Proceedings of the Fourth Australian International Conference on Industrial Engineering and Operations Management, Melbourne, Australia, November 25-27, 2025| ***ID:137***

Proceedings of the International Conference on Industrial Engineering and Operations Management

Publisher: IEOM Society International, USA DOI: 10.46254/AU04.20250137
Published: November 25, 2025

Raising Project Delivery Reliability: An Integrated Baseline Validation Model for Industrial Engineering Using Design Science Research

Michael Bosch, Jan Harm C Pretorius and Leon Pretorius
University of Johannesburg
Faculty of Engineering and the Built Environment
PO Box 524, Auckland Park
mbosch962@gmail.com, jhcpretorius@uj.ac.za, pretoriussystems@gmail.com

Abstract

The persistent challenge of late completion in construction- and engineering projects highlights the need for a rigorous, standardized approach to baseline validation. This research develops and empirically tests a Baseline Validation Model (BVM) using Design Science Research Methodology (DSRM), addressing the global trend of projects overrunning by up to 45% in duration. Recognizing the industry's historical focus on financial models over the robustness of baselines, the BVM combines leading assessment frameworks—the PMI Conformance Index, DCMA 14-Point Assessment, GAO Schedule Assessment Guide, and NASA Schedule Management Handbook—into a unified, quantitative model. The BVM is designed for integration as an automated, objective plugin for commercial scheduling tools, enabling users to evaluate compliance across scheduling essentials such as logic, constraints, float, durations, resources, and critical path integrity. Empirical application of the BVM to three complex project case study baselines demonstrates the model's effectiveness in identifying compliance gaps and recommending targeted improvements, strengthening adherence to industry standards and methodologies. Iterative testing validates that implementation of the BVM improves the accuracy of critical path identification, enhances delay and disruption analysis, and enables more reliable project tracking and defensible claims analysis. Findings confirm that baseline validation promotes greater project robustness, baseline quality, and overall risk reduction, with scalability across diverse project types, thereby raising project delivery reliability. This model contributes substantively to project management best practices and proposes future research to further automate the BVM for deeper integration with emerging digital project management platforms and to empirically test the model across broader project typologies.

Keywords
Project Scheduling, Baseline Validation, Design Science Research, Baseline Risk, Industrial Engineering

1. Introduction
Timely project completion is crucial, yet most projects experience significant delays with 45% increased duration on average. Late completion adversely impacts costs, goal achievement within allotted times, create opportunity costs (Rooholelm and Abourmasoudi 2022). While comprehensive financial assessments are customary, the time aspect is frequently overlooked. Project management literature highlights a historical emphasis on financial models like return on investment (ROI), net present value (NPV), and cost-benefit analysis (CBA), often neglecting robust baselines for scope, schedule, and cost (PMI, n.d.). This bias contributes to overruns, skewed decisions, and poor long-term planning in infrastructure and general projects.

Traditional metrics from capital-intensive sectors prioritize short-term gains, underfunding planning for baseline stability and fostering cynicism in knowledge-based settings (PMI, n.d.). In cost management, excessive reliance on CBA favors quantifiable benefits, ignoring non-financial aspects and eroding baselines via estimation errors or scope shifts (ResearchGate, 2025). Infrastructure funding similarly prioritizes expansion and reconstruction for economic perks, sidelining maintenance crucial for asset baselines and averting decay (Arizona Department of Transportation, 2025). These findings call for balancing financial priorities with baseline strength. Improving baseline quality can reduce these time-related risks. A baseline is a detailed plan specifying how and when project deliverables will be produced, serving as the primary tool for managing stakeholder expectations (PMI 2021).

Poor quality baselines have been identified as a key factor contributing to project delays (Braimah 2008). Validating baselines ensures they accurately represent the project system and can respond correctly to actual progress data and comply with scheduling industry standards and best practices (Glenwright 2008). Baseline validation is a process where stakeholders utilize third-party experts to evaluate the baseline's characteristics, scope, assumptions, and components to ensure this critical communication tool is accurate (Glenwright 2008).

1.1 Objectives

The primary objectives of this article are to develop, implement, and empirically validate a Baseline Validation Model (BVM) that improves the quality and compliance of project baselines in construction projects thereby raising project delivery reliability. This model aims to address the significant problem of late project completions, which commonly result in increased costs, missed targets, and stakeholder conflicts due to inadequate baseline management and validation practices.

1.1.2 Core Objectives

1. Enhance the quality of project baselines to accurately reflect project critical paths, improving the reliability of progress analysis and risk assessment, and supporting better management decisions.
2. Design and validate a quantitative model—the BVM—that systematically assesses baseline compliance with leading scheduling industry standards and best practices (PMI, DCMA, GAO, NASA) by consolidating existing matrices into a single unified tool.
3. Reduce project time-related risks and minimize stakeholder disputes by ensuring that validated baselines respond predictably and correctly to actual project progress data, thus supporting more precise delay and disruption (DD) analysis.

