Business Activity Monitoring System Design Framework Integrated With Process-Based Performance Measurement Model

KWAN HEE HAN[*1], †SANG HYUN CHOI[*2], JIN GU KANG[**], GEON LEE[*3]

Department of Industrial & Systems Engineering, Engineering Research Institute, Gyeongsang National University, Jinju, KOREA[*], Autoever Systems Corp., Seoul, KOREA[**]
hankh@gnu.ac.kr[*1], chois@gnu.ac.kr[*2] (†corresponding author), kjg@autoeversystems.com[**], binjis@nate.com[*3]

Abstract: - Recently, strong interests in the real-time performance management are increasing to gain competitive advantages in the rapidly changing business environment. For better business performance or continuous process improvement of an enterprise, real-time measurement and analysis of the performance of managerial activities is essential. Business activity monitoring (BAM) which provides real-time access to key performance indicators or business processes is one of core elements for successful business process management (BPM) system. Since performance measurement cannot be managed independently of business processes, BAM system needs to monitor performance metrics in terms of business process.

This paper proposes BAM system design framework integrated with the process-based performance measurement model (PPMM), in which monitored KPIs are closely related with business processes. The proposed PPMM consists of three sub-models: KPI model, process model, and K-P model. To show the applicability of proposed framework, BAM system prototype was also developed using a real case.

This paper is expected to be a practical help to the practitioners who are planning and executing the BAM system implementation for continuous process improvement.

Key-Words: - Business Activity Monitoring (BAM), Business Process Management (BPM), Business Performance, Key Performance Indicator (KPI)

1 Introduction

Most enterprises are struggling to change their existing business processes into agile, product- and customer-oriented structures to survive in the competitive and global business environment. In today's dynamic business environment, the ability to improve business performance is a critical requirement for any organization. So many enterprises have recently been pursuing process innovation or improvement to attain their performance goal. The management of business performance is a series of organizational process and applications designed to optimize the execution of business strategy, and needs to identify the key activities that contribute most to enterprise's success [7].

Since the business performance is achieved through the execution of business processes, business process and enterprise performance measurement are closely interrelated. A business process is a sequence of activities that carries out a complete business goal. To comprehensively support business process execution, the concept of business process management (BPM) has been recently proposed. Not only does it encompass the discovery, design and deployment of business processes, but also the executive and administrative control over them to ensure that they remain compliant with business objectives for the delight of customers [20]. It is itself a process that ensures continued improvement in an organization's performance.

The BPM cycle is composed of process diagnosis, design, and execution phase. In the diagnosis phase, the operational processes are analyzed to identify problems and find areas for improvement. In the process design phase, to-be processes are newly designed and their performance evaluation is conducted. According to Van der Aalst *at al*., there are three types of analysis: validation, i.e., testing whether the workflow behaves as expected, verification, i.e., establishing the correctness of a workflow, and performance analysis, i.e., evaluating the ability to meet requirements with respect to throughput times, service levels, and resource utilization [22]. In the execution phase, business activities are monitored, coordinated and controlled continuously for better performance.

Business activity monitoring (BAM) was firstly defined by Gartner as the concept of providing real-time access to critical business performance indicators to improve the speed and effectiveness of business operations [17]. BAM is usually conducted during the execution phase of BPM. It communicates strategic objectives and enables business people to measure, monitor, and manage the key activities and processes needed to achieve their goals.

The goal of BAM is to provide real-time information about the status and results of various business operations, processes, and transactions [23]. Enterprise-wide task of BAM is to reduce or eliminate delays, bottlenecks and inefficient use of labor and materials, while providing real-time financial and performance data [9]. Typical feature of BAM is that it monitors many enterprise systems simultaneously and displays exceptional situation on the dashboard if symptoms of problem are identified by pre-defined rules.

Recently, many companies that are running knowledge management (KM) system or introducing BPM system want to derive and monitor key performance indicator (KPI) to assure the effectiveness of their innovation or improvement efforts [12, 13, 15]. This requirement can be achieved by BAM system that collects and analyzes the related data in real-time and responds with appropriate reaction when a business event occurs. Therefore, BAM is the critical element for attaining the business goals aligned with business strategies.

Since performance metrics show how well the business is doing relative to a defined strategy, they help managers to derive better business decisions. For aligning with enterprise strategies, BPM activities must be closely related to performance metrics because the metrics are the drivers and evaluators of business processes. In other words, performance measurement cannot be managed independently of business processes in order to attain the goal of an enterprise. As a result, BAM system needs to monitor performance metrics in terms of business process.

