

Combines SSM and Six Sigma Approach to Reduce the Turn Around Time of Inventory

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Abstract

Six Sigma methodologies have become increasingly popular in Taiwanese manufacturing industries in the recent years. When used, the Six Sigma methodology focuses mainly on the enhancement of manufacturing spot inspections rather than the enhancement of such supportive activities as the turn around time of inventory. The Soft Systems methodology (SSM) is a style of “systems thinking” that allows us to understand the various perceptions that exist in the minds of those involved in complex management systems; it seeks to evaluate as many different options as possible. We proposed an approach which integrates SSM into the Six Sigma methodology in order to demonstrate the continuous movement of such supportive activities as the turn around time of inventory. The results showed our proposed method as being effective not only in the improvement of supportive activities but also in the improvement of manufacturing spots.

Keywords : Six Sigma Methodology, Soft Systems Methodology, Turn Around Time

1. Introduction

The Six Sigma methodology has been recognized as an effective method in improving product and services quality as well as reducing manufacturing costs. The Six Sigma methodology is a disciplined application of statistical problem-solving tools that identifies and quantifies wastes and indicates steps for improvement (Brue G, 2002). A successful six-sigma strategy will move an organization toward zero defects (Mikel H, Schroeder R, 2000). When we experimented with the Six Sigma methodology in Taiwan, we found that the majority of researches focused mainly on the improvement of manufacturing spots. Little emphasis was put on the management performance from the viewpoint of supportive activities such as the process for reducing inventory cost. As a result, a way to improve the performance of supportive activities must be discovered. Soft systems methodology (SSM) is a way of “systems thinking” that helps us understand the various perceptions that exist in the minds of different people involved in a complex management system; it seeks to evaluate as many different options as possible. Our proposition integrates SSM into the improvement phase of the Six Sigma methodology so as to demonstrate the needed emphasis on supportive activities for manufacturers. The rest of this paper is organized as follows: Section 2 reviews the

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associated researches on Six Sigma methodology and SSM. Section 3 presents a case study using our proposed model to exemplify the improved performance on supportive activity. The final section presents the conclusions and directions for future research.

2. Literature review

An increasing number of manufacturing companies are choosing to employ quality programs to improve their manufacturing performance. By focusing on the performance of a product, the companies gain procedure experience. After using such quality programs over time, increases in product and services quality as well as lower rejection costs should be attained. In the past, process improvement has been achieved through the use of problem-solving techniques such as quality improvement, quality improvement through defect prevention, the improvement process, the improvement and business process, the total quality tools and classic statistical analysis (Wiklund H, Wiklund SP, 1999), and integrating Six Sigma and theory of constraints (Ehie I, Sheu C, 2005).

The Six Sigma methodology as an improvement program has received considerable attention in the last few years (Harry MJ, 1998; Hoerl RW, 2001; Brevfogle FW, 1999; Bergman B, Kroslid D, 2000). Montgomery (2005) identified three generations of Six Sigma: Generation I (1987-1994) which focused on reduction of defects, Generation II (1995-2000) which focused on cost reduction, and Generation III (after 2000) which is currently focused on enterprise value. A successful Generation III enterprise does not stop the activities of Generation I and II, but builds onto it; it will require the deployment of new methods and techniques to address service and commercial business processes and transactional system qualities.

Motorola launched Six Sigma in 1987, and was the first winner of the Malcolm Baldrige National Quality Award in 1988. With such achievements, corporations such as General Electric (GE) and 3M have utilized Six Sigma, and as a result have become recognized internationally as best-in-class companies (Fuller HT, 2000; Sanders D, Hild C, 2000). Antony (2004) investigated the essential ingredients that are required for the successful deployment of Six Sigma in the service sectors of UK service organizations. Tsou and Chen (2005) studied a car-seat assembly company using the classical economic production quantity (EPQ) model and following the Six Sigma DMAIC approach to car seat assembly lines, which generates significant financial return in production lines. Antony et al. (2005) proposed that management involvement and participation, which links Six Sigma to customers and business strategies, are the most critical factors for the successful deployment of Six Sigma in small and medium sized enterprises (SMEs). Tong et al. (2004) applied the DMAIC approach to improve the sigma level of the screening process in the manufacture of surface mounted printed circuit boards. Mahesh et al. (2006) presented a Six Sigma methodology for the benchmarking of rapid prototyping & manufacturing processes. Chang and Wang (2008)



applied Six Sigma methodology to improve the collaborative forecasting in a paper company.

