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Project Performance Evaluation and Workload Monitoring Technique by Using Input/Output Bipolar Diagram

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ABSTRACT

Company A, an embedded system manufacturer, provides its products to Company P which is the parent company of Company A. Both companies learned that they needed to find over 4,000 bugs before market release in order to meet the acceptable quality level. Traditionally, they had utilized time-series line graphs as their common performance measurement tool. These graphs compared accumulated numbers of bugs fixed with accumulated numbers of bugs found. Engineers in Company A had been under pressure to improve the process capacity because the line for bugs fixed was always below than the line for bugs found. By using a newly designed Bipolar diagram, engineers in Company A analyzed the process performance. And they were in a position to be more flexible for internal or inter-companies meeting. Authors explain an empirical study of a graphical and practical performance measurement tools relating to mainly the Bipolar diagram. As a result, the Bipolar diagram provides workload monitoring and performance measurement functions in a given timeframe by using the concepts of Optimum Process Line (or band) and Fair Process Capacity Zone.

☞ keyword : Project management, Performance Measurement, Bipolar Diagram, Dashboard

1. Introduction

Company A, an embedded system maker, provides its GPS navigation products to Company P. Company A is a subsidiary of Company P, an automobile manufacturer. Both companies learned that they needed to find over 4,000 bugs before market release in order to meet the acceptable quality level.

When the alpha version of new application released, quality management engineers at Company A and PM group in Company P started searching for bugs by using GPS simulators and taking actual test drives on roads. Bugs or Voice of Customers (VoC) were input into the Issue Management System (IMS) like JIRA, Mantis and Redmine. They put great emphasis on two performance indexes: the accumulated numbers of bugs found and bugs fixed, even though they classified the bug for analysis. These indexes were concurrently represented such as Fig. 1. The matching points between the accumulated bugs found on vertical scales and the accumulated bugs fixed on same vertical scale were plotted at regular time intervals. This graph with the list of bugs or issues was utilized during joint Quality Review meeting between the two stakeholders.

Mostly, engineers in Company A had been under pressure to improve the effectiveness of Quality Assurance (QA) process because the line for bugs fixed was always below the line for bugs found. This pressure sometimes degraded the morale of the engineers and caused them to change profession or to retire. Consequently, upper management was now faced with the challenge of optimizing resource planning and balanced process.

Through our empirical research, we have found that the 'Bipolor Diagram' had been used successfully to monitor project health and progress relating to bug or issue management, and therefore provided a strong support for decision making about when and how much human resource to commit. Bipolar Diagrams were usually regarded to be more effective compared to Fig. 1 line chart by both management groups.

Authors had studied other graphical analysis tools including business intelligent dashboard and Bipolar diagram was compared with 'Shewhart chart or Run chart', which is a traditional process control tools. Some functional limitation of traditional tools in Company A will be presented when used in Company A's environment. It is not intended to undermine

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the advantages of traditional tools. Bipolar diagram represents neither a causal relationship, nor a linear time-series graph. It represents the health condition of process capacity by using quantitative bipolar scale of net bug input (reported or found) on vertical axis and net bug output (fixed or resolved) on horizontal axis. Bipolar Diagram is intended as a complementary tool to be used with traditional tools. But, authors believe that Bipolar Diagram has advantages for steady-state long term projects, in which engineers are the most importance resource for issue handling.

The proposed 'Bipolar diagram' is evaluated as an effective and intuitive monitoring tool for the judgment of process capacity and human resource management as compared to Shewhart chart, time-series line chart and histogram.

The structure of this paper is as follows. The next section 2 presents the background of Bipolar Diagram in Company A. We will describe their previous tools for performance measurement and explain the limitation of the accumulated line chart. In Section 3, a literature review of traditional process measurement tool will be presented. And the proposed Bipolar Diagram model and some metrics will be explained in Section 4. Lastly, conclusions and research contribution are exposed with future study plan.

