An Implementation of the Shingo System

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Abstract

Shingo’s mistake proofing (a.k.a. Poka-Yoke), and Single Minute Exchange of Die (SMED, a.k.a. quick changeover) process improvement systems have been used in industry for many years. Despite their pervasiveness, little is known about how these systems are implemented or work in real world settings. This study documents a successful waste elimination project for a building products company using Shingo’s Scientific Thinking Mechanism (SSTM). Using the Action Research method, several strategic and tactical decisions were identified and developed into a general implementation model. These stages proved to be critical for the success of the program. First, strategic analysis was performed which is often driven by market or customer. Second, in order to drive the improvement a high level cross functional team was established. Third step, overall improvement tools were identified. Fourth, a high-level process map and prioritization of improvement opportunities were performed. Fifth, a detailed plan executed by shop level workers. Sixth, perform the implementation, documentation and periodic revision of the plan. A significant contribution of this research is that this is the first study to propose a model for implementing Shingo’s System by integrating strategic and tactical decisions important for both practicing managers and academic researchers. In doing so, a theory explaining why SSTM works is articulated.

Keywords: Shingo System; Waste Elimination; Action Research
1. Introduction

Shigeo Shingo’s contributions to manufacturing excellence are well known. Widely recognized as the co-developer of Toyota’s production system with Taiichi Ohno, the Shingo System is a collection of improvement strategies delineated in numerous books. Shingo is best known for his mistake-proofing (Poka-Yoke), and Single Minute Exchange of Die (SME), a.k.a. quick changeover) techniques. Mistake proofing systems prevents errors from turning into defects (Shingo, 1986). These systems are included in QS 9000, and are widely used in manufacturing and service operations (e.g., Stewart and Grout 2001; Grout 1997; Chase and Stewart 1994). Similarly, quick changeover systems reduce machine setup time which, in turn reduce the size of the production runs, thus eliminating the waste of over production (Shingo, 1985, McIntosh, et al. 2000; Womack and Jones, 1996). To date, we have found no study explaining how to systematically implement Shingo Systems in real-world companies, or the theory underlying why these systems work to improve performance.

One purpose of this exploratory study is to show how Shingo's process improvement systems were systematically implemented in a successful waste elimination project for a building products company (BPC). The implementation effort was initiated due to the company’s worsening performance in the market. Customer returns due to quality issues had risen from 4% to 15% in the preceding six months. This led to extensive rework putting pressure on purchasing for material and production for priority schedule. As a result, production lead-time performance had increased 20% to 40% over the last year, which put additional pressure on the purchasing and production departments to keep up. Poor performance was forcing many of the company’s customers to seek other suppliers. Given the highly competitive environment of the market, this was a serious problem for the company. After implementing other improvement initiatives over the years — i.e. Six Sigma, Lean, etc... upper managers wanted to try something new. They were frustrated over the poor long-term performance of other programs - usually abandoning them within 12 months. Managers felt that prior improvement initiatives were difficult for the average worker to understand and were isolated in different departments - rarely applied across functions to improve the performance of overall value creation process. To address this problem, managers wanted the SSTM initiative to be a core improvement strategy that was simple to understand so that the program could eventually be driven from the lowest levels – shop floor/functional levels - of the organization.
To guide the waste elimination project, a cross-function team (C-FIT) was tasked with implementing mistake-proofing and quick changeover systems using Shingo’s Scientific Thinking Mechanism (SSTM). SSTM consists of four stages namely [1] problem identification, [2] basic approaches to improvement, [3] making plans for improvement, and [4] translating improvement plans into reality. During implementation of SSTM the researchers were able to identify several activities at both the strategic and tactical level that made the implementation successful. To our knowledge, this is the first study to describe the stages that a company goes through to successfully implement Shingo’s system. Using these stages, a model is proposed for Shingo System implementation by identifying the strategic and tactical decisions important for both practicing managers and academic researchers.

2. Literature Review

2.1 The Shingo System

The Shingo system is a collection of improvement strategies developed by Shigeo Shingo. The details of the Shingo System are delineated in several books (Shingo 1985, Shingo 1986, Shingo 1987, Shingo 1988). The central theme behind the system is finding and eliminating seven basic types of waste. Shingo (1987, p.18-19) notes:

“Unfortunately, real waste lurks in forms that do not look like waste. Only through careful observation and goal orientation can waste be identified. We must keep in mind the greatest waste is waste we don’t see.”

While working with Shingo during the development of the Toyota Production System (TPS), Ohno (1988) identified seven categories of waste: waste from defects, waste from overproduction, waste from inventory, waste from motion, waste from processing, waste from waiting, and waste from transportation. The elimination of these forms of waste is the focus and motivation behind the evolution of the Shingo System.

The best-know activities of the Shingo System are Source Inspection, Poke-Yoke (mistake proofing), and SMED (quick changeover) systems. One of the most obvious areas of waste in manufacturing comes from scrap and rework. In an effort to eliminate all scrap and rework, Shingo (1986) developed the idea of source inspection. Source inspection is a proactive approach to quality assurance that identifies elements that can create defects and corrects them before the process starts. By taking action at the source, errors are prevented from turning into
defects. Shingo refined the concept further by developing mistake proofing devices that are used to overcome a common source of defects – human forgetfulness.

Shingo’s other well-known contribution, quick changeover system, was developed to assist in reducing the waste of over production. As setup times are reduced, the size of the production run can also be reduced, and small-lot production becomes an economic reality. Quick changeover systems consist of three major phases (Shingo 1985). The first phase involves separating internal components of a setup (i.e. activities that can only be done when a machine is not in operation) from external components (i.e. activities that can be done while the machine is in operation). The second phase involves transforming internal setup components into external components by preparing all of the tooling for a changeover in advance – so that downtime is minimized. The final phase consists if streamlining all aspects of the setup so that only value-added activities are performed while a line is down.

2.1. Shingo’s Scientific Thinking Mechanism

Shingo’s Scientific Thinking Mechanism is delineated in his two books explaining the procedure (Shingo 1987; Shingo 1988). Shingo (1987) describes how he was influenced by the work of Alex Osborn - known for using brainstorming techniques to generate creativity (Osborn 1953). The central theme behind SSTM is finding and eliminating all forms of waste using a sequential four-stage process. This process is outlined in Figure 1.