1.1.3 Research Approach

1. The article sets out to empirically test the hypothesis that applying the BVM to real-world projects will lead to measurable improvements in baseline robustness, scheduling compliance, critical path identification, and reduction of project delays. The artifact development uses an iterative design and evaluation cycle, emphasizing stakeholder requirements, system architecture, and interaction patterns to validate the mechanisms and effectiveness of the BVM.
2. In summary, the article aims to advance project management by scientifically defining, measuring, and enhancing baseline quality, thereby offering practical solutions to an industry-wide problem through the creation and deployment of a novel, standards-driven Baseline Validation Model.

2. Literature Review

The literature review centers on the critical role of project baselines in construction project management and the persistent industry challenge of late project completion due to deficient baseline validation practices. The literature emphasizes the substantial investment made in financial modeling during project feasibility phases yet reveals that comparable rigor is lacking in establishing robust and compliant project baselines, which are crucial for time management and risk mitigation (Glenwright 2008).

2.1 Extent of Project Delays

Global construction projects routinely suffer severe time overruns, with up to 45% average duration increase cited by Rooholelm and Abourmasoudi (2022) and supported by World Bank (1974–1988) studies reporting 50–80% of projects finishing late (Soliman 2017). National research in both the UK and India describes similar trends, with 40–70% of projects affected and typical overruns spanning one to two years (Lowsley and Linnett 2006; Iyer and Jha 2005). In the UAE, Faridi and El-Sayegh (2006) found that 50% of construction initiatives missed original deadlines, directly impacting cost, goals, and opportunity realization.

2.2 Baseline Deficiencies and Their Impact
Project baselines serve as the backbone of schedule control and progress measurement (Bramble and Callahan, 2000). When baselines are poorly constructed, omitted logic links, absent resources, inaccurate constraint usage, exaggerated or negative float, and lack of earned value analysis significantly undermine their usability for delay and disruption analysis (Braimah 2008; Han et al. 2022). Winter and Johnson (2000) observed that many contractor baselines are devised simply to win contracts rather than to monitor progress, resulting in baselines not reflecting actual field activities or progress. Such deficiencies make it virtually impossible to forecast completion accurately or process delay claims efficiently.

2.3 Principal Reasons for Delay
Leading causes of baseline-related project delays fall into three categories: poorly compiled baseline programs, failure to perform scheduled updates, and inadequately updated baselines (Braimah 2008). Kursave (2003) warns that infrequent or incomplete updates obscure critical path changes, milestone status, and remaining work, impeding real-time disruption analysis, and escalating late completion risk. Other significant contributors, catalogued by Yaseen et al. (2020), include owner payment delays, inefficient contracting and design teams, supply chain issues, labor shortages, and external disruptions such as weather and regulation changes. Singh et al. (2023) and Griffith (2005) underscore that inadequate planning and schedule management are consistent root causes in documented global cases

2.4 Summary
Construction projects often face delays up to 45% due to poor baseline programs, infrequent updates, and lack of adherence to scheduling standards (Bramble & Callahan, 2000; Glenwright, 2008; Han et al., 2022). To raise delivery reliability, it is proposed to use rigorous baseline validation models and integrate them into scheduling tools to ensure baseline logic, scope, and resource accuracy. Regular audits and third-party validation, combined with frequent updates, are essential for dynamic schedule control and early risk detection (Braimah, 2008; Kursave, 2003; Bragadin, 2016; PMI, 2021). By aligning baselines with industry best practices and provide transparent review and response structures for continuous improvement. Validated and well-managed baselines empower teams to track performance, resolve delays quickly, and achieve successful, on-time project completion (Faridi & El-Sayegh, 2006; Singh et al., 2023; Yaseen et al., 2020).

3. Method and Data Collection
3.1 Introduction
The research approach is a case study where we aim to develop a BVM to enhance the quality of project baselines by ensuring compliance with scheduling industry standards and best practices. This is crucial for reducing project time risk and improving the reliability of critical path identification. The proposed BVM integrates components from various scheduling models, including the PMI Conformance Index (PMI 2007), DCMA 14-Point Assessment (DCMA 2005), GAO Schedule Assessment Guide (GAO 2012), and NASA Schedule Management Handbook (NASA 2010). The model objectively assesses and scores ten key baseline components against defined parameters to determine an overall compliance rating. This comprehensive approach aims to provide a robust framework for project managers to ensure their baselines are both realistic and achievable, thereby minimizing the risk of project delays and disruptions. By establishing a quantifiable measure of baseline quality, the BVM can help identify areas for improvement and facilitate proactive risk management strategies.

The development of the BVM is driven by the acknowledgement that project baselines are often plagued by unrealistic assumptions, inadequate resource allocation, and a lack of adherence to industry's best practices. These deficiencies can lead to inaccurate critical path identification, compromising the project's ability to meet deadlines and budgets. The BVM seeks to address these challenges by providing a comprehensive and objective assessment framework that integrates multiple scheduling standards and methodologies.

