Proceedings of 2013 International Conference on
Technology Innovation and Industrial Management
29-31 May 2013, Phuket, Thailand

EVALUATING ACCURACY OF A TIME ESTIMATOR IN A PROJECT

Thanh-Lam Nguyen, Graduate Institute of Mechanical and Precision Engineering
National Kaohsiung University of Applied Sciences, Kaohsiung 80778, Taiwan

Wei-Ju Hung, Department of Industrial Engineering and Management
National Kaohsiung University of Applied Sciences, Kaohsiung 80778, Taiwan

Ming-Hung Shu, Department of Industrial Engineering and Management
National Kaohsiung University of Applied Sciences, Kaohsiung 80778, Taiwan

Lin-Ying Hsu, Department of Industrial Engineering and Management
National Kaohsiung University of Applied Sciences, Kaohsiung 80778, Taiwan

Yueh-Hung Yeh, Department of Industrial Engineering and Management
National Kaohsiung University of Applied Sciences, Kaohsiung 80778, Taiwan

ABSTRACT

Purpose: *Each activity in a project must be clearly defined and specified with when to start, how much time is required for completion and when to finish. It is vital that the time estimates for each work obtained be realistic in order to produce a good schedule for meeting deadlines and avoiding unnecessary project costs. This paper aims at evaluating the effectiveness and accuracy of the time estimator.*
Design/Methodology/Approach: *As tracking signal, a widely used method in forecasting domain, has alarming ability in detecting structural changes in time series by responding to out-of-control signals, it is, therefore, strongly suggested to be employed in monitoring the time estimation of critical tasks, through which the effectiveness and accuracy of the time estimator is accordingly evaluated.*
Findings: *In this paper, it was found that although the total time of a project was well estimated and met, the quality of the time estimation was still not good enough. Therefore, the estimator must take special attention to assign more realistic time and more appropriate personnel in the critical tasks that were detected out-of-control. By doing this way, he/she can perform his/her job better and get to know the employees better and better.*
Originality/Value: *Though tracking signal has been widely used in monitoring the performance of a forecasting model, it is the first time in this paper that it is addressed to be used in evaluating the accuracy of a job performance.*

Keywords: Time estimation, accuracy evaluation, monitoring critical tasks

INTRODUCTION

Project management in the business and industry fields is defined as managing and directing time, materials, personnel and costs to complete a particular project in an orderly economical manner and to meet established objectives of time, cost and technical results (Spinner, 1992). The management usually involves in using one or several techniques such as network planning, cost analysis, personnel allocation, and management by objectives, etc. Among them, network planning has been considered the most popular (Spinner, 1992). Usually being used to plan, schedule and control a project consisting of a group of interrelated activities, network planning is especially useful for those projects which have a well-defined starting point and a well-defined objective. It has several applications in practice, for example, construction projects, administrative programs, maintenance operations and any other series of activities that, when combined, can form a complete program with a start and a finish (Spinner, 1992).

There are three phases in the project management cycle: planning, scheduling and control. In planning phase, it is critical to determine what activities must be done in completing a project, their sequence and interrelations which are then often presented on an arrow diagram; whereas, in the scheduling phase, timing aspects of each work are carefully considered. Each activity must be specified with when to start, how much time is required for completion and when to finish. It is vital that the time estimates for each work obtained be realistic in order to produce a good schedule for meeting deadlines and avoiding unnecessary project costs. The time estimates can be either done along with the initial diagram to make proper adjustments based on pre-defined objectives or modified after the project begins to identify if there is a delay in the work that will extend the duration of the project or the work is progressing faster than expected.

The network diagram normally uses a single time for each work. The time estimate, usually determined by an experienced person, is the amount of time that the work will require under a specified set of conditions. As suggested based on personal experience, the estimate is usually biased and may be higher. In order to offset this bias, three time estimates, including optimistic, normal and pessimistic, are used to create one time estimate as per the equation (1).

$$Time\ estimate = \frac{Optimistic\ time + 4 * Normal\ time + Pessimistic\ time}{6} \quad (1)$$

Normal time is the time that would be most frequently required if the work were repeated many times under the similar conditions. While optimistic time is the shortest possible time required for completing a work under the assumption that everything goes one as planned, for instance, material deliveries are on time as scheduled, machines operate without major breakdowns, personnel perform work within work standard, etc., pessimistic time is the maximum possible time required for completing the work in the worst situations; particularly, delayed deliveries, accidents, bad weather, and so on (Spinner, 1992).

Spinner (1997) pointed out that the three-estimate approach can cause the expected time to be biased toward the pessimistic time which is usually overly pessimistic; thus, the method is used only when the results from one time estimate are probably unrealistic.