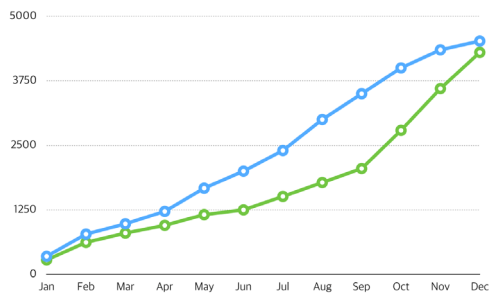
2. Background

Traditionally, QC 7 tools are recommended by Kaoru Ishikawa to evaluate the efficiency of the process. These are Fishbone diagram, Pareto chart, Checklist, Histogram, Stratification, Scatter diagram and Run chart. In the case of Run chart, user may want to modify the chart style, scale and other context to provide a more intuitive value. Moreover, other types of diagram including circle, bar and line shapes can be adapted for better representation of process issues. Fig. 1 line chart used by Company A, conceptually belongs to an accumulated Run chart. The upper limit line represents the accumulated number of bugs found, not allowance line of Run Chart. The lower line shows the accumulated number of bugs fixed, so the lower line never overtakes the upper limit line. Ideally, the end points of two line graphs should meet at product release time. But, that event usually does not happen in real life situations. Companies are usually willing to risk the release of a new product with a small number of what they consider to be minor bugs.

In the software industry, the term "issues" is regarded to be a wider concept than the term "bugs". When Company A mentioned issues, it includes the various engineering change requirements for increasing the customer satisfaction or for responding VoC beyond software bugs. We are going to use term "issues" as the superset term for "bugs". Issue Management Process (IMP) includes the subset function of the bug management process (BMP).

In Company A, IMP was performed as the following process before the introduction of Bipolar Diagram. Fig. 1 shows a graphical performance presentation of IMP process. In most cases, the number of accumulated discovered bugs will form an S type curve. Skew will be smooth when time approaches the end of the project. Otherwise, accumulated bugs fixed will form a slacked C type curve

- Accumulated issues found used to be marked weekly and monthly as the upper lines.
- Simultaneously accumulated issues fixed used to be plotted as the lower lines.
- So, accumulated issues found minus accumulated issues fixed makes the residual pending issues.
- Pending issues were classified as four layers of Top, A, B, C according to severity levels. Top is the most critical issue which causes machine being killed. A numeric table categorized by Fig. 3 severity level is also referred with Fig. 1 diagram during quality review meeting.



(Figure 1) Accumulated Line Chart for Issue Management

As you can see, Fig. 1 only shows total issues, not severity classification. To utilize for decision making, the above graphic tools have some limitation as the following.

- Total number of issues seems not to be resolved during the whole project duration. This situation keeps engineers in a constant state of stress.
- It is not easy to evaluate matters of productivity and workload on engineers.
- Due to accumulated graphical presentation, it is counterproductive for engineers to calculate weekly or monthly work performance.
- It is inefficient for managers to evaluate whether the engineering workload balance lies within their grasp or not.
- During the project, it is difficult to check any work patterns like net change of input, output and both.

3. Literature Study

Alfaro and et al. (2009) explained the business interoperability and collaborative performance measurement. They classified two scopes for collaboration lifecycle field. The first was engineering scope (definition, representation, design and construction), and the second was the operational scope (analysis and execution). These two scopes are performed at the intra-organizational levels as well as inter-organizational levels. According to this scope model, Company A mainly takes charge of the engineering scope even if the two parties collaborate during the definition stage. Analysis and executionin operational scope belong to inter-organizational work. Bipolar Diagram is designed for operational scope. But, it is also utilized for intra-operational level in engineering scope [1].

In an effort to achieve a competitive advantage via cost reduction and improved market responsiveness, organizations are increasingly employing outsourcing as a major component of their supply chain strategies [2]. Company P, an automobile manufacturer may utilize the accumulated line chart as one of the supply chain risk management (SCRM) tools. Otherwise Bipolar Diagram gives value to Company P as another SCRM tool and to Company A as another process performance measurement tool with the insight of resource planning.