However, current measurement practices have not clearly defined and managed the relationships between business processes and KPI. Therefore, it is necessary to establish a process-based performance measurement model.

The objective of this paper is to propose BAM system design framework integrated with the process-based performance measurement model, in which monitored KPIs are closely related with business processes and are composed by combining the other lower-level KPIs. Dotted box of Figure 1 shows the scope of this paper within an overall BPM life cycle. To show the applicability of proposed framework, BAM system prototype was also developed using a real case.

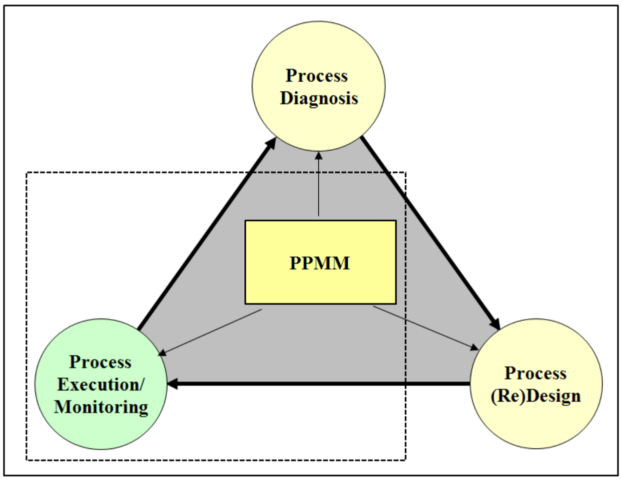

Figure 1. Scope of this paper within BPM life cycle

The rest of this paper is organized as follows. Section 2 describes related works. Section 3 presents process-based performance measurement model (PPMM), which is an underlying scheme of performance-centric BAM. Section 4 shows proposed BAM system design framework and its prototype implementation. Finally, the last section summarizes the results and suggests directions for further research.

2. Related Works

Of the research related to the business performance measurement and modeling, Ghalayini *et al*. classified the performance measures for manufacturing enterprise into the following three layers: general area of success, performance measure, and performance indicator [8]. They defined hierarchical relationships between the layers, but did not show the relationship between performance measure and business process. Berler *et al*. classified a hospital's KPIs based on the concept of balanced score card (BSC) [2]. They also defined hospital workflows in detail, and then assigned a KPI to each unit task-level activity. However, they addressed the interrelationship between KPI and business process merely by simple one-to-one mapping at a single flat level.

Chan [6] and Beretta [1] decomposed the business process hierarchically into sub-processes, and then proposed a method of calculating the performance measure by summing up the measures of the lowest level activities. Theirs is a top-down approach that defined the business processes level-by-level, and mapped the performance measure to each business process. Nevertheless, they suggested that the business process has a simple one-to-one relationship with a performance measure. Bititci conducted a case study that applied the information systems modeling techniques to the modeling of a performance measurement system and implied that KPIs are interrelated with multiple and weighted relationships [3]. Munehira *et al.* suggested that it is necessary to identify which processes should be improved or created to achieve the business performance goals described in BSC [18]. For this purpose, they defined the relations between BSC structure and business model elements, yet they did not implement their proposed method to a real business case. In the previous research, authors of this paper proposed two-stage business process analysis, which precedes execution phase of BPM, based on PPMM and business process simulation for the new process design [11].

In the area of BAM, Goverka *et al.* emphasized that the potential problems with BAM are a shortage of the skilled workers, doubt over the ability of software vendors, union concerns, and so on [9]. Buytendijk *et al.* asserted that creating an effective BAM environment is not only about having the right technology and processes [5]. They pointed out that enterprises should define the right set of metrics for BAM.

White proposed a BAM framework through the comparison with business intelligence (BI) framework [22]. He emphasized the followings to prepare the BAM system: First, it is important to gain a good understanding of BAM technology and its business benefits. Second, BAM must be integrated with existing BI and enterprise integration (EI) solutions. Third, it is important to realize that although there are already a number of successful BAM implementations, this is immature technology that will undergo rapid evolution over the next few years. Last, it is crucial to recognize that BAM is not just a technology alone.

Broda *et al.* proposed key steps and critical success factors to BAM implementation [4]. The key steps are as follows: define a vision, establish the data model, build real-time data streams, and roll out operational dashboards. They suggested that the critical success factors are performance, heterogeneous data access, and usability. Popovic *et al.* analyzed BI system's impact on performance on business performance improvement [19].