Once a project is carefully planned and scheduled, monitoring its activities is of importance to keep it under control. By comparing the start and finish schedule with the actual performance, certain warning signals may arise for further investigation and corrective actions. Some activities may be behind schedule and some may be ahead. In order to compensate the lateness in some activities to keep the project on target, there is frequently an effort to adjust the timing of other critical ones which may lead to a certain revision of the entire project plan depending on the severity of the timing problem. However, when critical jobs are finished ahead of schedule, future critical ones need checked and rescheduled if required. These are the fundamentals of monitoring a project performance. Therefore, it can be said that good estimates reflect not only the capability and level of experience of the in-charge person but also his/her level of knowing the actual ability of the employees' performance and result in less adjustment in the schedule during the project cycle. But, there has hardly been any research in evaluating how good the time estimates for the whole project are as well as how efficient the performance of the employees is. Thus, this paper aims at using tracking signals to evaluate the effectiveness and accuracy of the estimator in terms of assigning time estimates.

This paper is organized as the following. Section 2 discusses the use of tracking signals. An empirical study is presented in Section 3 to illustrate the applicability of tracking signals. Conclusion makes up the last section.

REVIEWS ON TRACKING SIGNAL

In monitoring the forecast errors, tracking signal is usually employed due to its alarming ability in detecting structural changes in time series by responding to out-of-control signals (Snyder and Koehler, 2006). Providing accurate and unbiased estimate is the ultimate endeavor of any forecasting issues (Wisner et al., 2008; Chary, 1995). Inaccurate and/or biased estimate is one of the main factors making substantial increase in both operational and opportunity costs to the involved organizations that use the forecast result being significantly different from the actual figure. Forecast error is actually the difference between the observed and the forecast as expressed in equation (1).

$$\varepsilon_t = OV_t - FV_t \tag{1}$$

where ε_t, OV_t and FV_t respectively denote the forecast error, the observed value and the forecast value at the period t.

Forecast bias, the tendency of a forecast to be consistently higher or lower than the actual can be expressed in cumulative forecast error (CFE) and mean absolute deviation (MAD), shown in equation (2). They are two among several indexes usually used to measure the forecast accuracy (Wisner et al., 2008).

$$\begin{aligned} CFE_t &= \sum_{i=1}^{t} \varepsilon_i \\ MAD_t &= \left(\sum_{i=1}^{t} |\varepsilon_i| \right) / t \end{aligned} \tag{2}$$

The ratio between CFE and MAD is named as tracking signal (TS) which was developed by Page (1955). It is a widely used tool to check the forecast bias (Wisner et al., 2008; Wallace and Stahl, 2002). Several scholars have thoroughly accessed and improved it (Gardner, 1985; Li et al., 2012). Brown (1959) suggested a new definition of the tracking signal by defining it as the quotient between the simple cumulative sum of errors and the simple smoothed MAD. The Brown's tracking signal (BTS), given in equation (3), is commonly employed in practice nowadays (Li et al., 2012).

$$BTS_t = CFE_t / SMAD_t \quad (3)$$

where $SMAD_t = \alpha|\varepsilon_t| + (1-\alpha)SMAD_{t-1}$ denotes the simple smoothed MAD at the period t. In the denotation, α is a smooth parameter $(\alpha \in [0,1])$ and the initial value SMAD is assumed to be zero (Chary, 1995).

By using tracking signal, forecast errors can be efficiently monitored with a control chart with two control limits (upper and lower) which represent the track where the errors should go (Mele et al., 2001). If a signal falls outside the control limits, the forecast is considered biased, either under or over-estimated (Li, 2007; Chary, 1995); hence, further investigation is needed (Wisner et al., 2008). Ideally, the value of tracking signal is either zero or close to zero (Stevenson, 2005; Khanna, 2007). With these characteristics, tracking signal is, therefore, strongly suggested to achieve the objective stated previously. The control limits under the method are set as the following.

Under the Brown's method, with the assumption that the errors are normally distributed with a mean of 0 and a standard deviation of σ, the relationship between σ and MAD is given by $\sigma \approx 1.25MAD$ (Lawrence et al., 2009). As such, if the control limits for BTS are set at ± 3.75 which is equivalent to $\pm 3\sigma$, the probability of an out-of-control signal is only 0.27% (Montgomery, 2009). Practically, the value of the control limits ranges from ±4 to ±8 be considered acceptable in some particular circumstances (Li, 2007; Wisner et al., 2008).

This approach can be employed in various applications. As an example, in this paper, it is used to evaluate the accuracy of the time estimator in a project.