The Six Sigma methodology focuses on the elimination of hidden costs generated as a result of producing defective products and services. These costs are often difficult to measure, but their elimination can increase a company’s profit by 30 to 40 percent (Mikel H, Schroeder R, 2000). These added costs may be the result of poor training, time spent in revisions, process bottlenecks, litigation, lost credibility, prevention costs, delays, defective work, misused resources, communication problems, and costs related to customer dissatisfactions pertaining to product/service quality. The Six Sigma approach is only used when creating processes that contain random variations. An organization operating at six-sigma level can expect its products and services to contain no more than 3.4 defective parts in a population of a million. To achieve this level of quality output means reducing process variation through a technique called DMAIC – Define, Measure, Analyze, Improve, and Control. Generally, after the project’s Definition phase, key process characteristics are identified and benchmarked in the Measure and Analyze phases; it is then followed by the Improve phase in which the process is modified for better performance and the Control phase, which aims at monitoring and sustaining the gains. A brief review of the major phases and tools used in the Six Sigma DMAIC methodology are summarized in Table1.

Table1 Summary of main activities and major tools in the Six Sigma methodology (Brue G, 2000)

Phase	Main activities	Major tools
Define	<ol style="list-style-type: none"> 1. Identify the important problems in processes 2. Select a project to combat one or more problems and define the parameters of the project 3. Determine the vital few factors to be measured, analyzed, improved and controlled 	<ol style="list-style-type: none"> 1. Project selection 2. Impact and benefit analysis 3. Project road-mapping 4. Project charter
Measure	<ol style="list-style-type: none"> 1. Select CTQ (critical-to-quality) characteristics for your product or process (where Y=CTQ characteristic) 2. Define performance standards for Y 3. Validate the measurement system for Y 4. Establish the process capability of achieving Y 	<ol style="list-style-type: none"> 1. CTQ identification 2. Quality function deployment 3. Failure mode and effects analysis 4. Target and specification formulation 5. Quality benchmarking 6. Descriptive statistics 7. Measurement system analysis



Phase	Main activities	Major tools
Analyze	<ol style="list-style-type: none"> 1. Define the improvement objectives for Y. 2. Identify the sources of variation in Y 3. Screen potential causes for change in Y and identify vital few initial X's (where X=key variable in the process) 	<ol style="list-style-type: none"> 1. Capability analysis 2. Hypothesis testing 3. Identification of causes of variation 4. Analysis of variance 5. Correlation analysis 6. Regression analysis
Improve	<ol style="list-style-type: none"> 1. Discover variable relationships among the vital few initial X's 2. Establish operating tolerances on the vital few initial X's 3. Validate the measurement system for the vital few initial X's 	<ol style="list-style-type: none"> 1. DOE 2. Factorial designs 3. Fractional factorials 4. Balanced block designs 5. Nested designs 6. Mathematical modeling
Control	<ol style="list-style-type: none"> 1. Determine your ability to control the vital few initial X's 2. Implement a process control system for the vital few initial X's 	<ol style="list-style-type: none"> 1. Control plans 2. Process monitoring and control 3. Mistake proofing 4. Quality system documentation

Checkland (1999) introduced soft systems methodology (SSM) as being under the “soft” operation research tools as opposed to the “hard” mathematical and decision models that have traditionally existed in the operations research field. SSM is a methodology for analyzing and modeling rare and complex systems that integrate both hard and soft systems. Although SSM may be used to analyze any problem or situation, it is more effective when the problem “cannot be formulated as a search for an efficient means of achieving a defined end; a problem in which ends, goals, purposes are themselves problematic”.

SSM uses “systems thinking” in a cycle of action research, driving one in learning and reflection so as to better enhance one’s knowledge of the various perceptions that exist in the minds of the different people involved in the situation. It is particularly suited to complex management systems, seeking to evaluate as many different options as possible. This approach is applicable to many domains of which include change management, planning for business systems, information systems planning, human resource management, analysis of logistics systems, and expert systems development. However, SSM is mainly used in research associated with knowledge management, project management, and engineering and construction management. SSM includes seven stage processes.