3. Process-Based Performance Measurement Model

The need for systematic performance measurement based on business processes has been steadily increasing. However, the proper correlation scheme between business processes and KPIs is not clearly established in the current measurement practices. As a result, in the diagnosis phase of BPM, it is difficult to decide which process should be improved to achieve a specific performance goal or which performance index is influenced when a specific business process is executed successfully. In the execution phase, it is also difficult to decide which KPIs or business processes are monitored for attaining business goals and to define the relationships between monitored KPI and other KPIs. Consequently, a performance measurement model that is closely correlated to business processes should be established to achieve the goal of an enterprise.

The proposed PPMM consists of three sub-models, as shown in Figure 2: KPI model, process model, and K-P model. Firstly, KPIs are hierarchically classified into three levels in the KPI model according to the following management decision level: strategic level KPI (SLK), tactical level KPI (TLK), and operational level KPI (OLK). The contribution index having a 3-point scale, which is a measure of the contribution of a specific KPI to other same level or higher level KPI, is determined in the KPI model.

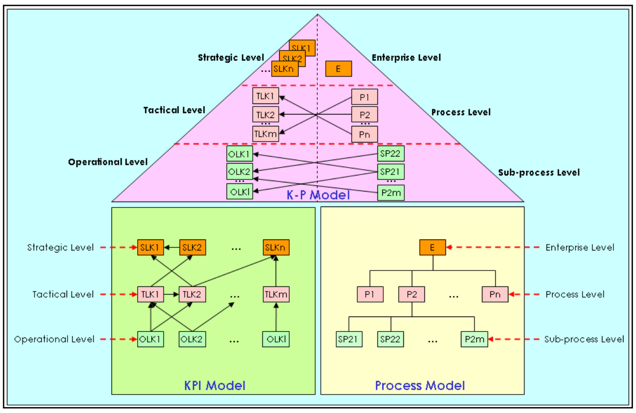

Figure 2. PPMM structure

Figure 3 shows 12 SLKs of *Case Company S* in terms of BSC perspective, which is a large shipbuilding company in Korea. Figure 4 shows an example of KPI model, in which the contribution index of 'output quantity' TLK to the 'productivity' SLK is marked as 3.

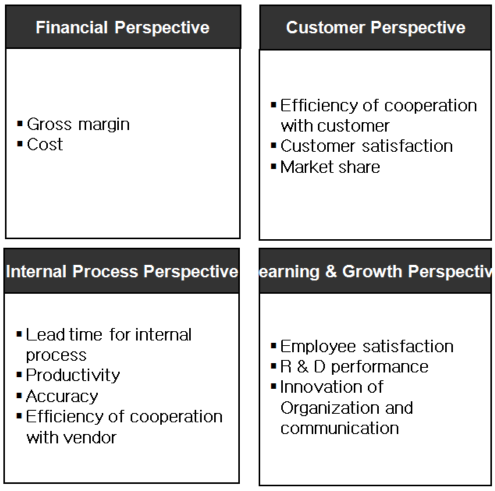

Figure 3. Example of SLKs

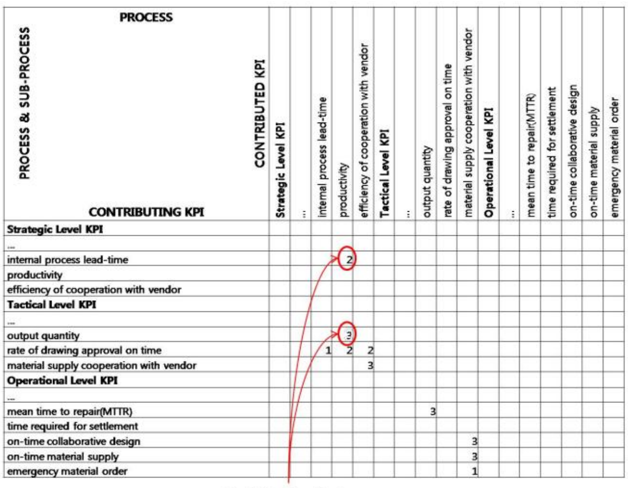

Figure 4. KPI model (part)

Secondly, business processes are classified into three levels in the process model in accordance with the size of process control span as follows: enterprise level, process level, and sub-process level. Each sub-process has a network composed of unit activities as shown in Figure 5. The definition of process, sub-process and activity in this paper is compliant with the definition of workflow management coalition (WfMC).

