International Journal of Technology (2011) 3: 215-223
ISSN 2086-9614

STUDY ON SUPPORT SYSTEM OF KAIZEN ACTIVITY FOR SUSTAINABLE IMPROVEMENT OF GLOBAL COMPETITIVENESS

Koichi Murata[1*], Hiroshi Katayama[1]

[1]*Department of Industrial and Management Systems Engineering, Graduate School of Creative Science and Engineering, Waseda University, Japan*

(Received: May 2011 / Revised: June 2011 / Accepted: June 2011)

ABSTRACT
The purpose of this paper is to describe a proposed support system of Kaizen activity which contributes to improve related performance indicators in a production department. Background research consisted of the following three parts. First, a Decision Support System (DSS) provided an illustration for the proposed system; its three elements of interest include Kaizen case-base, Model-base and User-interface. The first element accumulates useful cases for developing new cases. The second element accumulates models to utilize the case-base effectively, including the Kaizen strategic model, Kaizen objective model, Kaizen data analysis model, and model building blocks and subroutines. The third element links Kaizen case-base, Model-base and Kaizen engineers. The linkages are realized by four procedures: installation of proposed support system, construction of Kaizen case-base, evaluation of the case-base, and development of new cases. The second portion of our research was a discussion of Kaizen case-base from three viewpoints: its utilization purpose, its information structure, and data types accumulated in it. Thirdly, investigation of the three primary model types mentioned above was performed and the proposed model-base was constructed. Proposed system was designed to maintain and improve Key Performance Indicators (KPIs) in a manufacturing system through discussions with Kaizen experts whose factory collaborated in this research.

Keywords: Decision Support System (DSS); Global manufacturing; Kaizen case-base; Key Performance Indicators (KPIs); Knowledge management

1. INTRODUCTION
Reliable and effective production systems which help ensure safety in the work environment are foundational to manufacturers' delivery of various services to customers. Kaizen activity has been utilized to construct such a production system described in this study. Most of the projects in the activity depend on acquired expertise, often obtained over a long period of time through "trial and error," that is useful for factory performance improvement. Companies typically place value on accumulating experience through participation in many projects that they design and utilize as educational tools for Kaizen engineers; simply learning about related methodologies is not viewed as sufficient preparation for development of new Kaizen cases. Kaizen engineers who will support their production systems in the future have to learn Kaizen know-how, improve their skills, and demonstrate the ability to complete projects effectively. Experts must transfer their knowledge and technology to less experienced engineers. Systematization of both cycles is a key point for any company striving to maintain competitive superiority in a global environment.

[*] Corresponding author's email: k-murata@kata.mgmt.waseda.ac.jp, Tel. +81-3-5286-3297, Fax. +81-3-5286-3297

In particular, an enhancement of Visual Management (VM) technology as one of the representative Kaizen technologies is expected to be effectively applied to large-scale and complicated production systems because it contributes to the improvement of related Key Performance Indicators (KPIs), i.e., reliability, productivity, and safety, and operates as an interface between manufacturers and the production system. Based on the facts noted above, the purpose of this research was development of a framework of a support system of Kaizen activity and its structural elements.

2. MANAGEMENT OF KAIZEN ACTIVITY

Two axes to find attributes of management activities were proposed by Gorry and Morton (1971). One axis represents the purpose of management activity, which consists of strategic planning, management control, and operational control. Objectives of strategic planning are prediction of business environment and construction of business strategy. Management control is a process to confirm suitable supplementation and effective utilization of various resources such as personnel, the newest equipment, and environmental-friendly materials. Operational control is a process to confirm implementation of specified operations in each department (Ishiwata, 1979, 1984). The other axis represents a support system for management activity; it consists of structured support, semi-structured support, and unstructured support. An example of a structured support system is Electronic Data Processing (EDP), and an example of an unstructured support system is the Decision Support System (DSS). A semi-structured support system is a blend of both systems.