In 1989, analyst Howard Dressner with market research firm Gartner Inc. coined the term "business intelligence(BI)" [3].The greatest value of BI competency comes from being able to respond to market demands faster and more intelligently [4]. From a cognitive point of view, diagrammatic representation for BI system is easy to understand when compared to textual or numerical presentation [5].

Diverse business process data are generated during the business management process. As a result, there is an increasing focus on visualization techniques that are intended to be effective on a limited screen, with business process data and analysis results [6]. Graphical dashboard also belongs to representational styles of BI systems. In order to get an effective planning and control tool, management team should consider designing a simple perceptual model of graphical dashboard, which is oriented towards understanding and enhancing organizational performance of corporate business processes. The Bipolar Diagram can be used as a type of dashboard if implemented in IT framework. But, Company A had not yet implemented Bipolar Diagram on IT platform. They had used it for interdepartmental communication tools on Excel or PPT drawing and print-out document.

Highly perceptual graphical dashboard will increase decision speed because decision makers can detect warning signs faster than other types of data representation. This paper details the results of an empirical graphic model for process capacity management and useful metric samples for project issue management in an embedded software company.

The dashboard design core relates key performance indicators (KPI). Bauer (2004) classified dashboards into a total of 25x14 matrixes which consist of 25 styles for graph, and 14 attributes for data series. He also emphasized that graph selection and presentation were critical to the success of corporate performance management (CPM) [7]. Dashboard contents should present information that is personalized, actionable and meaningful - in short, relevant. Also, it needs to be fresh, efficient, credible, and convenient - in short, useful [8]. The Bipolar Diagram can be personalized if each team wants to have team performance data. And it can be actionable by setting up the fair performance line or band. We named it as Optimum Process Capacity (OPC) Line or Band as the below.

OPC means the threshold of process input/output under certain limiting factors governed by Liebig's law of the minimum in agricultural science. If the job requirement is beyond OPC, then the workload will increase and the due date will be delayed. This will be one of the risk factors for labor dependent organizations like software companies. The OPC Line is similar to a "Plimsoll Line", which is a visual disaster control scheme designed to protect a ship against sinking due to overage in cargo weight capacity. OPC Band may serve as a milestone for an organization's sustainable operation.

Statistical Process Control (SPC) is a widely used technique for quality control. The basic objective of SPC is to quickly detect the occurrence of special cause variation [9]. One important tool in SPC is the control chart, which is used to monitor the performance of a process over time to keep the process in an in-control state [10]. Shewhart's control charts are the most important tool for statistical process control (SPC), since they indicate out-of-control conditions [11]. A control chart is very useful for monitoring the quantitative variation over standardization within certain periods of time. Operators can make immediate adjustments if the measurement index passes upper or lower limit lines such as the function of Plimsoll line. But, Shewharts chart is applicable for physical parameters such as length, weight, stress-strain and etc. For hybrid issue management including bug handling, we consider the Bipolar Diagram to be advantageous in measuring process performance.

From management's point of view, too much or too less are not good for resource optimization. This study will present a graphical analysis tool, namely 'Input/Output Bipolar Diagram' or 'Bipolar Chart' in short. Also, some measurement calculation logics will be proposed for proper resource management according to empirical view of Company A. If the job requirements move over or move down the OPC Band, managers can easily recognize the situation and trigger the load balancing works.

The most important part of project management is communication among stakeholder groups [12]. Tsiotras (1993) points out two kinds of meeting held during the lifetime of the project. They are task team meeting and task team/supervisor meetings [13]. This study offers a type of dashboard or graphical process control tools, especially addressed to the human resource management for the latter meeting. Authors believe our recommendation of the Bipolar Diagram will give a better context of understanding between service requesters and service fulfillment team.

Ingason and Jónasson mentioned that many organizations do better in defining their objectives and strategies than in actually executing them in a proficient and effective way [14]. The Bipolar Diagram is intended to focus on execution and craftsmanship. It was originally designed from process improvement activities for better communication between development engineers and quality engineers in the automobile industry.