Process model of *Case Company S* consists of 14 main processes as follows: understand market and customers, develop vision and strategy, research and development, engineering, marketing and sales, purchasing, production, customer satisfaction, manage information, manage human resource, finance, execute environmental management program, manage external relationships, and manage changes. 14 main processes are further decomposed into totally 84 sub-processes as shown in Table 1.

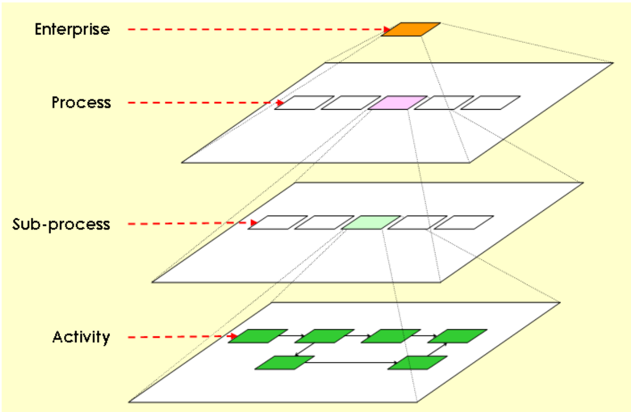

Figure 5. Hierarchy of process model

Table 1. Business process and its sub-process of *Case Company S*

Process	Sub-process	
understand market and customers	Market analysis, customer information mgt.	2
develop vision and strategy	Mgt. strategy planning, new business development	2
research and development	project planning, project evaluation, register task/MH, cost estimation, dept. performance analysis, establish R&D KPI, tech. level analysis, patent mgt.	8
engineering	Spec. pre-review, eng. strategy planning, eng. drawing, drawing approval, drawing release, drawing document mgt.	6
marketing and sales	Sales strategy planning, sales promotion, enquiry development, milestone confirm, ship price calculation, tender preparation, contract negotiation, contract closing, invoice & receipt, result analysis	10
purchasing	Material cost planning, planning purchase order, due data change mgt., bonded goods traffic, customs clearance, material warehousing, pallet mgt., material delivery, receipt disbursement settlement, utensil stock mgt.	10
production	Production planning, building milestone, production scheduling, process control, equipment maintenance, logistics support,, writing white paper	7
customer satisfaction	Owner mgt., contract mgt., inspection item control, daily inspection, NCR mgt., claim mgt., ship life cycle mgt., quality problem feedback	8
manage information	Information strategy planning, promoting IT, automation level evaluation, security mgt.,	4
manage human resource	Org. analysis & innovation, system improvement, recruit, wage mgt., personnel mgt., welfare, education, general admin., society contribution, career development plan	10
finance	Accounting standard establishment, managerial strategy planning, accounting, tax, costing, asset mgt., capital mgt., budget mgt., business performance evaluation	9
execute environmental management program	Environment risk assessment, company hospital mgt., medical examination, working condition mgt., equipment safety control, disaster mgt.	6
Manage external relationships	Public relations,	2
Manage changes	Change mgt.	1
14		84

Finally, the K-P model represents the relation between KPI and business process. Enterprise, process, and sub-process levels in the process model correspond to SLK, TLK, and OLK in the KPI model, respectively. The influence index having a 3-point scale, which is a measure of the influence of a business process on a specific KPI, is determined in the K-P model. Figure 6 shows the integrated view of PPMM of the C*ase Company S*. In the left side of Figure 6, influence index of ‘production’ process upon the ‘output quantity’ TLK is marked as 3.

During the execution phase of BPM, the impact of each unit task’s performance on the enterprise-level performance and the influence of business process upon certain KPI can be monitored and measured in real-time, and the analysis result of monitoring activities can be reflected to the business process operations by integrating this PPMM and the BAM system. The detailed procedure to develop a PPMM in an organization was previously addressed by authors of this paper in [10].