A framework for a management information system of Kaizen activity is illustrated in Table 1. Strategic planning by top management of Kaizen activity provides a framework for construction of a future production system. Management control of Kaizen activity is a process conducted at the manager level to analyze results of implemented projects and identify subsequent projects. Operational control occurs at the manufacturer level and is a process to implement projects and measure their results. Structured support systems support management of plan value of KPIs and actual value of KPIs by management level and management of how to measure both values by manufacturer level. A common role support of evaluation of Kaizen activity. Examples of management objectives in a structured support system regarding planned value of KPIs include evaluating rate of machine operation, operation efficiency, rate of material consumption, amount of products in stock, and production in progress. Examples of the activities in the operational control level are a design of how to measure both values of KPIs and when to measure them. Semi-structured support systems support management of Kaizen technology assets at the management level and supervision of progress on projects at the manufacturer level. A common role of management in a semi-structured support system is accumulation and classification of developed Kaizen technologies and their reuse. The manufacturer is responsible for implementation of Kaizen activities, such as recovering lost time for each project plan. Unstructured support systems support Kaizen strategic planning by top management levels, management of skill of Kaizen engineers by management, and support for project implementation from the manufacturer level. A role of top management is the determination of a basic Kaizen scheme, such as Total Productive Management/ Maintenance (TPM) (Shirose, 1996), Total Quality Management (TQM), and Lean Management (Womack & Jones, 2003). A common role of second and third managerial tiers is the support of education of Kaizen engineers. Examples of the activities in the management control level include a clarification of Kaizen skills a clarification of Kaizen skills which each engineer should to acquire, an education plan for each engineer, and an assessment of their education progress. Examples of the activity in the operational control level are development and application of teaching material.

Table 1 A framework of management information system of Kaizen activity

Type of support system	Purpose		
	Operational control	Management control	Strategic planning
Structured	Management of how to measure plan value of KPIs and actual value of KPIs • How to measure both values of KPIs • When to measure both values of KPIs etc.	Management of plan value of KPIs and actual value of KPIs • Rate of machine operation • Operation efficiency • Rate of material consumption • Amount of products in stock • Amount of products in progress etc.	-
Semi-structured	Management of project progress	Management of Kaizen technology assets	-
Unstructured	Support of implementation of each project	Management of skill of Kaizen engineers	Kaizen strategic planning

3. SUPPORT SYSTEM OF KAIZEN ACTIVITY

DSS has developed a number of systems (Chan, et al., 2000; Halsall & Price, 1999; Suri & Whitney, 1984). Sprague and Watson (1979) proposed a DSS framework consisting of three elements: Data-base, Model-base and Decision-maker. Also, in order to control information flow among the two databases and Decision-maker, Data-base management system, Model-base, and User-interface are located within DSS. Decision-maker accesses Data-base and Model-base to obtain useful data and/or models and delivers information via User-interface.

The proposed system described in this study consists of Kaizen case-base, Model-base, and User-Interface. Figure 1 shows the relationship among the three elements. Utilization of the proposed system is based on four procedures of User-Interface: installation procedure of support system, construction procedure of VM Case-base, evaluation procedure of VM Case-base, and development of the new VM case. All procedures except the installation procedure of the support system are discussed in this paper. Also, the object of the three procedures is VM technology, a useful Kaizen technology for the production sector. In the construction procedure of VM Case-base, two defined terms are utilized for classification of a VM case. One is “driver” which means category of attributes of a VM case. The other is “instance”, which means member of a driver- characterized VM case. Kaizen engineers extracted instances from each driver of each case from developed cases by instances of each driver and models offered from proposed system. In the evaluation procedure of VM Case-base, engineers identified the relationship of data between cases and KPIs based on accumulated data in the case-base, analysis of the data models offered from Model-base, and evaluated the degree of contribution of cases to improved KPIs. If the evaluation results were not favorable, it became necessary to add cases by which results could be improved. In the development procedure of new cases, they analyzed a current burden by useful methodologies such as operation analysis and/or Why-Why analysis offered from Model-base, retrieved suitable cases from VM Case-base based on the analysis, and developed new cases by retrieved cases for resolving the current burden. Details of these procedures are described in Murata and Katayama (2010a and 2010b).

