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ANALYSIS OF THE SUCCESS OF A CONSTRUCTION PROJECT WITH REGARD TO THE S-CURVE

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Abstract

This research is an attempt to show the relationship between construction project success and the position of the mean of a planned S-curve by comparing a planned S-curve and an earned S-curve. The analysis has been performed on 44 buildings within a residential and business complex located at the Stepa Stepanovic barracks in Vozdovac, Belgrade, in the Republic of Serbia. We have taken the completion date as the criterion for a successful project, i.e. was the project finished on time, in accordance with the agreement and planned schedule, or was it finished with a delay? The results have shown that the planned and earned S-curves differ significantly due to ineffective planning, as well as a predicted increase of 1.129 months in the actual duration of the project execution for every month of the planned execution. Also, all of the projects that were executed behind schedule had the S-curve mean positioned above the S-curve. According to the results, we suggest that an early check on the position of the planned S-curve mean ought to take place.

Keywords

Duration of construction projects; earned cash flow; mean of S-curve; planned cash flow; S-curve

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1 INTRODUCTION

The basic element in the financial calculation of construction works is the unit price within the bill of quantities. The unit price comprises labour costs, material, machine costs, and other direct and indirect costs. Interconnecting costs with single work activities enables the creation of time-cost relations. Connecting costs and time is a very important component of the planning process. Developing an acceptable project schedule is often an iterative process [1].

Earned value management and earned schedule metrics play an important role in project control by measuring the deviation between planned and earned performance in terms of cost and time [2]. A typical tool for cost control is the cumulative S-curve [3, 4]. It can help us understand the correlation between project duration and budget expenditures, while providing us with a good sense of where the highest levels of budget spending are likely to occur [3]. It is essential to plan for cash flow in all phases to ensure a successful and profitable project [4, 5].Whether a project will be a success by the time it is completed is often determined before it has even started [6]. When detailed information for a project is available, the traditional approach to the S-curve estimation is analytical and based on a schedule of planned activity times [7].

2 LITERATURE REVIEW

We have performed a search of scientific journals and magazines using the Library Consortium of the Republic of Serbia and the EBSCO Discovery Service. The keywords used were the following: S-curve, construction projects, project management and S-curve forecasting. Secondly, we applied the following criteria in order to narrow our search and to gain a sample of relevant articles for our research:

- Full text articles
- Texts in English
- Time frame is limited to the current year (2016)
- Source type is academic journal

The literature selection has been widened by a selection of the books relevant to the subject matter, which are necessary in order to establish the theoretical background for the case study research.

Many authors [8] would agree with the statement that the success of a construction project is complex, while others [1] advocate that the success of a project is measured by project quality, timeliness, budget compliance and the degree of customer satisfaction. Three most important performance indicators for construction projects when measuring project success are time, cost and quality. The assessment of quality is rather subjective and, within the construction industry, it is defined as the totality of features [8].

Construction delays are often responsible for turning profitable projects into loss-making ventures. These delays can be avoided or reduced provided that the major causes of such delays can be identified and dealt with in a timely fashion [9]. After analysing factors affecting delays, it appears that the main causes of time overruns on construction projects were identified as (1) lack of commitment, (2) inefficient site management, (3) poor site coordination, (4) improper planning, (5) lack of clarity regarding the project scope, (6) lack of communication and (7) substandard contract [10].
According to experts, ineffective planning by the contractor is one of the main reasons that influences the delay [11].

According to Sweis et al. [9], the major causes of delay in residential construction projects are the poor planning and scheduling of the project. Both the owner and the consultant share this view.

3 METHODOLOGY

The core documentation for the research has been acquired from the Building Directorate of Serbia and relates to the construction of 44 buildings in a residential and commercial building complex at the Stepa Stepanovic barracks in Belgrade, Serbia.

For the purpose of this research, we have performed document data retrieval and collected the following information for 34 of the 44 buildings in the aforementioned complex:

- Baseline schedule, which is the first planned schedule approved by the investor, i.e., the Building Directorate of Serbia
- Cash flow with the S-curve, as part of the approved baseline schedule, or the one created for it
- Construction contract together with all appendices (where applicable)
- Monthly payment certificates and the final payment certificate

The complex covers an area of 42.31ha. There are 44 buildings, the structure of which comprises a ground floor, six upper floors and a setback floor. The total number of apartments is 4,578, while the number of commercial office units is 148. The total gross area of the buildings is 441,000 m^2.

We have tried to collect all the above-listed documentation for each of the buildings. In line with the detailed investigation into the available documentation, we have collected the following information and stored them on an Excel spreadsheet for further use:

- Planned duration of the execution of works
- Actual duration of the construction works
- Planned monthly costs/building (cash flow)
- Earned monthly costs/buildings (cash flow)
- Planned S-curve (cumulative planned cash flow)
- Earned S-curve (cumulative earned cash flow)

For the statistical analysis of the collected data and its visual presentation, we have used Minitab 17.1.0 and SPSS Statistics 23.

