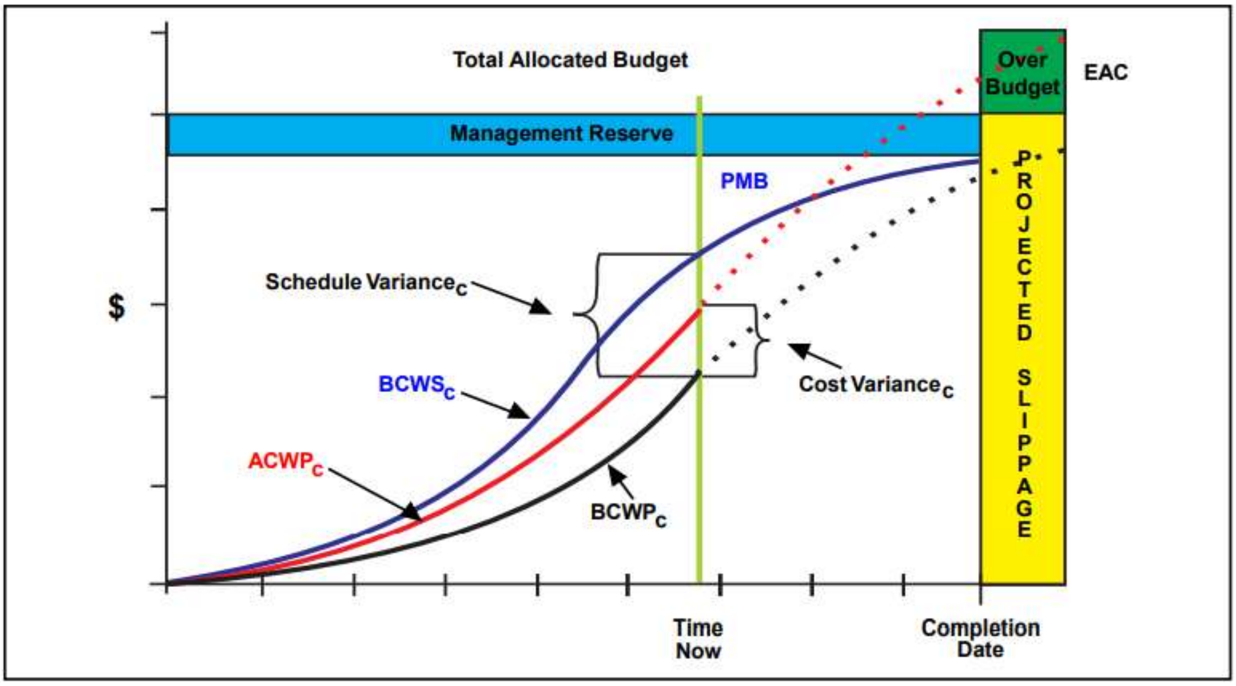

Figure 1: Earned Value Concept [ocw.mit.edu].

Product metrics, the event schedule, the calendar schedule, and Earned Value all have relationships:

1. The Event Schedule lists the actions that must be completed for each event and exit criteria in order to satisfy important system requirements that are directly tied to product metrics.
2. The Schedule (Detail) Schedules involve deadlines set out to accomplish the same goals connected to product metrics.
3. Earned Value comprises the financial and time consequences of failing to accomplish those goals, and when compared to product measurements, it might reveal new programme and technical risks.

Process Metrics

Measuring the management process helps to monitor the system's development, construction, and introduction processes. They cover a broad variety of possible parameters, and each programme determines which ones are chosen. They track things like resource availability, activity time rates, finished items, completion rates, and client or team satisfaction. These include, for instance, the number of trained employees hired, the typical time it takes to accept or reject ECPs, the number of lines of code or drawings issued, the number of ECPs resolved each month, and the number of team risk identification or feedback evaluations. It is important to choose the right metrics to monitor important management operations. The planning phase for systems engineering includes choosing these metrics.

How Much Metrics?

The decision of how many metrics to use and how deep to use them is a planning function that looks for a balance between risk and expense. It relies on a variety of factors, including the complexity of the system, the organisational structure, the frequency of reporting, the number of contractors, the size and makeup of the programme office, the political prominence of the contractor, and the kind of contract.

I. CONCLUSION

In conclusion, metrics are essential to system engineering because they provide impartial measures and indicators for evaluating and tracking the effectiveness, development, and quality of systems throughout the course of their lifecycles. Metrics are quantitative or qualitative measurements that help stakeholders and project managers make wise choices, monitor progress, and pinpoint areas for improvement. System engineers may efficiently assess and manage a system's performance, cost, schedule, quality, and risk by setting the right metrics. Metrics provide a standardised and reliable method of gathering and processing data, enabling meaningful comparisons and trend analysis.

Metrics usage in system engineering has a number of advantages. First and foremost, metrics provide stakeholders insight into the system's performance, assisting them in understanding the system's present condition and progress in achieving project goals. This makes it possible to identify problems early and take quick remedial action. In conclusion, metrics are crucial tools in system engineering for evaluating and tracking the performance, development, and quality of systems. They foster efficient communication, encourage continual development, and allow data-driven decision-making. System engineers may improve project management, optimise resource allocation, and guarantee the effective design and operation of complex systems by using metrics.

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