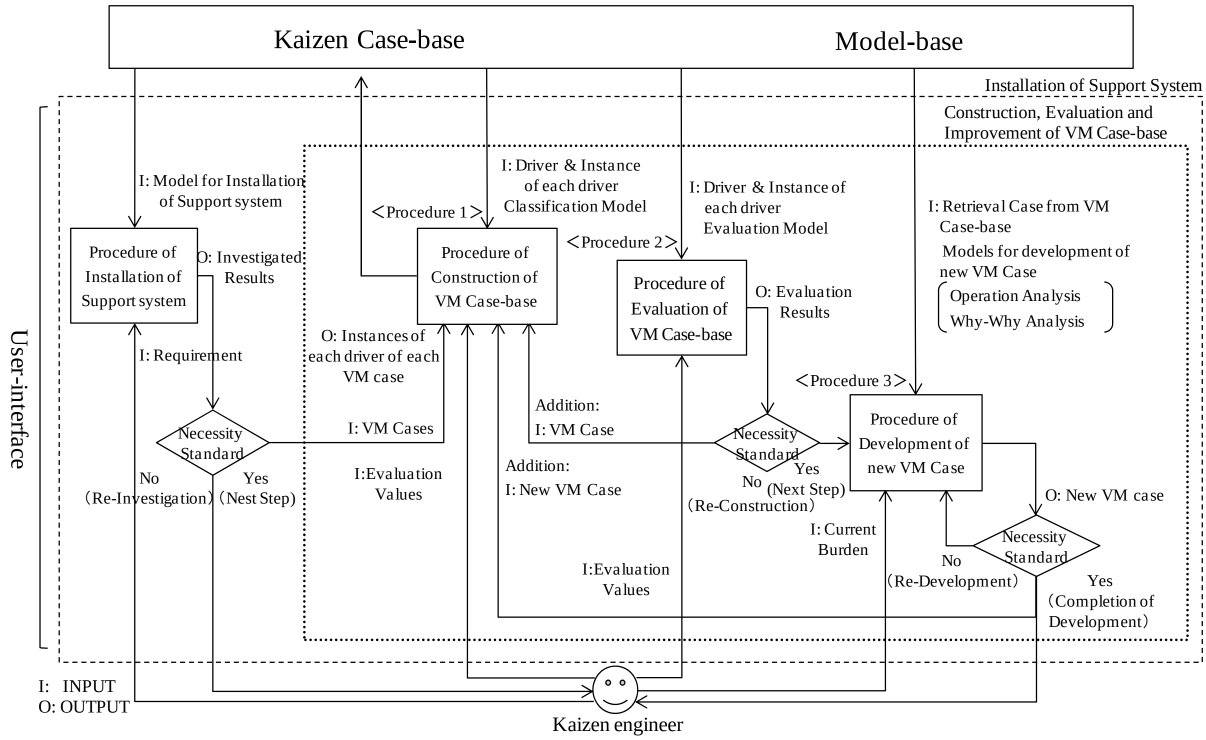

Figure 1 Proposed support system of Kaizen activity

4. KAIZEN CASE-BASE

The PDCA (Plan-Do-Check-Action) Cycle is essential to the success of a performance improvement project for a high productivity organization, skilled manager and fine product and service. The KPI/KAI (Key Activity Indicator) database (Murata & Katayama, 2009), which is the center of the proposed evaluation system of factory performance, is useful for supporting Check step, Action step, and Plan step in the PDCA Cycle (Figure 2). KAI data was accumulated in the KPI/KAI database, and KPI data was registered to the KPI/KAI database after the improvement project was completed. Based on data from two categories in the KPI/KAI database, factory performance value was calculated. In the Check step, KPI data, KAI data, and factory performance values, proved useful for evaluating results of the improvement project. Also, a gap between target value and obtained actual data was analyzed. In the Action and Plan steps, data from three categories' was useful for investigating past improvement projects and setting target values for the next improvement project. These operations performed during the Check, Action, and Plan steps are considered as the benchmarking process. In Figure 2, it is noted that a Do step is included in the Kaizen activity. Compact and useful Kaizen technologies, e.g., VM technology, POKAYOKE, and KARAKURI, were accumulated in Kaizen case-base, which supplied suitable Kaizen technologies for use in the improvement project. The KPI/KAI database and Kaizen case-base provided effective support throughout the entire PDCA Cycle.

4.1. Utilization purpose