Stage1: Situations considered problematic. A considerable amount of information



needs to be gathered (e.g., organizational history, perspectives and assumptions, culture, structure, and types and number of stakeholders). The purpose of this analysis phase is not to recognize a definition to a problem, but rather to obtain a vague and unstructured idea of the parameters and structure of a problem. Through this, a range of relevant choices can be found

Stage2: Problem situation expressed. The product obtained from the Stage 1 is used to develop a rich picture of the situation being examined. This picture should depict the structure and processes of the organization as well as the environment in which it operates. Structure includes the physical layout, hierarchy, reporting structure, and the formal and informal patterns of communication. By process, we mean the organization’s basic activities (i.e., resource allocation, deployment, monitoring, and control). The relationship between an organization’s structure and process should illustrate the problems, tasks, and elements of the environment in a clear and cohesive manner. It should identify relevant themes, develop a shared understanding of different perspectives, and be a basis for further discussion

Stage3: Root definitions of relevant purposeful activity systems. Generally the most difficult part of the process, the root definition defines what is relevant to the system and also people who might either influence or be influenced by the system. To construct root definitions, the mnemonic CATWOE should be used. The mnemonic CATWOE is used to guide the development of a root definition. CATWOE stand for **C**ustomer: people affected by the system, **A**ctor: people performing activities in the system, **T**ransformation: the transformation carried out by the system, **W**eltanschauung: the “world-view” or viewpoints held of the system, **O**wners: the person(s) with the authority to decide how (and if) the system will be carried, and **E**nvironment: the larger system within which the system under consideration exists and operates. The elements of CATWOE emphasize the need to examine the problem from a number of viewpoints (see in Table 2). The Root Definition and CATWOE provide the analyst with a framework that ensures consideration of all the different viewpoints.

Table2 The mnemonic of CATWOE

C (customer)	Who would be the victims/beneficiaries of the purposeful activity?
A (actors)	Who would do the activities?
T (transformation process)	What is the purposeful activity expressed as “Input → Transformation → Output”?
W (Weltanschauung)	What view of the world makes this definition meaningful?
O (owner)	Who could stop this activity?
E (environmental constraints)	What constraints its environment does this system take as given?



Stage4: Conceptual models of relevant systems named in root definitions. The conceptual model is not intended to be a description of the real world, but rather to understand the activities needed to bring about change. It also conceptually constructs a system that represents stakeholder perspectives about the desired system as well as associated human activities. The conceptual model is based only on the agreed root definitions of the desired system and is measured against the five criteria mentioned above. This stage prepares the participants for discussions that will take place in “the real world” (Checkland PB and Scholes, 1990).

Stage5: Comparison of conceptual models. The conceptual model(s) constructed in Stage 4 gives structure to a meaningful and coherent debate about the problem situation. It surfaces a wide range of questions, highlighting the differences between the perception and reality. The discussions around this model(s) provide an opportunity for participants to rethink their assumptions. It also allows them to discuss changes that could bring about an improvement in the problem situation. This discussion leads to Stage 6.

Stage6: Determining desirable and feasible changes. The aim of this stage is to identify and explore changes that are systemically desirable and culturally feasible. Checkland (1999) described three kinds of change: changes in structure, in procedures, and in attitudes. Structural changes refer to organizational groupings, reporting structures, or structures of functional responsibilities. Procedural changes include all the activities that go on within the organization, such as operational processes and reporting conventions. Changes in attitude refer to changes in the expectations that people have of the behavior of other actors as well as changes in their readiness to categorize certain kinds of behavior as either bad or good.

Stage7: Action to improve the problem situation. This is the implementation step. Who is to take action? What kinds of action should be taken? Where and when should the action be taken? Timetables, resources and a scope are critical resources to have. Attitudinal and behavioral changes need to be considered along with the impacts and effects on current systems. Change for the sake of change should be avoided. This stage seeks to solidify commitment and responsibility in order to formulate an action plan.

3. Case study

We proposed an approach that integrated SSM into the improve phase of Six Sigma approach to demonstrate the continuous improvement of supportive activities. The case study in this research is a practical project that involves the improvement in reducing turn around time of inventory. This case company called company-A is a leading manufacturer of LED (Light Emitting Diode) business in the world. In the LED manufacturing industry, one of the major concerns of the business model is to control the inventory cost. Profits from business depend on the capability of inventory control. For nearly five years, company-A has provided high quality products to both local Taiwanese companies as well as foreign



companies. With over 1500 employees in Taiwan and Mainland China, company-A adopted a strategic plan “to make services quick and on time delivery for all customers”. In 2007, due to the hyper-competition in LED business, the top management of company-A decided to further strengthen its competence of on cost-based competition by utilizing the Six Sigma approach. The process of reducing inventory costs project in this article was only one part of a larger project in the company which targets cost savings by reducing the turn around time of inventory. The representative activities of the Six Sigma methodology and SSM in this case study are demonstrated as follows:

3.1 Define Phase:

The three steps from the define phase are as follows:

Step 1: Project selection - according to the experience of company-A, it takes a much longer time and resources to handle the inventory. Consequently, the accuracy of material forecasting and control is the most important issue for the company. Thus, for better capital turnover efficiency, according to the voices of inner customers, the project title is identified as able “to reduce the turn around time of inventory”.

