Assessing the Influence of Various Work Breakdown Structures on Project Completion Time

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ABSTRACT

In project management, a clear definition of the objective is required for the success of a project. Scope management is a performance indicator used to ascertain compliance with predefined project boundaries. The Work Breakdown Structure (WBS) is an essential part of the scope management process and a tool in project planning. Although there is much research on WBS, there is a lack of information regarding the relationship between the selection of WBS orientation and project completion time. In this paper, the influence of alternative WBS orientations on project completion time is assessed. The Project Life Cycle (PLC) and technology (T) WBS were applied across two projects—the construction of a Liquefied Petroleum Gas (LPG) facility and the Renovation of an Office Complex (ROC)—using a top-down decomposition methodology. The PLC-WBS and T-WBS were created utilizing Figma software. The project duration was determined using the critical path method, which was implemented in the Python programming language. Based on WBS selection, differences were discovered in the definition of the project deliverables, network construction, and aggregation of work packages. These discrepancies had an impact on the technological relationships between activities by reducing opportunities for parallel processing. The LPG project was completed in 86 days using the PLC-WBS and in 80 days using the T-WBS orientation. For ROC, the project can be accomplished within 128 and 126 days, using the PLC-WBS and T-WBS orientation, respectively. This outcome suggested that there might be an association between the WBS and the project objective. Therefore, an assessment of different WBSs in project scope management demonstrated their potential influence on decision-making in activity planning and scheduling, network construction, and project objectives.

Keywords-wbs-orientation; project completion time; project lifecycle-WBS; technology-WBS

I. INTRODUCTION

Scope Management (SM) is a performance indicator and a significant component of the project knowledge area [1-2]. Performance metrics are essential for evaluating the effectiveness of decisions taken to achieve organisational goals [3]. SM is essential for obtaining a comprehensive understanding of the tasks, limitations, and anticipated results/deliverables of a project [4]. A lack of clarity in defining and analyzing the SM process will have a direct influence on the project's cost, duration, and quality [5]. Furthermore, a deficient description of the scope could result in multiple challenges occurring during the next phases of project development [6, 7]. This sort of situation is often referred to as scope creep. The occurrence of scope creep arising from unplanned and uncontrollable changes is evident in project completion time and cost overrun [8, 9]. Hence, to reduce the frequency of project failures due to scope creep and other factors, it is necessary to encourage transparent and consistent communication between stakeholders and project team members [10, 11].

The SM process comprises the following steps: (i) planning to define, validate, and control the scope, (ii) planning for requirements and documentation, (iii) determining the scope and stakeholders' needs, (iv) developing a Work Breakdown Structure (WBS), (v) requesting approval from the project owner, and (vi) assessing the performance of the scope [1-2]. The intention of developing a WBS is to generate a formal statement of the project's deliverables. The WBS presents project deliverables in a structured manner, including planning information such as the actual work needed, the impact on resources and costs, and schedule details [12, 13]. A WBS is a hierarchical breakdown of the work that the project team must do to achieve the project objective and serves as a project taxonomy. While the WBS is derived from the project scope, different approaches (or orientations) used to construct the WBS can greatly impact the objective of the project [14].

A. WBS: Design, Orientation, and Decomposition

WBS is an essential document that establishes a direct connection between project objectives and their implementation through a continuous iterative process. In Project Management (PM), WBS is a multilevel system indicating logical connections among the work activities that constitute a project. The WBS breaks down the project into a hierarchical framework, enabling monitoring and control [15]. A comprehensive WBS supports the clear identification and description of project deliverables [16]. Therefore, the attainment of deliverables in a project can be achieved through the implementation of a strong WBS [17]. In the design of a WBS, measures such as man-hours, dollar value, and completion time can be introduced to determine the performance of the work packages [2, 18]. Work Packages (WPs) are deliverables that exist at the lowest feasible level of a WBS (i.e. work to be done to complete each task). An inadequately planned WBS can result to unclear job allocations, scope modifications, unsatisfactory deliverables, prolonged project timelines, etc.