Kaizen case-base has three utilization purposes: detection and solution of hidden abnormalities in the production system, prevention of the occurrence of abnormalities in the production system, and loss reduction. When hidden abnormalities are detected in the production system, Kaizen engineers deal with them urgently based on information obtained from the technologies, such as Diagnosis technology Case-base and VM Case-base.

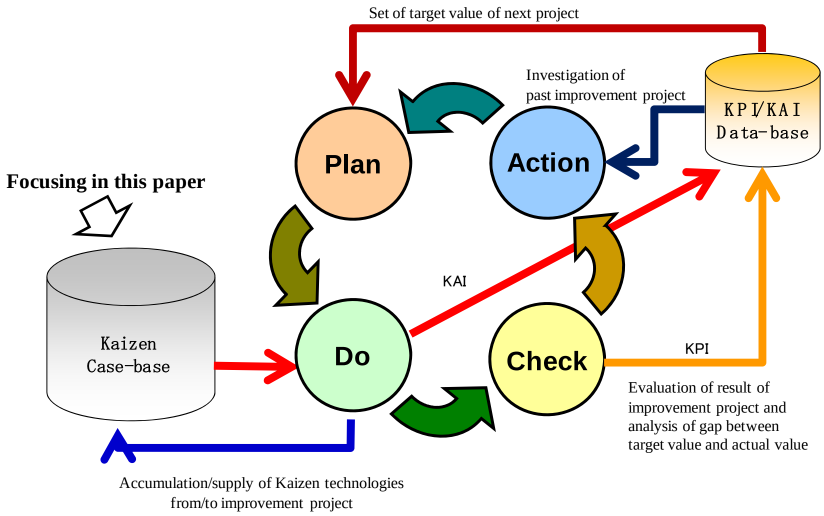

Figure 2 A framework database of Kaizen activity in a production site

Case-base examples utilized in preventing a recurrence of past abnormalities are POKAYOKE Case-base and Maintenance Prevention (MP) Case-base. 5S Case-base technology and Wight reduction technology Case-base were used to detect and eliminate losses, a root cause of abnormalities. Case-base examples for each purpose are summarized in Table 2.

Table 2 Examples of Kaizen case-base by utilization purpose

Utilization purpose	Example of Kaizen case-base	Example of member of Kaizen case-base
1) Detection and solution of hidden abnormalities in	Diagnosis technology Case-base	Cases of diagnosis of processing point
production system	VM Case-base	VM cases
2) Prevention of the	POKAYOKE Case-base	POKAYOKE cases
occurrence of	Maintenance Prevention (MP) Case-base	MP cases
abnormalities in	KIKEN YOTI Training (KYT) Case-base	KYT cases
production system	One point lesson (OPS) sheet Case-base	OPS cases
3) Loss reduction of production system	5S technology Case-base	Seiri cases, Seiton cases, Seisou cases, Seiketu cases, Shituke cases
	Wight reduction technology Case-base	Wight reduction cases
	Lead time reduction technology Case-base	Concurrent cases
	Automation technology Case-base	Robotization cases
		KARAKURI cases
	Balancing technology Case-base	Balancing cases
	Standardization technology Case-base	Standardization cases
	Specific technology Case-base	Cases with specific technology