Step 2: Define project scope - based on the step 1, the project team analyzes the high-level process of SIPOC related activities. A SIPOC is a high-level process map that includes Suppliers, Inputs, Process, Outputs and Customers. It is a very effective communication tool in supportive activities. It ensures that the team members are all reviewing the process in the same way. It also informs leadership of exactly what the team is working on. The process is mapped at a high-level. Then working from the right, identify the customers, the outputs, the inputs and the suppliers show as Figure 1. Based on the high-level process of SIPOC, we set up the project scope which the activity is either “value added” or “non-value added” as the circle area in sub-process of Figure 2.

Step 3: Define defects - according to the data analysis, there is approximately 75 days turn around time of inventory. Comparing to the benchmark of 30 days, it is obviously an inefficient performance. For in-scope, the project team defines “more than 45 days turn around time of inventory” as one defect in this case.

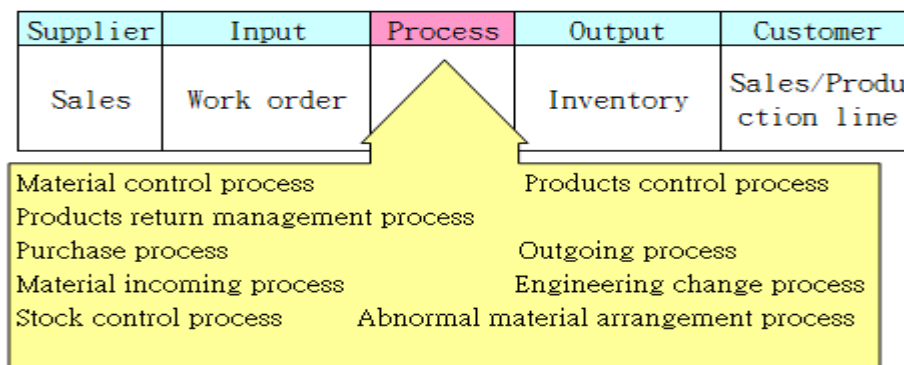


Figure1 The high-level process map with project scope



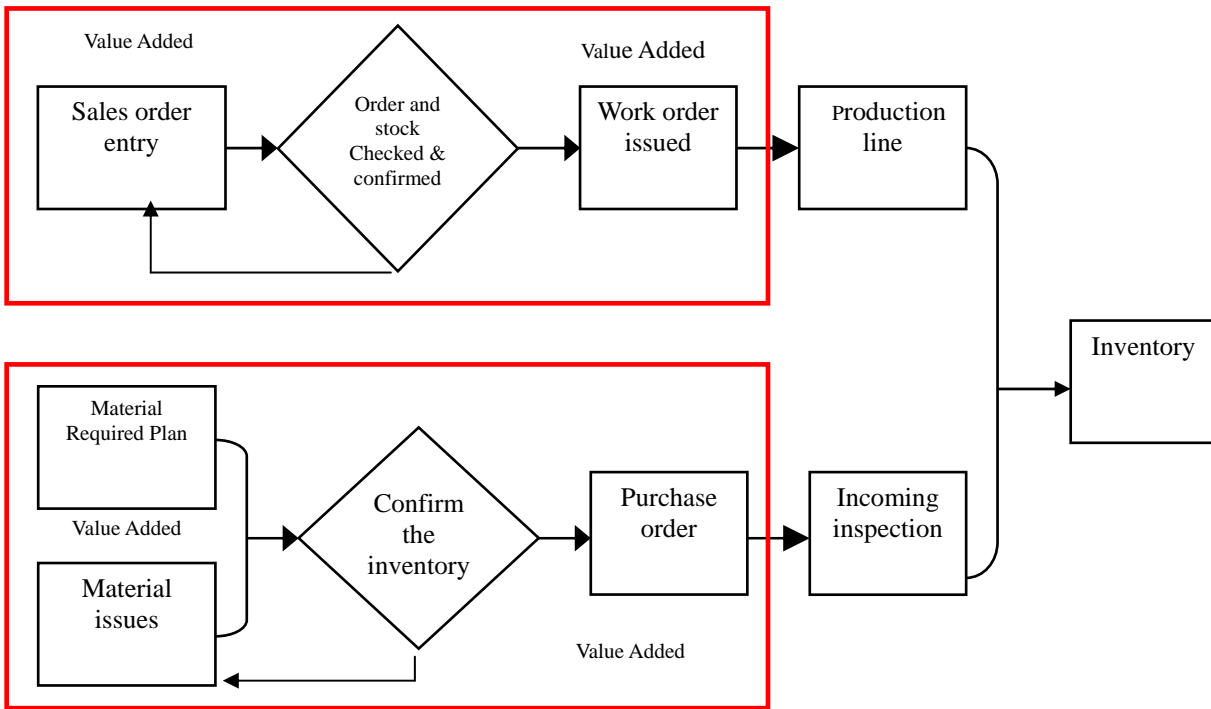


Figure2 The sub-process map with project scope

3.2 Measure Phase:

In the measure phase, the performance standard of the process is verified and established to obtain a baseline for future improvements. Two steps are given as follows:

Step 1: Data collection plan - in order to understand the process capability before improvement, a data collection plan is deployed to gather sample data from actual inventory turn around time and costs.

Step 2: Measure as-is process capability. According to the individual control chart of latest 180 samples (see in Figure 3), the samples mean the difference between current turn around time and target days, and the result shows that this process is out of control. Thus, the current-state process capability is not available at this point.

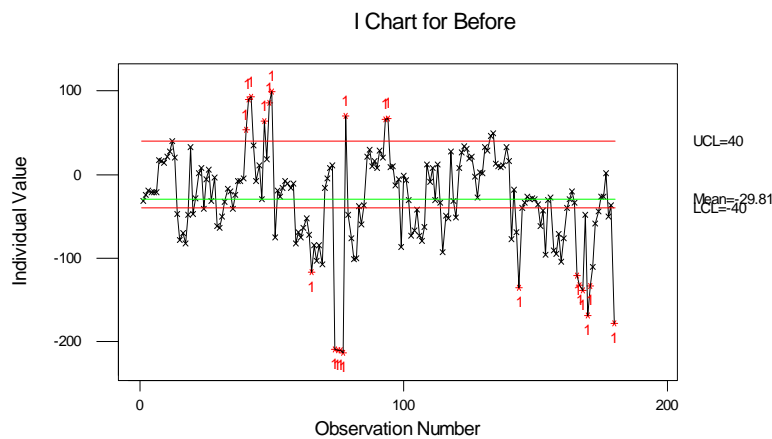


Figure3 The individual chart for before project



3.3 Analyze Phase:

In the analyze phase, the performance objective is defined and the key variations sources are identified. Three steps are given as follows:

Step 1: Identify root causes- the root causes of the problem of variation between actual turn around time and target days are identified by using ANOVA and a Pareto diagram (see in Figure 4). According to ANOVA, the *p* value is 0.000 less than 0.05 shows that significance among different turn around time during last two years. The Pareto diagram illustrates 80% problems are from 20% root causes.

Step 2: Failure mode and effects analysis (FMEA) – the purpose of FMEA is to filter the factors that may cause the function failure with high risk priority number (RPN) in the key process in advance, the high number of the RPN, usually defined as greater than 125, will be selected and will have the recommended corrective actions as Table 3.