Before deciding on the direction of the decomposition process, it is necessary to determine the WBS orientation or pattern. The design of a WBS orientation can be established by considering the following factors: (i) the product or deliverable, (ii) the stages of the Project Life Cycle (PLC), (iii) the technology involved, (iv) the geographical aspects, and (v) the underlying processes [19]. A Deliverable WBS (D-WBS) is a systematic grouping of components required for the manufacturing of a product or the successful completion of a project [2]. A PLC-WBS facilitates the procedure of converting a concept into a tangible outcome. The PLC-WBS can be planned or change-driven. If change-driven, the degree of change can be predictive, iterative, or incremental [20]. Furthermore, the utilization of the PLC strategy in designing the work breakdown structure facilitates the efficient tracking of significant project milestones. Nevertheless, its utilization is uncommon [21]. The Technology WBS (T-WBS) is preferred for projects with a high level of specialization, functional hierarchy, and discrete technology. Additionally, the T-WBS facilitates centralized project control in the presence of diverse technologies. For a Geography-based WBS (G-WBS), the project is divided into homogeneous subprojects with similar activities. For example, a project involving the construction of similar structures in three regions may require three project managers. Therefore, the culture, language, and legal system associated with the project's execution may have an impact on a G-WBS. The Process-WBS (P-WBS) involves breaking down a project into discrete steps, work activity phases, and functions, with each level having specific deliverables [17]. A decentralized system supports the use of a P-WBS.

Decomposition, also known as disintegration, is a planning technique in which the scope of a project is divided into manageable segments or elements [22]. This involves the division and further subdivision of the scope into smaller entities. Decomposition facilitates the analysis of a project at both the work package and organisational levels. A guideline in the decomposition process is the 100% rule. According to this rule, the subsequent breakdown of a WBS element, also known as a child, must encompass the entire previous task, referred to as the parent [23]. In the literature, there are two decomposition approaches: bottom-up and top-down [2]. The top-down strategy is recommended for centralized decision-making and the division of a project into subprojects. In the bottom-up approach, the project framework is constructed starting from the work package level. A bottom-up strategy is preferred for projects with a high level of complexity [24]. Hence, the selection of a WBS technique is subjective and typically relies on factors such as the project manager's expertise, the project team's composition, the management approach, consideration of alternative methods, and the nature of the project.

B. Related Literature

The utilization of the WBS, a fundamental tool in project scope management, has been associated with the level of project success [19, 25]. Specifically, scheduling, network planning, resource allocation, and cost allocation require the WBS as a point of reference [26]. In [27], it was demonstrated that it is possible to use several WBS approaches to break project activities into tasks and work packages. In addition, several organisational structures can be utilized during project conceptualization and implementation. The design and integration of WBS have received much attention in the PM literature. Using neural networks, authors in [12] designed a WBS as a decision support system. The authors in [29] created a comprehensive decision support system that utilizes building information management and WBS. Authors in [17] integrated the cost breakdown structure and WBS to enhance decision-making in construction projects. For corporate events, a WBS was created in [29]. Authors in [30] examined the relationships between critical success factors and PM techniques in the construction sector of Malaysia. Their analysis revealed the limited use of PM tools and methods. Authors in [31] interviewed 40 professional staff members at a university planning department. They observed that the WBS is a statistically significant tool for determining the successful completion of a project based on its scope. Nevertheless, the literature on methods for comparing different work breakdown structures and the expected impact on project completion time is sparse.

C. Research Objective

In traditional and modern projects, the choice of a WBS orientation is different. For example, the type of PLC and organisational structure is different in construction and IT projects [32]. Invariably, a discrepancy between the WBS and organisational structure may delay or hinder the success of a project [33]. The WBS has not been given sufficient attention in the literature [27, 34], although, it is considered a fundamental and reliable instrument for planning and specifying work packages. Furthermore, information is sparse regarding the relationship between the selection of different WBS orientations and project completion time. The current research aimed to assess the influence of the PLC-WBS and T-WBS on project completion time.

II. METHODOLOGY

This section focuses on the assumptions made during project selection, the framework that connects the work breakdown structure to the project objective, the process of selecting WBS, and the estimation of the project completion time.

A. Assumptions

The following assumptions guide the selection of projects for this research:

- The project scope remains constant throughout its entire duration.
- The cost of materials and resources remains constant throughout the project duration.
- The equipment will be fully functional during the project's implementation.
- The project's quality is assured.
- Organisation breakdown structure is assured.

B. Framework for Determining the Relationship between WBS Orientations and Project Completion Time

In Figure 1, the framework for assessing the influence of the selected WBS orientations on the project completion time is presented.