EMPIRICAL STUDY

In our study, we followed a specific project at a well-known company which specializes in manufacturing electronic devices in Kaohsiung industrial park, Taiwan. Its research and development (R&D) department is in charge of not only improving the performance of its current products but also searching for, designing and testing new products. Because several functions of an organization concurrently are obligated with the planning and implementation of research and development projects and basic scientific researches as well as the execution of the clients-commissioned technical services responsible for internal and external customers, the majority of the members are in charge of a different proportion of research and development projects, basic scientific researches and technical service tasks. There is only one leader who assigns the in-charge person with time estimation for each task. He is called time estimator. Due to the fact that R&D department is in charge of various activities, whose execution time can be as short as a few hours or as long as up to three months or more, the time estimator sometimes has some errors in his estimation. In order to improve his capability and working experience in the time estimation, it is quite important to track the accuracy of his estimation. Therefore, we suggest using the tracking signals to detect any abnormal situation where his estimation is significantly different from the actual observation.

In the project, there were 20 critical tasks to be conducted within 240 hours. Each of the tasks was expected to be completed within "expected time" as shown in Table 1. However, due to the knowledge and skills of the engineers, some tasks were finished sooner but some were later than expected. The actual completion time of each task is named as "observed time", also shown in Table 1. In this paper, for the ease of comparison the performance of the tracking signal under different α values, we consider it under the α values of 0.20, 0.25 and 0.30. The relevant values are plotted on a control chart with the control limits of ±3.75 as shown in figure 1.

Table 1. Tracking signals under different α values

Task No.	Expected time *(hours)*	Observed time *(hours)*	ε	CFE	α = 0.20		α = 0.25		α = 0.30	
					SMAD	BTS	SMAD	BTS	SMAD	BTS
1	4	4	0	0	0.00		0.00		0.00	
2	11	10	1	1	0.20	5.00	0.25	4.00	0.30	3.33
3	7	10	-3	-2	0.76	-2.63	0.94	-2.13	1.11	-1.80
4	10	12	-2	-4	1.01	-3.97	1.20	-3.32	1.38	-2.90
5	4	6	-2	-6	1.21	-4.97	1.40	-4.28	1.56	-3.84
6	9	6	3	-3	1.57	-1.92	1.80	-1.67	1.99	-1.50
7	18	18	0	-3	1.25	-2.40	1.35	-2.22	1.40	-2.15
8	26	23	3	0	1.60	0.00	1.76	0.00	1.88	0.00
9	8	12	-4	-4	2.08	-1.92	2.32	-1.72	2.51	-1.59
10	14	12	2	-2	2.07	-0.97	2.24	-0.89	2.36	-0.85
11	20	16	4	2	2.45	0.82	2.68	0.75	2.85	0.70
12	12	14	-2	0	2.36	0.00	2.51	0.00	2.60	0.00
13	5	10	-5	-5	2.89	-1.73	3.13	-1.60	3.32	-1.51
14	15	18	-3	-8	2.91	-2.75	3.10	-2.58	3.22	-2.48
15	12	10	2	-6	2.73	-2.20	2.82	-2.12	2.86	-2.10
16	8	10	-2	-8	2.58	-3.10	2.62	-3.05	2.60	-3.08
17	20	22	-2	-10	2.47	-4.05	2.46	-4.06	2.42	-4.13
18	15	14	1	-9	2.17	-4.14	2.10	-4.29	1.99	-4.51
19	10	8	2	-7	2.14	-3.27	2.07	-3.38	2.00	-3.51
20	12	5	7	0	3.11	0.00	3.31	0.00	3.50	0.00
Total	240	240								

Based on the tracking signals in Table 1 and Figure 1, there are five, four and three out-of-control points detected, respectively to the α values of 0.20, 0.25 and 0.30. Although the total project time was strictly met, the estimation was not really good enough. The estimator should pay more attention to the characteristics of each task and assign appropriate engineers to perform the task efficiently. Furthermore, it is easily found that the smaller value of α, the smoother the tracking curve and the more out-of-control signals. Hence, it is suggested that if the estimator is qualified as really experienced, we should set the α value small so that it can give more tolerance of the abnormal estimation; whereas, larger α value is more suitable for senior estimator.