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Stage 1: Problem Identification

This objective of this stage is to identify problems by persistently challenging the existing system. In other words, to discover problems where one thinks none exist. To illustrate his point, Shingo (1987) used an example of a banana to distinguish between the parts of a job that add value and those that don't. He argued that the banana skin only adds cost, and the fruit adds value. According to Shingo (1987, p.19):

“Just as no one really resents paying for the banana skins, we do not question what goes on in the workplace. Even when most of the work only increases cost and little is done to increase value, we become
habituated to the situation, satisfied that a good job is being done if the work is performed conscientiously. Frequently we do not perceive the intrinsic value of the work. We must take another hard look at work and recognize what is fruit and what is skin.”

Stage 2: Basic Approaches to Improvement
The objective of this stage is to develop a thorough understanding by compiling relevant information about the problem and its existing conditions. The information should be gathered using quantitative and qualitative methods such as published materials (quality reports, catalogues), interviews and discussion with managers and workers, observation of machines and process, and impressions, which include feelings and insights. Through rigorous examination of information, one can grasp the truth underlying a problem, Shingo (1987).

Stage 3: Making Plans for Improvement
This stage has two objectives. First objective is to generate a number of new solution ideas for the identified problem without immediately evaluating (or criticizing) the ideas. Once ideas have been generated, the next objective is to evaluate the ideas. The evaluation process includes carefully determining strengths and weakness of each idea, modifying ideas to develop another idea, and, if necessary, discarding ideas that are no longer necessary. Shingo (1987) cautions that the people should not be quick in discarding ideas; instead, they should try harder, more positive ways to develop ideas for implementation.

Stage 4: Translating Improvement Plans into Reality
The purpose of this stage is to put the ideas into practice. In order to put ideas into practice, a plan needs to be in place to overcome people’s resistance to change. People are prone to inertia of old ways of working, therefore extraordinary efforts are necessary to break people into new ways of working Shingo (1987). To convince shop workers, first put the initial idea into action, and then demonstrate the benefits from such an idea to everyone else. By making the benefits visible, many people can be persuaded that improvements are really possible (Shingo, 1987).

2.3. Creativity and Problem Solving
The theoretical basis for the success of Shingo’s systems is that SSTM is grounded in basic problem-solving techniques – which have shown to be successful in many applications – and are the basis for the scientific method. The evidence for this comes from other conceptual models of
problem solving, which include similar step-wise processes (Dewey 1910; Wallas 1926; Rossman 1931; Polya 1945; Johnson 1955; Parnes 1967; Noller 1977; Isaksen and Treffinger 1985; Deming, 1986; and Cougar 1995). Usually, the process begins problem identification or opportunity delineation, which emphasizes the correct identification of a problem. This is important because if a problem is not properly identified, then the appropriate solution can not be found. As Einstein and Infeld (1938, p. 95) note, “The formulation of a problem is often more essential than its solution, which may be a matter of mathematical or experimental skill. To raise new questions from a new angle requires creative imagination…” Generally the next step in most problem-solving techniques deals with information-gathering. (Cougar, 1995). This can involve both qualitative and quantitative evidence related to the problem or its solution (Yin, 1994). For many models, the next step deals with issues of generating ideas and evaluating possible solutions. Shingo based his idea-generation process on Osborn’s (1953) work that introduced the brainstorming technique to generate new ideas through creativity, and more importantly, emphasized the separation of idea generation step from idea evaluation step. In other words, according to Cougar (1995, p. 265), during the idea generation step, we must keep an open mind and refrain from asking such a question as, "Why did you come up this idea for a possible solution?" Instead, the question should be framed as “Could you please elaborate your idea?” Once a large number of ideas have been generated then, the next step is to evaluate and prioritize the ideas. While evaluating ideas, according to Isaksen and Traffinger (1985), it is important to keep in mind that the purpose is not to “kill” ideas but to look closely and critically at them. An outcome of generating new ideas is creativity. Some researchers, e.g. Guilford (1964) and Nickerson (1999, p. 394), even consider problem solving and creativity as the same mental phenomenon. Hayes (1981, p. 199) describes creativity as “a special kind of problem solving that is the act of solving an ill-defined problem.”

For many models, the last stage in problem solving is to develop a plan to implement the ideas into practice. According to (Cougar1995, p.304), “Far less has been published on this topic of implementing ideas than on the subject of originating ideas.” In order to implement any plan, an appropriate plan needs to be in place to overcome people’s resistance to change (Deming 1986).

3. Methodology

3.1. Action Research
This discussion of this methodology relied heavily on previous work in Chakravorty and Hales (2007). Action Research has been described as one of the Soft Operations Research methods designed to answer how and why questions on variables difficult to observe or model mathematically. The goal of action research is to provide rich explanation of linkages among events rather than their frequencies or occurrences. Many operations researchers in leading journals (e.g. Prybutok et al., 2005; Coughlan and Coghlan, 2002) propose the use of Action Research to overcome observational limitations. Stated differently, “The action researcher is not an independent observer, but becomes a participant in the process of change . . .’’ (Benbasat et al., 1987, p. 371). To this end Shingo’s systems should be studied in real-world settings in order to identify important variables that affect their successful implementation. To date no one has examined how Shingo’s systems are implemented or theoretically why they work, because it is difficult, time consuming and expensive to conduct experiments or directly observe many of the important variables in a real-world setting.

Action Research was chosen to document and analyze the researcher’s experience because the company's senior managers wanted a rigorous, systematic, and collaborative participatory process to implement and evaluate Shingo's systems. The researchers wanted to employ a scientific methodology appropriate for contributing to the existing literature in participatory research. To this end, action research is most appropriate because it involves solving problems through intervention while simultaneously contributing to the body of knowledge (Davidson, et al., 2004). Other studies have recently applied action research to implement improvement techniques in Operations Research. For example, Chakravorty and Hales (2007) used action research to implement Group Technology in a manufacturing plant. Hales et al. (2006) and Hales and Chakravorty (2006) used action research to implement quality improvement programs in plastics companies.