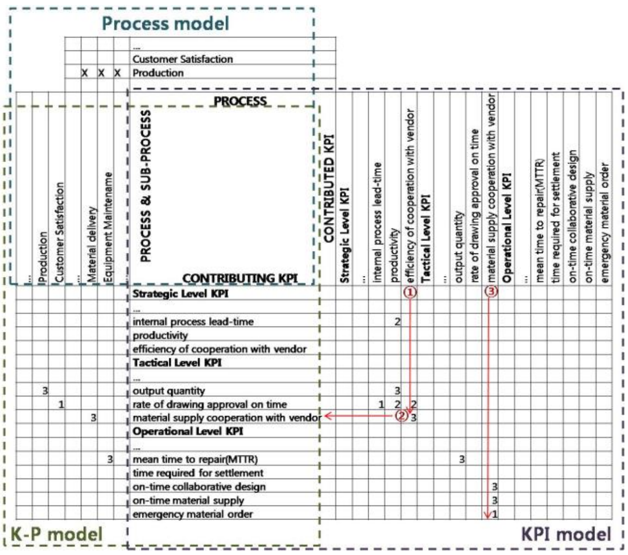

Figure 6. Integrated view of PPMM (simplified)

4. Performance-Centric Business Activity Monitoring System Design Framework

Proposed BAM system design framework consists of 2 phases as depicted in Figure 7: 1) Preliminary survey of existing enterprise information systems, 2) BAM system design. Preliminary survey phase investigates the structure of existing enterprise information system to identify the data flows from heterogeneous data sources required for activity monitoring. BAM system design phase, which consists of 5 steps, addresses general design procedure, methods and tools for BAM.

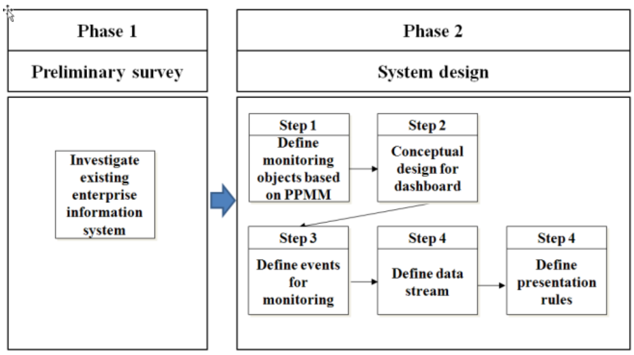

Figure 7. Proposed BAM system design framework

4.1. Preliminary Survey Phase

Before designing a BAM system, it is necessary to investigate the structure of current enterprise information system (EIS) for defining communication architecture between a BAM system and other application systems. Generally, enterprise information system can be classified into two categories: a transaction processing system and an analytical processing system. A transaction processing system contains a group of enterprise systems that process large amount of transactions for daily operation of enterprise. Large amount of transaction data, which are related to many applications and databases, are generally processed in real-time and continuous basis. ERP system is the typical application for the transaction processing system. An analytical processing system includes a group of systems that collect and analyze data for the decision support.

In general, databases in one application are operated independently from the other application because of system performance problem. In other words, the analytical processing system is separately managed from the transaction processing system to protect the predefined performance of transaction processing system from the effect of the analytical processing system which requires many computing resources. Data warehouse (DW) and On-line Analytical Processing (OLAP) are representative applications of the analytical processing system. A BAM system is classified into one of the analytical processing system.

As an example, Figure 8 shows the structure of EIS of *Case Company H*, which is a global automotive company in Korea. The transaction processing system of this company includes BPM system, ERP system and other legacy systems. BAM system belongs to one of analytical processing system that contains a separated database and dashboard.

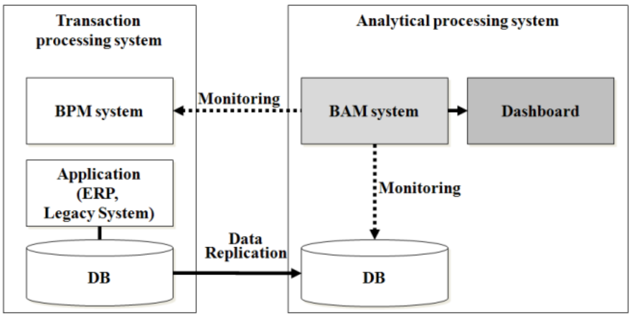

Figure 8. Enterprise information system structure of *Case Company H*

4.2. BAM System Design Phase

The general BAM system design procedure based on PPMM consists of 5 steps as follows: 1) define monitoring objects based on PPMM, 2) conceptual dashboard design, 3) define events for monitoring, 4) define data stream, and 5) define presentations rules.

4.2.1 Define monitoring objects based on PPMM

Monitoring objects of which performance should be measured in real-time are selected in this step. Candidates for real-time performance measurement in an enterprise can be categorized into two groups.

