Use of the bar chart/S-curve and computerized precedence diagram method on scheduling and controlling building construction projects by contractors: a cross-sectional study

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RESEARCH ARTICLE

Use of the bar chart/S-curve and computerized precedence diagram method on scheduling and controlling building construction projects by contractors: a cross-sectional study [version 1; peer review: awaiting peer review]

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Abstract

Background: Building construction projects have very complex activities, so they require precise and accurate methods of scheduling and control. Using the right method, the project executor can carry out the project according to plan and any schedule deviations can be controlled effectively. This study aims to compare the effectiveness of using the bar chart/S-curve and computerized precedence diagram method (PDM) on scheduling and controlling building construction projects.

Methods: The use of the two methods and their effectiveness during project work were analysed using a survey directed to building construction workers.

Results: A total of 50 workers completed the survey. The use of PDM (using Microsoft Project) was significantly more effective than the bar chart/S-curve method in scheduling building construction projects (t count 15.516> t table 2.660) and controlling building construction projects (t count 17.233> t table 2.660). In addition, PDM was associated with allowing the project to find the critical path more quickly, overcoming project delays more effectively.

Conclusions: By using PDM, a on a building construction project's schedule for the implementation of the work can be changed immediately, if there is a delay or deviation of work. The findings of this study are useful for construction service companies and the development of construction management science in civil engineering study programs.

Keywords

S-curve, PDM, scheduling, control

Open Peer Review

Reviewer Status *AWAITING PEER REVIEW*

Any reports and responses or comments on the article can be found at the end of the article.

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Introduction

Cost, quality and time are the three main indicators that determine the success of a construction project. A construction project is successful if the costs incurred are in accordance with the budget, the time for completion is in accordance with the scheduled time, and the resulting quality is as planned. This is consistent with the description by Soemardi *et al.*,[1] who stated that cost and time are among the keys to project success. The successful implementation of a project is inseparable from the effectiveness of the scheduling and controlling, which provides accurate information about the schedule for the work plan to be carried out and the actions that need to be taken if deviation from the project occurs. The purpose of scheduling is to determine the sequence of activities to be carried out, the dependency relationship of each activity, the resource requirements of each activity and the allocation of expected implementation time. With the development of information technology, construction managers are starting to look for suitable applications to make it easier to plan and control a project so that it is on time, on budget and meets the required quality. Many programs are offered to process data related to controlling a project. These programs make it easier for construction workers to input the work that has been carried out. The increasing demand for the acceleration of work schedules has led to the development of computerized planning and scheduling.[2]

Pandey *et al.*[4] stated that delay in a project is due to the use of inaccurate information in preparing work schedules. Memon *et al.*[5] ascribed delay to incorrect planning and scheduling by the construction manager, while ineffective scheduling and control were the reasons given by Pourrostam and Ismail.[6] Further, according to Odeh and Battaineh,[7] improper planning was responsible, while inadequate planning and scheduling were the causes according to Romuald-Kokou *et al.*[8] Therefore, project planning requires a precise and accurate method.

Today's computer application programs greatly assist construction managers in entering project data, managing project activities and people, project control, and project reports. Harris[9] describes a project as a set of operations or activities that must be planned and arranged in a logical order to achieve a determined outcome at a definitive end time. Before the schedule is drawn up, the project manager plans the manpower that will be involved in the work, which is outlined through a hierarchy known as the work breakdown structure. Several scheduling methods that are often used by construction managers include bar charts, S-curves, and network methods, such as program evaluation and review technique (PERT), critical path method (CPM) and precedence diagram method (PDM). The PDM is now being used in the field because it is assisted by computer applications. Although the PDM can be computerized with Microsoft (MS) Project, many construction managers still use the S-curve as a scheduling and control tool.[3]

A bar chart is a set of activities arranged vertically and a time scale arranged horizontally based on the length of the bar chart, which means that the beginning of the bar indicates the start of work and the end signifies work completion. A bar chart is always accompanied by an S-curve, which is arranged based on the budget and completion time of each task. The S-curve can show the progress of the project based on activities, time, and work weight represented as a cumulative percentage of all project activities. Figure 1 shows two curves that have different meanings, namely the work plan and the actual work. In Figure 1, it is shown that the project was delayed, did not go according to plan and underwent deviations. According to Luthan and Sitanggang,[10] the mismatch between plan and implementation is shown by the S-curve as the magnitude of the deviation that occurs.

