A Heuristic Method for Measuring Material Procurement Progress in Industrial Projects

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Abstract

Material procurement is mainly considered the critical path for industrial project. Monitoring its progress in an effective manner is key to a project success. Delays in material procurement are one of the major identified causes of delay in projects. The aim of this paper is to introduce a heuristic method to measure material procurement progress and implement that method in a case study.

A survey was conducted to explore the effectiveness of the current procurement methods and identify the factors influencing material requisitions. Based on a survey finding, 61% of 75 respondents in the field believe that current methods of measuring material procurement progress are inefficient. In addition, three major factors were identified to consider when calculating weights of material requisitions: material lead time, fabrication complexity, and material monetary value. A heuristic method was proposed to properly report material procurement progress after collecting project data and feedback from practitioners. The method was developed and tested in a real case study project. The results proved the effectiveness of the proposed method, which detected delays two months earlier than the method in use for the same project. In addition, the proposed method calculated the achieved progress 20% less than the current method at some points through project life cycle. The proposed method helps decision makers to take corrective actions by providing a more accurate for material procurement. Thus, the heuristic method helps to reduce the reducing risks of overpaying contractors, ensures delivery of material in a timely manner, and save costs that may occur due to delays.

Keywords
Material Procurement; Progress Measurement; Industrial Projects; Capital Projects; Controlling and Monitoring.

1. Introduction
Material Procurement is a crucial process that directly affects the success of any project. Industrial projects depend heavily on material availability, which smoothens the execution and assures achieving project targets. A project schedule is built based on expected delivery dates of the material. Material-related delays are identified as one of the major causes of delays in construction projects (Fashina et al. 2021). Hence, having an effective way of monitoring and controlling material procurement progress is vital to avoid delays during project construction.

There are several phases each procured material undergoes during the material procurement cycle. The progress of these procurement phases is monitored by the project management team to ensure achieving delivery dates. If the used metrics to calculate material procurement progress cannot detect delays at the right time, the project management team cannot perform effective corrective actions. As modularization is now practiced in many industries, the delivered components are planned to be installed as delivered, which minimizes chances of workarounds in the case of unavailability.

In a study on performance metrics for capital projects, material procurement management has been identified as one of the major key performance indicators that helps improve the performance of ongoing projects (Luu et al. 2008). An effective progress measurement ensures maintaining project schedule and identifying delays at early stages allowing decision makers to take appropriate actions. In this paper, a heuristic method to calculate material procurement progress is developed and tested on real data from an industrial project. The performance of the proposed method is compared with the current material progress measurement method to evaluate the method's effectiveness.

The paper is further outlined as follows. Section II presents the literature review. The methodology of the study is presented in section III, followed by the data collection in section IV. A heuristic method to calculate material procurement progress and a Case Study to implement it are illustrated in sections V, and VI respectively. Finally, the Conclusion is presented in section VII.

2. Literature Review

Companies spend a large amount of money on material procurement as part of their development projects. Thus, high attention must be given to the way they manage processes related to material procurement (Rwoti 2005). Delays due to lack of monitoring tools may increase costs and affect the schedule adversely, which leads to additional money spent on a project to recover occurred delays. Rakesh et al. (2016) illustrated that around 54% of the project total budget is allocated for material in construction projects. Therefore, the material availability is one of the main causes of project success. Moreover, Saadi and Hejji (2006), identified material delays as one of the most severe causes of projects delays, with material delay was ranked fourth out of 73 different causes of delay.

Patil and Pataskar (2013) identified that 5% of the project variation was due to unavailability of material, where they emphasized that having an effective material procurement progress measurement tool is essential to ensure project efficient performance. Avoiding delays can be achieved by properly tracking different phases along the material procurement lifecycle, with relevant details such as material approval, material lead time, delivery dates (Kamalaeaswari and Vedhajanani 2015). In addition, a study was conducted by Komatina et al. (2019) stated that it is essential for an organization to choose the optimum measurement tool that can help to maximize the efficiency and effectiveness of the procurement process.

Adopting effective material management tools ensures achieving project schedule targets, improve labor productivity, and open work front for site activities. Furthermore, material procurement is accountable for about 50-60% of project cost, and it can impact around 80% of the project schedule. Therefore, organizations shall adopt effective material management tools to ensure meeting procurement process objectives (Caldas et al. 2014).

Yun et al. (2016) presented a survey performed on industrial projects through different phases to measure schedule deviance of each phase. The results indicated that the procurement phase encountered 17.5% schedule growth. The study revealed that this was mainly due to lack of management and control. This leads practitioners to pay attention to tools that monitor and control material procurement in order to mitigate adverse events the project may undertake.

