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Extension of KPI measures for effective lean management -Some evolutional directions for more leanised organisation-

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Abstract: The word "lean production" was born during late 70s to early 80s through International Motor Vehicle Program, a US-driven international project, and has been well known world-widely thereafter. It has been provided substantial contribution for corporate performance management and now, it is the time to change the industrial world again by its extended scheme. The topics being discussed in this paper include, as a starting point, interpretation of historical constitutional concept, the way of thinking and the sense of value of lean management followed by introduction of recent conceptual/technological advancements in the world industrial scene. There are many evolutional directions recently launched and/or attempted to realise by leading industries to cope with drastically changing business environment. Some significant issues such as structurisation of KPIs, IoT-assisted leanised management, evolution on PDCA style of management, black-box technology and hybrid management style of reactive and proactive operations are spotlighted and discussed, all of which will bring us to hopeful future.

Topic: Digital supply chain design, analysis and operation
Keywords: Lean Management, Evolutional Direction, Total Productive Maintenance and Management (TPM), Toyota Production System (TPS), KPI Structure, IoT, PDCA, Black-box Technology, Hybrid Management Style, Reactive/Proactive Operations

1. Introduction

The word "lean production" was born during late 70s to early 80s through International Motor Vehicle Program, a US-driven international project, and has been well known world-widely thereafter (Womack *et al.*, 1990). It has been provided substantial contribution for corporate performance management.

However, origin of lean way of thinking and its sense of value might be fostered in warrior's era in Japan. Historic background is summarised as follows.

a. In 15th-16th century

Original concept was formulated in this Japanese turbulent period, for example, by the particular armour called "**AKAZONAE**" for battle, which is a type of military unit used in feudal Japan and soldiers who wear bright red varnished armour were originated by Takeda and Sanada family warriors illustrated in Figure 1. The key point of the concept is encouraging the fight with an indomitable spirit.

Figure 1. Illustration of "AKAZONAE" Armour used in Warriors Era in Japan

b. Early Meiji Era (1868~)

After Edo era dominated by Tokugawa family warriors, Japanese newly established civilian government conducted to creating industrialised society to overcome their constitutional poorness, catch up the latest technologies from western countries and compete equally with them. These activities are all based on their obsession against western culture.

c. Early Showa Era (1926~)

Industrialisation has been took off gradually including establishment of Toyota Motor Co. with many relevant methods contributing productivity and these, including the mind of obsession to compete, were transferred among industries over the country.

This obsession causes the concept of making unremitting efforts for business and the idea of perfect elimination of "Muri" (Strained), "Mura" (Variegated) and "Muda" (Wasted) on the platform of Plan, Do, Check and Action Cycles (PDCA) formulated the conceptual legend of lean management (Katayama, H. *et al*., 1999).

2. Way of lean thinking

In this chapter, following 3 distinctive features of lean management are summarised which are based on the lean sense of value formulated through historical transition of Japanese society (Katayama, H., 2010).

2.1 Contradiction-driven Approach

First distinctive feature on the lean way of thinking might be "Contradiction-driven Approach", which the first author has been emphasizing for many years (Katayama, H., 2014b) **(**Katayama, H.; 2017). This style of management starts by delivering leaders' mission which is so-called "mission impossible

or difficult" in general, then, followed by subordinates to think and act on the PDCA platform to move to the object as close as possible. There are some examples in lean management schemes born in Japan such as TPS (Monden, Y., 1993) and TPM (Shirose, K., 1996) (Suzuki, T., 2015).

2.2 Resource-focused

Second issue is essential way of recognition on manufacturing function, which is the conversion process of transactions from resources to outcomes. Where, resource consists of human (called meta-resource because it is only resource that can control others), machine, material, method, money *etc*. and outcome consists of skilled human, advanced machine, value-added material (or product), improved method, increased money *etc*. respectively. Therefore, in lean management, not only transforming material to product but also all other resource must be transformed to its higher value than before. For instance, manufacturing is considered as a learning process of human resource.