4 RESULTS AND DISCUSSION

In order to impose tighter control over the execution of the project and be able to react on time where there is slippage, the investor, the Building Directorate of Serbia, has introduced an article into each of the construction contracts, setting limits for penalties in such an eventuality. First, the approved planned schedule and its financial histogram, as well as the S-curve as a cumulative histogram, become an integral part of the construction contract.

Most of the contractors violated the contract in terms of being behind schedule two months in a row, as shown in Figure 1.

Fig. 1: Chart of Execution [12]

The majority of buildings were finished behind schedule, while a small percentage were finished on time; for others, however, it was not possible to determine the duration (N/A on the chart in Figure 2) because some of the data were not available.

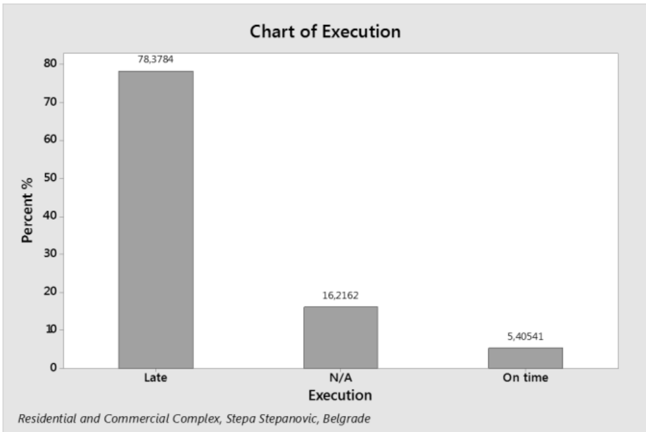


Fig. 2: Chart of Execution [12]

4.1 Definition of the S-curve Mean

Focusing on geometrical elements in order to estimate an S-curve is not a new idea. The shape of the cumulative S-curve is defined by the growth of expenditures, which are initially low and increase rapidly during the major project execution stage, before starting to level off again as the project gets nearer to completion [3]. Some authors [7] have investigated the slope and position of the inflection point, while we focused on the position of the financial distribution mean, which is plotted in the middle of the project, in terms of both time and costs.

For the purpose of this research, we have defined the mean of financial cost distribution as the point determined by two components. The mean has been plotted on the same graph as the S-curve. On the *x*-axis, we plot time in months and on the y-axis we plot costs. Following this logic, the mean of financial distribution is a dot mean (*x*,*y*), whereas:

$$x = \frac{t_{total}}{2}$$
$$y = \frac{c_{total}}{2}$$

t_{total} – total project duration (days)
c_{total} – total costs (currency units) (1)

Its position can be above, under or on the S-curve. As shown in [13], a good investment is when the mean of financial investment is under or on the S-curve; otherwise, it is not a good investment. Figure 3 presents an example of an S-curve and the position of the corresponding mean for one of the buildings in the Stepa Stepanovic complex.

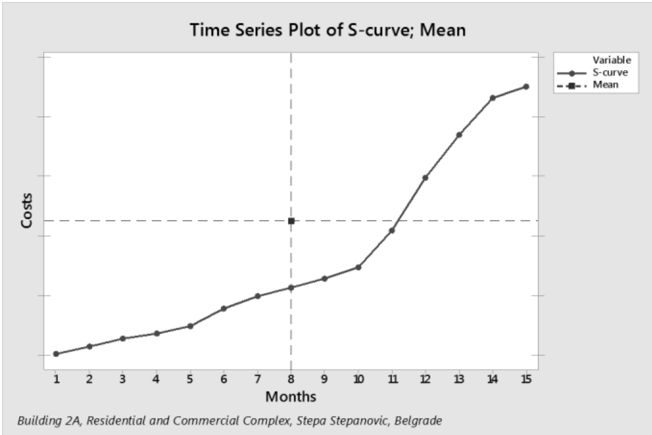


Fig. 3: S-curve and Mean [12]

4.2 Position of the Mean of the Planned S-curve vs. the Earned S-curve

A paired sample t-test was conducted to compare the position of the mean of financial distribution of the planned baseline S-curve and the mean of the earned S-curve. We have checked for unusual paired differences, as they can have a strong influence on the results. There were no unusual paired differences found. We also checked for normality. As our sample size is 34, normality is not an issue, and the test is accurate with non-normal data. The sample size is sufficient to detect the difference between the planned mean and the earned mean.

The results in Table 1 show that there was a significant difference in the scores for the planned mean (M=113.35, SD=15,693) and the earned mean (M=97.477, SD=14.774) conditions; t(33)=7.359, p = 0.000. Graphical presentation of the variables is on the Figure 4.