One group is such KPIs that are significant to attain an enterprise goal through the real-time performance measurement. Target KPIs for monitoring can be selected based on KPI model of PPMM at any KPI level. For example, in the *case company S*, 'efficiency of cooperation with venders' of customer perspective of BSC in the Figure 6 is selected as a target SLK.

Since this SLK is enterprise level, it is too broad in scope and difficult to calculate and monitor in a comprehensive way. Therefore, most contributing TLK to selected SLK is the candidate KPI for monitoring. Based on the PPMM, we identify that the most contributing TLK to this SLK is 'material supply cooperation with vendor' in the KPI model (number-1 and number-2 arrow in Figure 6). The contributing OLKs for this TLK can be found in the KPI model (number-3 arrow). These are on-time collaborative design (OTCD), on-time supply (OTS) and emergency material order rate (EMO). As a result, 'material supply cooperation' is selected as a monitoring object, and is calculated by weighed average of 3 contributing OLKs as mentioned above.

The other group is such business processes that are controlled and executed by the BPM system. Proposed PPMM is used for determining which processes should be executed successfully to achieve a target SLK. For example, in the *Case Company S*, the problem is to select process and sub-process we have to improve for enhancing the 'productivity' SLK of internal process perspective of BSC. By using the proposed PPMM, we identify that the major contributing TLK to the 'productivity' SLK is 'output quantity' in the KPI model (number-1 arrow), as shown in Figure 9. Then we determine that the major influencing process on 'output quantity' TLK is 'production' process in the K-P model (number-2 arrow). To find the major influencing sub-process, we see that the major contributing OLK to the 'output quantity' TLK is 'Mean time to repair (MTTR) in the KPI model (number 3 arrow). This result indicates that the major influencing sub-process on 'MTTR' OLK is 'equipment maintenance' sub-process in the K-P model. Finally, we find that 'equipment maintenance' is the sub-process of 'Production' process in the process model (number-4 arrow).

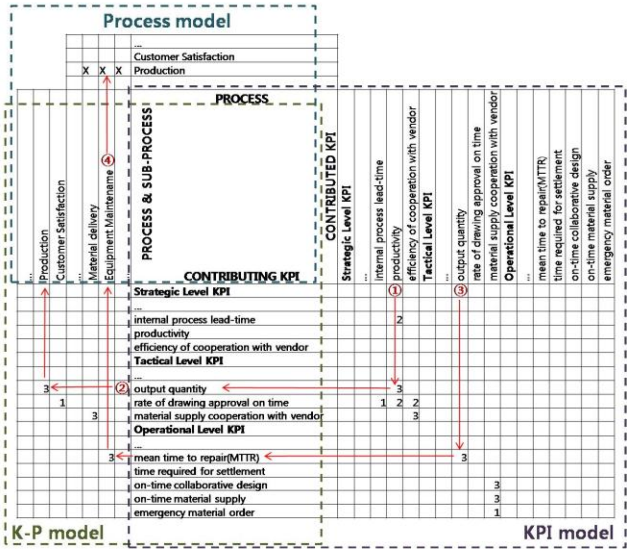

Figure 9. Selection of sub-process for monitoring

4.2.2 Conceptual dashboard design

In this step, the structure and display format of dashboard are designed schematically to properly present the status and trend of selected KPIs or business processes. Generally, bar chart, broken line chart, pie chart, dial gauge, and list are used.

Figure 10 shows the conceptual design for dashboard to present the status of equipment maintenance process of *Case Company S*. Pie chart is used for displaying proportion of occurred maintenance by department. Vertical bar charts are used for the number of maintenance by plant. Treatment delay activities or alert processes are displayed by list format.

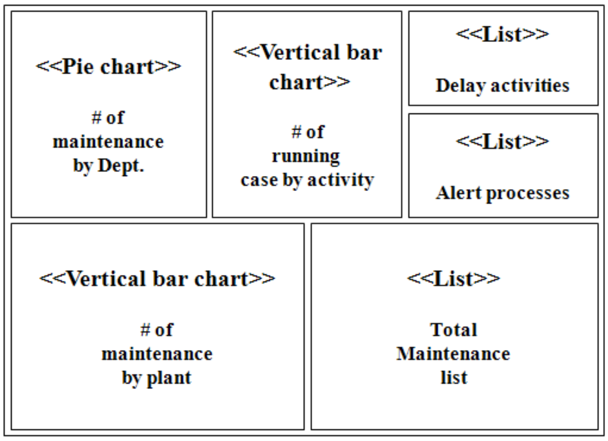

Figure 10. Example of conceptual dashboard design

4.2.3 Define events for monitoring

In this step, the events that should be monitored to follow up the status and trend of the selected KPIs or business processes on the dashboard are defined and categorized. Event is defined as “a record of specific activity in a system” [16], and events are further categorized into a business event or a technical event.