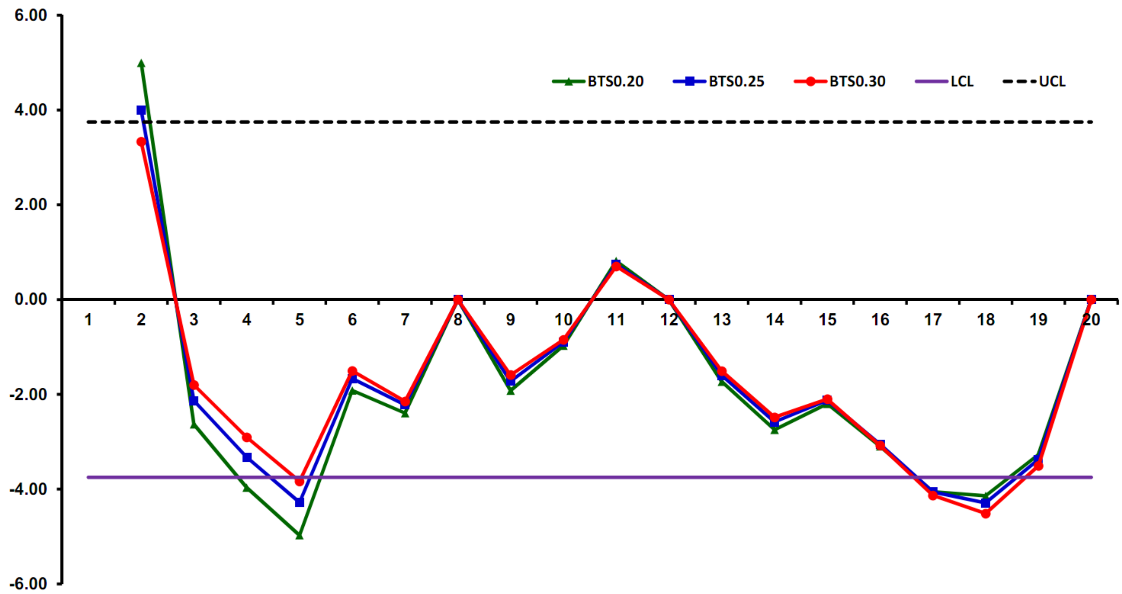

Figure 1. Tracking signals under α values 0.20, 0.25 and 0.30

CONCLUSION

Keep track on the time performance of employees in a project is critical because any out-of-control issue will affect the whole timeline of the project. There are some circumstances where the employees already try their best but they still can't meet the time target and there are other ones where they can easily achieve the set goal. These happen because of the inaccuracy of the time estimation and personnel assignation given by an estimator and/or his/her shortage in well knowing the actual capability of the employees. In order to evaluate the effectiveness and accuracy of the estimator in performing his job, it is suggested that we should keep monitoring the time estimation of critical tasks by using tracking signal method. In this paper, with a practical example, it is found that although the total time of a project is well estimated and met, the quality of the time estimation is still not good enough. Therefore, the estimator must take special attention to assign more realistic time and more appropriate personnel in the critical tasks that were detected out-of-control. By this way, he/she can perform his/her job better and get to know the employees better and better.

REFERENCE

1. Brown, R.G. (1959), Statistical forecasting for inventory control, McGraw-Hill, New York.
2. Chary, S.N. (1995), Theory and Problems in production operation management, Tatt McGraw-Hill Education, New Delhi.
3. Gardner, E.S. (1985), "Exponential smoothing: State of the art", Journal of Forecasting, Vol. 4, pp. 1-28.
4. Khanna (2007), Production and Operations Management, PHI Learning, New Delhi.
5. Lawrence, K.D., Klimberge, R.K. and Lawrence, S.M. (2009), Fundamentals of forecasting using excel, Industrial Press, New York.
6. Li, L. (2007), Supply chain management: Concepts, Techniques and practices, World Scientific, Singapore.

7. Li, Y., Lange, M. and Stocks, C. (2012), "Monitoring forecasting systems- Revisit Trigg's tracking signal", paper presented at the 32nd Annual International Symposium on Forecasting (ISF2012), Boston, USA, available at: http://www.forecasters.org/proceedings12/LiYikangISF2012.pdf (accessed 25 January, 2013).
8. Mele, M., Secchiari, P., Serra, A., Ferruzzi, G., Paoletti, F. and Biagioni, M. (2001), "Application of the 'tracking signal' method to monitoring of udder health and oestrus in dairy cows", Livestock Production Science, Vol. 72, pp. 279-284.
9. Montgomery, D.C. (2009), Introduction to Statistical Quality Control, Wiley, Asia.
10. Page, E.S. (1995), "A test for change in a parameter occurring at an unknown point", Biometrica, Vol. 42, pp. 523-527.
11. Snyder, R.D. and Koehler, A.B. (2006), "Incorporating a tracking signal into state space models for exponential smoothing", working paper 16/06, Monash University, Australia.
12. Spinner, M.P. (1992), Elements of Project management: Plan, Schedule and Control, Prentice-Hall, New Jersey.
13. Spinner, M.P. (1997), Project Management: Principles and Practices, Prentice-Hall, New Jersey.
14. Stevenson, W.J. (2005), Operations management, McGraw-Hill/Irwin, New York.
15. Wallace, T.F. and Stahl, R.A. (2002), Sales forecasting: A new approach, T.F. Wallace & Co, Ohio.
16. Wisner, J.D., Tan, K.C. and Leong, G.K. (2008), Principles of supply chain management: A balanced approach, Cengage Learning, Ohio.