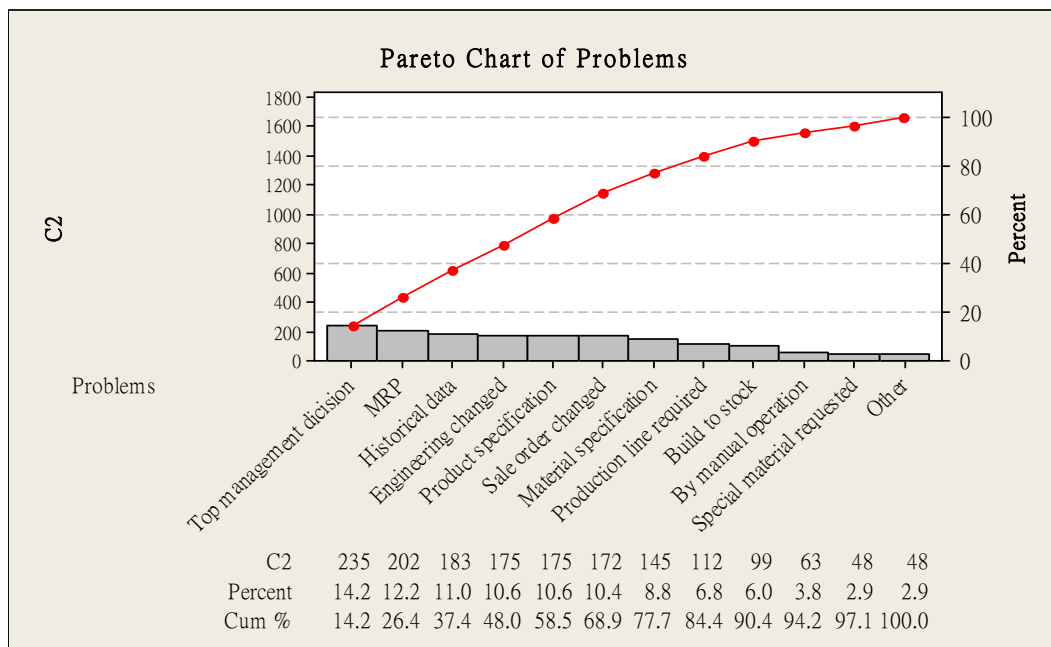


Figure4 The root causes analysis based on Pareto diagram

Table3 FMEA analysis for the key process

Specific function(s) of Process Step	Potential Failure Modes	Potential Effects of Failures	Severity	Potential Causes of Failure	Occurrence	Current Process Controls	Detection	Risk Priority No. (RPN)	Recommended Corrective Actions
Material control process	Historical picked data	Forecasting quantities is not accurate	9	Lack of SOP for forecasting	6	Not applicable	10	540	Construct standard process for forecasting
	MRP of BOM	The variation of requirements	6	Lack of ECN control process	6	ECN control process	6	216	Improving ECN process



Specific function(s) of Process Step	Potential Failure Modes	Potential Effects of Failures	Severity	Potential Causes of Failure	Occurrence	Current Process Controls	Detection	Risk Priority No. (RPN)	Recommended Corrective Actions
Material control process			3	Lack of control production order	3	Not applicable	10	90	Construct control production order
	Top management decision	The variation of strategy	9	Lack of planning production principle	9	Not applicable	10	810	Construct standard process for forecasting
			6	Lack of SOP for forecasting	3	Not applicable	10	180	Construct standard process for forecasting
	Sales order changed	Work order error	6	Poor cancel order definition	9	Notice of order revised	6	324	Improving ECN process
Abnormal Engineering Changed Notice (ECN)	ECN changed	Wrong specification	3	Poor feedback process	6	ECN control process	6	108	Improving ECN process
	Raw & Buck material specification	Slow moving stored	3	Poor feedback process	6	ECN control process	6	108	Improving ECN process
	Products specification	Wrong purchase order	3	Lack of control production order	3	Not applicable	10	90	Error proofing established

Step 3: Identify vital few initial X's- among the ANOVA and Pareto diagram as depicted in Figure4, the project team concludes that the vital few initial X's can be attributed to (1) Lack of SOP for forecasting, (2) Lack of ECN control process, (3) Lack of planning production principle, (4) Poor feedback process, (5) Lack of control production order .

3.4 Improve Phase using SSM:

In the improve phase, improvement activities using SSM are proposed. Four steps are given as follows:



Step 1: Develop solutions- based on the findings of the significant causes in the Analyze phase, the solutions are proposed by project team members through seven stage processes of soft systems methodology (SSM). First, the root definition is a system that establishes a procedural system for feeding concepts into business model. Second, the CATWOE defines clients as business models; actors are cost forecasting and control managers; transformation is need for procedure and need met to departments objective; world-view as a objective-related concept is necessary and feasible and using of concepts can be engineered; owners are those who the project team members and sales department manager; environment is the corporate business objective and external information. Third, build up the conceptual model for this relevant system in Figure 5.