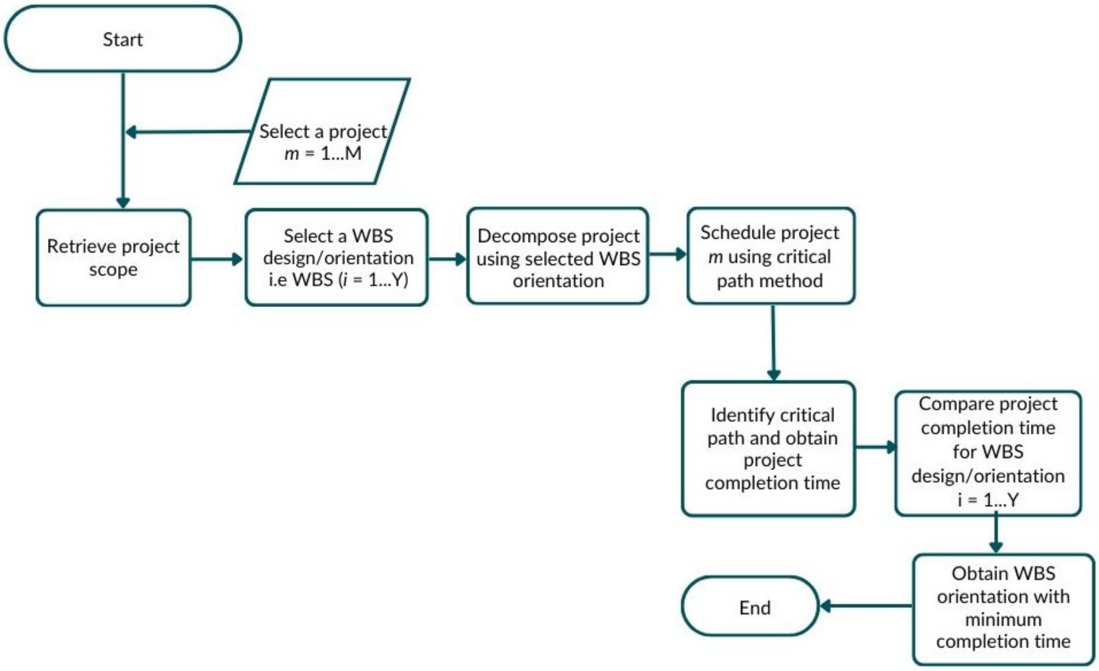

Fig. 1. Framework for assessing the influence of alternative WBSs on project completion time.

C. Project Selection

Data were gathered from two projects. The projects involve building a Liquefied Petroleum Gas (LPG) facility and the Reconstruction of an Office Complex (ROC). The LPG and ROC are denoted as $m = 1$ and $m = 2$, respectively. The aim is to minimize the time required to complete these projects.

D. Selection of WBS design and Orientation

The design and orientation of the WBS were based on the PLC and T pattern using the top-down decomposition approach. In the design of the WBS, the following frameworks were considered: (i) the 100% rule, (ii) work package naming and coding, and (iii) sizing. The relevant tasks in the project were identified and classified at the parent and child levels. Subsequently, PLC-WBS and T-WBS were designed. The design of the WBS was achieved using Figma software [35].

E. Determination of Project Completion Time

In a project, three fundamental objectives are common: (i) maximizing the use of limited resources, (ii) using allocated resources within the specified time frame, and (iii) delivering a product or service within the agreed quality or standard requirements. Minimizing project completion time (or makespan) is the most researched objective in the literature. The development of the Critical Path Method (CPM) and Project Evaluation and Review Technique (PERT) advanced the use of network diagrams in project scheduling. The use of CPM assumes unlimited resource availability with time restrictions (i.e. a project has an imposed date to be completed). In this work, the project completion time was determined using the CPM methodology implemented in Python v3.10.9.

III. RESULTS

A. Project Decomposition

In Figure 2, the PLC-WBS is presented for the LPG project. The parent elements are start-up/design (1.1), procurement (1.2), execution (1.3), quality control (1.4), and finishing (1.5). In Figure 3, the PLC-WBS is presented for the ROC project. The parent elements are design (1.1), procurement (1.2), equipment/procurement (1.3), start-up operations (1.4), and training and retraining (1.5). In Figure 4, the T-WBS is presented for the LPG project. The parent elements are plan/schedule (1.1), site preparation (1.2), construction (1.3), procurement (1.4), operations and maintenance (1.5), and finishing (1.6). In Figure 5, the T-WBS is presented for the ROC project. The parent elements are planning and scheduling (1.1), construction (1.2), procurement (1.3), maintenance (1.4), operations (1.5), and human resources (1.6).

