

## KPIs Target Adjustment Based on Trade-off Evaluation Using Fuzzy Cognitive Maps

Ibrahim Y Sokar, Md. Yusoff Jamaluddin, Mardina Abdullah, Zayed Alarabi Khalifa

Department of Electrical, Electronics and System Engineering Universiti Kebangsaan Malaysia, Malaysia.

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**Abstract:** Continued improvement of performance has become a real challenge for most companies and organization. This paper presents a framework using Fuzzy Cognitive Maps (FCM) method to quantitatively analyze the influence and relationship among the KPIs used to monitor performance. The proposed method can help the top management and decision-makers to identify the improvement behavior of one Key Performance Indicator (KPI) target on the other KPIs and in the Performance Management System (PMS) as whole. A different scenario was conducted in one of the engineering organizations to analyze the interconnections between the KPIs and the impact of changing the targets. Fuzzy Cognitive Maps have been fruitfully used in decision making and simulation of complex PMS and help the management in order to adjust targets of performance.

**Key word:** KPIs; fuzzy cognitive maps; PMS; trade-off.

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### INTRODUCTION

Key Performance Indicators (KPIs) is an important management tool in a complex and competitive business environment which is designed to measure the organization's defined strategic objectives and whether the objectives have been achieved (accomplished) or otherwise. However, according to management experts, a real performance not only seeks to achieve the defined target but to extend those targets within a reasonable time frame and accomplish them. One of the greatest shortcomings in the domain of performance measurement today is that few people are actively exploring the issue of how the evolution of performance measurement systems can be managed over the long term (Neely 1999).

Generally KPIs describe how far a metric is above or below a pre-determined target. KPIs usually are presented as a ratio of actual achievement to the target and are designed to directly allow the managements to know if they are on or out of their plan without having to consciously focus on the metrics being represented. Organization should identify these KPIs and expected level of performance (goals, targets) for these measures (Dolence and Norris 1994). Intensive study has been conducted regarding Performance Measurement System (PMS) and KPIs defined within the PMS. Despite the importance and the popularity of the KPIs in any organization and firm's performance measurement, there are still critical issues requiring further research. One of the critical issues identified from the literature is the trade-off relationships that exist among the KPIs. Recently, FCM have been widely used in a variety of application such as political decision making Andreou *et al.* (2005) fault detection Peláez and Bowles (1996) process control Groumpos (2000) data mining in internet Lee *et al.* (2002) medical decision system Papageorgiou *et al.* (2003) modelling LMS critical success factors (Salmeron 2009). Xiao *et al.* (2011) used FCM to solve the supplier selection problem.

In this research, the relationships among the KPIs are addressed where the method of Fuzzy Cognitive Maps (FCMs) was used to compute and analyze the relationships that exist among the KPIs. Organizations and performance measurement experts often ignore or do not take into consideration the cause-and-effect or interdependencies among those KPIs. Only a few researches have been penetrative enough and able to identify the relationships that exist among the KPIs. Alisha (2003) for example, used Multi-Attribute Utility (MAU) to identify the trade-off between performances metrics defined within the PMS. However, it is important to realize that the use of MAU and correlation in the analysis is limited since it considers pairs of KPIs instead of analyzing all the KPIs at the same time. Kung *et al.* (2007) employed grey relation analysis and grey decision-making to evaluate financial performance and its relationship with the company attributes. In addition, Deshmukh *et al.* (2006) proposed the Interpretive Structural Modeling (ISM) and Analytical Network Process (ANP) to link the relationship between measures and the strategic objectives. The aim of this paper is to use FCM to analyze trade-off issues among KPIs. Hair *et al.* (1995) applied a statistical technique such as multivariate analysis between variable. However, applying statistical analysis required more effort to accomplish such as approximation, independence to normal distribution and homoscedasticity (Rodriguez *et al.* 2009). Felix and Riggs (1983) stress the importance of monitoring trade-off so that there is less likelihood of process improvement resulting in the decline of quality or service.