Supply chain management is one of the key areas that require high attention to achieve material procurement milestones. However, it is difficult to anticipate the delay of the material procurement process with complex supply chains. Therefore, practitioners shall consider a plan to overcome these delays utilizing effective monitoring tools (Wibowoa and Sholeh 2015). Glowinski (2019) discussed that monitoring and controlling of material procurement shall be considered to forecast the performance of construction activities in industry. Furthermore, he emphasized on the importance of utilizing project performance data by decision makers to take actions.

Another study was conducted by Dolber and Burt (1996), the authors claimed there are no universally accepted performance measurement tools that can be implemented to measure the performance of procurement. This raises the importance of having a standardized simple method to measure the performance during the material procurement lifecycle. To overcome the obstacles of rapid change in the global market, practitioners requires to utilize more effective tools to measure project performance in order to continuously evaluate and take corrective actions aligned with the business objectives (Yun et. al 2012).

3. Methodology

A survey was conducted to identify the major factors that practitioners selected to be considered for measuring the material procurement progress. After that data was collected from an ongoing project, and the data analyzed. Based on the survey and collected data, a new material procurement measurement method has been introduced, which is further described in section V. The new measurement method has been implemented on a real project data in a case study and results were discussed. An illustration of the followed methodology is shown in Figure 1.

Figure 1. Methodology followed

4. Data Collection

Material data for an ongoing project was collected, to provide a real representation of what is being currently followed to measure procurement progress for industrial projects. The data were analyzed and segregated, depending on different characteristics, such as lead time, level of inspection, and monetary value. In addition, the dates for each procurement milestones were identified. The milestones for the material procurement cycle are Request for Quotation, Technical Bid Evaluation, Placing Purchase Order, Approving the Material Specification as applicable, Receiving the Material Certification and Fabrication Drawings as applicable, Delivery to the Site, and full Documentation of Material Specifications including Spare Parts Data Cataloging.

A survey was conducted to capture the feedback from the practitioners in the project management field regarding the current used methodologies effectiveness and the factors that need to be considered in measuring material procurement progress. Seventy-five (75) responds were received, 84% of the respondents had more than five years' experience in projects. They have worked on different types of projects, and around 73% of them worked on industrial projects. Figure 2 shows that around 61% of respondents believe that their currently used methodology to measure procurement progress is not efficient. In Figure 3, 84% of practitioners had selected material lead time as a factor that needs to be considered in measuring material procurement progress. Also, fabrication complexity and material monetary value was selected by more than 50% of the practitioners as factors that need be considered in measuring material procurement progress.