4.2. Information structure

An information structure for future Kaizen case-base applications is a relational database described in this paper. It is illustrated in the upper two tables of Figure 3. Left side case-base is utilized by an implementation department engaged in Kaizen activity and right side case-base is utilized by a support department. In this study, common information structures between the two case-bases were considered. For instance, with Kaizen cases lined up in a column and drivers lined up in a row, a matrix can be made as shown in the lower table of Figure 3.

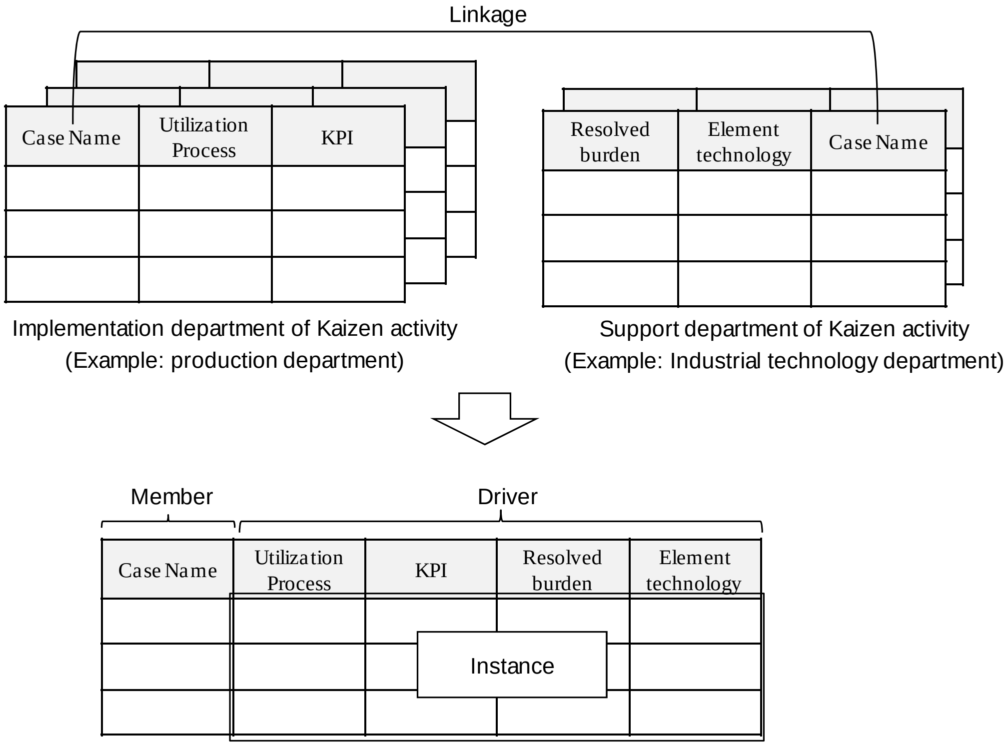

Figure 3 Information structure of Kaizen case-base

4.3. Accumulated data

Image data, sentence data and numerical value data are categories of accumulated data in Kaizen case-base (Table 3).

Table 3 Examples of Kaizen case-base by utilization purpose

Accumulated data	Example of Kaizen case-base	Example of member of Kaizen case-base
1) Image data	Case-base comprised of images	Photo of bird's eye view of case and detail sketch of Kaizen technology
2) Sentence data	Case-base comprised of sentences	Profile data of case by keyword and/or sentences
3) Numerical value data	Case-base comprised of numerical values	Plan value of KPIs, actual value of KPIs, development cost, development period

5. MODEL-BASE

Model-base accumulates models for the effective utilization of Kaizen Case-base. It includes the Kaizen strategic model, Kaizen objective model, Kaizen data analysis model, and model building blocks and subroutines, as indicated by the Model-base structure of Sprague and Watson's DSS. In this research, investigation of examples of the three specific model types was performed, and a proposed model-base was constructed based on the results.