The bar chart and S-curve method is used to bid for projects by contractors. The S-curve is used as a control tool based on the costs incurred by each work item using MS Excel to input the actual data on the bar chart, as shown in Figure 1 on the implementation curve, so that the construction manager will know that the project has been delayed by 22%.

Meanwhile, MS Project is an application developed based on a network method, namely PDM, which is structured to make a comprehensive schedule that can determine the critical path.[11] On MS Project, the project will show a bar chart and the dependency relationship of each activity; this depiction is not different from the S-curve/bar chart method. The relationship between two activities in PDM consists of four varying types: (1) Finish to finish, (2) Finish to start, (3) Start to start, (4) Start to finish.

Hermawan[12] explained that large-scale projects with numerous activities can no longer be controlled manually, so an application that can detect problems in the field is needed. MS Project-PDM is an application that can be used in the field for scheduling and control. According to Harris,[9] there are four stages/levels in planning and scheduling: planning without people; monitoring progress without people; scheduling with people, roles, and budget; and monitoring the progress of a resource schedule. For details, see Table 1.

MS Project-PDM is used to determine the critical path to completing the activity immediately; if it is not completed within the specified time, it will affect other activities. According to Krajewski,[13] determining the critical path is based on the

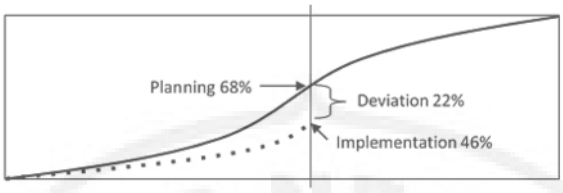


Figure 1. S curve of planning and implementation. This figure has been reproduced with permission from Luthan, P.L.A. & Sitanggang, N. (2016). Penerapan Earned Value pada Aplikasi MS. Project Sebagai Pengendali Proyek (Studi Kasus Pada Proyek di kota Medan), Prosiding Konferensi Nasional Teknik Sipil 10, Universitas Atmajaya Yogyakarta, 26-27 October.

Table 1. Stages of project scheduling and controlling, as per Harris.[9]

	Schedulling	Controlling
Without people	LEVEL 1: Scheduling without people	LEVEL 2: Controlling progress without people
With people	LEVEL 3: Scheduling with people, roles, and budget	LEVEL 4: Controlling progress of a resourced schedule

network planning method to estimate the right time to carry out and end an activity. Furthermore, Bansal and Pal[14] stated that the linkage of activities in the critical path using a 3-dimensional model will show an easy-to-understand sequence of activities, so that construction managers can determine the actions to be taken. Sabariah *et al.*[3] found that the use of the PDM is still relatively low. Based on the description above, an important question arises: between the bar chart/S-curve and MS Project-PDM methods, which one performs better in scheduling and controlling of building construction projects? In this study, a comparison of the performance of the two methods was done. The findings provide useful information for construction companies and the development of construction management science in civil engineering.

Methods

Study design

This study used a cross-sectional survey method design, and was carried out from March to April 2020.

Participants

Purposive sampling was used to select workers in building construction. Participants were approached through collaboration with the Indonesian Project Scheduling Expert Association (PAPPI); the researcher contacted PAPPI to distribute questionnaires to participants. Inclusion criteria included workers who had attended training in the use of the MS Project application (PDM) organized by the Indonesian Project Scheduling Experts Association. A total of 50 PAPPI members fit the criteria needed to fill out the questionnaire.

Data collection

To collect data, a survey was sent online using the Google Form application (see *Extended data*[16]). The survey included various statements (see Table 2) and respondents were asked to response to each statement with the following options: STS, strongly disagree; TS, disagree; N, neutral; S, agree; SS, strongly agree.

Instrument testing was carried out on three workers prior to the study. This was done to determine the readability of the instrument, the clarity of the content in each statement, and the language of the instrument. After the test was conducted, it was concluded that all statement items had a good readability level, contained clear content, and the language used was easy to understand. The instrument reliability coefficient of using the S-curve was 0.98, and the instrument reliability coefficient of using the MS Project-PDM was 0.96.

Data analysis

Descriptive analysis and a t-test (Sugiyono[15]) were carried out for data analysis using Microsoft Excel 2010. Descriptive analysis was used to determine the distribution of answers from respondents which in turn described the use of S-curve and MS Project for scheduling using the S-and supervision. A t-test was used to test the significant differences in scheduling and supervision between the use of the S-curve and MS Project.