#### **Trade-off and Relationship Of Kpis:**

In practice, once the PMS has been created, they are kept unchanged for a long period of time and the system is considered as static. In fact however, the measurement system is dynamic, especially the KPIs which

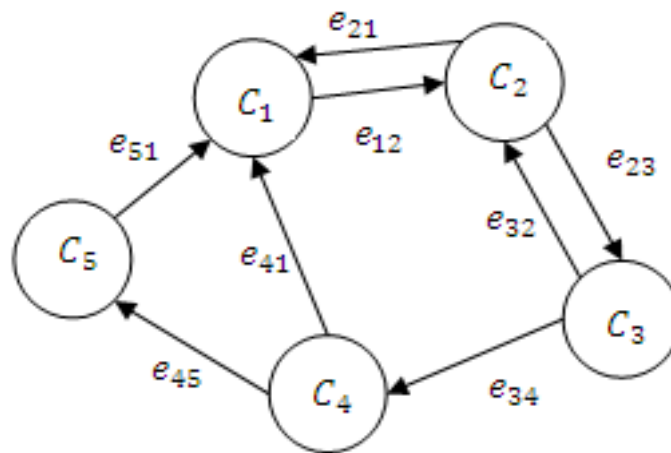
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**Corresponding Author:** Ibrahim Y Sokar, Department of Electrical, Electronics and System Engineering Universiti Kebangsaan Malaysia, Malaysia.

can get outdated since the business environment changes rapidly. It is important for the organization to continuously update and change the strategic objectives to cope with the business environment. To clarify, many decision-makers face difficulties in figuring out ways of dealing with such a situation since the KPIs often correlate and have tangled trade-off interplays (Klejinen and Smits 2003). Many of authors have conceded that more research are required in order to identify the relationships exist among measures (Bititci and Turner, 2000; Flapper *et al.*, 1996; Neely, 1999). Indeed, occasionally improving one KPI might subvert performance of other KPIs. In other words, the interdependence and influences among KPIs may lead to conflict in-between those KPIs; in this case, accomplishment of one KPI may cause extra cost, effort, or even damage to other KPIs. For instance, efforts to accomplish the KPI target for ‘manufacturing costs’ will usually lead to extra efforts/cost for KPI of accomplishing ‘customer satisfaction’. Furthermore, in some other scenario improvement of one KPI may lead to good performance improvement for many other KPIs. In essence, we believe that there is an optimum point of performance (where KPI is to be increased/decreased) that would positively affect other KPIs. Under the circumstances mentioned above, the FCM is proposed to handle this vagueness as management often faces difficulty in identifying optimization of performance improvement.

**Fuzzy Cognitive Maps:**

Fuzzy cognitive maps are an intelligent computing tool which is considered a combination of neural network and fuzzy logic. FCMs were introduced by Bart Kosko in 1986 and since then FCMs have been used in a variety of domains such as engineering, planning and management, decision analysis and psychology. Simply explained, FCM is a fuzzy diagram that illustrates the complex system behavior in terms of cause-and-effect relationship existing between the nodes/concepts. FCMs consist of nodes/concepts and edges/arcs where the nodes/concepts are connected with each other by direct connection or by path and the edges/arcs represent the causal relationship between the nodes/concepts. The nodes/concepts may stand for goals, events, variables, actions, etc. In our case, the concept is a KPI. Each edge is accompanied by a weight to identify the causality among the concepts. The sign of the weight indicates whether it is a positive or negative causality while zero denotes that there is no causality. The FCM concepts can be formed as  $C=\{C_1, C_2, \dots, C_n\}$ . Additionally, the edges among the concepts are written as  $(C_j, C_i)$  which are oriented to represent how the concept  $C_j$  causes the concept  $C_i$ .



**Fig. 1:** A simple fuzzy cognitive map.

The weights of edges are gathered in a weight value matrix  $E_{n,n}$ , where each element of the matrix  $e_{ij}$  ranges in the interval  $[-1, 1]$ . Thus,

- $e_{ij} >0$  represent positive causality that indicates increase/decrease in the value of  $C_j$  leading to increase/decrease in the value of  $C_i$  (direct causality).
- $e_{ij} <0$  represent negative causality that indicates increase/decrease in the value of  $C_j$  leading to decrease/increase in the value of  $C_i$  (inverse causality)
- $e_{ij} =0$  indicates no causality relationship.