2.3 Loss Zerotisation

Third issue that must be a fundamental sense of value of lean management is "Loss Zerotisation". Generally, loss is created in relation to resources used in operations as listed in the previous issue. Therefore, lean management is often considered as a way of loss zero resource management.

3. Future Horizon (Drivers of new style of lean management)

Now, it is the time to change the industrial world again by extension of lean scheme. The topics being discussed in this chapter is recent conceptual/technological advancements in the world industrial scene. There are many evolutional directions eagerly argued recently in the context of lean management to cope with drastically changing business environment. Some significant issues such as structurisation of KPIs, IoT-assisted leanised management, evolution on PDCA style of management, black-box technology and hybrid management style of reactive and proactive operations are spotlighted, all of which will bring us to hopeful future.

3.1 Directions of possible Evolution

Here, in this section, some of the noteworthy directions for lean management evolution are summarised and First issue of (A)-1), 2) and (B)-1) (*underlined*) are examined.

(A) Reinforcement of technological aspect of lean management

1) Technological evolution of current assets

   e.g. <u>IoT-assisted lean management</u>

   e.g. Green lean technology, which is for responding world-wide movement on green operations being encouraged through COPs.

2) <u>White Box vs. Black Box Approaches</u>, which mean open-based and closed-based intellectual property managements

3) Development of Synergetic Loss Reduction Procedure

   How to detect root cause which contribute many types of loss occurrence

   (FTA+FMEA combined Analysis *etc*.)

4) Development of Decomposition Logic of Overall Target

   Evaluation of Significance by AHP *etc*.

5) ROI Performance Improvement of Performance Management Project
Way of Improvement Cost Reduction (Low Cost Automation *etc*.) + Kaizen Outcome Estimation (Simulation)

6) Human-Hour Reduction + Human-Resource Shift
Exploration and Settlement of More Value-Added Jobs

7) Case Base Development of Green Lean Activities and Horizontal Deployment

8) Lean Management Technology Transfer

(B) Reinforcement of conceptual aspect of lean management

1) Proactive vs. Reactive Operations, which are planning phase-focused and recovery phase-focused styles respectively.

2) Similarity-based Model Building/Analysis, which is transferability-attended way of thinking by referring to other useful cases.

3.2 IoT-assisted Lean Management

Recently, lean is considered to merge with ICT to reinforce its effectiveness. Especially, IoT is considered as an effective infrastructure for management of firms' performance, which is evaluated by KPIs.

A possible procedure to construct IoT-assisted lean management using big data captured from shop-floor consists of 5 steps listed below followed by explanation of each step.

1) Classification of Performance Data
2) Data Collection and Database Creation for Performance Benchmarking, Road Mapping & Competitiveness Analysis
3) Causal Analysis among Categories of Performance Data
4) Constitutionalisation of Excellence through PDCA Platform
5) Horizontal Deployment of Best Practices

1) Classification of Performance Data

In general, performance data is often called KPI, however, noticing that there is structural relationship among KPIs, it might be appropriate to classify in terms of some layers.

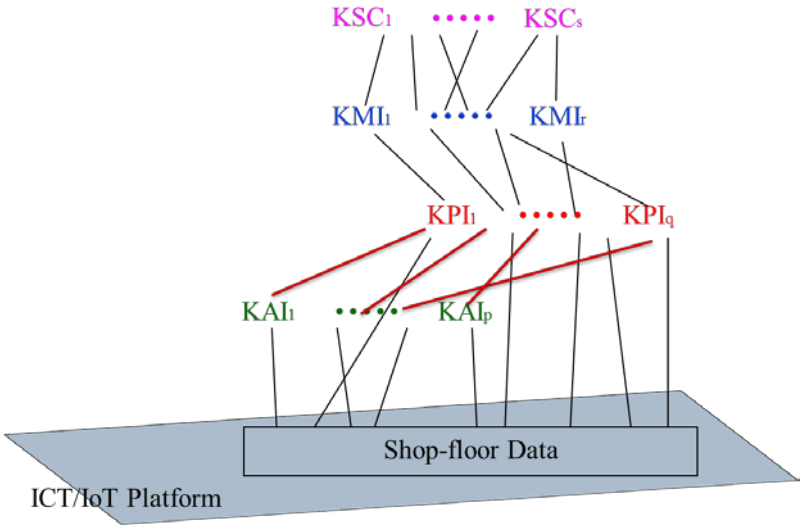

Figure 2. Cascade Structure of Categorized Indicators (Katayama, H., 2017)