Table 2. Survey statements.

S-curve/bar chart scheduling		MS Project-PDM scheduling		S-curve/bar chart control		MS Project-PDM control	
X11	S Curve-Bar Chart is used to bid	X21	MS Project-PDM method is used to bid	X31	S Curve-Bar Chart method is used as project control tool	X41	MS Project-PDM method is used as project control tool
X12	S Curve-Bar Chart at the time of bidding completed with job details	X22	MS Project-PDM method for bidding is complete with job details	X32	S Curve-Bar Chart method is very useful as a project control tool	X42	MS Project-PDM method is very useful as a project control tool
X13	S Curve-Bar Chart method is used for the scheduling of the project	X23	MS Project-PDM method used for the scheduling of the project	x33	S Curve-Bar Chart serves as a strategy to reduce delays in work	X43	MS Project-PDM method serves as a strategy to reduce delays in work
X14	S Curve-Bar Chart method is created by experienced planner	X24	MS Project-PDM method is made by experienced planner	X34	S Curve-Bar Chart method can show actual conditions that occur in the field	X44	MS Project-PDM method can show actual conditions that occur in the field
X15	S Curve-Bar Chart method is made in detail (WBS)	X25	MS Project-PDM method is made in detail (WBS)	X35	S Curve-Bar Chart method can be used to make decisions	X45	MS Project-PDM method can be used to make decisions
X16	S Curve-Bar Chart method can make a clear dependency relationship	X26	MS Project-PDM method can make a clear dependency relationship	X36	S Curve-Bar Chart method is used as the right method to make decisions if there is a delay	X46	MS Project-PDM method is used as the right method to make a decision if there is a delay
X17	S Curve-Bar Chart method in the project can find out the workforce used	X27	MS Project-PDM method in the project can find out workforce used	X37	S Curve-Bar Chart method can change the actual schedule quickly	X47	MS Project-PDM method can change the actual schedule quickly
X18	S Curve-Bar Chart method can find out the activities that have free time (free float)	X28	MS Project-PDM method can find out activities that have free time (free float)	X38	S Curve-Bar Chart method can control work costs until the end of the project	X48	MS Project-PDM method can control work costs until the end of the project
X19	S Curve-Bar Chart method can determine the critical activities	X29	MS Project-PDM method can determine the critical activities	X39	S Curve-Bar Chart method can determine the amount of people available for each job	X49	MS Project-PDM method can determine the amount of workforce available for every job
X110	S Curve-Bar Chart method for making a schedule in our project can show the time/ date of work	X210	MS Project-PDM method for making a schedule in our project can show the time/date of work	X310	S Curve-Bar Chart method can determine the actual work by comparing with the costs that have been incurred.	X410	MS Project-PDM method can determine the actual work by comparing with the costs that have been incurred.

WBS: Work breakdown structure.

Ethical considerations

Ethical approval was not sought for this study due to the low risk nature of the survey and study population. At the beginning of the Google Form, information about the study, data collection and data use was presented to participants. Completion of the survey was taken as consent to participate in the study.

Results and discussion

A total of 50 workers responded to the survey. Based on work experience as project scheduling experts, 28% of participants had experience of less than 5 years, 20% had 5-10 years of experience, 18% had 10-15 years of experience, and most, 34%, had experience over 15 years. The majority of participants were male (n = 47).

Table 2 shows the ten statements distributed to respondents for each method of scheduling and control.

S-curve/bar chart project scheduling (Figure 2)

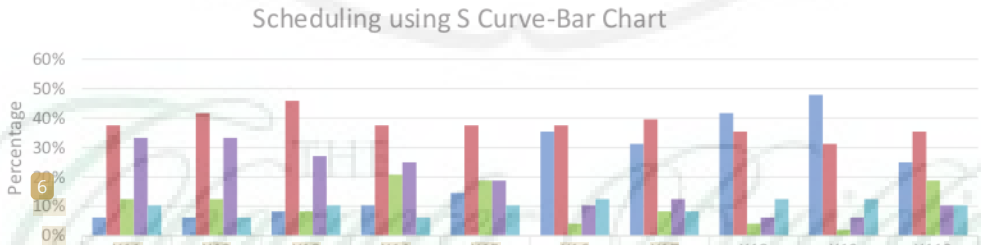
Regarding the distribution of answers to the ten questions on the use of S Curve-Bar Chart in project scheduling, 47.92% of respondents chose 'strongly disagree', while 45.83% chose 'disagree'. Very few respondents chose 'strongly agree', ranging from 6.25-10.42%. Regarding the responses to questions about the use of the S-curve/bar chart in project scheduling, the largest number of respondents chose 'strongly disagree' (47.92%), that is, the S curve-bar chart cannot show critical work. 'Strongly agree' was chosen by the least number of respondents (6.25%), that is, when making a bar chart schedule, the S-curve does not need to be done in detail; this option was not chosen by experienced people. Regarding respondents' answers to scheduling with the use of S-curve/bar charts, 43.75% of respondents chose 'agree' or 'strongly agree', that is, construction managers still use S-curve/bar chart as a tool to make project bids.