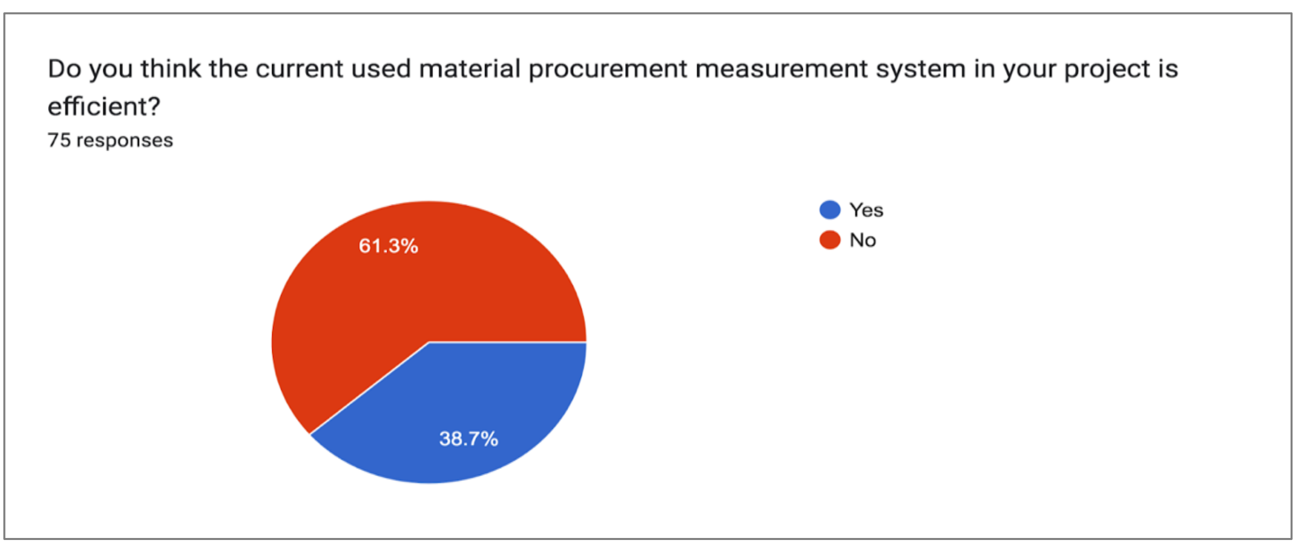

Figure 2. Representation of satisfaction with the currently used methodologies

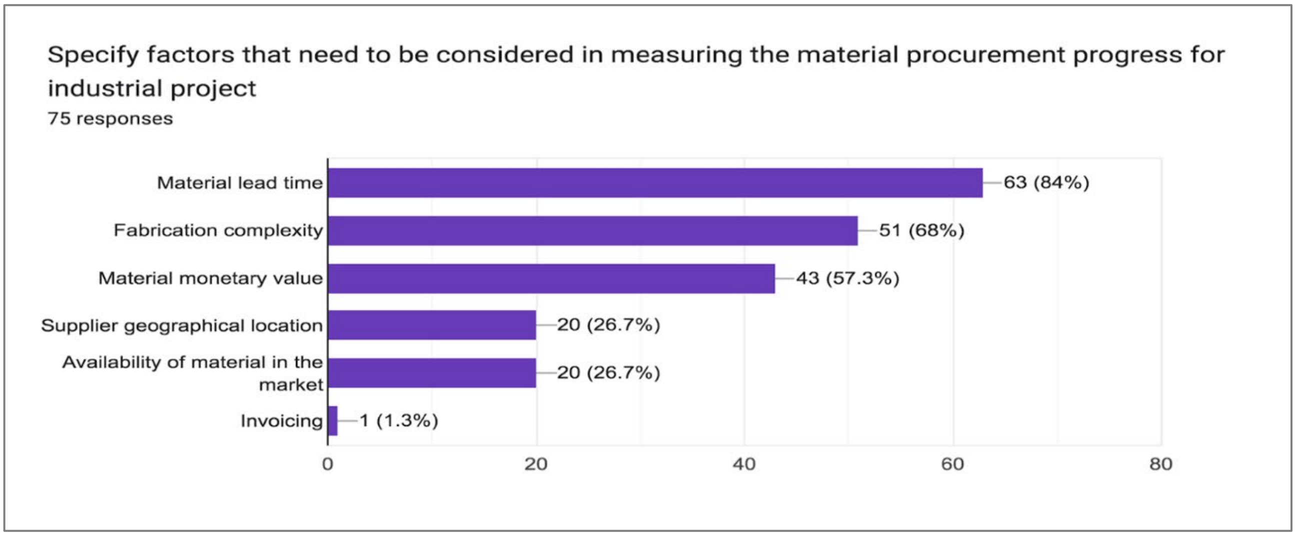

Figure 3. Major factors that impact material procurement progress

1. Introduction of Proposed Method

This section discusses the proposed heuristic algorithm for measuring the progress of material procurement. Procurement weightage for project material was distributed based on the major three identified factors from Figure 3, material lead time, fabrication complexity (level of inspection), and material monetary value. The fabrication complexity was referred to the level of inspection since the complexity of fabricating a material increases with the level of inspection where it starts from level 0 to 4. Thus, a formula was derived from the previously mentioned factors to calculate a score for each material/purchase order to be procured, as shown in Eq 1.

$$Material\ Score = \frac{Material\ Value}{Total\ Materials\ Value} \text{ x } (Level\ of\ inspection\ + 1) \text{ x } Material\ Lead\ time\ (weeks) \qquad (1)$$

After that a unique score for each material was introduced, which will represent a percentage from the total weight of procured materials. In order to get the material weightage percentage for each material, every material score shall be divided by the total number of project material scores as shown in Eq 2. An example to further explain the method is presented in section 6.2.

$$Modified\ Material\ Weight\ (\%) = \frac{Material\ Score}{Total\ Materials\ Score} \qquad (2)$$

2. Case Study

A real industrial project was selected to implement the newly introduced heuristic method. The selected project was executed in an oil processing facility, spanning over the period from 2019 to 2022. The project was awarded to a local Saudi Contractor, who is responsible for engineering, procurement, and construction. The project faced major delays pertaining to material procurement. A comparison between the current methodology for procurement material progress and the newly introduced methodology was done and the results are shown in section 6.3. The project data for 82 inspectable materials was collected, and shown in Appendix-A.

3. Current Method

This part describes the current method used for calculating the material procurement progress. Procurement progress in the project has been measured by following the current practice. All project material requisitions are equally weighted regardless of different factors such as, material lead time, manufacturing complexity, and commodity value. Each requisition is divided over the number of project material requisitions, as shown in Eq 3. For this project, with a total of 82 requisitions each requisition weighs 1.22% regardless of the aforementioned factors. The progress of each material is calculated based on the achieved procurement step. The procurement milestone steps are shown in Table 1. Thus, a material will reach its total weight by submitting all documents in step 7, the calculation is done as shown in Eq 4.