According to Keemis and McTaggart (2000, pg. 572), there are three reasons why action research is appropriate for our objectives. First, action research focuses on "… learning from trying to bring about change…", where the typical participants are shop-floor employees, middle managers, etc. In this case, the researcher’s roles were participants as academic researchers and Shingo experts, who were actively involved in the waste elimination project. Second, action research is appropriate when applying theory to practice. In other words, the purpose is to
develop professional knowledge by applying formal knowledge in real-world settings. Formal
knowledge is theory, and is defined as the common knowledge that all competent professionals
share in a particular discipline. Professional knowledge is the knowledge of how to interpret and
apply formal knowledge in a real world context (Keemis and McTaggart, 2000; Denzin and
Lincoln, 2000). While the factors in this study - mistake proofing and quick changeover systems
- are common knowledge, to date no one has described how these systems are implemented
successfully in real-world companies. Third, action research is empirically based, exploratory
research, and as such does not require control over the behavioral elements. Instead, it relies on
reflection and participation of subjects to evaluate phenomenon rather than control and statistical
analysis. Because of its flexibility, action researchers have the ability to deal with a variety of
evidence including direct participation and observation, documents, archival records, and
interviews (Davidson, et al. 2004) which may be difficult to quantify.

3.2. Study Design
The study design is based on Susman and Evered's (1978) seminal work on how to conduct
rigorous scientific action research, Davidson, et al.’s (2004) interpretation and extension of their
work in general, and Chakravorty and Hales’ (2007) development of a specific methodology to
Operations Research. Their procedures are so highly regarded that they are commonly referred
to as 'canonical action research' (Davidson, 2004), or 'action science' (Keemis and McTaggart,
2000). Davidson clearly articulates five stages of rigorous action research. They are the
principles of (1) Researcher-Client Agreement, (2) Cyclical Process Model, (3) Theory, (4)
Change through Action, and (5) Learning through Reflection. For more on describing canonical
action research see Davison et al. (2004). Next, we discuss how our study generally complied, as
well as differed, with their recommendations as we applied it to Operations Research.

3.2.1 Researcher-Client Agreement (RCA)
The researcher-client agreement articulates the relationship between stakeholders (researchers,
managers, owners) and is key to establishing the internal validity of the research findings. In this
study, the stakeholders include the researchers, workers, and managers, who will potentially
benefit from the success of the implementation. As part of the RCA, the researcher's were given
access to all pertinent data and personnel who can provide insight into phenomena observed
during the study. In turn, the researchers documented the effort and were forthcoming about the
findings and limitations of the study – except those deemed proprietary by BPC’s President. It was expressly understood that the focus of our action research project could change several times in order to reveal root causes of an event. This characteristic differentiates action research from other methodologies requiring strict adherence to original focus.

3.2.2. Cyclical Process Model (CPM)
CPM is the procedure for systematically applying solutions in an action research study (Davidson et al., 2004). Susman and Evered (1978) describe five stages for systematically applying solutions in action research. In summary, they are (1) diagnosis; (2) planning; (3) intervention; (4) evaluation; and (5) reflection. Their description of the CPM is similar to the four stages of SSTM used in this study, and to other problem-solving techniques in general.

3.2.3 Theory
The express purpose of scientific action research is to create knowledge. Deming (1986) says that without theory, no knowledge exists. In the context of action research, McKay and Marshall (2001) argue that action research that is not grounded in theory cannot be characterized as research. To this end, the findings in this study are explained through development of a Shingo Implementation theory (See Figure 2), and to describe how this model was applied in a real-world company.

3.2.4 Change through Action
Action research creates knowledge through the reflections of the stakeholders as they take action to solve a problem. The processes of action and the resulting changes are indivisible because both exist in successful problem solving. If action does not bring about change, then (1) no problem truly existed, (2) the intervention (action) was inappropriate, or (3) the problem could not be solved because of practical obstacles (Davidson, et al., 2004). In this study we used the observations and participation of managers and workers to develop solutions to solve problems.

3.2.5 Learning through Reflection
Action research studies must articulate what has been learned through the experience of the participants. Davidson et al (2004) suggests that existing studies either fail to apply an existing theory or develop a new one that explains the phenomenon they observed. Reflection can also
take place outside of the immediate participants. Reviewing the findings of this research with other researchers and practitioners not involved in the study provided valuable insight for learning.

3.3. Data Collection
Multiple sources of evidence were used to validate the findings. Six types of evidence, identified by Yin (1994), were used. First, qualitative data was collected through documentation obtained in the form of letters, memoranda, minutes of meetings, progress reports, and strategic planning reports, etc. Second, quantitative data was collected in the form of archival records of customer complaint reports, ordering processing, manufacturing and quality reports, and shipping reports, purchase orders, operational data (such as machine and labor utilization), routing information, performance measurements (such as defects and lead-time). Third, additional qualitative data was collected through extensive interviews with participants and stake-holders such as senior managers, supervisors, and workers. While it is difficult to isolate the expectancy effect (Vroom, 1964) on the implementation’s success caused by the researchers rather than the program, the interviews were conducted in an open-ended nature, which implied that the respondents provided objective opinions and insights to the events. These interviews generally followed the guidelines outlined by Fontana and Frey (2000). Fourth, both authors were involved with decision-making during the implementation, and qualitative data was collected in a participant-observation mode. Fifth, quantitative data such as defective units provided scrap rate, while defect classification provided clues to determine where mistakes were occurring in the order fulfillment process. During the study the researchers kept a research log and documented each problem during the implementation, as well as insights gained.

3.4. Content Analysis
The researchers identified patterns and common themes by using content analysis to find commonality among the experiences of themselves and other participants. Content analysis worked well for identifying possible root causes and prioritizing alternative solutions. In essence, content analysis is the counting of words, sentences, or ideas within categories of interest. In this case, we used it to collect ideas on how Poke-Yoke and SMED were implemented. Three general guidelines are applicable to all content analysis studies. First, two judges were used for performing the analysis so that the consistency of results could be
estimated. Second, the activities of implementing SSTM were applicable to the research objectives. In this case, we collected data specifically on the implementation and use of Poke-Yoke and SMED. Third, the units of analysis were upper managers and workers at the shop floor level because they were the best source for strategic and tactical information on implementing Poke-Yoke and SMED. To examine the flow of products through the system, we employed Shingo's process mapping methods (Shingo, 1988). Areas where products wait are noted, with average wait and processing times calculated for each stage. These maps helped identify where parts had long wait times and were processed through redundant or unnecessary activities. As part of our RCA with the company, the researchers agreed not to publish a list of the problems; as such, we were not able to publish the results of the content analysis; however, several examples are discussed in Appendix I.