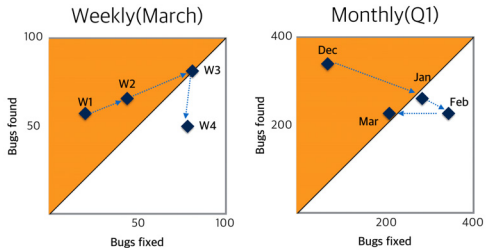
Project managers usually evaluate project risk in cost, time, scopes and client satisfaction [15]. The Bipolar Diagram is mainly for client satisfaction because it represents the progress of deliverable's conformation (output) to client expectation (input) and partially for scopes.

4. Alternative Bipolar Diagram

4.1 Basic Model

We proposed a new graphical tool, *Input/Output Bipolar Diagram* as Fig. 2, which is superior to Fig. 1 line chart from a contextual standpoint. Along with the Fig. 3 bar chart, the Bipolar Diagram provides the following features and benefits.

• As shown in Fig 2, the vertical axis represents the influx number of bugs found. On the other hand, the horizontal axis shows the efflux number of bugs fixed. The intersection



	W1	W2	W3	W4	SUM
BoW	10	40	57	57	10
In	55	65	80	50	250
Out	25	48	80	77	230
EoW	40	57	57	30	30

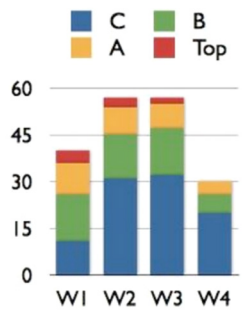
	Jan	Feb	Mar	Q1	Eval.
BoM	110	100	10	110	
In	270	250	250	770	
Out	280	340	230	850	Good
EoM	100	10	30	30	

(Figure 2) Bipolar Diagram and Table

points between input and output numbers make track plots on the rectangular frame. Be careful that the plots do not show the causal relationship.

- The graph can mainly be plotted weekly and monthly, if desired, quarterly and yearly. The track of the different interval plots can be compared with the previous tracks.
- The graph can plot multiple departmental performances and be compared on a same regular tetragon.
- A line that leads to a diagonal from zero point to 45 degrees indicates a balanced line of process capacity. We call it 'OPC Line.'
- The above triangle on the tetragon frame means a region with a higher number of requests (influx) than resolutions (efflux). We call this area as overloaded space.
- Otherwise, the lower triangle on the tetragon frame means a region with higher number of resolutions (efflux) than requests (influx). We refer to this area as allowance space.

Fig. 3 named as residual bug table. For risk evaluation purposes, risk classification 3x3 or 5x5 matrixes were proposed and well accepted by industry [16]. Company A does not distinguish the severity types on Bipolar Diagram. But, Company A has their own risk priority scheme with four levels of Top, A, B, C such as Risk Priority Number (RPN) in Failure Modes and Effects Analysis (FMEA) methodology. The stratified Bar Chart in Fig. 3 shows the number of Top, A, B, C severity types weekly or monthly. Company A engineers utilize Fig. 3 as a complementary tools for decision making.



(Figure 3) Bar Chart - Residual Issues

4.2 Interpretations

Compared to Fig. 1, the Bipolar Diagram in Fig. 2 gives some useful information and insights to engineers and managers for process capacity and resource management with the following implications.

- The track of sequential plots in the overloaded triangle space indicates the risk of overload. A high number of plots on the upper triangle, during a certain period, represents resource shortage and overloaded jobs on engineers. Immediate action by management may be required.
- Otherwise, the track of sequential plots in the allowance triangle space discloses the fact that human resources are plentiful. Manager may reassign human resource for other pressing projects.
- Fluctuation across the OPC Line between the overloaded space and the allowance space may send other messages to managers. If the track of plots is around OPC Line or in OPC band, there are no problems for resource capacity.
- But, if the track of plots is outside of OPC band, managers should investigate any radical change of issue characteristic or ensure whether there are any changes for responsible engineers or not.
- Also, too much variation in influx may represent the human resource change for quality inspection.
- Otherwise, too much variation in efflux might be done by more skilled resource allocation or be according to the issue complexity.
- Right arrow direction means performance enhancement of resolution works. Otherwise upside arrow direction means performance enhancement by inspection engineers, but overload for issue handling engineers.