Table 1. Weightage of Procurement Milestones

Steps	Milestone	Weight (%)
1	Request for Quotations (RFQ)	10
2	Technical Bid Evaluation (TBE)	15
3	Purchase Order (PO)	15
4	Approval of Fabrication Drawings (NMR 601)	10
5	Certification of fabrication documents, test certificate.etc (NMR 602)	10
6	Delivery to the Job Site	30
7	Submittal of all NMR documents and SPDS	10

$$\text{Material Weight (\%)} = \frac{1}{\text{No.of Material Requisition}} \text{x } 100 \qquad (3)$$

$$\text{Progress weight (\%)} = \sum \text{Procurement steps weight(\%) x Material Weight(\%)} \qquad (4)$$

For example, if we select MR-02 from Appendix-A, assuming at the time of calculation it is currently in step 4. The material and progress weights are 1.22 % and 0.61% respectively, as calculated below by utilizing Equations 3 and 4.

$$\text{MR02 Weight (\%)} = \frac{1}{82} \text{x } 100 = 1.22\%$$

$$\text{MR02 Progress weight (\%)} = (0.1 + 0.15 + 0.15 + 0.1) \text{x } 0.0122 = 0.61\%$$

By adding all material progress weights at a specific point of time, it shows the overall material procurement progress of the project. It can be noticed that regardless of the type of material requisition, whether it is a pumps requisition or gaskets requisition they all have the same weight, any achieved progress step will be claimed identically.

4. The Proposed Method

The list of 82 inspectable materials with the data needed to utilize Eq 1 is shown in Appendix-B. After calculating material score (Eq 1) and modified material weight (Eq 2), progress weight is calculated using Eq 4. This shows a reasonable representation of material procurement progress since the modified material weight accounts for different factors.

To illustrate the newly introduced method, consider MR-02 from Appendix-B, assuming at the time of calculation the material in step 4. The total materials score of 82 materials is 91.75. The material and progress weights are 12.2 % and 6.1% respectively, as calculated below by utilizing Eq 1,2, and 4.

$$Material\ Score = \frac{\$3{,}892{,}579.45}{\$82{,}347{,}418.79} \text{ x } (3 + 1) \text{ x } 59 = 11.16$$

Then

$$Modified\ Material\ Weight\ (\%) = \frac{11.16}{91.75} = 12.2\%$$

and

$$MR02\ Progress\ weight\ (\%) = (0.1 + 0.15 + 0.15 + 0.1) * 0.122 = 6.1\%$$

It is observed from this example that a more reasonable weight representation of MR-02 is 12.2% rather than 1.22% compared to the current method. Thus, reaching step 4 shall have a higher weight to be claimed in progress.

5. Result and Discussion

After collecting the data and calculating progress weights under both methodologies, it needs to be tested against the planned material procurement progress for the project. Measuring progress weight of each method against planned progress at different periods to illustrates the effectiveness of each method. Calculations were performed depending on collected data from the achieved progress milestones throughout the project timeline using Microsoft Excel. Figure 4 shows the planned material procurement progress over the project timeline. The procurement activities were supposed to commence in March 2019 and reach 100% by December, 2021.