3.2 Consolidated Scheduling Standards and Best Practices
The BVM incorporates the following scheduling industry standards and best practices:

3.2.1. PMI Conformance Index (PMI 2007): Provides a template for identifying baseline and updating components. This index is widely recognized in the project management community for its detailed guidelines on maintaining project baselines. It serves as a foundation for the BVM, ensuring that all essential baseline elements are considered.

3.2.2. DCMA 14-Point Assessment (DCMA 2005): Establishes commonality and weighting factors for baseline components. This assessment is particularly useful for its rigorous criteria, which help in identifying potential issues in project baselines early on. The weighting factors derived from this model ensure that the BVM prioritizes the most critical components, reflecting their relative importance in baseline quality.

3.2.3. GAO Schedule Assessment Guide (GAO 2012): Contributes best practices for baseline components. The GAO guide is known for its comprehensive approach to schedule assessment, ensuring that all critical aspects of project scheduling are covered. By incorporating these best practices, the BVM aligns with industry-recognized standards for schedule development and maintenance.

3.2.4. NASA Schedule Management Handbook (NASA 2010): Offers a color-coded rating system and criteria for assessing component compliance. NASA's handbook is instrumental in providing a clear, visual representation of schedule health, making it easier for project managers to identify and address issues. The color-coding system enhances the interpretability and communication of the BVM's findings.

By consolidating these standards and practices, the BVM aims to provide a comprehensive and objective evaluation of baseline quality. This integration ensures that the model is not only thorough but also adaptable to various project environments, enhancing its utility across different industries. The combination of these diverse scheduling methodologies allows the BVM to leverage the strengths of each approach, resulting in a more robust and holistic assessment tool.

3.3 Model Components and Parameters

The BVM consists of ten components that are measured against defined parameters to determine the baseline's level of compliance:

- 3.3.1. Calendars (task, resource, and project):
- 3.3.2. Logic (missing links):
- 3.3.3. Leads:
- 3.3.4. Lags:
- 3.3.5. Relationship Types:
- 3.3.6. Hard and/or Soft Constraints:
- 3.3.7. High Float:
- 3.3.8. High Durations:
- 3.3.9. Resources:
- 3.3.10. Critical Path Test:

The methodology used to establish the relevant components and parameters is illustrated in Figure 1, a graphical representation of the researcher's Excel model.