If the business process is executed based on the BPM system, the start or the completion of each activity within the specific process is defined as a business event. If the business process is executed without BPM system and the KPI is calculated by data manipulation in the database (i.e. addition, deletion, and update of data records), this manipulation is defined as a technical event.

4.2.4 Define data stream

In this step, the data flow from various source data, which are directly used or need to be transformed, to the presentation layer for displaying the monitored data on the dashboard are specified.

In case of *Case Company H*, Figure 11 shows the data stream for the status of regional monthly inventory ratio (MIR). The data source for MIR is DB table for regional sales status in the overseas sales information. And the sales and inventory data are transferred to the independent DB table within the analytical processing system once per one minute by means of enterprise application integration (EAI) tool. The EAI methods are classified as follows: information oriented approach, business process oriented approach, service oriented approach, and portal oriented approach. Information oriented approach is further classified into data replication, data federation, and interface processing method [14]. The data replication method is used in this case in order to transfer sales and inventory data from the transaction processing system to the analytical processing system.

BAM system monitors its own DB table within the analytical processing system and calculates the value of MIR according to the predefined formula and presents the MIR value on the dashboard. MIR is the ratio of the current sales inventory to the average monthly sales as follows: MIR = (current sales inventory / average monthly sales).

Figure 12 shows the data stream for the status of equipment maintenance process which is conducted through the BPM system in the *Case Company S*. The equipment maintenance process consists of the five activities. The start and the completion events of each activity are monitored and presented on the dashboard.

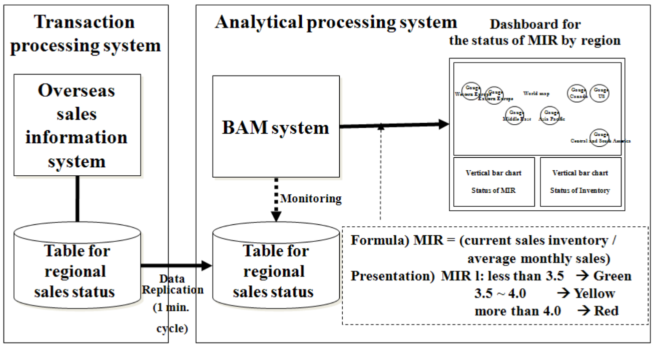

Figure 11. Data stream for monitoring regional monthly inventory ratio of *Company H*

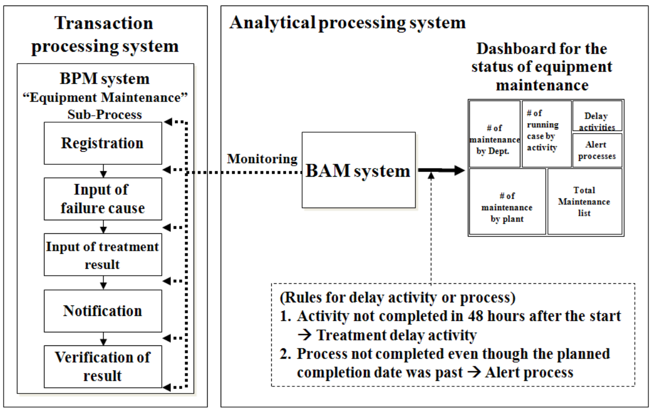

Figure 12. Data stream for monitoring equipment maintenance process of *Company S*

4.2.5 Define presentation rules

In this step, presentation rules for KPI or business process are defined.

As an example for the KPI monitoring, in case of *Case Company S*, monthly material supply cooperation with vendor (MSC) TLK index is calculated as a monthly weighed average of 3 contributing OLKs (i.e., OTCD, OTS and EMO). Its formula is as follows:
MSC= 3/7*OTCD + 3/7*OTS + 1/7*(100-EMO), where OTCD= (monthly # of on-time collaborative design completion)/ (monthly completed total # of collaborative design) * 100,
OTS= (monthly # of on-time supply/ monthly total # of supply) *100,
EMO= (monthly # of issued emergency order)/ (monthly total # of purchase order)*100.