Tab. 1: Paired Sample T-test for Planned Mean vs. Earned Mean

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Planned Mean	113.3521	34	15.69346	2.69141
	Earned Mean	97.4774	34	14.77387	2.53370

As the p-value is less than 0.05 (p=0.000), we can conclude that the planned mean differs significantly from the earned mean at a 0.05 level of significance.

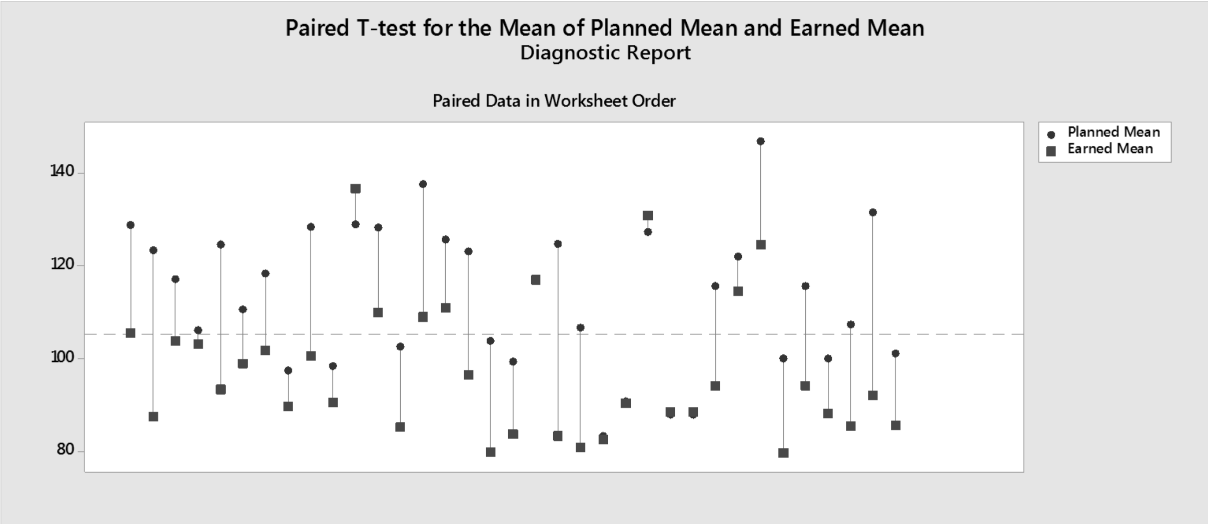


Fig. 4: Mean of Planned S-curve vs. Mean of Earned S-curve [12]

The planned and earned S-curves differ significantly due to ineffective planning, as it was found that the construction schedule for the buildings in this complex were completed in a very short time (less than seven days), mostly by a single person and without the use of construction norms [14].

In order to determine how much the planned mean differs from the target of 100, a one-sample t-tests was performed. The planned mean scores were normally distributed, as assessed by the Anderson-Darling test ($p>0.05$); there were also no outliers in the data, as assessed via an inspection of a box plot. In total, 34 observations were made, which sufficient in order to adequately represent the distribution of data. The lowest position of the planned mean of financial investment is at 83.33% of the theoretical mean. The mean with the biggest distance from the S-curve is at 46.9% above the S-curve.

The one-sample t-test was sufficient to detect a difference between the mean and the target. The distribution of data is bimodal. The planned mean score was statistically significantly higher by 13.35% (95% CI, 7.78 to 18.83) than the target mean of 100; $t(33)=4.961$, $p=0.000$.

4.3 Planned Duration vs. Earned Duration

Furthermore, we have examined the relationship between the planned duration of the project and the actual duration. With regard to the planned duration, information was taken from the construction contract, while the actual duration was calculated based on the monthly payment certificates and the final certificate. Several assumptions have been made in order to use regression as a statistical tool. The dependent variable is the actual duration of the project and the independent variable is the planned duration of the project. Both of them are continuous variables. A scatter plot was created to check for a linear relationship between the dependent and independent variables. The Durbin-Watson test was used to detect possible autocorrelation. There was an independence of residuals, as assessed by a Durbin-Watson statistic of 1.153 (Table 2). There was homoscedasticity, as assessed by the visual inspection of a plot of standardized residuals vs. standardized predicted values. Residuals were normally distributed, as assessed by the visual inspection of a normal probability plot.

Tab.2: Mean of Planned S-curve vs. Mean of Earned S-curve

Model Summary[b]

Model	R	R-square	Adjusted R-square	Std. Error of the Estimate	Durbin-Watson
1	0.712[a]	0.507	0.492	2.23586	1.153

a. Predictors: (constant), planned

b. Dependent variable: actual

The average planned duration accounted for 50.7% of the variation in the actual duration of the project execution, while the adjusted R^2=49.2%, which is a large size effect according to Cohen [15].