R. T. de Oliveira Lacerda(2016) mentions that an objective of the measurement process is to provide valid and viable information about the performance of a context. Accordingly, the indicators built must be capable of measuring all the possible consequences of what will be measured related with the measurement theory to provide scientific support [17]. For this purpose, we designed some equations for measuring quantitative performance.

By using Fig. 2 table, some useful performance metrics can

be calculated. If management sets up the range between -15% and + 15% as the OPC Band, we figure out the workload status by the following formula. In Company A, there are several opinions on selecting the proper denominator. Some managers insisted that it should be the average number of issues resolved. But it is not good to compare the performance change because of frequent resource fluctuation. Some managers advocate the net number of issues resolved instead of the net number of issue request. But, authors finally recommended the number of issues found because performance metric should be compared to input denominator rather than output.

- Workload indicator on March= (No. of Request – No. of Resolved) / No. of Request = (250-230) / 250 = 8%. It means 8% over OPC. Or, just described as 108% loaded. So, workload is under process capacity range.
- If issues found (requested) are zero within a given period, the above formula is uncalculated. In that case, calculation period will be reasonably expanded.

Instead of workload indicator, metric options, such as average resolution time per bugs or engineering working hours can be formulated for performance measurements. Let's assume there are total 100 engineers and that average direct labor cost per hour is approximately $50. These calculations can be referred for managerial accounting such as activity based costing (ABC).

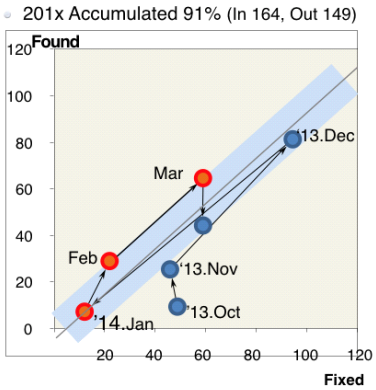
- Average resolution time per bugs on March = Average working hours per month / Output = 8 hrs. x 20 days / 230 = 0.7 hour per issue.
- Total engineering working hour per issue = Average resolution time per bugs x total engineers = 0.7 hr. x 100 = 70 hours.
- Total engineering cost per issue = 70 hours x $50 = $3,500

The above metrics are general tools for measuring Company A's process performance.

4.3 Model Variation

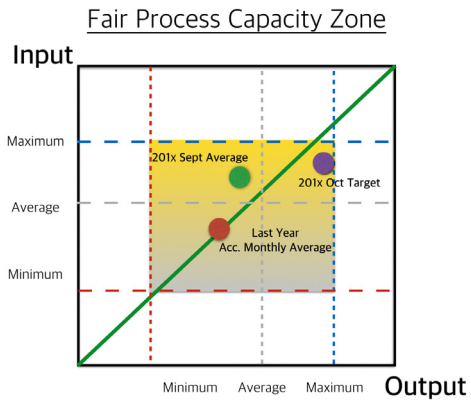
From the Fig. 2 basic graphical presentation model, authors recommended several derivative visual tools as the following Fig. 4 which was for a development team in Company A. The major difference between Fig. 2 and Fig 4 is that there is OPC Band in the chart. The bandwidth will vary according to company policy or management goals. Company A started to use Bipolar Diagram from the beginning of 201x. After the introduction of Bipolar Diagram, each team had tried to meet their work performance target within OPC Band.