5.1. Kaizen strategic model

This model delivers an organizational structure and an implementation procedure synthetically and systematically to promote Kaizen activity. Through utilization of this model, strategic activity can be realized to improve KPIs of each factory and to reinforce the character of an enterprise. Model examples are shown in Table 4 (Kaplan & Norton, 1992).

Table 4 Example of strategy model of Kaizen activity

TPM	:	Total Productive Management/ Maintenance
TQM	:	Total Quality Management
Lean Management (TPS: Toyota Production System)		
TPM	:	Total Productivity Management
MRPII	:	Management Resource Planning
BSC	:	Balanced Scorecard

5.2. Kaizen objective model

This model delivers a prototype of various functions in a production system. In the case of improvement of a function in a production system, essential problem-solving can be expected through analysis of a gap between current state and target state given by the related model and establishment of a suitable project plan. There are eight kinds of models in order of model scale: a) demand forecast model, b) order management model, c) ordering and indicating model, d) production system model, e) production planning model, f) layout model, g) delivery system model, and h) operation model. Examples of each model are illustrated in Table 5.

5.3. Kaizen data analysis model

This model is utilized to analyze data accumulated in Kaizen case-base, make decisions based on the data, and develop graphs based on the results of data analysis, decision-making, and other data. There are three kinds of models based on technological features: multivariate analysis model, decision-making model, and model for making graphs. Advanced models can be developed by integrating these fundamental models so that accumulated data in Kaizen case-base is utilized effectively. Examples of each model are illustrated in Table 6.

Table 5 Examples of Kaizen objective model

Type of Kaizen objective model		Examples
1) Demand forecast model	Total demand model	Stone & Rowe model (Durable goods), Houthakker & Taylor model (General consumption goods)
	Initial purchase model	Bass model (Durable consumption goods), Fourt & Woodlock model (Repeat purchase goods)
	Repeat purchase model	Parfitt & Collins model, Horsky & Simon model, Dolan & Jculand model, Tracker model, Assessor model,
	Time-series analysis model	T.CSI type model, Self-regression type model
	Regression model	Pluralism-regression type model, Robust regression model, Distributed lag models, GMDH model
	Integration model	ARMA model, ARIMA model
2) Order management model		MTB model (Make to Buy) MTO model (Make to Order) -BTO model (Built to Order), ETO model (Engineer to Order), DTO model (Design to Order)
3) Production ordering model		Fixed size ordering system, Fixed interval ordering system, Other system (Double-bin ordering system, Replenishment ordering system, S-s-T ordering system, Kanban system) Vassian's production loading system, MRP: Material Requirement Planning
4) Production system model		Line production system, Lot production system, Job shop production system
5) Production planning model	Route scheduling model	BOM: Bill of Material, 3S: Standardization, Simplification, Specialization etc.
	Loading model	Forward loading, Backward loading
	Scheduling model	Sequencing method, Dispatching method, Network method, GA: Genetic Algorithm
6) Layout model	Layout by products	Specialized line, Mixed line
	Layout by processes	Cell production system, Workplace for multi-process, Workplace by a kind of machines
7) Delivery system model		AGV: Automatic Guided Vehicle, Conveyor, Monorail
8) Operation model		Principle of motion economy