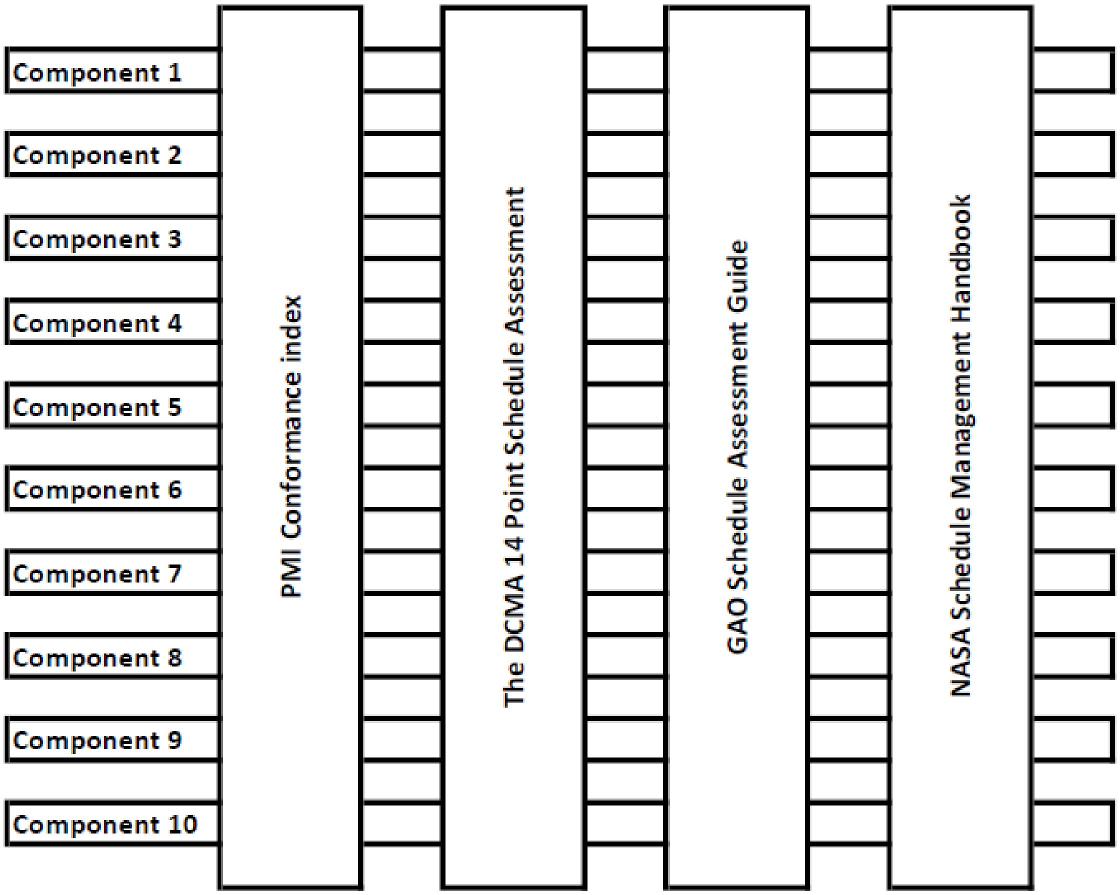

Figure 1. Graphical representation of model design approach (Source: own)

Each component is assessed based on the parameters defined in the NASA Schedule Management Handbook (NASA 2010), and a color-coded rating system (red, yellow, green) is applied to indicate the level of compliance. This visual approach helps project managers quickly identify areas of concern and take corrective actions.

The components are assigned specific weighting factors based on their level of importance, as suggested by the DCMA 14-Point Assessment model (DCMA 2005). The overall compliance rating is calculated by dividing the total actual rating by the total maximum rating, resulting in a single percentage score. This single "Go/No-Go" score provides a clear, quantifiable measure of the baseline's compliance with industry standards, making it easier for stakeholders to understand the baseline's health.

3.4 Empirical Research Setup

The empirical research setup, as depicted in Figure 2, involves the BVM as the Object of Study (OoS), interacting with three baselines (the population) to measure the outcomes and apply treatments for improvement.

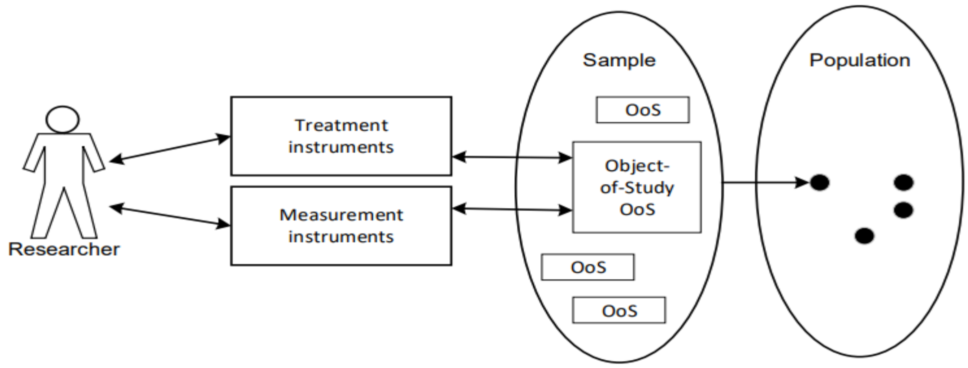

Figure 2. Empirical research setup (Wieringa 2014:122)

This setup ensures that the BVM is tested in a real-world context, providing valuable insights into its effectiveness and areas for improvement.

External validity is established by defining the representativeness of the cases in terms of the architecture of the population (baselines). The objective is to determine the essential architecture for the phenomenon being studied, where all baselines are composed of components with capabilities and limitations. This approach ensures that the findings are generalized to a broader range of projects, enhancing the BVM's applicability.

The empirical research setup follows a rigorous design, adhering to the principles outlined by Wieringa (2014) and Shadish (2002). By carefully considering the units, treatments, outcomes, and settings (UTOS) involved in the research, the study aims to establish a causal relationship between the application of the BVM and the observed improvements in baseline quality and project performance.

3.5 Testing and Validation

To thoroughly evaluate the effectiveness of the proposed Baseline Validation Model (BVM), three real project baselines were examined through the model's structured methodology. These baselines were chosen to reflect complex, real-world development scenarios and to provide valuable understanding into the BVM's performance.

- Data#1: This project is part of phase 1 of a mixed-use Social Housing Development Project containing 2,500 residential units, 100,000 square meters of commercial space, and a variety of amenities, including schools, parks, and a community center. The project works consists of the construction of 281 housing units, 50m2 to 60m2, in 6 blocks of three storey walk-up units with varying number of units from 24- to 76 units per block. The construction execution strategy enabled two construction teams to construct the units in 480 working days, with each team completing 177 and 104 units, respectively. The baseline has 7095 activities in the network.

- Data#2: This project involved the construction of a large shopping mall located in Cape Town, one of the largest shopping malls in the Western Cape province. The mall boasts a total gross leasable area of 57,000 square meters and houses over 150 retail stores. The baseline for this project included a total of 3,344 activities, and the planned duration for the construction was 362 days. The project was successfully completed as planned, demonstrating the effectiveness of the baseline.