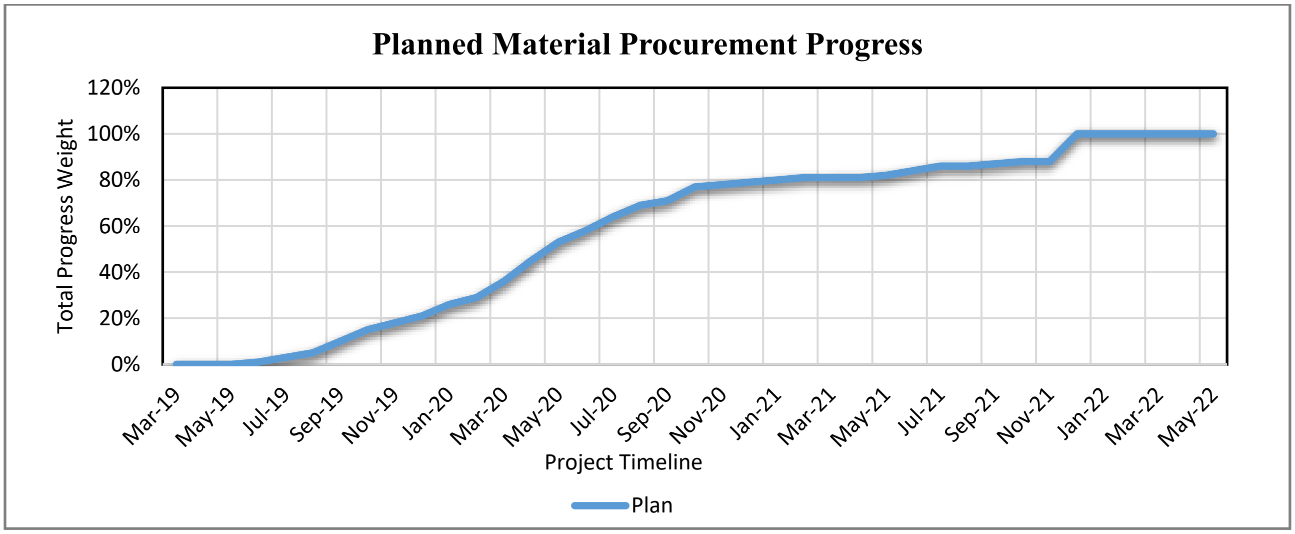

Figure 4. Planned procurement progress

Figure 5 shows the planned material procurement against the current used method for measuring material procurement progress. As illustrated in the graph, the procurement progress was ahead of schedule from the starting of the project until May 2020 with around 49% of achieved progress compared to a planned 53%, where it suddenly went behind schedule, which leaves the decision makers helpless to take corrective actions. As the project activities continues, the progress shows an indication that it is slightly ahead of schedule in July 2021, with 88% of achieved progress, which is unrealistic since it went back behind schedule in January 2022. Following this method is misleading since it provides false indications to the decision makers. This also may lead to overpaying contractors if the contract mandates payments on progress milestones.

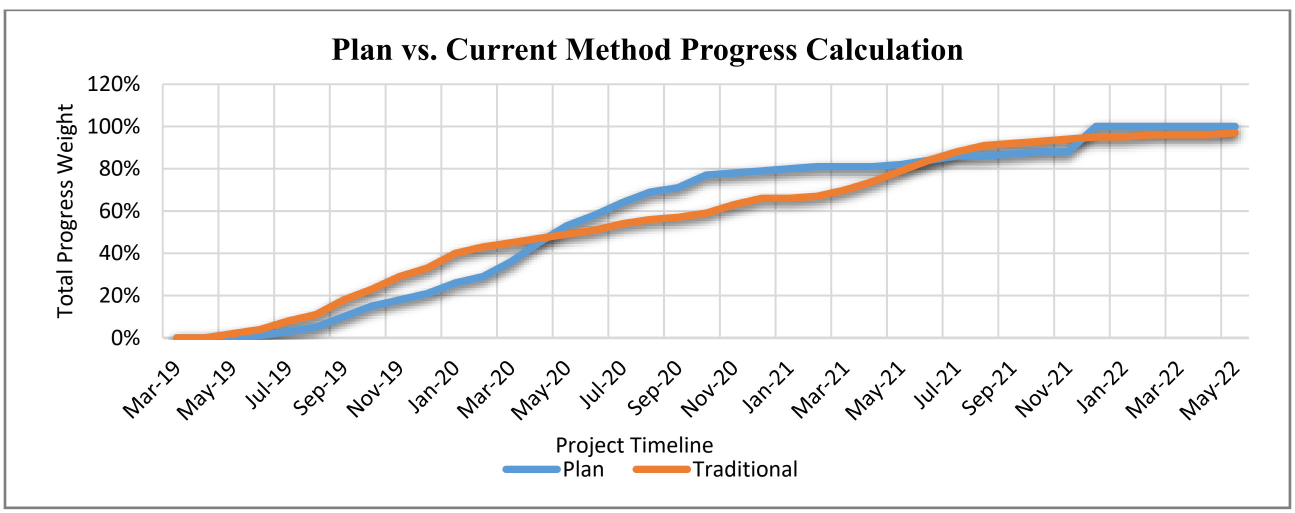

Figure 5. Planned Versus Traditional Material Procurement Progress

The proposed method of progress calculation versus planned progress is shown in Figure 6, The calculated material procurement progress by using the proposed method falls behind the schedule starting from March 2020, with 31% achieved progress compared to a planned 36% progress. Detection of being behind was two months earlier compared to the current method, which could've reduced the impact dramatically if the method was implemented.