Even if engineers draw Bipolar Diagram for their weekly meeting, monthly Bipolar Diagrams are used for cross functional meeting. At that meeting, each project team prepared their Bipolar Diagram for minimum 3 months and maximum 7 months because too many plots made it difficult to track the trace. Authors recommended that the first plot might be the last month in the last quarter. There are two ways to distinguish overloaded or allowance plots. First one is color pattern in overloaded or allowance space as Fig. 2. The other way is color change of the plot itself as Fig. 4. Arrow can be solid for actual, dotted for target movement.



(Figure 4) Bipolar Diagram with OPC Band

After multiple year experience, managers can gather large amounts of practical data in order to enhance the process management metrics. Authors proposed another measure for Fair Process Capacity (FPC) Zone like Fig. 5. Because of technology change, 3 year average metrics will be reasonable for setting up FPC zone. Some meaningful metrics and calculation logics will be explained as the followings.



(Figure 5) Bipolar Diagram with FPC Zone

- Last year accumulated monthly average plot is calculated with total input and output number divided by the number of months consumed for a project
- Maximum input or output lines come from the biggest monthly number during 3 consecutive years.
- Minimum lines for input and output come from the smallest monthly number during 3 sequential years. But, minimum line has not any specific meaning for management control.
- Average lines come from 3 year accumulated monthly averages.
- The definition of Fair Process Capacity Zone can be from average to maximum or from last year average to maximum. Definition selection belongs to company policy.
- Monthly target plots can be defined as Fig. 5. If there are discrepancies, project manager must analyze the root cause to derive any lessons for future decisions.

5. Conclusion and Future Study

Any manager who could not draw their process on a single A4 piece of paper is unlikely to be able to manage it [18]. Also, tracking measures incur costs in money and time. Ultimately, too much information is as confusing as too little [19]. We consider the Bipolar Diagram as an effective and useful tool for project managers to analyze and evaluate the progress of issue management in the software industry.

The main contribution of this empirical research is a proposed Bipolar Diagram as a contextual performance analysis tool and a sample calculation for measuring KPI of labor intensive company in software industry. Referenced Bipolar Diagram is useful for project managers to easily evaluate and compare the progress of software bugs & issues resolution, and immediately respond with resource contingency.

The contextual level of Bipolar Diagram is relatively higher than other performance management tools. Weekly or monthly chart is common even if it can apply to quarterly chart. Main objective of using these diagrams is to increase immediacy for project managers, especially for software issue management.

To save money, no one would request a vehicle without a dashboard. It sounds crazy [20]. Company A's management was satisfied with the proposed Bipolar Diagram or dashboard for their weekly staff meeting or monthly executive meeting, because it provided graphical representation for management to keep up with contingency situations like resource shortage. For other implementers, this paper presents KPI definition processes for steady state development or issue management work, especially useful for measurement works in long term projects.

In the future, we plan to solidify a broad and relevant model for Bipolar Diagram and measurement metric design process by applying this model to other companies. Also, we are going to search for detailed statistical approach relating to metrics in Bipolar Diagram. 'Accumulated Input/Output Bipolar Diagram will also be addressed in order to check any meaningful implications for resource management.

In a data oriented society, the skill of presenting excellent charts and graphic is more important than writing skills [21]. If manager groups motivate their professional employees to make one page dashboards which explain their KPI, it will enhance their company's maturity level one step further.

Reference

[1] J. J. Alfaro and et al., "Business process interoperability and collaborative performance measurement," *International Journal of Computer Integrated Manufacturing*, Vol. 22, No. 9, pp. 877-889, Sep. 2009. http://dx.doi.org/10.1080/09511920902866112

[2] A. Lockamy III and K. McCormack, "Analysing risks in supply networks to facilitate outsourcing decisions," *International Journal of Production Research*, Vol. 48,

No. 2, pp. 593-611, Jan. 2010.
http://dx.doi.org/10.1080/00207540903175152

[3] S. Ortiz Jr., "Taking Business Intelligence to the Masses," *Computer*, pp. 12-15, July 2010.
http://dx.doi.org/10.1109/MC.2010.208

[4] D. A. Price, "The Dawn of a New ERA," *DM Review*, pp. 18-22, Feb. 2006.