- Data#3: This project involved the construction of the largest shopping mall in Africa at the time of its completion in 2016. The scope of the mall included a variety of retail stores, restaurants, and entertainment venues, such as a cinema, a bowling alley, and an ice rink. The mall has a total gross leasable area of 130,000 square meters and houses over 300 retail stores. The baseline for this project included a total of 12,275 activities, and the planned duration was 589 days. Despite the ambitious scope, the project faced numerous challenges and was completed late. This case highlights the complexities and risks associated with large-scale projects and underscores the importance of a robust baseline validation process.

The compliance scoring procedure is executed by systematically assessing the individual components against the established criteria, implementing the designated color-coded rating methodology, and determining the aggregate compliance outcome via the allocation of corresponding weighting factors. The effectiveness and practicality of the BVM are validated through this rigorous real-world assessment, demonstrating its operational value within real-world project contexts.

Following the compliance evaluation, remedial actions are identified for components that necessitate enhancement, such as minimizing the prevalence of leads and lags, scrutinizing instances of excessive float logic, and resolving challenges related to resource allocation. These corrective measures serve to optimize the baseline, thereby guaranteeing its feasibility and attainability.

The iterative framework inherent in design science research methodology facilitates ongoing refinement and advancement of the BVM, based on continual testing and empirical validation. This sustained approach ensures that the BVM retains its relevance and efficacy, evolving in alignment with the dynamic shifts in industry standards and recognized best practices. The pivotal role of design science's iterative nature between design and evaluation functions—serving as a mechanism of continuous enhancement—is illustrated in Figure 3

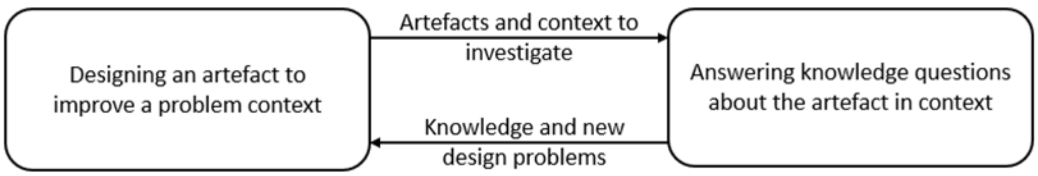

Figure 3. Iterative nature of design science (Wieringa, 2014)

Furthermore, the testing and validation phase provides an opportunity to gather feedback from project stakeholders and scheduling professionals. Their insights and experiences can make further enhancements to the BVM, ensuring that it remains aligned with practical considerations and real-world challenges faced by project teams. This approach ensures that the BVM is both practical and effective, providing a valuable tool for project managers to ensure their baselines are compliant with industry standards and best practices.

3.6 Summary and Conclusion

The proposed BVM represents a novel approach to assessing and scoring project baselines against industry standards and best practices. By integrating components from multiple scheduling models and leveraging objective parameters and weighting factors, the BVM aims to provide a comprehensive and quantifiable measure of baseline quality. This approach ensures that project baselines are both realistic and achievable, reducing the risk of delays and disruptions.

The iterative design science research methodology employed in this study ensures a rigorous and continuous improvement process, enabling the BVM to evolve and adapt to emerging industry needs. The potential implications of the BVM include enhanced project time-risk management, improved critical path identification, and increased stakeholder confidence in baseline reliability. These benefits can lead to more successful project outcomes, as stakeholders can trust that the baselines are well-constructed and dependable.

Furthermore, the BVM's quantitative scoring system facilitates benchmarking and comparative analysis across projects and organizations. By establishing a standardized measure of baseline quality, project managers and decision-makers can identify best practices, track performance over time, and implement targeted improvement strategies.

4. Results

The research results can be explained by referring to the conceptual framework, which asserts that by examining the composition, behavior, and nature of an architectural structure, a comparison can be drawn to a Baseline (B). Both the architectural structure and the baseline are composed of "components" with specific capabilities and limitations. These components are arranged in such a way that they exhibit "patterns of interaction" known as mechanisms, which produce system-level phenomena. The BVM is a novel artifact designed to evaluate and study these interactions among components. In the scheduling industry, this is often referred to as understanding "how activities interact and produce program phenomena, an understanding of cause-and-effect."

During the research execution and compliance testing performed on the baselines, several treatments were identified as significantly influencing the interaction of the components that produce system-level phenomena. These treatments are as follows:

1. Leads: Substantially decreasing the number of leads. Leads are the amount of time by which a successor activity can be advanced with respect to a predecessor activity. Reducing leads can streamline the baseline and reduce complexity.
2. Lags: Substantially decreasing the number of lags. Lags are the amount of time delay between the completion of one activity and the start of another. Reducing lags can help in maintaining a more continuous workflow.
3. High float: Investigating the baseline logic, particularly when the achieved percentage score is significantly higher than the parameters. High float indicates that there is a lot of slack time in the baseline, which may need to be optimized to ensure efficient resource utilization.
4. Resources: Assigning resources to the baseline. Proper resource allocation is crucial for the timely completion of activities and overall project success.