MS Project-PDM project scheduling (Figure 3)

Regarding the distribution of answers to ten questions on the use of the MS Project-PDM in project scheduling, respondents dominantly chose 'strongly agree' (81.25%), while 'strongly disagree' recorded 0%. Very few respondents chose 'disagree', ranging from 4.17-10.42%. Concerning responses to questions about the use of the MS Project-PDM method in project scheduling, the largest number of respondents chose 'strongly agree' (81.25%), while no respondents chose 'strongly disagree' (0%).

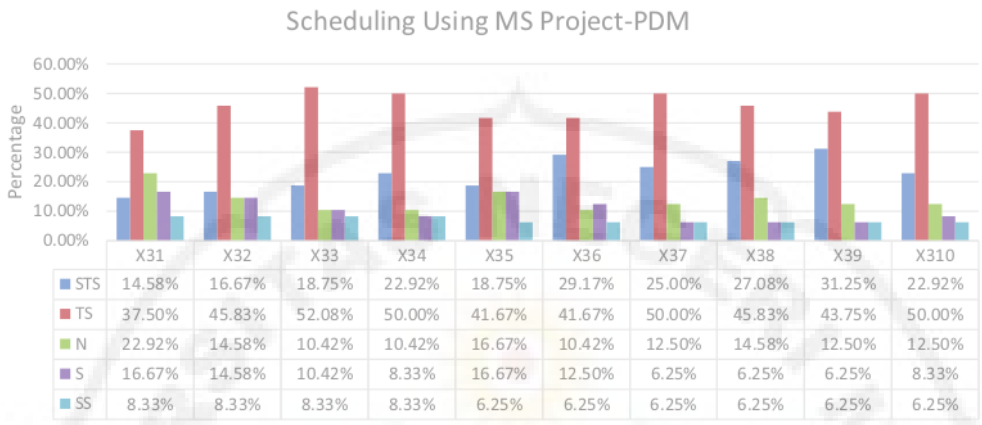
S-curve/bar chart project control (Figure 4)

With respect to the distribution of answers to ten questions on using S-curve/bar chart for project control, respondents dominantly chose 'disagree' (52.08%). Very few respondents chose 'strongly agree', ranging from 6.25-8.33%. Regarding the responses to questions about the use of the S-curve/bar chart method in project control, the largest number of respondents chose 'agree' (52.08%), that is, the S-curve/bar chart cannot be used as a strategy to reduce delay. The lowest number of respondents chose the 'strongly disagree' option (6.25%), in the categories of X35, X36, X37, X38, X39, and X310 (see Table 2).