Here, we proposes with JIPM (Japan Institute of Plant Maintenance) headquarters, which is the driving organisation of TPM, that KPIs must be deployed into sub-categories such as KSC, KMI, KPI and KAI indicators (Katayama, H., 2017). These meaning and schematic cascade structure is given below and in Figure 2 respectively.

a) KSCs: Key Social Contributors, which relate to CSR issue.

b) KMIs: Key Management Indicators directly relating to corporate management, and therefore, has monetary dimension.

c) KPIs: Key Performance Indicators relating to operational outcomes and has physical dimension.

d) KAIs: Key Activity Indicators relating to operational input and has physical/monetary dimension.

Example list of categorized KPIs used for TPM activity is given in Table 1, where aforementioned new deployment is under construction.

Table 1. Outline of KPIs list defined by TPM Scheme (Example)

Category of Criteria	Performance Measure
P	Production Volume/ Productivity
	SKU
	OEE/OLE/OPE
	Break Down
	Minor Stoppage
	MTBF
	MTTR
	Loss (Set-up *etc*.)
	-
Q	In-flow Off-Q
	In-process Off-Q (Defects)
	Out-flow Off-Q (Claim/ Complaint)
	Rework
	Waste
	Q-points
	-
C	Loss (Each Category)
	Cost (Fixed/Variable)
	Investment
	-

Category of Criteria	Performance Measure
D	OTIF
	Inventory
	Lead-time
	JIT Rate
	-
S	Fatal
	LTA
	No LTA
	Near Misses
	-
M	OPL
	Teams (+AM Steps)
	Recognition (Participation)
	Kaizen Projects
	-
E	Environmental Accidents
	Environmental Complaints
	Landfill
	Return/Reuse/Recycling
	Resource Consumption
	-

Partial cascade structure of OEE/OLE/OPE (Overall Equipment/Line/Plant Efficiency) in Table 1 is easily figured out through its definition established by JIPM (JIPM *Ed*., 1999) (Nakano, K., 2005).

Definition of OEE: Availability Rate×Performance Rate×Quality Rate

Where, Availability Rate (AR) = Actual Operating Time / Loading Time

Performance Rat (PR) = Effective Operating Time / Actual Operating Time

Quality Rate (QR) = Number of Non-defective / Planned Production Quantity
= Value-added Operating Time / Effective Operating Time

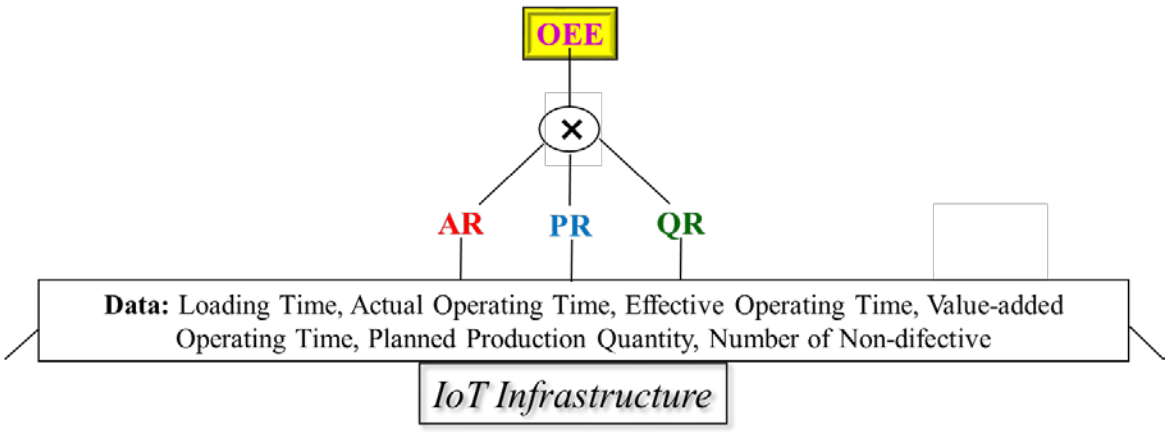

Figure 3. Cascade Structure of OEE

Some of the guide lines for KPI deployment is summarised below.