By implementing these suggested treatments, the interaction of the components will change, thereby enhancing the Baseline's ability to "react" to progress data. The application of the BVM is proposed to identify these treatments as areas of concern in relation to the baseline. This allows the scheduling professional to correct deviations and enhance the quality of the baseline. The BVM serves as a diagnostic tool that helps in pinpointing specific issues within the baseline and provides a structured approach to address them.

In this article, the lab-to-field generalization approach is used. This approach refines generalizations by dropping idealizing assumptions, as confirmed by (Wieringa 2015). This method achieves a realistic generalization, albeit with a limited, less-than-universal scope. The strategy can be performed in two ways: case-based generalization or sample-based generalization. In this article, a case-based generalization is followed. This involves studying individual cases and generalizing about components and mechanisms found in a case by similarity. The underlying assumption in this approach is that components are less varied than the cases they occur in. This method allows for a more detailed and context-specific understanding of the interactions and mechanisms at play.

In conclusion, the BVM provides a structured framework for evaluating and improving the quality of project baselines. By focusing on the interaction of components and applying targeted treatments, the BVM helps in aligning the baseline with industry standards and best practices, leading to more successful project outcomes.

5. Discussion
5.1 Introduction
The late completion of projects has been identified as a universal issue, affecting various industries and sectors. The baseline factors contributing to these delays were meticulously identified, and a recommendation was made to address these factors by employing a BVM. This model was developed using a robust Design Science Research Methodology. The results from the research underscore the effectiveness of a well-structured Design Science Research Methodology (DSRM), providing a comprehensive and systematic framework for research. By enhancing project baselines, time-related risks can be significantly reduced, thereby raising project delivery reliability.

The BVM represents the first attempt to consolidate and measure all scheduling industry standards and best practices into a single, cohesive model. By applying the BVM to a baseline, it is possible to establish its level of compliance with industry standards, identify areas for improvement, and ensure that the baseline will accurately respond to progress data. This, in turn, improves the baseline's critical paths and reduces the likelihood of project delays. The

BVM serves as a diagnostic tool that helps in pinpointing specific issues within the baseline and provides a structured approach to address them, thereby enhancing the overall project management process.

5.2 Common observations and general remarks
5.2.1 Cases

The input data and completed BVM for each of the three case-study projects were meticulously analyzed to draw meaningful insights. In Figure 4, the BVM results from the three baselines are compared to allow for common observations and general remarks.

Data analysis - DATA #1, -#2 & #3

The overall project rating is determined by assigning numeric value to the different colous, i.e. red=1, yellow=2 and green=3
The numbers are summed and a weighting factor is applied to determine the final results. The average results are colour coded as follow:

	Measurable components	Parameters	DATA #1	DATA #2	DATA #3
	A	B		C	
1	1) Calendars (task-, resource-& project-)	Calendar complaint - (yes green, no red)	Green	Green	Green
2	2) Logic (missing logic links)	Missing predecessors (<5% is green, 5% to 10% yellow and >10% red)	Green	Green	Green
		Missing successors (<5% is green, 5% to 10% yellow and >10% red)	Green	Yellow	Green
3	3) Leads	Leads should not be used, goal 0% (0% green, <5% yellow, >5% red)	Red	Green	Red
4	4) Lags	Lags should not be used, not exceed 5% (0% green, <5% yellow, >5% red)	Yellow	Green	Red
5	5) Relationship types	Finish to Start at least 90% (>90% green,90% - 80% yellow, <80% red)	Green	Red	Green
		Start to Finish, counter-intuitive and should not be used (yes green, no red)	Green	Green	Green
6	6) Hard - and/or soft constraints	Constraints and deadlines (< 10% green, 10% to 15% yellow and > 15% red)	Green	Green	Green
7	7) High float	High float > 44 days, if % high float > 5% network may be unstable (HF <5% green, 5%-10% yellow, >10% red)	Red	Green	Red
	8) Negative float	Negative float <0 working days (< 2% green, 2% to 3% yellow and > 3% red)	Green	Green	Green
8	9) High duration	Dur >44 days, no of high duration act not > 5% (< 3% green, 3% to 5% yellow and > 5% red)	Green	Red	Green
9	10) Resources (ZAR or hours)	% missing resources (< 10% green, 10% to 15% yellow and > 15% red)	Red	Red	Red
10	11) Critical path test	Critical path act pass(15 no (5start. 5middle,5end)) (<5% is green, 5% to 10% yellow and >10% red)	Red	Red	Red
		Overall rating	**81%**	**77%**	**79%**

Figure 4. Combined BVM (Source: Own)

The number of activities varies significantly among the projects: Data#1 has 7,057 activities, Data#2 has 3,344 activities, and Data#3 has 12,275 activities. It should be noted that while the number of activities increases the granularity of the baseline, it does not necessarily enhance its quality or increase the positive outcome of the project. This observation underscores the importance of focusing on the quality and accuracy of the baseline rather than merely increasing its complexity.