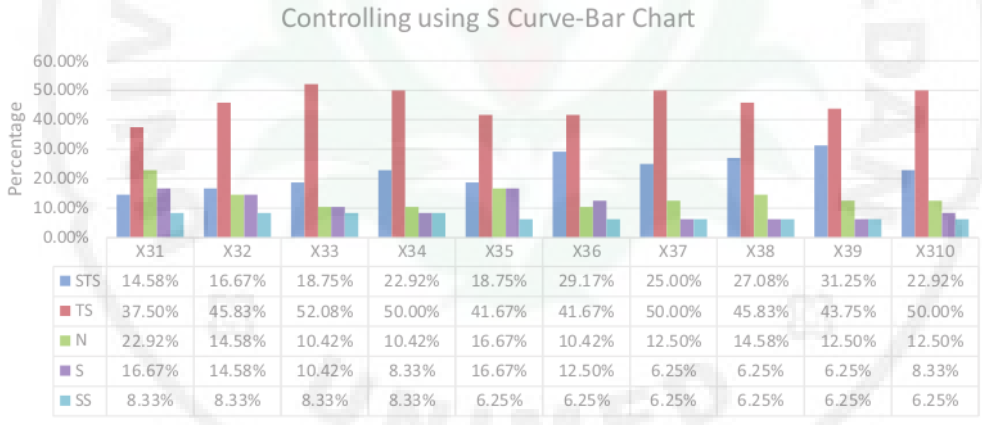
	X11	X12	X13	X14	X15	X16	X17	X18	X19	X110
STS	6.25%	6.25%	8.33%	10.42%	14.58%	35.42%	31.25%	41.67%	47.92%	25.00%
TS	37.50%	41.67%	45.83%	37.50%	37.50%	37.50%	39.58%	35.42%	31.25%	35.42%
N	12.50%	12.50%	8.33%	20.83%	18.75%	4.17%	8.33%	4.17%	2.08%	18.75%
S	33.33%	33.33%	27.08%	25.00%	18.75%	10.42%	12.50%	6.25%	6.25%	10.42%
SS	10.42%	6.25%	10.42%	6.25%	10.42%	12.50%	8.33%	12.50%	12.50%	10.42%

Figure 2. Project scheduling using S-curve/bar chart relating to the questions in Table 2. STS, strongly disagree; TS, disagree; N, neutral; S, agree; SS, strongly agree.



	X31	X32	X33	X34	X35	X36	X37	X38	X39	X310
STS	14.58%	16.67%	18.75%	22.92%	18.75%	29.17%	25.00%	27.08%	31.25%	22.92%
TS	37.50%	45.83%	52.08%	50.00%	41.67%	41.67%	50.00%	45.83%	43.75%	50.00%
N	22.92%	14.58%	10.42%	10.42%	16.67%	10.42%	12.50%	14.58%	12.50%	12.50%
S	16.67%	14.58%	10.42%	8.33%	16.67%	12.50%	6.25%	6.25%	6.25%	8.33%
SS	8.33%	8.33%	8.33%	8.33%	6.25%	6.25%	6.25%	6.25%	6.25%	6.25%

Figure 3. Project scheduling with MS Project-PDM relating to the questions in Table 2. STS, strongly disagree; TS, disagree; N, neutral; S, agree; SS, strongly agree.



	X31	X32	X33	X34	X35	X36	X37	X38	X39	X310
STS	14.58%	16.67%	18.75%	22.92%	18.75%	29.17%	25.00%	27.08%	31.25%	22.92%
TS	37.50%	45.83%	52.08%	50.00%	41.67%	41.67%	50.00%	45.83%	43.75%	50.00%
N	22.92%	14.58%	10.42%	10.42%	16.67%	10.42%	12.50%	14.58%	12.50%	12.50%
S	16.67%	14.58%	10.42%	8.33%	16.67%	12.50%	6.25%	6.25%	6.25%	8.33%
SS	8.33%	8.33%	8.33%	8.33%	6.25%	6.25%	6.25%	6.25%	6.25%	6.25%

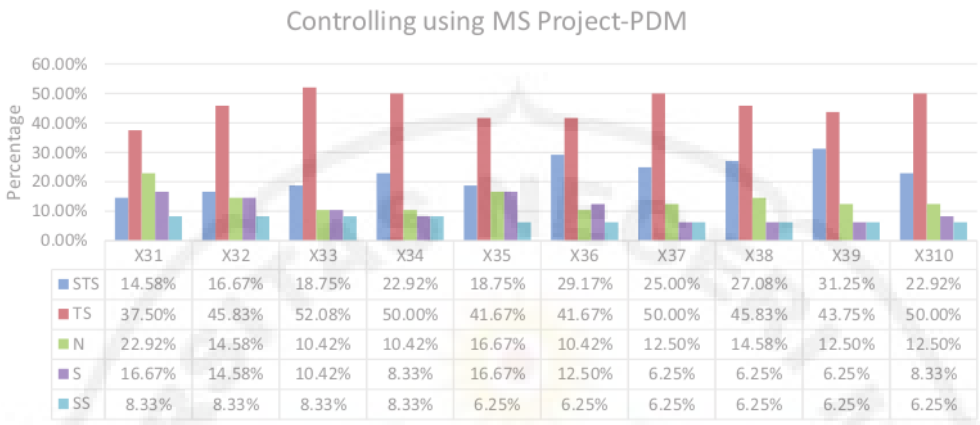
Figure 4. Project control using S-curve/bar chart relating to the questions in Table 2. STS, strongly disagree; TS, disagree; N, neutral; S, agree; SS, strongly agree.