Each evening the researchers reviewed the information and data for the current day. Several hours were spent brainstorming ideas for root causes and reflecting on what had happened during the day's events with several participants. This satisfies the 'problem identification' stage of SSTM. The collection of data and development of possible solutions satisfied the 'basic approaches' stage to SSTM. Results of the ideas implemented during the current day were reviewed for performance. The ideas with the greatest potential for success and most support from the group were prioritized for implementation on a small scale. In doing so, the researchers planned for the implementation of theses ideas thus utilizing the 'planning for improvement’ stage of SSTM. Those that provided improvement were noted, as well as our preliminary insights into why they worked. This satisfied the 'implementation' stage of the CPM. Other areas in the order process that could benefit from the same solutions were identified for implementation on the following day. Each morning, the team chose the next problems to attack based on consensus. In doing so, the researchers practiced the iterative process, i.e. starting over at the problem identification stage. All planned solutions were implemented during the first shift operations of the company so that the researchers could participate in the process.

3.5. The Company

We conducted this study in BPC, a manufacturer and supplier of residential and light commercial building products located in Georgia and Alabama. The plant used in this study was the firms’ manufacturing operations located in the Georgia facility. These plants employed 123 managers
and workers who processed customized building products. It utilized lines comprised of Norfield, and other custom equipment. At the time of this implementation, the company held an estimated 5% of the Southeastern residential and light commercial building product market.

4. Implementing Shingo’s SSTM
4.1 Description of the Implementation

The redesign effort was initiated to stop the company’s worsening performance in the market. Increased customer returns and poor production lead-time performance were forcing many of the company’s customers to competitors. Given the highly competitive environment of the market, this was a serious problem for the company. Since successful improvement programs always have the support of senior management, it began with BPC’s President and management team – i.e. the VP Marketing, VP Production, VP Purchasing, VP Human Resources, and VP Accounting. The general consensus was that customer returns due to quality issues and longer lead-times were not due to a single problem, but were cross-functional involving mistakes in many departments such as Order Writing, Production, and Shipping - that were amplified as they progressed through the system. This led the management team to develop a cross-functional improvement team (called the C-FIT) comprised of managers and workers.

Each member of C-FIT was chosen based on experience and their enthusiasm and interest. In addition to the researchers, two members were chosen from Inside Sales and Order Writing, three members from the Production department, and two members from Shipping. C-FIT was responsible developing a charter for the improvement initiatives, timeline for the implementation, and budget. The group also analyzed the existing order fulfillment process, planning the change with active participation from all departments, implementing the change in process, and following up the effects on performance.

C-FIT began their analysis by interviewing personnel (managers, supervisors, and workers) from different departments and by reviewing customer complaint reports, order processing, manufacturing and quality reports, and shipping reports. The team’s initial assessment found that the deteriorating performance was due to many wasteful activities at each stage of the order fulfillment process. However, these wasteful activities had apparently existed for many years, while the quality and lead time problems had seriously impacted performance only in the
previous six months. A natural question was why? After extensive review, the team discovered that BPC senior management had initiated a “New Customer Focused” marketing policy to increase the number of new customers, rather than increasing business from existing customers. The new policy was initiated because sales growth from existing customers had flattened over the previous 18 months. The new customer focused policy had increased the number of new customers by 15%. During the same period, the company had not increased resources because the utilization of existing resources was still below 70% - sufficient capacity to meet demand.

After further deliberation, C-FIT came to the conclusion that the increased strain on resources had eliminated much of the excess capacity in the system. This meant that prior to the new policy, workers and managers had the time to check and recheck order writing, rerun orders that were incorrect, and sufficient raw material and finished goods buffers to prevent delays. Now that much of the excess material and capacity were being utilized, these redundancies were no longer possible. After reviewing the results, senior managers decided to improve the existing system rather than abandon the new customer focused policy. They were convinced that a long-term solution existed that would improve their operation without increasing resources. Their main objectives were to improve customer service by eliminating the need for redundancies from the order fulfillment process.

To standardize the problem-solving process, the President had chosen to use Shingo’s System. He wanted all participants to use the same terminology and techniques so that they could be applied cross-functionally. C-FIT deliberated using other techniques because the team recognized the importance of sophisticated tools such as Statistical Process Control (SPC). However, the general census was that the vast majority of the managers and the workers did not possess the requisite skill set to either fully understand or implement such tools at this stage. Additionally, the company needed to expedite a solution to prevent the further loss of business.

To begin the implementation on the shop floor, C-FIT worked diligently to develop the contents of a training program with illustrations, examples, and interactive simulation games to provide training in the basics of SSTM. The researchers provided one week of training on waste elimination for the departments. The first three days were spent teaching Shingo’s concept of waste elimination. The researchers used his books (Shingo 1985, Shingo 1986, Shingo 1987, and Shingo 1988) as references. Throughout the training session, many of Shingo’s anecdotes,
stories, and examples were used to illustrate waste elimination and the purpose of the four steps of SSTM. Over the next two days, many of Shingo’s mistake proofing (Poke-Yoke) and quick changeover tools (SMED) were presented. The researchers encouraged the managers to provide examples of similar systems from their respective departments because they suspected that various departments had implemented their own informal process improvement tools, and they wanted to use these to demonstrate the Shingo system. The researchers developed some examples of wasteful activities, and supervised a session where the managers and the workers applied SSTM to develop mistake proofing or quick changeover systems.