Table 6 Examples of Kaizen data analysis model

Type of data analysis model		Examples
1) Multivariate analysis model		Multiple regression analysis, Discriminant analysis, Principal component analysis, Factor analysis, Quantification Theory Category I-IV, MDS: Multi Dimensional Scaling
2) Decision- making model		Payoff matrix model, AHP: Analytic Hierarchy Process, ANP: Analytic Network Process etc.
3) Model for making graphs	Ordering quantity analysis	ABC analysis (Product-Quantity analysis)
	Production system analysis	GT: Group technology
	Production planning analysis	Operation process chart, Petri Net model, Pitch diagram
	Layout and delivery analysis	Activity relationship diagram, Flow process chart
	Operation analysis	Element operation analysis, Motion study, PTS: Predetermined Time Standards, Work sampling, Stopwatch method
	Others	5W1H, Why-Why analysis

5. CONCLUSION

There are three central findings emphasized through the discussions of this paper. First, a management procedure of Kaizen activity was essential before design of the proposed system could take place. Secondly, three elements of the proposed system such as Kaizen case-base, Model-base, and User-Interface were effective tools in this research. Thirdly, a probability of application of DSS to Kaizen activity is given through a design of the proposed support system. Owing to these findings, the initial step for the realization of a systematic approach of Kaizen activity will be taken. There are mainly two future studies as follows. Firstly it will be necessary to confirm the utility of the proposed system through several experimentations. Secondly a construction of VM case-base as an example of typical Kaizen case-base will be performed through collecting and classifying its cases.

6. REFERENCES

Chan, S. T. F., Jiang, B., Tang, H. K. N., 2000. The Development of Intelligent Decision Support Tools to Aid the Design of Flexible Manufacturing System. *International Journal of Production Economics* (IJPE), Vol. 65, No. 1, pp. 73-84.

Gorry, G. A., S. Morton, M. S., 1971. A Framework for Management Information Systems. *Sloan Management Review*, Fall, Vol. 13, No. 1, pp. 55-70.

Halsall, N. D., Price, R. H. D., 1999. A DSS Approach to Developing Systems to Support Production Planning and Control in Smaller Companies. *International Journal of Production Research* (IJPR), Vol. 37, No. 7, pp. 1654-1660.

Ishiwata, T., 1979. *Sale Management* - Hanbai Kanri, Maruzen, Tokyo [in Japanese].

Ishiwata, T., 1984. *Office Automation for Management - Management no tameno Office Automation*. Ohmsha, Tokyo [in Japanese].

Kaplan, R. S., Norton, D. P., 1992. The Balanced Scorecard - Measures that Drive Performance. *Harvard Business Review*, January/February, pp. 71-79.

Murata, K., Katayama, H., 2009. An Evaluation of Factory Performance Utilized KPI/KAI with Data Envelopment Analysis. *Journal of the Operations Research Society of Japan* (JORSJ), Vol. 52, No. 2 (A Special Issue on Operations Research for Performance Evaluation), pp. 204-220.

Murata, K., Katayama, H., 2010a. Development of Kaizen Case-base for Effective Technology Transfer: A Case of Visual Management Technology. *International Journal of Production Research (IJPR)*, Vol. 48, No. 16, pp. 4901-4917.

Murata, K., Katayama, H., 2010b. A Study on Construction of Kaizen Case-base and Its Utilization: A Case of Visual Management in Fabrication and Assembly Shop-floors. *International Journal of Production Research* (IJPR), Vol. 48, No. 24, pp. 7265-7287.

Shirose, K. (Ed.), 1996. *TPM New Implementation Program in Fabrication and Assembly Industries*. Productivity Press, Portland, Oregon.

Sprague Jr., R. H., Watson, H. J., 1979. Bit by Bit: Toward Decision Support System. *California Management Review*. Fall, Vol. 22, No. 1, pp. 60-68.

Suri, R., Whitney, K. C., 1984. Decision Support Requirements in Flexible Manufacturing. *Journal of Manufacturing Systems*, Vol. 3, No. 1, pp. 62-69.

Womack, P. J., Jones, T. D., 2003. *Lean Thinking: Banish Waste and Create Wealth in Your Corporation*. Revised and Updated, Free Press, New York.