Figure 13 shows dashboard for the monitoring of 'material supply cooperation with vendor' TLK trend. The left part shows the status of certain month as a bar chart: The upper bar represent current status of 'material supply cooperation' index by weighted average of other three indexes as formulated above. Lower three bar describes the current status of three OLKs contributing to 'material supply cooperation' SLK. The right part of Figure 7 show monthly trend of MSC index as a graph of broken line.

As an example of process monitoring, in case of *Case Company S*, 'equipment maintenance' sub-process has five activities as follows: 1) registration, 2) input of failure cause, 3) input of treatment result, 4) notification, and 5) verification of treatment. In order to reduce or eliminate delays, an uncompleted activity within 48 hours after the start time is categorized as a treatment delay activity. A process that is not completed until the planed due date is classified to an alert process.

Monitoring display consists of 5 parts as depicted in Figure 14. On the upper left part, the numbers of equipment maintenance by department are displayed by the pie chart. On the upper middle part, the running number of cases in each activity within sub-process is presented by the vertical bar chart. On the upper right part, the treatment delay activities are presented by the warning list and the alert processes are presented by the alert list. On the lower left part, the numbers of maintenance problems by plant are presented by the vertical bar chart. Lastly, on the lower right part, total maintenance problems processed on the BPM system are displayed by the list format. If one maintenance problem is clicked in this list, a screen showing the detail contents of the problem appears in a drill-down way.

By monitoring this dashboard and analyzing the cause of delay activities, the number of delayed activities can be reduced, and the total throughput time of this sub-process could be shortened.

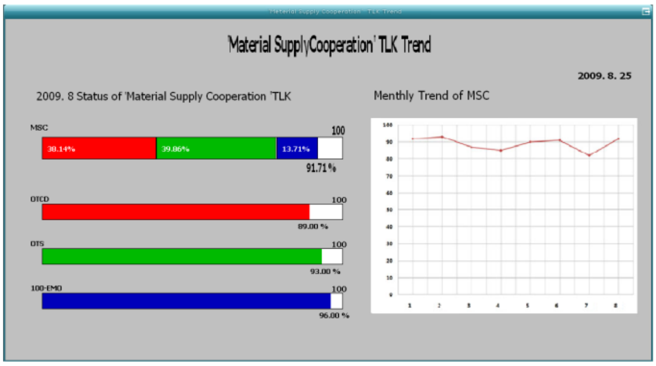

Figure 13. Display of MSC TLK monitoring

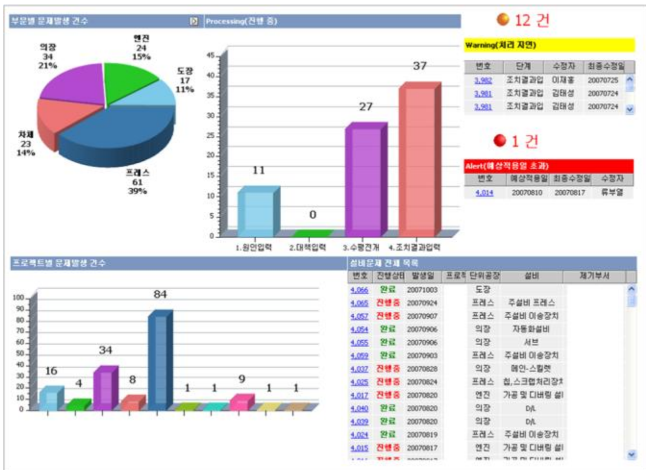

Figure 14. Display of 'equipment maintenance' sub-process monitoring

5. Conclusions and Further Research

Whether the enterprise focuses on profitability, earning per share or market share growth, hitting such goals is becoming ever more challenging. To cope with these challenges, companies must monitor and manage their performance to assure that they properly execute their strategies.

BAM is the key element for the real-time performance management aligned with business strategies. Proposed in this paper are a BAM system design framework based on the PPMM for continuous process improvement, and an implementation of BAM system prototype to show the applicability of proposed framework.

This paper is expected to be a practical help to the practitioners who are planning and executing the BAM system implementation for the real-time performance management.

As well as the importance of business process to an enterprise performance, knowledge is also treated as a critical driving force for attaining enterprise performance goals because knowledge facilitates the better business decision makings in a timely fashion. Therefore, enterprise-level perspective on the relationships among enterprise performance, business processes and knowledge should be established. Therefore, as a further research, development of process-centered enterprise structure integrating process, performance and knowledge in a value chain context is needed.

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