The next step involved mapping the systems using Shingo’s process mapping approach, (Shingo 1988). This was designed for C-FIT to understand the complex flow of information and material. They found that the existing order fulfillment process consisted of four distinct stages, (1) order processing by inside sales, outside sales or directly from customers, and writers who manually generate shop orders. They also release a 'shipping ticket' to the shipping department with date and time of delivery. Stage (2) consisted of separating the production orders by type, i.e. by doors, windows, etc. Many orders receive components from all shops. Stage (3) consisted of locating an order using the shipping ticket, loading and transporting the order to a job site, and unloading the order at the job site. Stage (4) consisted of installing the production units at the jobsite. While performing process mapping, C-FIT found examples of wasteful activities, such as outdated information on existing customers and incomplete information on new customers. This delayed many orders from being processed. They also found redundant procedures such as duplicate and confusing paperwork that in previous years helped catch inconsistencies in customer orders – as many orders would change by the time the shop order was cut. Because the tooling for machine setups were not organized before a line was shut down, equipment set idle waiting to be setup – creating a loss of capacity. Human errors in purchase orders and in incoming materials, etc. were not caught because the redundancies were no longer happening.

Because the team could not effectively address all of the problems simultaneously, they struggled on which ones to address first. By this time, the team had documented many wasteful activities from different departments. After several iterations, they agreed to prioritize the problems based on possible outcomes, i.e. improved quality or reduced lead time. The reduced lead times were reflected in faster response times, reduced inventory (raw material, work in
process, and finished goods), better utilization of bottlenecks, and improved quality based on a reduction in customer returns. Using the two potential outcomes, the team prioritized waste elimination projects based on those with the strongest support – derived from content analysis (i.e. those that were mentioned most by workers and managers). The priorities were presented to the senior management team for input and approval.

Using the priority list, a detailed implementation was developed consisting of five major activities. First, lower-level implementation teams consisting of 4 to 5 shop workers (or process owners) were established to carry out the implementation on the shop floor. Second, the researchers assisted the teams to become completely familiar with the shop and its operations. Third, the team verbalized some possible problem statements. At first, when a problem statement was first written there was no clear agreement among the team members for its cause. Fourth, a room was secured close to the shop floor for the researchers to conduct training, and workers to meet to discuss ways to identify and solve the problems. Fifth, the training was delivered by a researcher in an interactive manner using presentation slides with audio and video enhancements, and real examples from BPC.

To address failures that had plagued previous improvement initiatives, C-FIT identified “improvement champions” in each area that were responsible to lead shop floor efforts. Problems with previous initiatives involved a lack of general agreement on what to do, which improvement program to use, what training or communication was required, and trust and visual support of top management. C-FIT resolved these critical problems to prepare the company for the changes. For example, the team knew that the workers did not trust upper management’s commitment and were not interested in participating and giving their honest suggestions to mistake proof the process. Over four weeks the group held a series of formal and informal meetings with workers. During the last week of the meetings, the researchers provided a week-long training session on Shingo’s waste elimination process. By the time they completed their training program, the team and workers had met twenty times. Upper managers were involved at every stage and exhibited visual commitment to the effort. For the first time in the company's history, manager's answered questions openly and honestly, and solicited suggestions to improve the order process. After several weeks, the group and the workers were freely exchanging ideas and working with greater cohesiveness. To understand how low-level teams used SSTM to solve
a delivery problem see Appendix I.

4.2 Non-sequential Problem-solving

During the implementation, the researchers encountered an interesting phenomenon where the teams were no longer following the SSTM problem-solving process used in training. Instead they worked through SSTM in a hap-hazard manner - not adhering to the sequential step one – step four process. The reason for this was not immediately identified. An example of this phenomenon is described in Appendix I – Part 2. While reviewing the literature, the researchers discovered a number of texts and cases, e.g. Render et al (2002) describing a similar phenomenon involving problem-solving implementations. However, these texts did not discuss why it occurred. Therefore, in keeping with the action-research method, the researchers temporarily refocused their efforts on discovering why this happened. Flowcharts of several team activities were developed and showed that SSTM proceeded in a sequential and rational manner at times – beginning with stage one and ending with stage four. Although the amount of time spent in each stage varied, the group experienced the succession from one stage to another smoothly. At other times, SSTM proceeded in a non-sequential and reflective manner. In other words, the process did not always begin with problem identification, but instead went first to stage 2 for developing possible solutions. See Appendix I for an example of how the process started at different stages. This process appeared counterintuitive and irrational to participants and observers in the process. During this period, the amount of time spent in each stage varied greatly. Managers and workers became frustrated with the process. After comparing the two experiences over a number of iterations, the C-FIT team identified the Problem Identification stage of SSTM as the driver of the problem. This issue is best described in one of our research log entries at the end of the sixth week,

“While addressing difficult problems with no clear solutions, the members of the group interacted among themselves through intense deliberation with members vehemently arguing their points. This created anger, frustration, and resentment among the members of the group – inciting emotional outbursts on several occasions. There were major differences of opinions on either the source(s) or on the solution of the problem or both. Many of the solutions were too expensive to try randomly; therefore, the group had to choose only a few to examine further. When the group interacted with different departments to apply SSTM, there was rarely consensus. This led to a serious breakdown of communication between the group and the departments. In fact, many times departmental managers openly vocalized their disagreements, questioning upper management’s commitment to the waste
C-FIT found that when the problem was clearly identified, the teams behaved in predictable and rational manner - working through SSTM sequentially. When the problem was difficult and not clearly identified early in the process, consensus could not be reached on either the problem or a solution and the team painfully jumped from one stage to stage, with little rationale. This resulted in wide speculation, with solutions being implemented through 'trial and error' before the problem’s root cause was articulated. The researchers attempted to intervene and guide the efforts (believing the workers were to blame); however, some members became emotional and would not accept guidance at first. To stabilize the process, deliberation on difficult problems was temporarily delayed in favor of those for which the problem was easier to recognize. During the daily reflection sessions it was recognized that the workers may be correct – to correctly identify a difficult problem or its root cause often requires trying different solutions until one works. Based on this finding, training was revised to include sequential methods, as suggested in Shingo's literature, as well as non-sequential methods - where the problem or its root cause was difficult to identify.