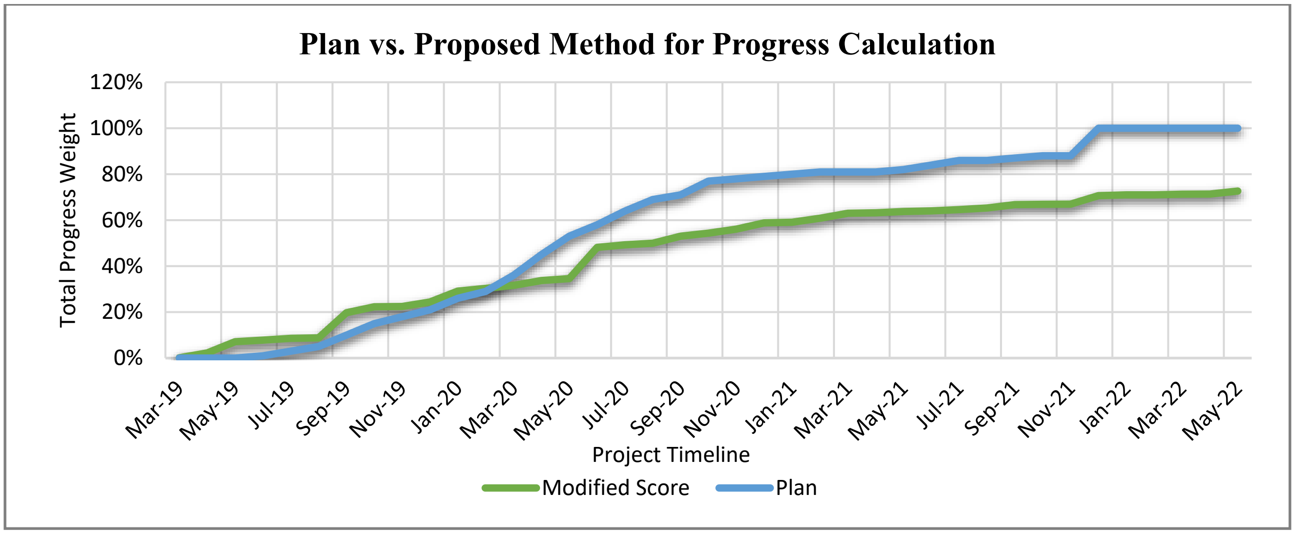

Figure 6. Modified Score Versus Plan Procurement Progress

Figure 7 shows comparison of measuring material procurement progress by the current and proposed methods. Even though detection of falling behind schedule is earlier in the proposed method, the difference between achieved progress between two methods can reach to 20%. It can be noticed that following the proposed method gave smoother shift moving from ahead to behind schedule, where progress was on schedule in January 2020, and February 2020, which may allow the decision makers to pay higher attention to material procurement, so it does not fall behind schedule. On the other hand, current method went immediately from ahead of schedule to behind the schedule. Moreover, the current method falsely indicated that in May 2022 the progress is 97% whereas following the proposed method shows progress is 72%.

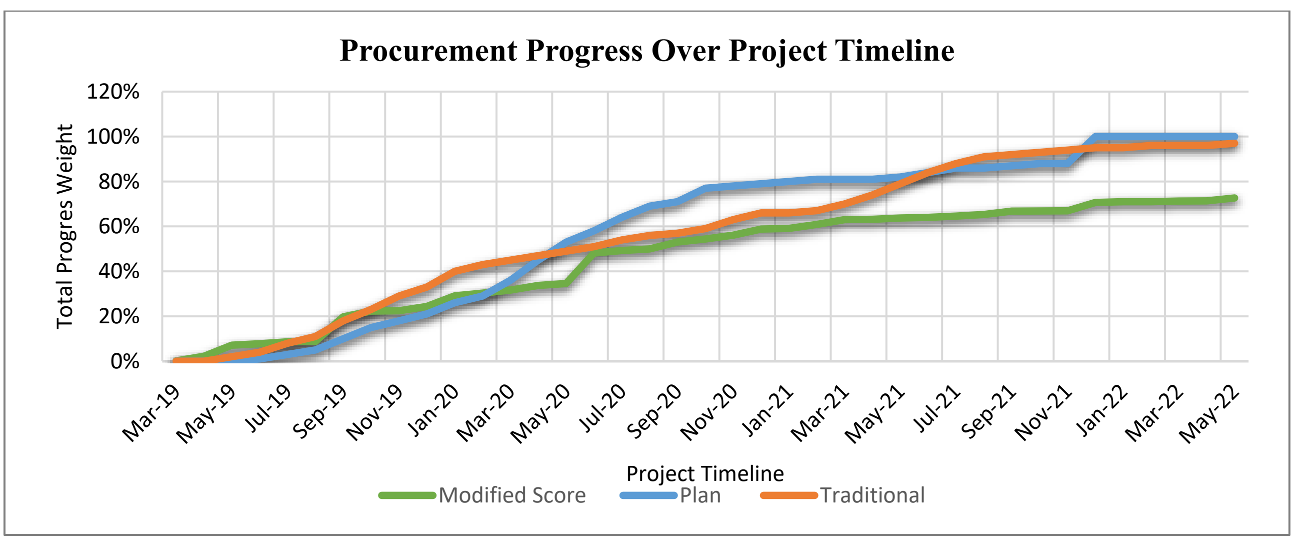

Figure 7. Modified Score and Traditional Methods of Calculating Procurement Progress

6. Conclusion

A survey with 75 respondents who have worked on different types of projects, found that 61% believes that current methods to report material procurement progress were not efficient. They have identified three major factors to be considered in weighing materials procured, which were namely, material lead time, fabrication complexity, and material monetary value.