The  $n \times n$  weight matrix  $E_{n,n}$  which gathers the weights  $e_{ij}$  of the interconnections between the  $n$  concepts can be organized in a matrix bellow



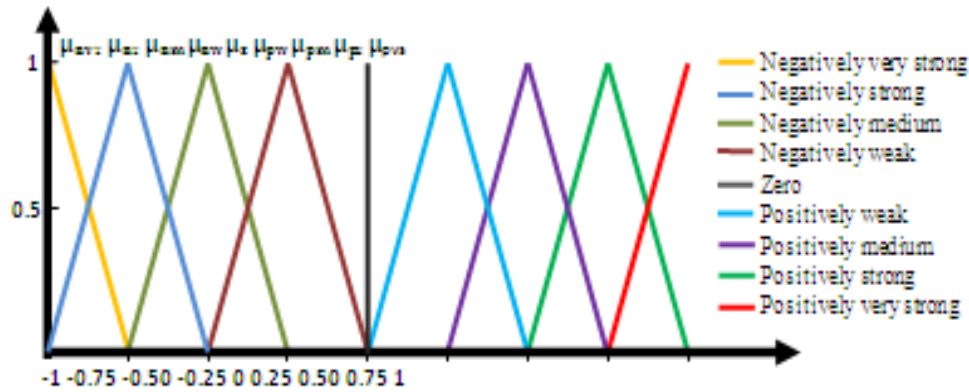


Fig. 3: Linguistic scales of influence between the variables.

Once the FCM structure and all the relationships of the concepts have been identified, then the behavior of FCM and how the changes on the level of one concept contribute to changes in other concepts whether positively or negatively (improving or undermining the performance) were explored. The KPIs under study are compiled from company involved in aircraft Maintenance Repair and Overhaul or MRO MRO business.

Fig. 3: Linguistic scales of influence between the variables

The top management of Job-Shop for aircraft component Maintenance Repair and Overhaul or MRO in a company monitors the performance of the business using a set of KPIs to ensure competitiveness in the market. Let us suppose that in normal circumstances, the targets of each KPI are as depicted in the table below.

Note: the competitiveness of the company in the world wide market is not mentioned due to the privacy

Table 1: The average level for each KPI.

KPIs	Target Level	FCM Level
Staff efficiency	76 %	50
Staff utilization	76 %	50
Staff productivity	75 %	50
Staff availability	92 %	50
Accident and incident	< 2	50
Turnaround time hit	< 5 days	50
Turnaround time rate	7 days per unit	50
Backlog	<95 unit per week	50
Logistic support	85 %	50
Competitiveness	-- %	50

### RESULT AND DISCUSSION

For FCM, we set the level to fifty as an average level for all KPIs (fifty here represent the KPIs target of the participated company). We simulated the FCM and after a few iterations, the simulation was stopped, the result showed no change; so that what we expect since all the level is the same. Next, we changed the level of one, KPI which is staff availability for two scenarios, the first scenario has an FCM level of (40) below the normal level (this set the KPI target for SA<92%) and the second scenario at FCM level of (60) above the normal level (this set the KPI target for SA>92%). As can be seen in Figure 4, when the SA staff availability KPI target is set below the target level of (92), the performance of other KPIs decreased and the backlog increased. However, after twenty two iterations the convergence of the system was reached, which indicated that it would negatively affect the performance of the MRO Job-Shop to some point and at that point, the decline in the performance will stop.