4.3 Impact on Performance

As a result of the implementation, the worsening lead time and customer return performance had subsided and began to improve slightly after approximately sixty days of implementation. After six months, BPC had the lowest stated lead time among its major competitors and had gained eight new customers during this period. Improvements were attributed to major reductions in setup times, which resulted in less WIP inventory and smaller batches, and fewer production mistakes – achieved without adding resources. This also reduced the need to carry safety stock. Due to the various poke-yoke devices installed in the order fulfillment process, mistakes in order writing and production processes resulted in fewer delivery mistakes of less than 1% of all deliveries – an improvement of almost 300% below the 4% levels reported prior to management’s implementation of the new customer focused policy. After one year, SSTM was still being used and process improvements continued, although the rate of improvement had slowed over what was achieved during the first six months.

5. Shingo’s SSTM Implementation Model
Throughout the study, the researchers noticed patterns in the activities used to address implementation issues. For example, most new problems were created, or exacerbated, by a change in company policy, e.g. new customer focus. Decisions at this strategic level tended to impact the performance of many business functions – requiring a cross-functional team to solve problems. These teams worked best when upper managers were involved and visually supported the team’s efforts. Next, we found that when all team members were trained in the same process improvement technique, they were more effective. As discussed in the literature review, successful programs are often repackaging of the same step-wise, problem-solving process. This required choosing the same tool to be used throughout the company and associated training materials to be developed. The experience of the researchers suggests that the materials are more effective if customized to the context of the company. The next stage is to map the major business processes. This stage compels the team to identify and document every major activity in their order fulfillment process, thus identifying and prioritizing improvement opportunities. Once the opportunities have been identified, the team develops a plan to gather information, develop solutions and implement those that have the greatest probability of success based on the priorities of improved quality and reduced lead time. Next, the process improvement techniques should be implemented at the lowest level of the organization – where most business processes actually take place. This is to ensure that both strategic and tactical improvements are translated into practice; otherwise, they will not lead to improved performance. Lastly, this study found that unless the improvements are documented and reviewed on a regular basis that processes tend to migrate back to old methods or do not change to meet new demands. This means that periodic revision is necessary to ensure the improvements are still effective and documentation allows the improvements to be applied to solve similar problems in other areas of the company. This evidence leads to our proposition of a general implementation model for Shingo’s systems.

The model, shown in Figure 2 shows the stages that a successful Shingo implementation goes through before performance improvement is realized. The process must begin with a Strategic Analysis of company policies that affect the demand placed on resources. Since customer demand drives all functional areas of business - the strategy to meet this demand should be reviewed for inconsistencies and relevance. This is important because policies are often left in place that no longer apply to an organization’s overall business strategy or changed without consideration for the resources needed to execute the strategy. Stage two involves forming a
**High-Level Cross-functional Improvement Team.** The term “High-Level” refers to the inclusion of both managers and workers that have the ability and authority to look at all functions and identify problems that are cross-functional in nature. This is important because strategic policies often affect all functional areas and therefore most performance problems are usually related. Stage three involves *Establishing Overall Improvement Tools.* This is important because different techniques of problem-solving use different tools and terminology. Choosing a single problem-solving technique to use company-wide ensures that the same terminology is used and understood by everyone in the organization and that managers and workers have common expectations about how the improvement process will progress. Stage four involves performing a *High-Level Process Mapping* exercise to understand how the functional areas work together. This map provides a tool for *Identifying and Prioritizing Improvement Opportunities.* Stage five is tactical in nature and involves developing a *Detailed Plan and Forming Low-level Improvement Teams* who actually implement the improvement programs in their respective business processes. This stage ensures that the strategic decisions made by the High-Level teams get properly translated and implemented at the shop floor level. Stage six is the tactical *Implementation, Documentation, and Revision* of the improvement plan. At this stage, the company begins to spend resources to improve the process. Documentation is important so that a record is kept of which problems were addressed, solutions were attempted, and the level of effectiveness of those solutions. This also acts as a feedback mechanism to the strategic components of the model and provides a basis for revising plans that did not work, or no longer effective.

**6. Discussion and Implications of the Findings**
The development of the Shingo Implementation Model occurred over a period of several months and after hundreds of iterations of SSTM with the C-FIT and Low-Level implementation teams. Working through a plethora of problems and solutions the activities and sequences shown in Figure 2 finally emerged. This study found that by following the six stages participants were able to address all of the problems encountered during the implementation experience. When the model was not followed, the problem identification and solution techniques worked only contextually and often created problems in other areas of business. Stated differently, when the model was not followed, process problems were not really solved, they were simply passed from one functional area to the next.
Next, this study is the first to articulate why SSTM works. It works because, like other problem-solving techniques, it is grounded in classical problem-solving and creativity-generation techniques that are the foundation of the scientific method. This discovery is important because it explains why the problem-solving process does not always occur sequentially as shown in Appendix I. This study finds that when a problem and its root cause are easy to identify, the problem-solving process occurs sequentially as shown in Figure 1. When the problem or its root cause is difficult to identify, the problem-solving process occurs non-sequentially and often appears irrational to observers. This is because the teams applying SSTM must often apply various solutions before the problem is accurately identified. While this non-sequential/irrational phenomenon is reported in many texts and cases, e.g. Render et al, (2002), the causes for it were unknown prior to this study. When the non-sequential phenomenon occurred in the study, the Making Plans for Improvement and Translating Improvement Plans into Reality stages occur before the problem was truly identified. Once identified, then Basic Approaches to Improvement allowed the solution to be applied in other areas where the problem may be duplicated. Only through Action Research, were the researchers able to discover why SSTM often occurred non-sequentially. The causes for the anger and frustration of the managers and workers when this happened can be explained through classic Expectancy Theory (Vroom, 1964). When the participants expected all problem-solving exercises to occur in a similar manner, as their training had implied, their roles were predictable and well-defined; when it didn’t, their roles had to be redefined, and the SSTM sequence revised. This required a great deal more effort and time on their part. Managers and workers need to understand that reflective behavior is important for solving difficult and messy problems and, at times, may appear as irrational behavior. Training programs should reflect this reality.

