Developing a Novel Framework for Quality System and Systems Thinking to Integrate: A Paradigm Shift in Maintenance

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***Abstract*—This paper presents a need of paradigm shift in maintenance system so as to improve performance of overall system in this global competition. It discovers flaws in present day maintenance strategies that were considered to be the rationale behind the need for this new paradigm; changing scheme from a problem solving maintenance to a problem understanding maintenance. To reply to that research gap, this study unveils want in quality system and systems thinking that must have got to be integrated into conception of the existing maintenance strategies.**

Having had demand for integration of these methodologies, this paper offers a novel framework that enable maintenance operatives to plan maintenance actions through the identification of true root cause of failures and the quest of optimal solutions by viewing problem as a system in its entirety. Unlike current maintenance strategies, the proposed framework will count not only 'hard' factors but also their relationships with nascent 'soft' factors as contributing elements in the cause of failure. It can then be developed from beneficial effect of integration between the Six Sigma and the System Dynamics benefiting from favorable merged characteristics of the two; quality system and systems thinking respectively, along with feedback mechanism. Details construction of the framework is explained thoroughly in every section of this paper.

***Keywords*—cybernetics system engineering, maintenance system, manufacturing management, quality system, systems thinking, system dynamics, six sigma.**

I. Introduction

A superb maintenance systems whereby the high-end maintenance technology and highly-skilled responsive crews were devoted seems unable to strive for its best potential [1, 2]. With the world becoming globally competitive resulting in dynamic and complexity in the business [3, 4], maintenance function needs a system which is able to deal with not only solving the problem per se but also understanding the driving force behind the system failure. It transpired that failing understanding of what really caused a failure can lead to recurring failure of the same problem [5]. This will leave maintenance department with low performance because of a backlog of reworks [6].

Necessity for this newly formed paradigm is in response to flaws embedded in the existing maintenance strategy. There is a lack of realizing the true root cause into the failure, moreover, viewing maintenance problem as an entire system is another deep deficiencies in present strategy of maintenance [5, 7-10]. They incline to ignore the non-technical factors, namely 'soft' factors, and have a focus solely on the 'hard' factors to be concerned as the only causal agents of the failure.

This paper offers an answer to fill the gap by proposing novel frameworks for quality system and systems thinking to integrate. The merged concept will enable maintenance operatives to first understand the system failure holistically for appropriate selection of maintenance action plan. In the following sections, rationale behind the paradigm shift will be further explained, as well as the ways in which six sigma and system dynamics can be utilized to develop the frameworks accommodating that concept integration will be presented.

II. Paradigm Shift in Maintenance

With today's growing demand on wider range of product types, higher level of quality product and lower product costs, the importance of maintenance function has increased not only in the operation phase but also all along the product life cycle [8, 11]. To support this function in a dynamic and complex system, existing maintenance strategies ought to have had the following features changed [6]:

1. maintenance performance is more likely to be assessed as quantity-based, rather than quality-based measurement [12]
2. with technology-driven maintenance management, they merely tend to pore over technically significant cause factors of failure, also known as 'hard factors', and neglect the 'soft' ones [5, 13-15]; e.g. human error, motivation, strategic policy
3. problems in maintenance have often been approached to only seek an initiating event in a chain of events leading to a failure, rarely viewed as a root cause resulting from interactions among sub-systems that violate the system constraints [6, 16]

Without altering those values, hardly does maintenance system contend with dynamic nature of the prevailing operations management when today's enterprise strategic management has to grapple with globally competitive

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business. It will suffer from worsening maintenance performance owing to short term problem solving, that is, to get problems in a complex and dynamic maintenance system sorted out as quickly as it can be to boost performance up.

This outdated paradigm of managing maintenance may put that function at risk for possessing false level of performance where a huge increase in maintenance reworks has hidden. It will befall for sure once rooting the cause of failure is only aimed at the symptoms, not for the true root cause factors contributing to the system failure in its entirety. Having this unreal measure, it simply captures decreases in downtime in itself; not that maintenance performance is aimed for. Performance assessment should be taken place in any efforts to represent overall processes in quality improvement of the system maintained.

To avoid that risk, there is a need to have a paradigm shift in maintenance. A shift that reforms a mindset of maintenance operatives from just fixing the failure into understanding first the process of what lies beneath the system failure. This will avail itself of examining system behavior towards failure, recognition of the true root cause factors, as well as analyzing every relationships among causal agents occurred in overall system classified as either 'hard' or 'soft' factors.