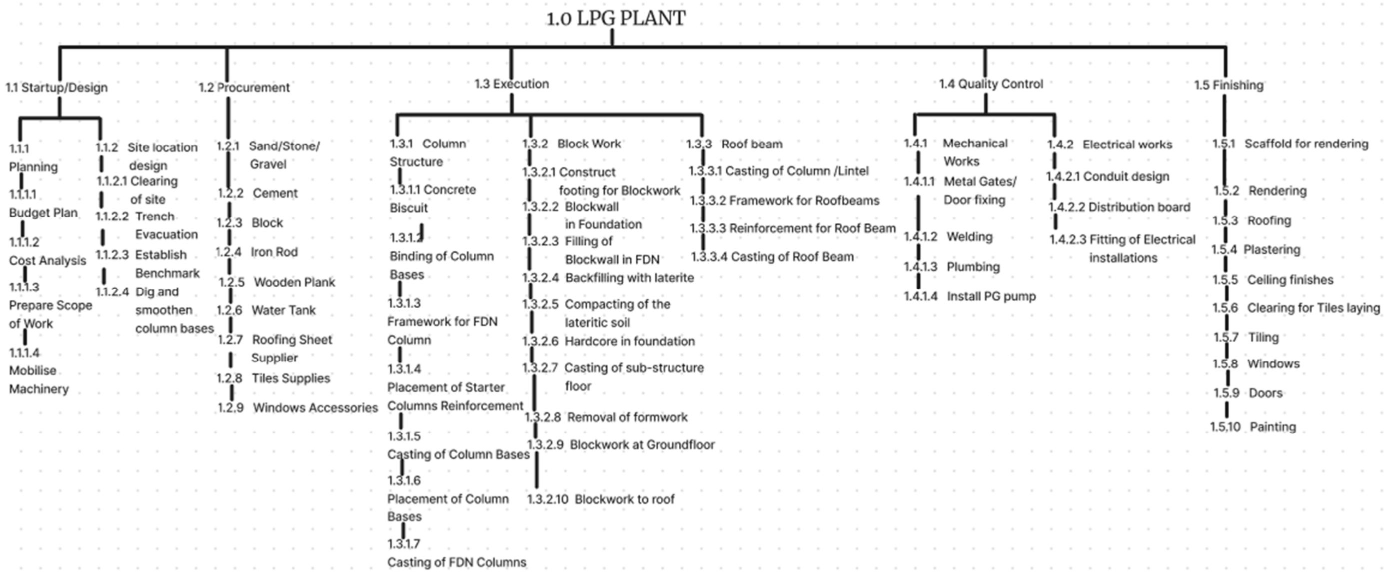

Fig. 2. PLC-WBS for LPG project.

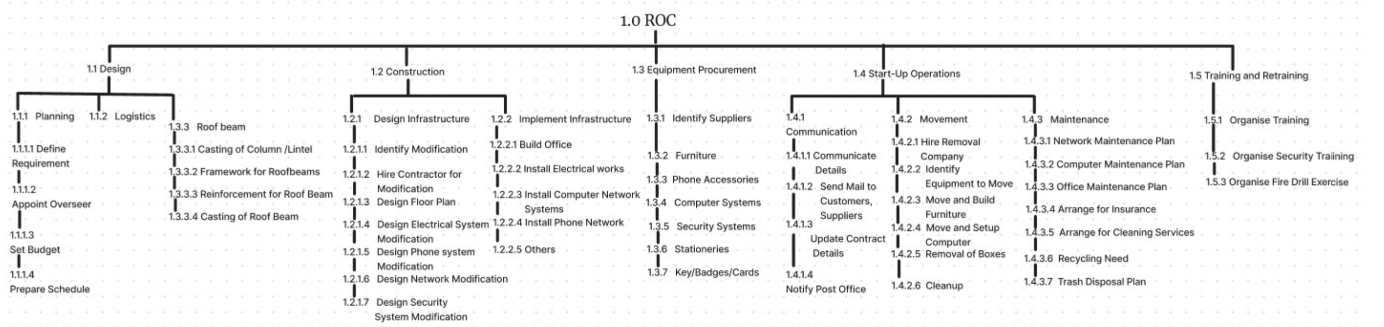

Fig. 3. PLC-WBS for the ROC project.