[5] N. E. Cagiltay, G. Tokdemir, O. Kilic, D. Topalli, "Performing and analyzing non-formal inspections of entity relationship diagram(ERD)," *The Journal of Systems and Software*, Vol. 86, pp. 2184-2915, 2013.
http://dx.doi.org/10.1016/j.jss.2013.03.106

[6] H. Ahn, KH. Pio Kim, "Treemapping Work-Sharing Relationships among Business Process Performers," *Journal of Internet Computing and Services*, Vol. 17, No. 4, pp. 69-77, Aug. 2016.
http://dx.doi.org/10.7472/jksii.2016.17.4.69

[7] K. Bauer, "The CPM Dashboard - The Graphs, Designing an Effective Dashboard is like creating a Steven Spielberg Film," *DM Review*, pp. 68-71, June 2004.

[8] D. M. Raab, "Selecting Customer Value Dashboard Contents, Part 2," *DM Review*, pp. 12, March 2006.

[9] Z. G. Stoumbos, M. R. Reynolds, et al. "The state of statistical process control as we proceed into the 21st century," *Journal of the American Statistical Association*, Vol. 95, pp.992-998, 2000.
http://dx.doi.org/10.1080/01621459.2000.10474292

[10] T. Sukchotrat, S.B. Kim and F. Tsung, "On-class classification-based control charts for multivariate process monitoring," *IIE Transactions*, Vol. 42, pp. 107-120, 2010.
http://dx.doi.org/10.1080/07408170903019150

[11] S.A. Lesany, A. Koochakzadeh, S.M.T. Fatemi Ghomi, "Recognition and classification of single and concurrent unnatural patterns in control charts via neural networks and fitted line of samples," *International Journal of Production Research*, Vol. 52, No. 6, pp. 1771-1786, 2014.
http://dx.doi.org/10.1080/07408170903019150

[12] J. G. Lee & S. R. Jeong, "A practical 1 Page Contextual Diagram for Monitoring Multiple Projects: An Empirical Study of an IT Organization," *Journal of Internet Computing and Services*, Vol. 17, No. 5, pp. 121-129, Oct. 2016.
http://dx.doi.org/10.7472/jksii.2016.17.5.121

[13] G. Tsiotras, "Quality improvement for group work management process," *Total Quality Management*, Vol. 4, No. 3, pp. 257-260, 1993.

[14] H. T. Ingason, H. I. Jónasson, "Contemporary Knowledge and Skill Requirements in Project Management," *Project Management Journal*, Vol. 40, No. 2, pp. 59-69, 2009.
http://dx.doi.org/10.1002/pmj.20122

[15] K. Schwalbe, Information Technology Project Management, *Course Technology*, International edition, 7th edition, pp. 8-9, 2014.

[16] J. Wickboldt, L. Bianchin, R. Lunardi, et al., "A framework for risk assessment based on analysis of historical information of workflow execution in IT systems," *Computer Networks*, Vol. 55, pp. 2954-2975, 2011.
http://dx.doi.org/10.1016/j.comnet.2011.05.025

[17] R. T. de Oliveira Lacerda and et al., "Research Opportunities in Business Process Management and Performance Measurement from a Constructivist View," *Knowledge and Process Management*, Vol. 23, No. 1, pp. 18-30, 2016.
http://dx.doi.org/10.1002/kpm.1495

[18] G. Parry and C. Turner, "Application of lean visual process management tools," *Production Planning & Control*, Vol. 17, No. 1, pp. 77-86, Jan. 2006.
http://dx.doi.org/10.1080/09537280500414991

[19] Paul Harmon, "Business Process Change," pp. 139-142, *Morgan Kaufmann Publishers*, 2007

[20] H. Mckew, "Tomorrow's Environment: Dashboard without an Operator," *Engineered Systems*, pp. 66, Nov. 2010.

[21] D. M. Wong, "Guide to Information Graphics," *The Wall Street Journal*, 2010.

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