The heuristic method to calculate material procurement progress has been proven efficient and insightful for decision makers to act upon. When this method was applied to a project, the method provided a more realistic representation of achieved progress where at some points a difference of around 20% was identified in comparison with the current method. In the considered project, the proposed method detected being behind schedule two months earlier than the current method for calculating progress. Having such a heuristic method may help realize several benefits such as, saving cost due to avoided delays, allowing timely corrective actions, reducing the risk of overpaying contractors, and ensuring achieving planned delivery dates. In the future, implementing the heuristic method on additional projects will avail opportunities for practitioners to enhance it and realize its full benefits.

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Biographies

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Turki Aldossary is a Project Engineer working in Upstream Oil Project Management at Saudi Aramco since 2016. He obtained his Bachelor of Science degree in Mechanical Engineering from Colorado State University. In addition, he holds a Master of Engineering degree in Construction Engineering and Management from King Fahd University of Petroleum and Minerals. Also, he is certified as a Project Management Professional and Risk Management Professional from the Project Management Institute.

Appendix-A

This Table summarizes a list of projects inspectable materials with the level of inspection, lead time, and monetary value.

Item No.	level of inspection	Lead Time (Weeks)	Value ($)
MR-01	3	59	2,713,009.82
MR02	3	59	3,892,579.45
MR-03	3	56	1,947,885.33
MR-04	2	30	2,503,871.96
MR-04B	2	22	1,132,376.17
MR-15	0	24	32,118.57
MR-24	2	30	24,495,754.40
MR-30	2	28	138,612.94
MR-30B	2	28	3,819.21
MR-31	2	28	2,824,869.04
MR-31B	2	28	16,255.58
MR-62	1	28	4,719,000.00
MR-48	0	26	981,804.00
MR-49	0	26	53,563.41
MR-36	0	14	89,076.00
MR-27	0	8	2,343,044.42
MR-28	2	30	8,669.64
MR-29	1	24	21,345.51
MR-32	2	32	9,601,262.56
MR-32B	2	32	206,582.69
MR-33	3	30	1,333,845.86
MR-33B	3	24	36,091.53
MR-34	1	24	18,183.26
MR-20	2	20	28,635.56
MR-53	0	16	28,635.56
MR-07	2	32	1,992,878.61

MR-07B	2	32	1,305,810.37
MR-08	3	32	1,248,654.65
MR-8B	3	32	183,123.28
MR-09	3	32	114,542.23
MR-09B	3	32	114,542.23
MR-25	3	8	2,343,044.42
MR-13	0	22	137,651.01
MR-16	1	26	1,917,811.09
MR-17	1	20	530,594.40
MR-39	1	28	708,365.99
MR-40	1	32	541,394.01
MR-05	2	24	298,512.85
MR-35	1	24	371,609.07
MR-38	1	18	135,747.87
MR-41	1	20	152,844.16
MR-06	1	18	458,524.91
MR-42	1	16	91,767.34
MR-44	0	16	152,841.64
MR-45	1	14	79,153.36
MR-46	0	10	67,042.12
MR-68	1	26	100,620.48
MR-21	2	26	749,569.59
MR-21	2	26	759,674.50
MR-22	2	26	931,833.28
MR-23B	2	26	2,034,308.49
MR-51	0	18	28,635.56
MR-52	0	18	57,271.12
MR-54	2	12	343,626.70
MR-55	2	16	114,542.23
MR-59	0	16	204,107.98
MR-61	1	13	361,589.64
MR-61B	1	13	10,618.00
MR-018	1	16	557,974.73
MR-10	3	16	369,658.65
MR-19	1	4	590,300.23
MR-65	0	2	18,276.00
MR-67	0	1	1,043,604.99

MR-66	0	12	137,736.72
MR-69	0	12	241,251.03
MR-70	0	22	91,767.34
MR-71	0	22	2,492.00
MR-77	0	4	62,388.00
MR-72	2	24	185,486.93
MR-73	2	20	15,776.40
MR-87	3	24	58,751.80
MR-83	2	12	15,390.00
MR-80	1	10	296,959.73
MR-84	2	20	2,454.00
MR-88	2	20	171,050.00
MR-47	0	24	112,800.00
MR-74	0	20	16,753.57
MR-40B	1	24	258,242.00
MR-76	0	20	32,180.22
MR-87B	0	4	142,643.80
MR-95	3	26	103,654.00
MR-93	0	12	6,081.00

Appendix-B

This Table summarizes the material weight after implementing the modified scoring methods.