5.2.2 Common observations and general remarks
Viewing the combined BVM of the three projects reveals a clear pattern. It is noteworthy that all three baselines are considered compliant with scheduling industry standards and best practices as per the model, as all three BVMs scored an overall rating is above 75%. The following common observations and remarks can be made:

1. Calendar: The calendars in all three baselines are compliant, accounting for all non-working days. This is one of the most overlooked components of a baseline, yet it has a severe impact on the accuracy of the projected completion

dates. Ensuring that non-working days are accurately reflected in the baseline is crucial for realistic scheduling and planning.

2. Logic: The logic of the baselines is well within the defined parameters. This component of the BVM has a high weightage as it significantly influences the logic of and subsequent critical paths. Proper logical sequencing of activities ensures that the project baseline is realistic and achievable, reducing the risk of delays.

3. Leads and Lags: The leads and lags of Data#1 and Data#2 are compliant or close to compliant, but the leads and lags of Data#3 were substantially higher than the defined parameters. As noted later under the evaluation of the critical paths, this may have contributed to the unstable nature of the baseline in project Data#3 and may have resulted in the incorrect reflection of the remaining work, leading to the inadequate baseline management and subsequent late completion of the project.

4. Relationship Types: Most of the relationship type parameters of all three baselines are compliant, except for the "Finish-to-Start" ratio in baseline Data#2. Ensuring the correct relationship types between activities is essential for maintaining the integrity of the project baseline and ensuring that dependencies are accurately represented.

5. Hard and/or Soft Constraints: All the constraint parameters were compliant with scheduling industry standards and best practices, with no additional notes to be made. Effectively managing constraints ensures that the project baseline remains flexible and adaptable to changes, reducing the risk of delays.

6. High Float: Two of the three baselines are non-compliant, with float higher than 44 days considered to have a negative impact on the quality of the critical calculations. High float indicates excessive slack time, which can lead to inefficiencies and increased project duration.

7. High Durations: Only Data#2 is non-compliant by a small margin. In general, this is not a common problem and is simple to resolve. Ensuring that activity durations are realistic and achievable is crucial for maintaining the accuracy of the project baseline.

8. Resources: None of the baselines are compliant in terms of resource allocation. Allocating resources to the baseline is required to manage the earned values (EV) of the baseline and to establish the percentage complete of the project based on the resources consumed to date. Resource allocation assists with resource leveling and ensures that the planned rate of execution is achievable. Not allocating resources to the baseline increases the risk of not achieving the project deadline due to over-optimistic planning. This is a significant risk for all three baselines.

9. Critical Path Test: The critical path is tested by inducing an intentional slippage of 300 days as per the DCMA 14-Point Assessment approach, i.e., the duration of the critical task is increased by 300 days, and the overall duration of the baseline is recalculated. It is expected that the overall project duration will increase by 300 days if the critical path is "well-constructed," implying that the "linking of the activities" is done correctly. This highlights the importance of the architectural structure of the system to understand the patterns of interaction that produce system-level phenomena.

The testing of the critical path on Data#3 revealed that the structure of the baseline was fundamentally flawed. When introducing the 300-day intentional slip and recalculating the remaining duration, the entire structure of the baseline collapsed, resulting in a completely incorrect remaining baseline. This finding was alarming and led to the hypothesis that this flaw may have contributed to the late completion of the project due to the inadequate baseline management and subsequent on-site activities because the baseline did not accurately reflect the remaining work, and the "patterns of interaction that produce system-level phenomena" were incorrectly structured.

During the execution of the BVM validation, the collapse of the baseline (Data#3) was the most alarming finding. This highlights the importance of a well-constructed baseline with the correct "linking of activities," ensuring accurate "patterns of interaction" and subsequent remaining baseline activities and logic. Sensitivity analyses of the critical path are an area of future research, as they can provide deeper insights into the robustness and reliability of project baselines.

In conclusion, the BVM provides a structured framework for evaluating and improving the quality of project baselines. By focusing on the interaction of components and applying targeted treatments, the BVM helps in aligning the baseline with industry standards and best practices, leading to more successful project outcomes. The findings from the case studies underscore the importance of a robust baseline validation process and highlight areas for future research to further enhance the effectiveness of project scheduling and management.

6. Conclusion

Globally, the late completion of projects is a critical concern that has been the subject of numerous research papers and peer-reviewed articles. In this article, the focus was to determine the extent to which the baseline contributes to late project completions, thereby justifying the design and development of an innovative artifact to address this issue in a unique and novel manner. In a study that analyzed 1560 actual projects confirmed that the applied software packages calculated the project durations significantly differently, this highlights the challenges facing the scheduling industry (Trautmann and Baumann 2009).