III. Shifting through Integration

To convey that shift swimmingly, a thorough wide-perspective of managing system failure in maintenance using system viewpoint is involved to understand the problem holistically. A part from that, perceived total quality awareness is also of paramount important to fostering the sense of quality improvement in maintenance system. Not until those two are to be integrated mutually inclusive can the new paradigm make the most of its objectives. Intense attempts have been done so as to make the integration of quality system and systems thinking feasible [5, 6, 17].

According to the author's study [17], there appears to be a promising solution for problems in dynamic maintenance to integrate the concept of Systems Thinking, in which Cybernetics System embedded within, with Quality System. Despite having different background knowledge, these methodologies share common features that are complementary each other.

Cybernetics System is a science of communication and control in dynamical system [18] benefiting from a feedback mechanism which deals with complexity adaptively and recursively [19]. *Systems Thinking* is a general science which helps conceptualize entities at systemic level [20] at which it has wholeness, interrelationships and dynamics as the core of system elements [21], while *Quality System* is a system of tasks, methods and means which are used by the organization for implementing quality management [22] to assure customer quality satisfaction and economics cost of quality towards the business goals [23]. These each support the other for developing a novel strategy in maintenance that is robust to changes in a dynamic system, challenging the innovation, and viewing the problem holistically [6]. The integrated concept is illustrated in Figure 1.

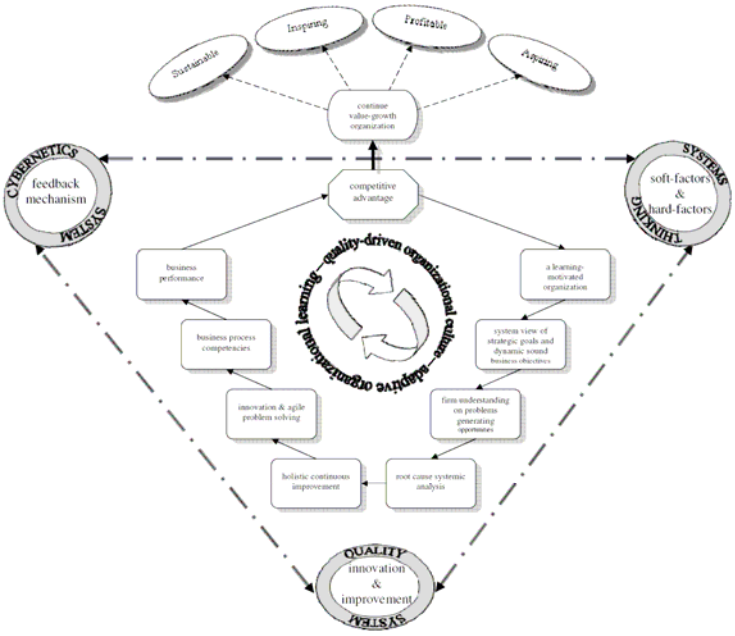

Figure 1 – *An Integrated Concept for A New Paradigm*

IV. The Frameworks for Novel Maintenance Strategy

To establish a firm base for that concept integration takes novel frameworks for the maintenance strategy equipped with the new paradigm. The author, in other publication [5], argued that a synergy of System Dynamics and Six Sigma may establish a fundamental infrastructure for the underlying merged characteristics of Cybernetics System, Systems Thinking, and Quality System. The frameworks developed from this synergy will benefit from hybrid features where System Dynamics and Six Sigma share common characteristics. Both disciplines are rooted in the problem solving approach [19, 24], whereas both originate only from specific additional roots in theory which are unique to it [25]; in particular, total quality concept is for Six Sigma , while systems thinking and cybernetics system are for System Dynamics.

System Dynamics (SD) is a problem structuring methodology to capture behavior of complex dynamic systems by means of modeling simulation and feedback mechanism with systems thinking [26, 27]. Despite becoming a powerful approach to dealing dynamic complexity with system viewpoint [19, 25, 28-30] however, it often needs to include complementary methodologies to help promote innovation [31-34]. *Six Sigma* is a process improvement statistic-based methodology with total quality concept to improve business profitability and to drive innovation [35-37] through the identification of root cause and better understanding of the problem. Like SD, Six Sigma is powerful but limited in the issues it can deal with. Namely it lacks specific features for capturing dynamics aspects of a complex system [38] and apparently not a holistic quality management system [39]. Of these are the reason why they need to be complemented in order improve maintenance improvement by solving the problems holistically along with system view and true root cause identification [6]. A

synthesis between *system modeling and simulation* of System Dynamics and *Define-Measure-Analyze-Improve-Control* of Six Sigma can be illustrated in Figure 2, whose frameworks for novel maintenance strategy developed.