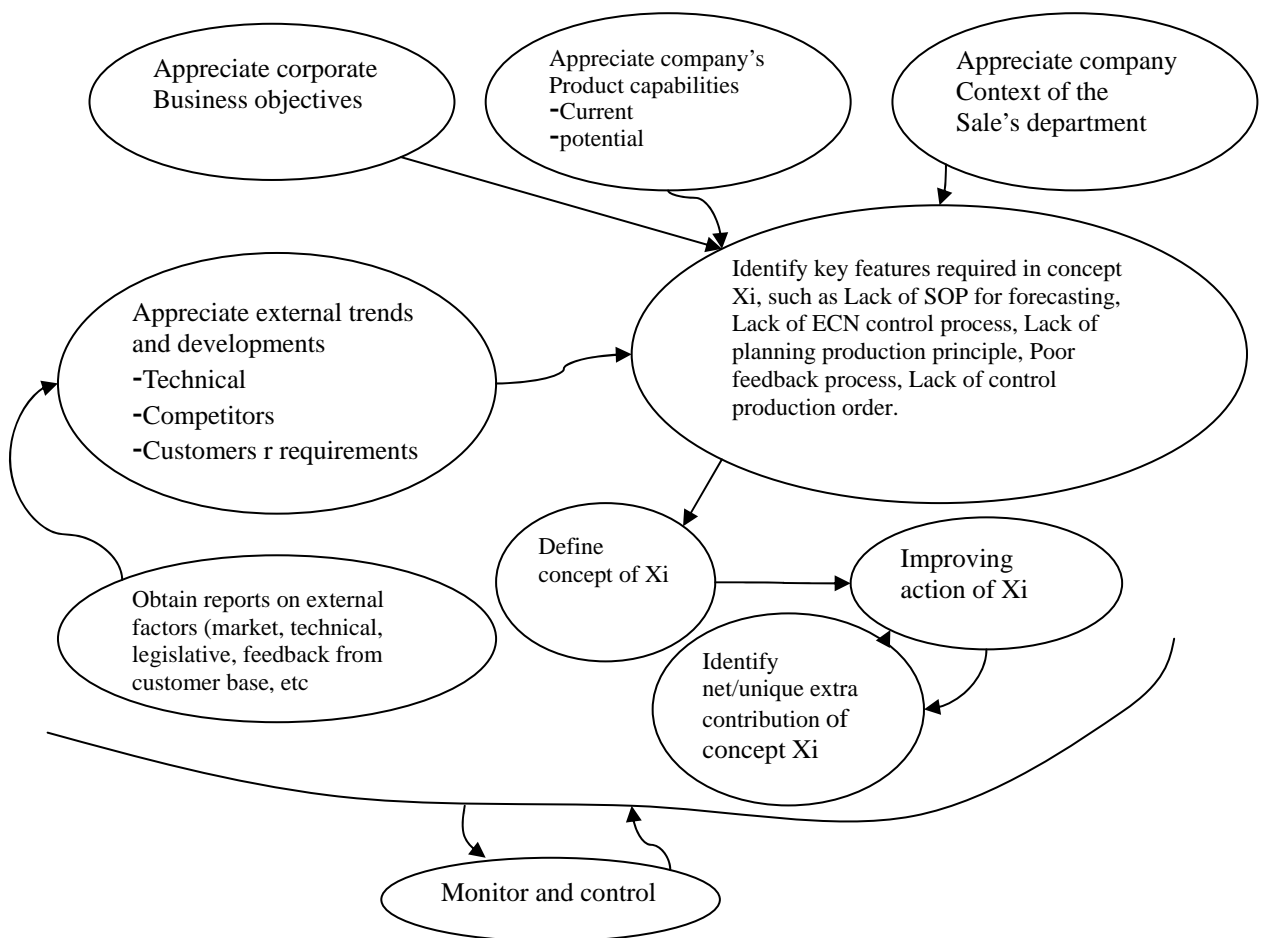


Figure5 The improvement model in reducing turn around time of inventory

Step 2: Implement improvement plan- after the step of solutions development, an improvement plan that contains improvement actions, respective in-charge departments and introduction schedule is given in Table 4.



Table4 The improvement plan of cost forecasting activity

Root causes	Improvement Action	In-charge Dept	Schedule
Lack of SOP for forecasting	Set up the standard procedure for material forecasting	Material & Inventory	July 2007
Lack of ECN control process	Set up the standard procedure for Engineering Changed Notice	R & D	July 2007
Lack of planned production principle	Set up the planned production principle for manufacturing	Sales	July 2007
Poor feedback process	Re-engineering for sales order procedure	Sales	July 2007
Lack of control production order	Set up the standard operational procedure for order decision making	Sales and Purchase	July 2007

Step 3: Identify the new process capability- after the improvement plan has progressed for approximately six months, the project team collects the latest 30 samples to calculate the new process capability in order to observe the improvement effectiveness. The results of analysis show that the average turn around time of inventory has reduced dramatically from 75 days to 40 days. Meanwhile, the inventory cost has reduced 34.24% as well. Furthermore, the process capability indices of Cp and Cpk are enhanced from almost zero value to 1.62 and 1.49, respectively.