Item No.	level of inspection	Lead Time (Weeks)	Value ($)	Total Score	Material Weight
MR-01	3	59	2,713,009.82	7.78	8.5%
MR02	3	59	3,892,579.45	11.16	12.2%
MR-03	3	56	1,947,885.33	5.30	5.8%
MR-04	2	30	2,503,871.96	2.74	3.0%
MR-04B	2	22	1,132,376.17	0.91	1.0%
MR-15	0	24	32,118.57	0.01	0.0%
MR-24	2	30	24,495,754.40	26.77	29.2%
MR-30	2	28	138,612.94	0.14	0.2%
MR-30B	2	28	3,819.21	0.00	0.0%
MR-31	2	28	2,824,869.04	2.88	3.1%
MR-31B	2	28	16,255.58	0.02	0.0%
MR-62	1	28	4,719,000.00	3.21	3.5%
MR-48	0	26	981,804.00	0.31	0.3%
MR-49	0	26	53,563.41	0.02	0.0%
MR-36	0	14	89,076.00	0.02	0.0%
MR-27	0	8	2,343,044.42	0.23	0.2%

MR-28	2	30	8,669.64	0.01	0.0%
MR-29	1	24	21,345.51	0.01	0.0%
MR-32	2	32	9,601,262.56	11.19	12.2%
MR-32B	2	32	206,582.69	0.24	0.3%
MR-33	3	30	1,333,845.86	1.94	2.1%
MR-33B	3	24	36,091.53	0.04	0.0%
MR-34	1	24	18,183.26	0.01	0.0%
MR-20	2	20	28,635.56	0.02	0.0%
MR-53	0	16	28,635.56	0.01	0.0%
MR-07	2	32	1,992,878.61	2.32	2.5%
MR-07B	2	32	1,305,810.37	1.52	1.7%
MR-08	3	32	1,248,654.65	1.94	2.1%
MR-8B	3	32	183,123.28	0.28	0.3%
MR-09	3	32	114,542.23	0.18	0.2%
MR-09B	3	32	114,542.23	0.18	0.2%
MR-25	3	8	2,343,044.42	0.91	1.0%
MR-13	0	22	137,651.01	0.04	0.0%
MR-16	1	26	1,917,811.09	1.21	1.3%
MR-17	1	20	530,594.40	0.26	0.3%
MR-39	1	28	708,365.99	0.48	0.5%
MR-40	1	32	541,394.01	0.42	0.5%
MR-05	2	24	298,512.85	0.26	0.3%
MR-35	1	24	371,609.07	0.22	0.2%
MR-38	1	18	135,747.87	0.06	0.1%
MR-41	1	20	152,844.16	0.07	0.1%
MR-06	1	18	458,524.91	0.20	0.2%
MR-42	1	16	91,767.34	0.04	0.0%
MR-44	0	16	152,841.64	0.03	0.0%
MR-45	1	14	79,153.36	0.03	0.0%
MR-46	0	10	67,042.12	0.01	0.0%
MR-68	1	26	100,620.48	0.06	0.1%
MR-21	2	26	749,569.59	0.71	0.8%
MR-21	2	26	759,674.50	0.72	0.8%
MR-22	2	26	931,833.28	0.88	1.0%
MR-23B	2	26	2,034,308.49	1.93	2.1%
MR-51	0	18	28,635.56	0.01	0.0%
MR-52	0	18	57,271.12	0.01	0.0%
MR-54	2	12	343,626.70	0.15	0.2%
MR-55	2	16	114,542.23	0.07	0.1%
MR-59	0	16	204,107.98	0.04	0.0%
MR-61	1	13	361,589.64	0.11	0.1%
MR-61B	1	13	10,618.00	0.00	0.0%
MR-018	1	16	557,974.73	0.22	0.2%
MR-10	3	16	369,658.65	0.29	0.3%
MR-19	1	4	590,300.23	0.06	0.1%
MR-65	0	2	18,276.00	0.00	0.0%
MR-67	0	1	1,043,604.99	0.01	0.0%
MR-66	0	12	137,736.72	0.02	0.0%

MR-69	0	12	241,251.03	0.04	0.0%
MR-70	0	22	91,767.34	0.02	0.0%
MR-71	0	22	2,492.00	0.00	0.0%
MR-77	0	4	62,388.00	0.00	0.0%
MR-72	2	24	185,486.93	0.16	0.2%
MR-73	2	20	15,776.40	0.01	0.0%
MR-87	3	24	58,751.80	0.07	0.1%
MR-83	2	12	15,390.00	0.01	0.0%
MR-80	1	10	296,959.73	0.07	0.1%
MR-84	2	20	2,454.00	0.00	0.0%
MR-88	2	20	171,050.00	0.12	0.1%
MR-47	0	24	112,800.00	0.03	0.0%
MR-74	0	20	16,753.57	0.00	0.0%
MR-40B	1	24	258,242.00	0.15	0.2%
MR-76	0	20	32,180.22	0.01	0.0%
MR-87B	0	4	142,643.80	0.01	0.0%
MR-95	3	26	103,654.00	0.13	0.1%
MR-93	0	12	6,081.00	0.00	0.0%