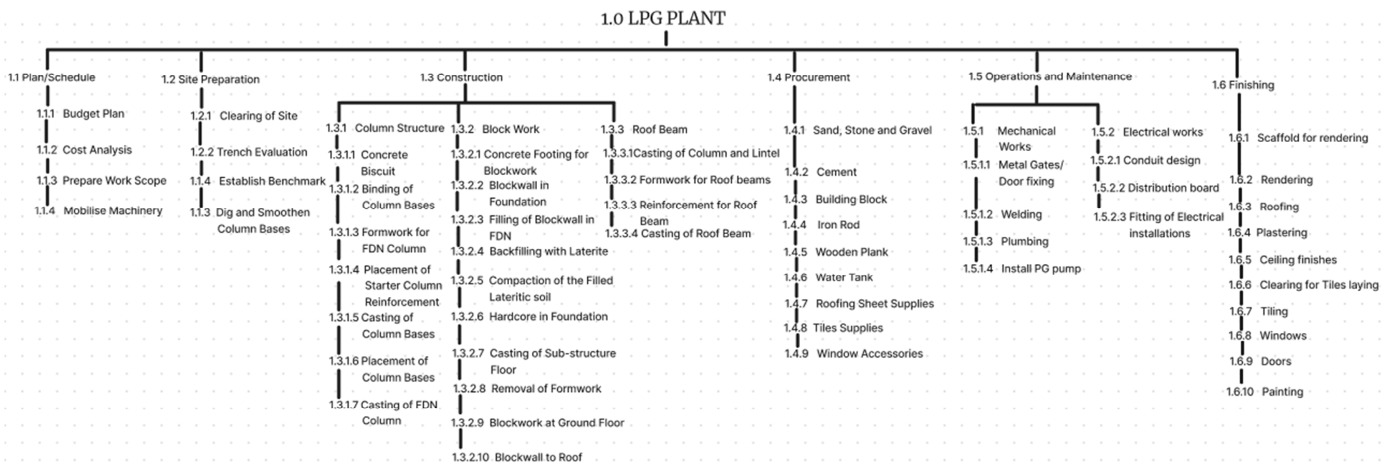

Fig. 4. T-WBS for LPG project.

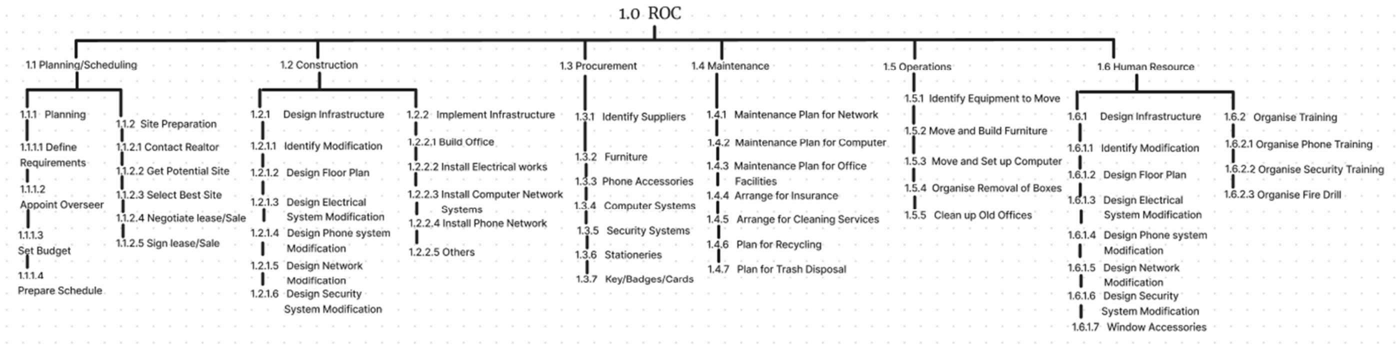

Fig. 5. T-WBS for the ROC project.

B. Project Completion Time

The impact of the two WBS orientations on project completion time (in days) is presented in Table I.