G1: Dimensions of indicator ◈Physical ◈Monetary ◈Esthetic

G2: Resource-side (KAI) vs. Outcome-side (KPI/KMI/KSC) indicators

G3: Positive (Rewards) vs. Negative (Losses) indicators

G4: Template structure establishment by learning best practices that might be effective general driver for competitive advantage

G5: Fair evaluation of cost issues by ABM (Activity-based Management) that fosters reliable management

2) Data Collection and Database Creation

Hopeful information infrastructure for this purpose is ERP (Enterprise Resource Planning) system combined with MES (Manufacturing Execution System). KAI/KPI/KMI database enables performance benchmarking, road mapping and competitiveness analysis as shown in Figure 4 (Katayama, H., 2014b).

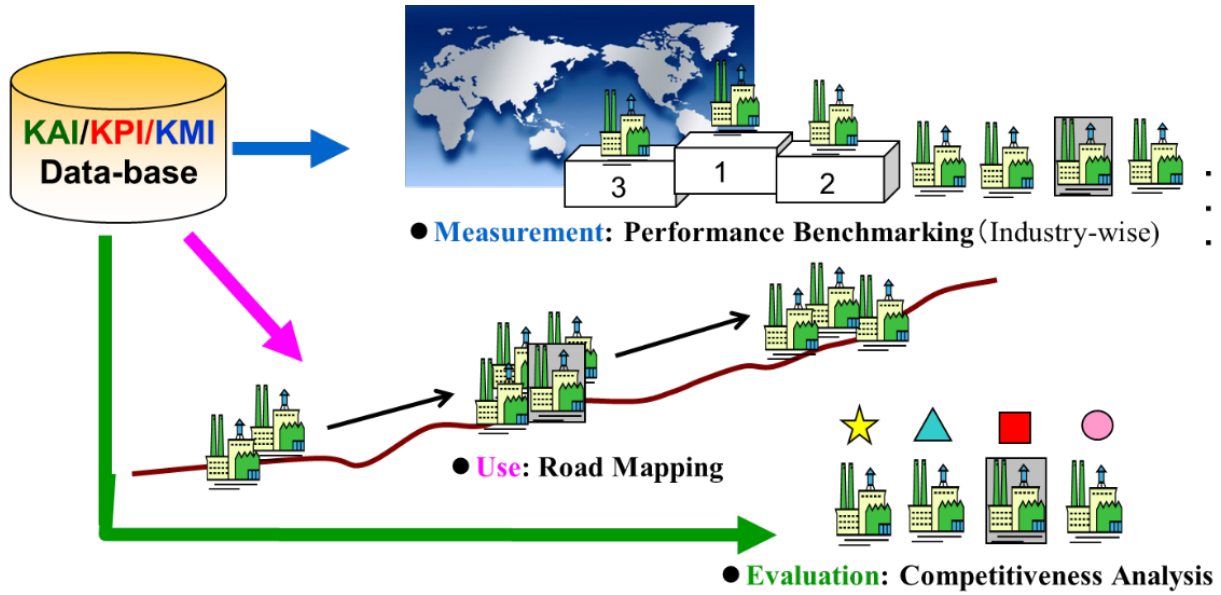

Figure 4. Framework of KAI/KPI/KMI Database enabling Strategic Consideration

3) Causal Analysis among Categories of Performance Data

Relation analysis between KAI and KPI is crucial as it provides the way how to improve certain KPIs by investing or providing effort on specific KAIs. Data structure of both indicators are illustrated in Figure 5 (Katayama, H., 2014b).