Step 4: Compare the differences before and after the improvement plan- as shown in Table 4, the trend chart demonstrates that there is tremendous progress after the implementation of the improvement plan as Figure 6. Not only has the average differentiate rate been reduced, but the cost of inventory has also been decreased.

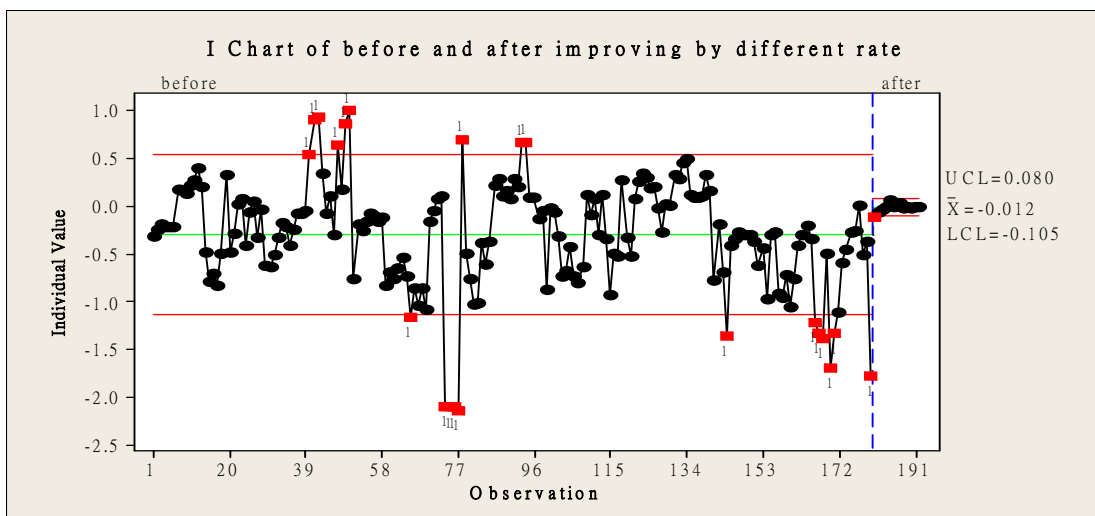


Figure6 The individual chart for before and after Six Sigma project



3.5 Control Phase:

In the control phase, a robust control plan of risk management to prevent system failure is proposed. The project team uses a range of JROTC rankings from 1-9 possible point and influence points to determine the final risk score, which is formed by multiplying influence. The representative example is demonstrated as Table 5.

Table5 Example of risk management in the control plan

Risk causes	Possibility	Influence	Risk score	Prevention actions
Employees withdrawal	3	5	15	Establish the document of processing guide
Inconsistence between SOP procedure and actual process	2	6	12	Check the difference and build mistake-proofing system

After the adaptation of Six Sigma management approach, the turn around time of inventory was reduced from average 75 days to 40 days. Additionally, the revenue of this SBU (Strategic Business Unit) in 2007 was around US\$ 84,280,000 and according to historical data the inventory cost was 15% of the revenue, around US\$ 12,642,000. Moreover, since the cost saving effect equals (sales revenue) * (inventory cost) * (reduced differentiate rate) = (84,280,000) * (15%)*(34.24%) = US\$ 4,328,620.

4. Conclusion

The majority applications of Six Sigma in Taiwan are usually focused on the improvement of the manufacturing spots instead of the supportive activities fields. The purpose of this paper is to demonstrate the improvement effectiveness of utilizing Six Sigma approach on the supportive activities, reducing turn around time of inventory, and as to provide company in a LED industry. Basically, for Six Sigma to work smoothly, managers at all levels must commit to invest the resources to initiate, promote, actualize, and support the program. In other words, providing employees with training, resources, knowledge, and authority to solve problems is crucial for the success of the Six Sigma project.

Thanks to the skillful execution of Six Sigma methodology of DMAIC and SSM, the case study company, company-A, successfully eliminates wasteful variation, modifies business cultures and creates the infrastructure to initiate and sustain greater productivity and profitability. The concrete performance of utilizing Six Sigma in company-A shows the cost saving of US\$ 4,328,620 and obvious enhancement the process capability indices of Cp and Cpk from almost zero to 1.62 and 1.49, respectively. The results prove that the application of Six Sigma approach when combined with SSM presents an effective progress in the improvement of supportive activities as well as the improvement of manufacturing spots.



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