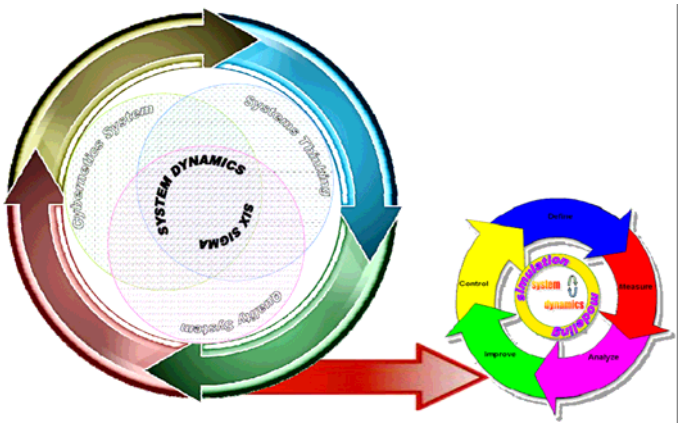

Figure 2 – *System Dynamics and Six Sigma for Novel Maintenance Strategy*

V. Root Cause Systemic Analysis

The frameworks for a novel maintenance strategy developed, namely Root Cause Systemic Analysis (RCSA), shoot for quality improvements in maintenance system through identification and analysis of the true root cause of failure in a systemic way. The frameworks integrate system thinking simulation modeling of SD into every phase of Six Sigma's DMAIC. With the phase of Define-Measure-Analyze-Improve-Control of Six Sigma, a generic framework of SD is designed and integrated into it to enhance the Six Sigma with system thinking-based root cause analysis. Synthesis of the generic integrated SD framework and the DMAIC of Six Sigma is captured in Figure 3 below.

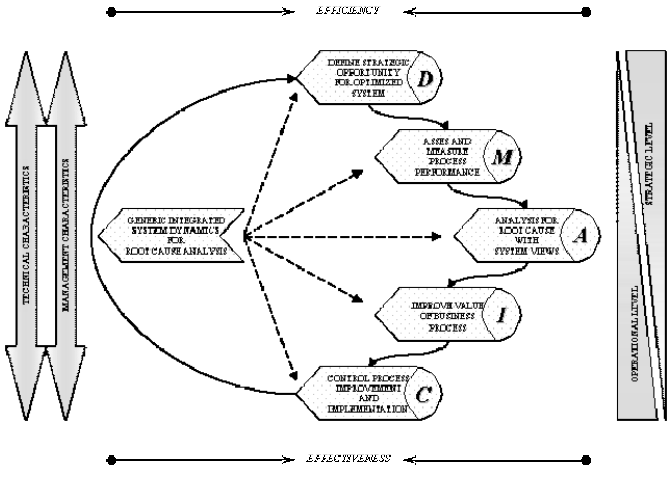

Figure 3 – *Root Cause Systemic Analysis*

The generic integrated SD framework with DMAIC for RCSA, as illustrated in Figure 4, enables maintenance operatives clearly understand the problems of how they will affect maintenance performance, identify system behaviour along with its factors contributing by simulation, and examine possible solutions proposed through "what-if" scenarios. Having done these issues with proportioning strategic level to operational level as well as soft factors to hard factors, RCSA will gain efficiency and effectiveness in improving maintenance performance by promoting dynamic system thinking in pursuit of the true root cause of failure. Definitely, this must have to be beyond the capability of a traditional Six Sigma [17].