The regression model (Table 3) is statistically significant; $F(1, 32)=32.906$, $p<0.0005$. It is statistically significant because $p<0.0005$. A statistically significant result also indicates that there is a statistically significant linear relationship. The average planned duration of the project predicted, with statistical significance, the actual duration of the project; $F(1, 32)=32.906$, $p<0.0005$.

Tab. 3: Regression Model for Actual and Planned Duration

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	164.500	1	164.500	32.906	0.000[b]
	Residual	159.970	32	4.999		
	Total	324.471	33			

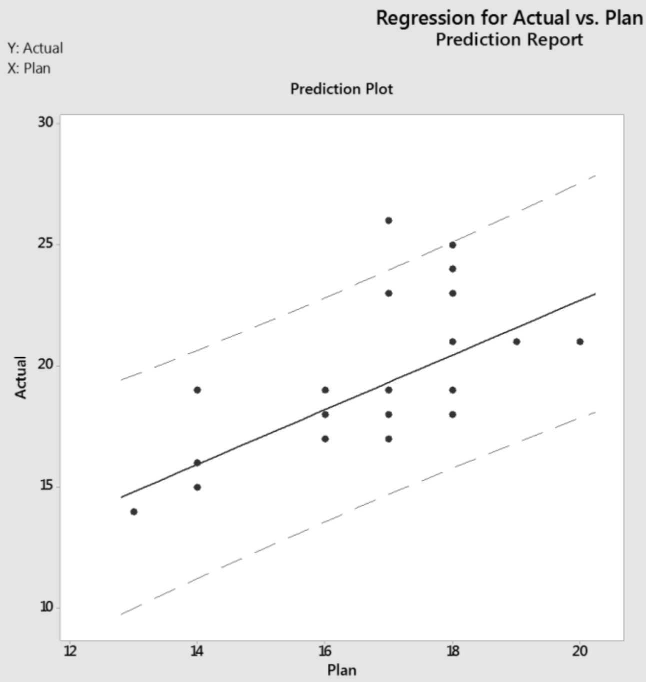
The intercept or the constant is not statistically significant, but the slope is (Table 4). The slope coefficient represents the change in the dependent variable for a one-unit change in the independent variable.

Tab. 4: Coefficients – Dependent Variable: Actual

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95,0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	0.134	3.230		0.041	0.967	-6.445	6.712
	Planned	1.129	0.197	0.712	5.736	0.000	0.728	1.530

We notice that there is a predicted increase in the actual duration of the project execution of 1.129 months for every month of the planned execution (Figure 5).



X	Predicted Y	95% (PI)
12,8	14,585	(9,7562; 19,413)
13,11	14,935	(10,141; 19,728)
13,42	15,285	(10,522; 20,047)
13,73	15,635	(10,901; 20,368)
14,04	15,985	(11,276; 20,693)
14,35	16,335	(11,648; 21,021)
14,66	16,685	(12,018; 21,352)
14,97	17,034	(12,383; 21,686)
15,28	17,384	(12,746; 22,023)
15,59	17,734	(13,105; 22,364)
15,9	18,084	(13,461; 22,708)
16,21	18,434	(13,814; 23,055)
16,52	18,784	(14,163; 23,406)
16,83	19,134	(14,509; 23,760)
17,14	19,484	(14,851; 24,118)
17,45	19,834	(15,190; 24,478)
17,76	20,184	(15,526; 24,842)
18,07	20,534	(15,859; 25,210)
18,38	20,884	(16,189; 25,580)
18,69	21,234	(16,515; 25,954)
19	21,584	(16,838; 26,331)
19,31	21,934	(17,158; 26,711)
19,62	22,284	(17,475; 27,094)
19,93	22,634	(17,789; 27,480)
20,24	22,984	(18,100; 27,868)

Residential and Commercial Complex, Stepa Stepanovic, Belgrade

Fig. 5: Prediction Plot for Actual Duration and Planned Duration [12]

5 CONCLUSION

According to the results of this research, we can conclude that the planned and earned S-curves differ significantly for the residential construction projects executed within the Stepa Stepanovic complex as a result of ineffective planning. The construction schedules for the buildings in this complex were completed in a very short time (less than seven days), mostly by a single person and without the use of construction norms.

In addition, with regard to the construction project of the residential and business complex at the Stepa Stepanovic barracks, there is a predicted increase in the actual duration of the project execution of 1.129 months for every month of the planned execution.

All of the projects that exceeded the work execution deadline had, on average, a *y*-component of the planned S-curve mean of 13.35% above the targeted mean. The planned S-curve mean is thus positioned above the S-curve.

In order to increase the probability of finishing the construction project on time, we suggest that an early check on the position of planned S-curve mean takes place.

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