MS Project–PDM project control (Figure 5)

Concerning the distribution of answers to ten questions on using the MS Project-PDM method for project control, respondents dominantly chose 'strongly agree' (62.50%), while 'strongly disagree' recorded 0%. Very few respondents chose 'disagree', ranging from 4.17-6.25%. With respect to responses to questions about the use of the MS Project-PDM in project control, the largest number of respondents (62.50%) chose the 'strongly disagree' option for X48, while none chose 'strongly agree' (0%).

Comparison of use the of S-curve and MS Project-PDM in scheduling projects

Some construction managers still use S-curve/bar chart as a tool to bid for projects (43.75%). However, in the future, S-curve/bar chart would no longer be used as a tool for project scheduling. Moreover, regarding the use of MS Project-PDM in scheduling, most respondents agreed with the questions, but there were questions that had the highest number of positive responses, including X29 (81.25%) and X28 (75%). X29 states that in the MS Project-PDM scheduling, the critical path is known. This is very important for construction managers because the critical path is a path whose activities need attention; if the activity on the critical path is delayed, it will affect the next activity and the project will experience delays. X28 states that the MS Project-PDM scheduling will show activities that have free time (free float), which means that even though the assigned duration of the activity is 5 days, if it is not completed within 5 days, the project will not experience delays. However, on the S-curve/bar chart, if the work time is not as scheduled, the project will experience delays.



	X31	X32	X33	X34	X35	X36	X37	X38	X39	X310
STS	14.58%	16.67%	18.75%	22.92%	18.75%	29.17%	25.00%	27.08%	31.25%	22.92%
TS	37.50%	45.83%	52.08%	50.00%	41.67%	41.67%	50.00%	45.83%	43.75%	50.00%
N	22.92%	14.58%	10.42%	10.42%	16.67%	10.42%	12.50%	14.58%	12.50%	12.50%
S	16.67%	14.58%	10.42%	8.33%	16.67%	12.50%	6.25%	6.25%	6.25%	8.33%
SS	8.33%	8.33%	8.33%	8.33%	6.25%	6.25%	6.25%	6.25%	6.25%	6.25%

Figure 5. Project control using MS Project-PDM relating to the questions in Table 2. STS, strongly disagree; TS, disagree; N, neutral; S, agree; SS, strongly agree.

The t value is 15.516> t table, 2,660. Therefore, the observed mean difference (mean value) is significant at 1% significance level. Thus, the use of MS Project-PDM is more effective than the S-curve/bar chart method in scheduling building construction projects.

Comparison of the use of S-curve/bar chart and MS Project-PDM in controlling projects

Regarding the use of S-curve/bar chart in controlling projects, very few respondents agreed that it can be used as a control tool. Of the ten questions, 37.50% to 52.08% of respondents chose the 'disagree' option, while 6.25% to 8.33% chose the 'strongly agree' option, meaning that the respondents actually answered that the S-curve/bar chart cannot be used as a control tool in a construction project. However, concerning the MS Project-PDM, 52.08-62.50% of respondents chose 'strongly agree', while 4.17-6.25% chose 'disagree'. This means that MS Project-PDM is an accurate tool for project control according to the respondents, who stated that it is the right tool for carrying out strategies and making decisions in case of delays. In addition, this method can quickly change the schedule if there is a delay or deviation of work, and it can also detect or control the costs used in completing a task.

The t value is 17.233> t table, 2.660. Therefore, the observed mean difference (mean value) is significant at 1% significance level. Thus, the use of MS Project-PDM method is more effective than the S-curve/bar chart method in controlling building construction projects.

Conclusions

This study concludes that the use of the MS Project-PDM is more effective than the S-curve/bar chart method in scheduling and controlling building construction projects. Knowing the critical path is needed by construction managers so that work delays do not occur. The critical path will be known if the construction manager uses MS Project-PDM in scheduling. Furthermore, the use of MS Project-PDM is effective in controlling delays and work deviations that occur; the schedule can be quickly changed so that work delays are resolved properly.

Data availability

Figshare: Supplementary Data for Comparative Study on the Use of S Curve-Bar Chart and Ms Project-PDM Methods in Scheduling and Controlling Building Construction Project, https://doi.org/10.6084/m9.figshare.14059202.v2.[16]

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