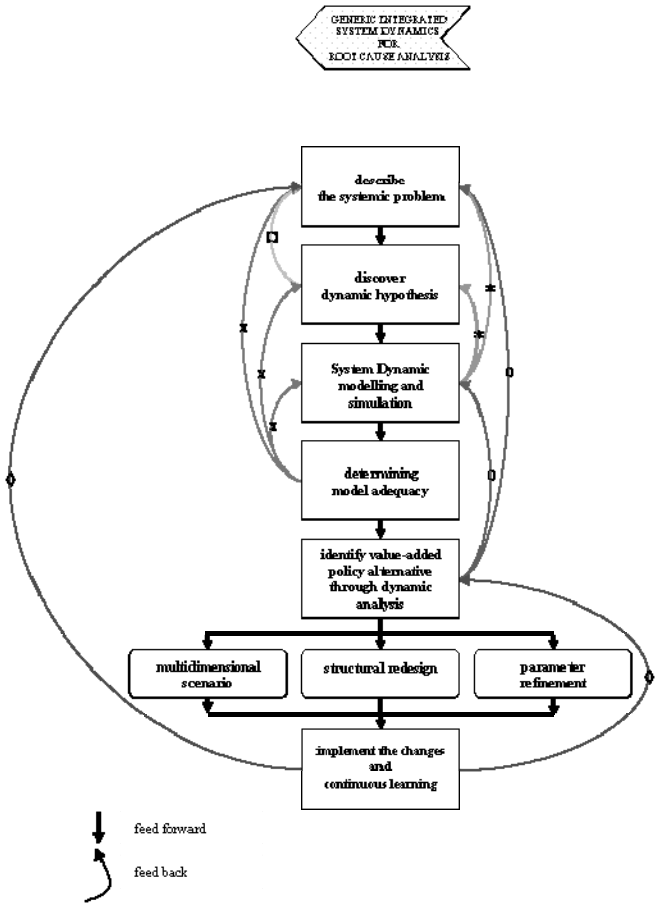

Figure 4 – *Generic Frameworks for RCSA*

Adopting RCSA to improve a fruitful maintenance performance could be in reality when new roles of SD are set up and integrated into each phase of DMAIC profiting by 'beyond' Six Sigma deliverables. As can be seen from Table 1, the roles of SD is described and matched on the phase of DMAIC to produce unique deliverables that can be a mean of shifting the paradigm of maintenance.

VI. Conclusions

The followings are conclusions that can be drawn from this study:

- A need for paradigm shift in maintenance: a scheme from problem solving maintenance to problem understanding maintenance
- The demand for quality system and systems thinking, along with cybernetics system, synergically imbedded in today's maintenance strategy
- Integration between System dynamics and Six Sigma may be well suitable to accommodate mutually merged characteristics of the quality system and the systems

thinking. The RCSA, the integrated frameworks then be named, will enable maintenance operatives to identify the true root cause of failure, to highlight contributions of the 'soft' factors as well as the 'hard' factors to the failure by viewing maintenance problem with a system vantage point in its entirety.

- The novel framework proposed needs to be validated and verified by implementing the framework in practice in industry. A case study in a multinational fertilizer company in Indonesia is still ongoing at which the data are not yet available to be described in this paper, but soundly discussed in the conference.

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Table 1 – *System Dynamics Roles in 'Beyond' Six Sigma*

			System Dynamics role in Six Sigma				
			D	M	A	I	C
			○ to define a problem as a system with its entirety and convert into adding value opportunities ○ using "know-how" systems thinking to understand the problem and establish boundary of the system being observed ○ discovering emergence of both soft and hard factor involved with system view	○ measuring the gaps for performance management ○ tracking all leading factors towards the increase in system failure ○ focusing only on measures adversely affect the system ○ selecting project to be improved	○ mapping out complexity and dynamics of the system ○ analyzing the relationships between the vital few leading factors and examine their impact on overall system ○ providing guidance in identification of high-leverage root cause of problem	○ describing behaviour of the system over various "what-if" scenarios ○ to prescribe potential solutions with the use of dynamic analysis	○ planning and controlling either implementation of a set of solutions or performance sustainability of the system improved ○ to establish continuous learning process through feedbacks and system-wide views
'Beyond Six Sigma' deliverables	D	○ thorough understanding of the system ○ problem articulation towards value-added opportunity ○ setting up purpose and strategic goals for improvement	✓	√	√	√	√
	M	○ positioning performance standards and objectives ○ a select group of projects in accordance with the strategic goals ○ finding out Critical-To-Stakeholders	√	✓	√	√	√
	A	○ establishment of Key Process Output Variables ○ clinching the Systemic Root Cause of failure	√	√	✓	√	√
	I	○ improved and optimized business process through adding-value to the entire system	√	√	√	✓	√
	C	○ smooth implementation of improvement process and sustainable high quality results ○ organizational learning	√	√	√	√	✓

√ secondary

✓ primary