The primary objective of the research presented in this article was to expand knowledge and enhance the quality of project baselines. By designing a BVM that aligns with scheduling standards and best practices, the aim was to ensure baselines accurately reflect the project's critical paths, improve progress analysis, reduce project risk, minimize potential conflicts between parties, and raise project delivery reliability.

The following main conclusions were made in this article:

1. The application of a Design Science Research Methodology is well structured research approach.
2. Based on its architecture, the overall system behaviour of the Baseline (B) can be evaluated. The BVM can be integrated as a software plug-in into commercially available scheduling software, reducing validation costs and increasing baseline quality.
3. Studying the baseline requires an understanding of the architectural structure of a system and how the "patterns of interaction" produce system-level phenomena. The similarities between a system's architectural structure and the Baseline (B) confirmed the researcher's belief that a design science approach can produce the desired result.
4. The late completion of projects was identified as a global issue; the baseline factors that contribute to the late completion were identified, and a recommendation was made to overcome these factors by employing a BVM.
5. Improving the baseline's quality by applying the BVM will ensure that the enhanced baselines can be better utilised in delay and disruption (DD) analysis, improve project management, and reduce the project's time risk.
6. The BVM addresses industry standards and best practices for scheduling and enhances the quality of the baseline, thereby raising project delivery reliability.

6.1 Recommendations for Future Research

The researcher proposes automating the validation process within commercial software packages by integrating the quantification of components using agreed parameters and applied weightages to calculate compliance levels with industry standards and best practices. Once the baseline scoring is calculated, a remedial action list can be provided that will, once corrected by the user, enhance the baseline, and improve the mechanism of interaction and subsequence patterns of interaction that produce system-level phenomena. This will lead to baselines that "react" more accurately to progress data and reflect the remaining critical paths more accurately, enhancing project management and reducing project time-risk.

Building on this concept, an investigation into the potential of automating scheduling and enhancing project efficiency through the integration of BIM and Natural Language Processing (NLP) in Construction Schedule Management (CSM) (Singh et al 2023). The integration aims to enhance CSM efficiency by generating dynamic work templates and learning from existing records, thereby streamlining scheduling preparation and improving accuracy.

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Biographies

Michael BOSCH holds a BSc in Construction Management, MBA in Financial Management from the University of Pretoria and a PhD in Engineering Management from the University of Johannesburg. With over 30 years of experience in large-scale construction and mining project management across South Africa and the Gulf region, he has developed extensive expertise in the field. He is currently working as a Project Planning Specialist on a world class and globally competitive Maritime Yard project. His diverse background and wealth of experience in project management contribute to the successful execution of complex projects.

Jan Harm C. Pretorius obtained his BSc Hons (Electrotechnics) (1980), MIng (1982) and DIng (1997) degrees in Electrical and Electronic Engineering at the Rand Afrikaans University and an MSc (Laser Engineering and Pulse Power) at the University of St Andrews in Scotland (1989), the latter cum laude. He worked at the South African Atomic Energy Corporation (AEC) as a Senior Consulting Engineer for 15 years. He also worked as the Technology Manager at the Satellite Applications Centre (SAC) of the Council for Scientific and Industrial Research (CSIR). He is currently a professor: Postgraduate School of Engineering Management in the Faculty of Engineering and the Built Environment where he worked since 1998. Head of School: Postgraduate School of Engineering Management (1 July 2015 – Aug 2021). Vice Dean of the Faculty (2005–2010). Departmental Head of Electrical and Electronic Engineering Science (Oct 2003–Feb 2005). He has co-authored over 320 research papers and supervised over 75 PhD and over 350 master's students. He is a registered professional engineer, professional Measurement and Verification (M&V) practitioner, senior member of the Institute of Electrical and Electronic Engineering (IEEE), fellow of the South African Institute of Electrical Engineers (SAIEE) and a fellow of the South African Academy of Engineering.

Leon Pretorius has more than 45 years' professional, engineering, academic, and academic management experience. He was professor at the University of Johannesburg, South Africa until 2007. In 2004 he was the last Dean of Engineering at the Rand Afrikaans University and then became Executive Dean of Engineering and the Built Environment at the University of Johannesburg in 2005. He was a professor in the Graduate School of Technology Management at the University of Pretoria from 2007 to 2020. He is currently Professor Emeritus in the Graduate School of Technology Management at University of Pretoria starting from June 2020. He has supervised more than 280 Master and PhD students' research. This includes the supervision and co-supervision of 64 successful PhD Doctoral theses. He is also the author or co-author of more than 310 technical peer reviewed conference and journal papers. He serves on the editorial boards of a number of international journals. He is an Honorary Fellow of SAIMechE, Fellow of SAIIE, Member of ASME and Member of IEEE up to 2023. He is rated as researcher by the National Research Foundation (NRF) in South Africa. He has received ESKOM utility Tesp Grants for more than 26 years.