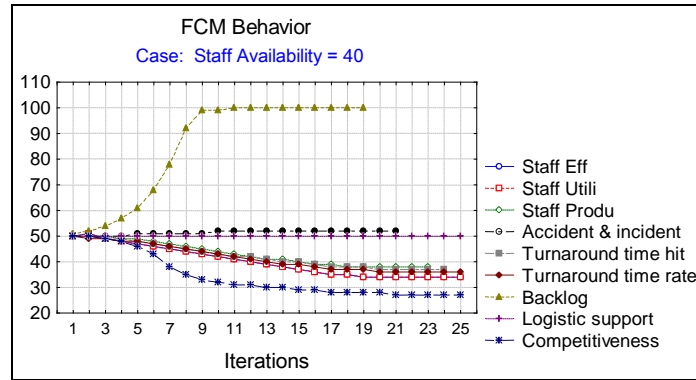


Fig. 4: The effect of one KPI on other KPIs (below normal).

Similarly, next we increased the level of staff availability target to sixty which means an improvement occur. Figure 5 shows the effect on all the other KPIs when the availability of the staff is set at a high level, in this case sixty. As we can see in Figure 5 there is improvement on one KPI, it will lead to attractive improvement on the whole result of the measurement system.

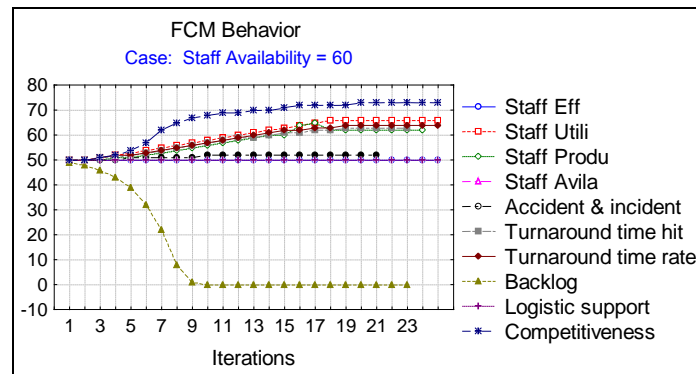


Fig. 5: The effect of one KPI on other KPIs (above normal).

In another scenario, competitiveness is increased and set at 54 to see its effect on other KPIs. As competitiveness is the result of an increase in the performance of all other KPIs, we expect that, as the competitiveness increase all other KPIs target increase too. So, to increase the competitiveness a remarkable increase required in the performance of several KPIs target.

The illustration in Figure 6 shows the effect of this scenario and the improvements that would need to be performed on all the other KPIs.

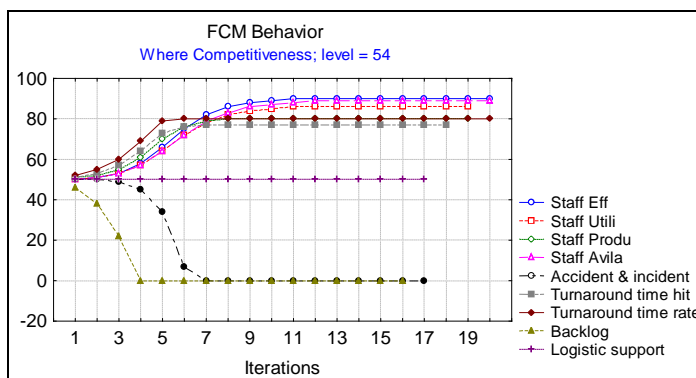


Fig. 6: The effect of increasing market competitiveness on other KPIs.

**Conclusion:**

This article presents a soft computing method of FCM that is used to evaluate the performance measurement system. The trade-off analysis showed how an effective PMS can be developed. One of the main

benefits from this proposed method is that an if-then scenario involving a change of one KPI and its effects on more than two KPIs can be analyzed and understood before the KPI change is implemented in a real situation. Furthermore, the estimation on the cost of improving one KPI on other KPIs can be computed in a systematic manner and additionally, how the changes made to one KPI could lead to improvements of other KPIs can be modeled and previewed beforehand. The previously work of Alisha (2003) weakness can be overcome and the analysis of all KPIs can be carried at the same time instead of pair-wise.

Fuzzy Cognitive Maps as a method used to model the behavior of PMS, where it is more attractive and practical to represent it in a graphical fashion showing the causal relationships among concepts. FCM is useful when designing performance measures, since the method of modeling and control of a system relies on human expert, experience and knowledge.

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