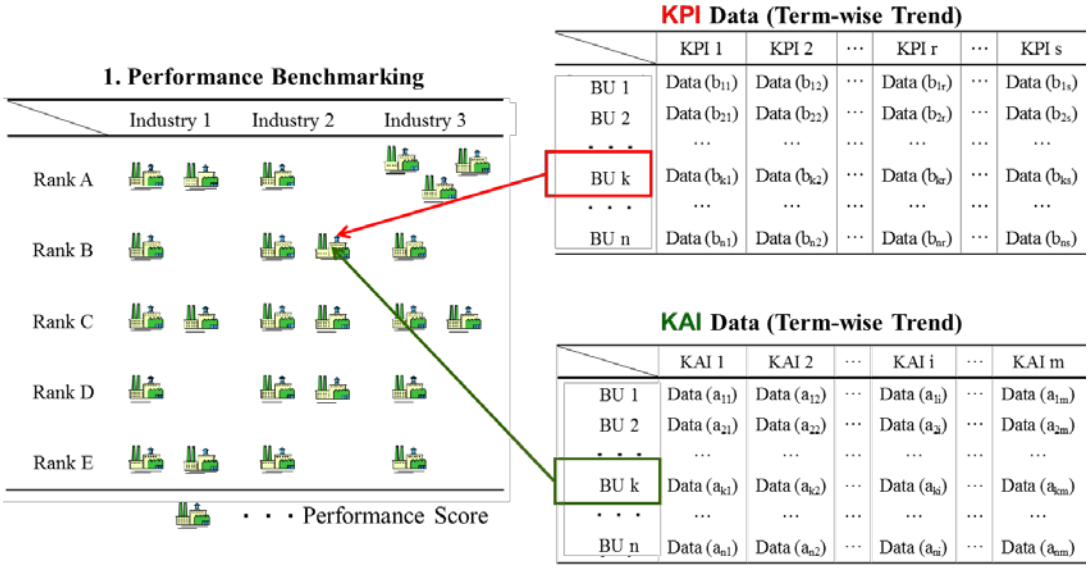

Figure 5. Structure of KAI/KPI Database

4) Constitutionalisation of Excellence through PDCA Platform

Figure 6 illustrates one hopeful structure of combination of improvement case-base and KAI/KPI/KMI database, where ICT is applied as a part of lean platform, *i.e.* PDCA iterative cycle with the cases of the improvement activities and their outcome database created by quantified KSC, KMI, KPI and KAI indicators (Murata, K. *et al*., 2013) (Katayama, H., 2014b).