Lastly, this research shows how the implementation model was used to implement mistake-proofing and quick changeover systems to eliminate waste. This is particularly relevant, as today’s competitive environment demands that companies eliminate waste to meet the efficiency and responsiveness demands by customers. There is increasing pressure to pursue new ways of thinking, as a source of competitive advantage. More research in this area should contribute to science and practice of improvement implementation model to eliminate waste.
7. Strengths and Weaknesses

Action research has both strengths and weaknesses. A strength of the method is that it provides a rich explanation of 'how' and 'why' phenomenon occur - which can't be expressed through statistical or regression models. Second, the phenomenon is studied in a natural setting which would be expensive, difficult, or impossible to replicate in a laboratory experiment. According to Stake (2000) real world studies are valuable for refining theory and suggesting complexities for further investigation. A weakness of the method is that when applying a theory to a real-world setting, action research fundamentally assumes that it adequately specifies action. However, according to the cognitivist perspective, this is rarely the case (Keemis and McTaggarart, 2000). Rather, the best theories are parsimonious and do not claim to replicate reality, which makes their application to problem-solving somewhat ambiguous. However, empiricists often develop models from real-world data, as in this study, which are often applied to problem-solving. Examples include Flynn's, et al., (1995) model on the hierarchy of quality improvement efforts. Third, the participants are exposed early-on to the ideas of the researchers which can create bias (or expectancy) when identifying root causes or explaining events. Next, the conclusions from a single study may only be contextual and too detailed - thus harming generalizability. Fourth, criticisms of action research often involve the way the study is conducted rather than the methodology itself. As Davidson, et al., (2004) points out, existing studies do not provide adequate detail for establishing reliability and validity of findings; however, their study also concludes that limitations on the length of journal articles may make this goal impractical.

Notes:

1The deficiencies in the old ISO 9000, led to the development of QS 9000 as a quality system, which was jointly developed by Chrysler, Ford, and General Motors. The goal was to develop a system that provides continuous improvement, emphasizes defect prevention, and reduces variation and waste in the supply chain. The first edition was published in 1994, and new editions are published periodically.

References:


Start Strategic Analysis
Market/Customer Driven

Stage 1
Problem Identification

Stage 2
Basic Approaches to Improvement

Stage 3
Making Plans for Improvement

Stage 4
Translating Improvement Plans into Reality

Waste Elimination
- Defects
- Overproduction
- Inventory
- Motion
- Processing
- Waiting
- Transportation

Strategic Decisions

Tactical Decisions

Continuous Improvement

Figure 2. The Shingo System Implementation Model
Part I
Stage 1: Problem Identification
The group was aware that many production orders were delivered incorrectly at the jobsite. Further analysis of the customer complaints reports revealed that over 7% of the orders were incorrectly delivered. The group identified two key customers with most of the customer complaints, and interviewed them extensively. The interviews revealed that most of the orders, which are delivered incorrectly were at the jobsite, were written correctly. The group studied production orders related to those customer complaints, and found that those orders were indeed written correctly. The group knew that the source(s) of the problem existed between shipping and production. The group decided to work backwards from the driver’s report in order to gather information.

Stage 2: Basic Approaches to Improvement
The group studied the driver report and found that there were many instances of multiple deliveries to the same order. The reason was the dispatching system was using outdated map coordinate system. The experienced dispatchers had mentally corrected the coordinates, however inexperienced dispatchers made many mistakes in delivering an order. In order to receive additional insights, many members of the group rode with the drivers. Several drivers believed that many orders were being incorrectly delivered because either production build the order incorrectly or the order was not at the designated place. They also acknowledged that the drivers made mistakes in pulling a production orders. The group wanted to investigate this further (see, Part II, Stage 2).

The group found that considerable amount of confusion existed in dispatching because order delivery times were frequently moved (e.g., 1:00 PM to 3:00 PM) by the outside sales. This confusion was contributing in sending many orders to the wrong jobsite. Since no data was available, the group collected data by observing the process for a day and the observation revealed that about 30% of the jobs were altered. Further analysis revealed that the orders with doors were late due to long setup time at the door shop. The group wanted to investigate this problem simultaneously (see, Part III, Stage 1).

Stage 3: Making Plans for Improvement
The group brainstormed to generate many solutions. Many suggested purchasing the latest map coordinates and with an option of receiving frequent updates. Some suggested that each salesperson should be allowed to alter a fixed percentage of daily orders scheduled for delivery. The group carefully evaluated the solution ideas. Given the competitive situation and the declining customer service, the group rejected the idea of limiting the number of changes allowed in the scheduled for delivery. The group evaluated that the new map coordinates and approved the purchase of new system.

Stage 4: Translating improvement plans into reality
The group took dispatcher’s and drivers’ opinions into consideration to fine tune the map coordinate requirements. To smoothen the transition process, several trial runs were performed before the actual installation of the system. As the dispatchers and drivers wanted the change, there was no resistance to change.

Part II
Stage 2: Basic Approaches to Improvement
The group gathered information on the daily operations of the production and after considerable analysis, deliberation, and reflection, discovered two problems. First, there was no designated place for the finished goods at the end of production line. Second, the drivers were making mistakes in pulling the orders because it was difficult to find the order on the production floor.

Stage 3: Making Plans for Improvement
The group brainstormed to generate solution ideas. The group deliberated to determine a place for finished goods and raw material. Many suggested that a warehouse floor space be allocated for both finished goods and raw material. Many others suggested that trolleys be purchased for stacking finished goods. The group carefully evaluated the solution ideas. First, the group found that either finished goods or raw material could not be placed on the floor. The door units are heavy and they need to be kept in a reclined position. In order to keep the doors in a reclined position, the group considered purchasing steel shelves. The group rejected idea because that the steel shelves were expensive, material flow was difficult, and future expansion was not possible. The group evaluated trolleys and found them relatively inexpensive, and decided to purchase.
Stage 4: Translating improvement plans into reality
The group took production workers and the driver’s opinions into consideration to refine the size and the number of trolleys. To smoothen the transition process, a few trolleys were purchased and tried in daily production runs. Once it was found that trolleys were working well, additional trolleys were ordered. Although purchasing the trolleys eliminated many mistakes by the production workers and the drivers, there were still many mistakes being committed in pulling and order. The group confirmed that there was a decline in customer complaints and now 4% of the orders were incorrectly delivered. The group was encouraged by the results, and decided to gather information to continue mistake proof the order pulling process (See, Part IV, Stage 2).