TABLE I. QUANTITIES IN DPS

m	Project Name	WBS orientation	
		PLC	T
		Completion Time	
1	LPG	87	80
2	ROC	128	126

The LPG project (m = 1) can be completed in 86 and 80 days using the PLC-WBS and T-WBS orientations, respectively. For the ROC (m = 2), the project can be completed in 128 and 126 days using the PLC-WBS and T-WBS orientations, respectively. The use of the T-WBS resulted in a 6-day and 2-day reduction in the project completion time for the LPG and ROC projects, respectively. The CPM implementation in Thonny 4.1.4 with Python version 3.10.11 is presented in Figure 6. The scheduling procedure utilized to derive the outcome presented in Table I was assumed to be deterministic, meaning that it involved planned activity duration. Clearly, the project completion time will vary when the actual duration of activities is utilized to calculate the project completion time. In practical scenarios, the total float acquired can be utilized to minimize time deviation.

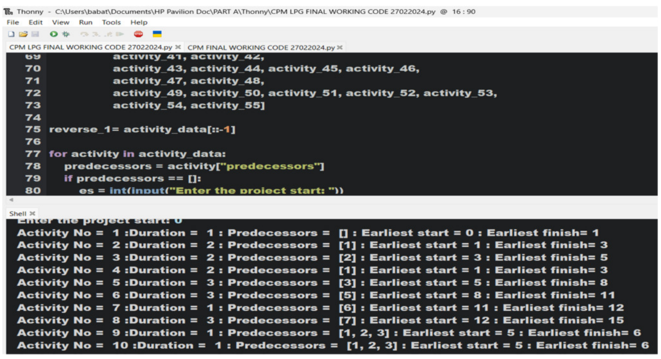

Fig. 6. CPM implemented in Thonny 4.1.4 with Python 3.10.11.

C. Discussion

The use of WBS in planning a project is significant; therefore, based on a WBS selection, differences in project deliverable definitions, network construction, and work package aggregation were discovered. These discrepancies impacted technological relationships between project activities, especially by constraining parallel processing between some activities. In Figure 2, using PLC-WBS for the LPG plant, the WBS element "startup/design" (i.e. 1.1) was subdivided into two work packages (1.1.1 and 1.1.2), with 4 sub-elements for each package. In Figure 4, the T-WBS for the LPG plant shows that the WBS element "startup/design" (1.1) need no additional decomposition but includes four sub-elements. This suggests that PLC-WBS orientation allows for more breakdown in this circumstance. Therefore, scheduling the LPG plant using the PLC-WBS further added more precedence relationships among the activities occurring before WBS element 1.2. The result supported the reason why PLC-WBS is not commonly used as stated in [21]. Also, the aggregation, decomposition, and development of the project network appear to influence the complexity of the scheduling process and project completion time as shown in Table I. Therefore, due to the possible mismatch that may arise from different WBSs, a one-size-fits-all organisational structure may not be possible in aligning WBS with the organisation breakdown structure. This supports the research findings in [5, 27, 31]. Clearly, the use of alternative WBSs can enhance completion time decisions during project scheduling. Additionally, technology-oriented WBSs appear effective for construction projects.

IV. CONCLUSION AND FUTURE WORK

The Work Breakdown Structure (WBS) serves as a descriptive representation of the overall work packages entailed in a project. The WBS enables the project team, customers, and other stakeholders to have concrete interactions with one another and follow the progress of a project from the initiation to the completion stage. In this study, two WBS orientation designs were applied to examine their influence on project success, with an emphasis on project completion time. The scopes of a Liquefied Petroleum Gas (LPG) plant and the Renovation of an Office Complex (ROC) were obtained, and through a top-down approach, the projects were decomposed using the Project Life Cycle (PLC) and Technology (T) WBSs. For the LPG and ROC projects, 8% and 1.5% decreases in project completion time, respectively, were achieved using the T-WBS orientation. The use of different WBSs in project scope management can reveal an effective approach to minimizing project completion time. Hence, our study employed the decision-making procedure illustrated in Figure 1 to evaluate the impact of WBS on project success by analyzing the time taken for completion.

Nevertheless, previous research claimed a relationship between the two factors, but the approach to support this assertion was sparse. In further work, the impact of multiple WBS orientations on the completion time of modern projects (e.g. research, new products, and software development) can be researched.

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