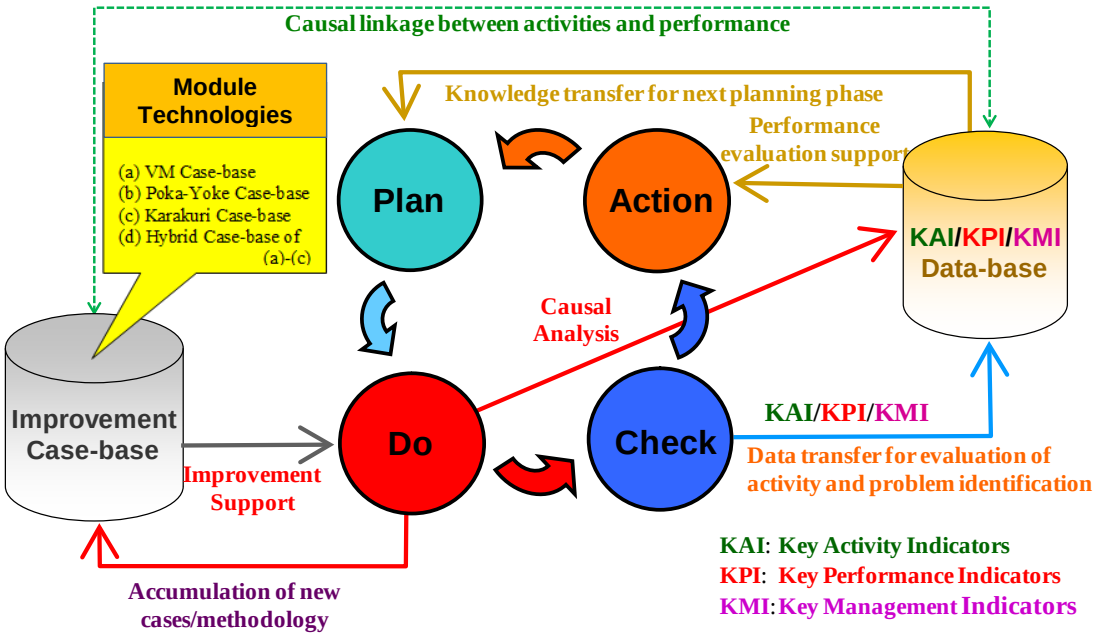

Figure 6. Structure of activated PDCA scheme with improvement case-base and performance data-base

5) Horizontal Deployment of Best Practices

Development and implementation of effective transfer methods (vehicles) between sites, business functions, business divisions and industries must be developed and applied for further reinforcement of the business, where, major attributes of deployment are listed below.

Vehicle: Performance Improvement Technologies (Example)

Activity: Mutual Learning (Example)

System: ERP (Example)

Future prospect on indicator-related research, especially about KAI and KPI, is listed below.

- ◈ Systematic collection and classification of KAI/KPI data
- ◈ Industry-wise performance analysis + similarity analysis
- ◈ Further causal analysis between KAI and KPI
- ◈ Identification of focusing KAI level for attaining and/or designing target KPI level
- ◈ Roadmap design of improvement activity to attain factory/corporate targets

3.3 White Box (WB) vs. Black Box (BB) Approaches

The approach called black box approach is recently emerged among Japanese manufacturing companies for protecting their product effectively from competitors (Katayama, H., 2012). Counterpart of this concept is white box approach and their definition might be as follows.

- □ White Box Approach: Open-based intellectual property management and used to be a basic approach of lean management
- ■ Black Box Approach: Closed-based intellectual property management and concentrated on secretisation

Some examples of both approaches are given as follows.

□ WB ➪ Education/Training

⇨ Visual Management

⇨ Technology Transfer Activity such as Australian WAGYU (example)

■ BB ⇨ ICT: Encryption (Secret Coding)

⇨ Seedless fruits, Front-end processing (powering) and Localised production (tea) in agri-business

⇨ Management: ◈Vertically integrated organisation with security systems,

◈Reverse engineering protection

◈Lean management-based product design and manufacturing

◈AI-assisted system

3.4 Proactive vs. Reactive Operations

The first author was invited to International Symposium entitled "Academic Re-illumination of Samsung New Management" organized by Samsung Company as one of the keynote speakers, which was held at The K Seoul Hotel in Korea on 20th June, 2013 (Katayama, H., 2014a).

One distinctive feature of the way of Samsung management, which was learnt through interview and investigation of operations performed prior to the keynote, is "Speedy and Timely Management (STM)". This style of management is formulated by miraculous balance of reactive operation and proactive operations. Three management styles regarding Samsung way are summarised in the next itemised description.

1) Reactive-focused: Relatively quick, but actually, very bad as bomb is transferred to customers. Also, it causes negative brand reputation.
2) Proactive-focused: In theory, very good, but a long preparatory lead time and concerned people will be tired due to huge volume and time consuming work.
3) The 3rd approach: Proactive/reactive-combined way of management which can overcome the demerits of both approaches described above. Where, potential of proactivity & reactivity are both required. From skill development point of view, this situation is very ideal as people have to concern both approaches and their skills are automatically trained through struggling with this way.

4. Concluding Remarks

In this paper, constitutional concept, the way of thinking with the sense of value of lean management were reviewed and recent conceptual/technological advancements on the way of manufacturing management was examined. Some evolutional topics such as structurisation of KPIs, IoT-assisted leanised management, evolution on PDCA style of management, black-box technology and hybrid management style of reactive and proactive operations are also discussed for hopeful future of lean management.

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