Part III
Stage 1: Problem Identification
The door shop machine had a setup time of about 20 minutes. In order to gather information on the setup time, the group studied the machine operation.

Stage 2: Basic Approaches to Improvement
The group observed the machine operation and organized the setup time into external and internal setups. External setup can be performed while the machine is not running, and consists of following activities. Door slabs must be picked from raw material inventory and staged at the door loader prior to enter the production cycle. Door slabs are assembled into ordered stacks according to production priority. The stacks are set in place at the door loader. Internal setup can only be performed while the machine is running and consists of the following activities. The loader picks up individual doors and sets them in place on the production line conveyor. The slab is loaded into the door machine. The operator loads hinge and strike jams into the door machine and hits a button to begin the automatic routing process. During this process, the operator loads each hinge applicator by hand. After the machine process is completed, the operator pulls jambs and slab out of the machine. Further analysis revealed that external setup was about 90% of the total setup time. There were two problems associated with external setup. First, often door slabs were not picked from the raw material inventory before the machine ran out of door slabs. This was because the door slabs were fed by a forklift, which was also shared by the Receiving Department to unload vendors’ trucks. Over time, as business picked up the forklift got busy in unloading the vendors’ trucks and the door shop starved for door slabs. Second, the supervisor of the door shop conceptually explained how the internal setup of the machine could be improved, but the group wanted to make sure that the suggested changes do not impact other parts of the machine and wanted to involve the vendors of the machine.

Stage 3: Making Plans for Improvement
The group deliberated to generate solutions ideas. As external setup was a significant portion of the entire setup, the group decided to focus its efforts on eliminating the external setup. In order to pick up door slabs from the raw material inventory, the group suggested to purchase a forklift and argued that the same forklift could also be used by other shops. Another solution idea was that a semi-skilled worker could be hired, who would pick up the door slabs trolleys from the raw material inventory. In addition, the group came to know that machine vendors had shortened the internal setup by 70% and improved the processing of doors by 50% in their latest model, and they were eager to sell the new model. The group carefully evaluated each solution idea. The supervisor of the door shop provided justification for a forklift. The group carefully evaluated and found that they could not justify purchasing a forklift at this time given the volume of business. The group found that they could justify hiring a semi-skilled and purchasing some trolleys, so they approved these decisions. The supervisor of the door shop was not very pleased with this decision. The group evaluated the possibility of buying a new machine and determined that a new door machine was not required at this time based on projected two years demand of doors. Since the door supervisor had ideas for improvement in the existing machine, the group contacted the vendors to send a design engineer to supervise the changes. Despite several requests and the vendors did not agree to send an engineer. The group did not want to take a risk and discarded the idea.

Stage 4: Translating improvement plans into reality
The group considered door shop supervisor and workers opinions were considered to fine tune the external setup elimination process. Many trial runs were performed painstakingly to make sure the process was working smoothly. Initially, the group did not encounter any resistance to accept the new ideas. However, after some time, the group found that the door shop supervisor was using neither using the semi-skilled workers nor the trolleys provided to him for feeding the door shop. The group held a meeting with the supervisor and found out that he was rejecting the idea because the group had rejected his idea. The group approached the problem differently by organizing a casual meeting between the customers and the door shop supervisor. Customers discussed how they were receiving incorrect orders at the jobsite and the group related the problem to long setup times at the door shop. After hearing the problems from the customers, the door shop supervisor decided to implement the solution ideas. As the door shop implemented the new solution ideas, the setup time for the door shop gradually declined, and additional capacity was generated. After several weeks, the supervisor of the door shop reported that setup time had significantly declined. The setup time was only 2 minutes, which also improved the productivity of the shop by 20%.

Part IV
Stage 2: Basic Approaches to Improvement
In order to gather information, the group interviewed many drivers and door shop workers. The production workers said that drivers were impatient and did not look hard in the trolleys to pull an order together. The drivers said that it is hard to differentiate each order and blamed the production workers for not being organized stacking the orders. After deliberation and reflection the group suspected that the root problem was that production orders came in different sizes and many times it was not
possible to stack one complete order in a trolley, therefore, multiple trolleys were used to stack the complete order – which separated the order.

Stage 3: Making Plans for Improvement
The group brainstormed to generate solutions. The groups considered purchasing different sizes of trolleys or keeping large orders on the production floor. The group also considered a unique color label for each order. In this manner, the existing trolleys could be used to stack order orders into two trolleys. The group carefully evaluated the solution ideas. The group found that different sizes of trolleys were available from the vendors and there was not much difference in prices from one size to the other. The group rejected the idea because even if the completed orders can be stacked in the trolleys, this did not help the drivers to mistake proof their order pulling process. The group concentrated their efforts on evaluating unique color labels for each order. This was considered a good idea because it was easy to introduce color label and was easily recognizable by the drivers.

Stage 4: Translating improvement plans into reality
The group considered order writers, dispatchers, production workers, and drivers opinions were considered to fine tune the color label concept. As several departments were impacted, many trial runs were performed painstakingly to debug the process. This process took a long time and many employees were frustrated and expressed their disagreement openly. Some suggested to purchase different sizes of trolleys to continue the status quo. Initially, the group encountered a lot of resistance to accept the new idea and, in fact, many workers and drivers tried to sabotage the process. The group diligently continued to implement, held meetings with the disgruntled workers, and demonstrated the usefulness of color labels to mistake proof the order pulling process. As many drivers used the new color labels, they found that they could easily pull an order. The drivers were saving considerable amount of time and there was not much friction between drivers and workers. Over time, the drivers and production workers got used to the new system. An analysis of customer complaint report revealed that complaints had significantly declined and only less than 0.5% the orders were incorrectly delivered.
The University of Rhode Island started to offer undergraduate business administration courses in 1923. In 1962, the MBA program was introduced and the PhD program began in the mid 1980s. The College of Business Administration is accredited by The AACSB International - The Association to Advance Collegiate Schools of Business in 1969. The College of Business enrolls over 1400 undergraduate students and more than 300 graduate students.

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