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Title: Interrelation between Single-Minute-Exchange-of-Die (SMED) System and Just-In-Time (JIT) Manufacturing

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Abstract

The purpose of this paper is to analyze the interrelation between Single-Minute-Exchange-of-Die (SMED) system and Just-In-Time (JIT) manufacturing through the investigation and evaluation of the effects of these concepts on each other, regarding the information gathered from the related literature and case studies.

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INTERRELATION BETWEEN SINGLE-MINUTE-EXCHANGE-OF-DIE (SMED) SYSTEM AND JUST-IN-TIME (JIT) MANUFACTURING

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Professor Richard F. Deckro

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ABSTRACT:

The purpose of this paper is to analyze the interrelation between Single-Minute-Exchange-of-Die (SMED) [11] system and Just-In-Time (JIT) [7] manufacturing through the investigation and evaluation of the effects of these concepts on each other, regarding the information gathered from the related literature and case studies.

INTRODUCTION:

In today's competitive world, the most significant factor differentiating the companies from each other, is the level of product diversity they can offer to the markets. Thus, being a globally competitive company depends heavily on how much it can meet the needs of the customer. Therefore, to maintain this high-diversification, a manufacturer should produce in small-lots, eliminating all kinds of wastes, such as the costs incurred as a result of scrap materials and parts, inventory carrying costs, and related to this one; setup costs.

Japanese manufacturers introduced numerous concepts and techniques to their manufacturing processes to reduce the production related costs, meanwhile increasing their product quality to stay competitive in the markets. One of the most effective methods they came up with was Just-In-Time production, which Schonberger [9, pp: 15] describes briefly as "decreasing the lot sizes and improving quality while eliminating the wastes." The SMED system [see 2, 7, 11, 12, among others] which basically consists of techniques for reducing setup times, was also developed by Shigeo Shingo as a set of tools for implementing JIT.

The main purpose of this paper is to investigate the level of relation between SMED system and JIT manufacturing, referring to the conceptual overlaps of these concepts and evaluate the results.

The paper is organized into two parts; first part consisting the introduction, applications and effects of SMED system. In the second part the interrelation between two concepts is examined in detail in conjunction with the fundamentals of JIT manufacturing. Also, two cases including the applications of both of the concepts are presented and the results are evaluated. In the last section of the paper, the conclusions reached as a result of this study are stated.

PART A.

1. FUNDAMENTALS OF *SMED* SYSTEM:

Basically, the term SMED, which stands for Single-Minute-Exchange-of-Die, refers to a theory and techniques for performing setup operations in under ten minutes, that is in a number of minutes expressed in a single digit [11, pp: 3-19]. Although it is obvious that, every setup can literally not be completed in single-digit minutes, this is the stated *goal* of the SMED system, and it can be met in a surprisingly high percentage of cases [11].

I believe that, reaching the understanding of the fundamentals of SMED system depends heavily on realizing the general structure of production and the procedures of the traditional setup operations.

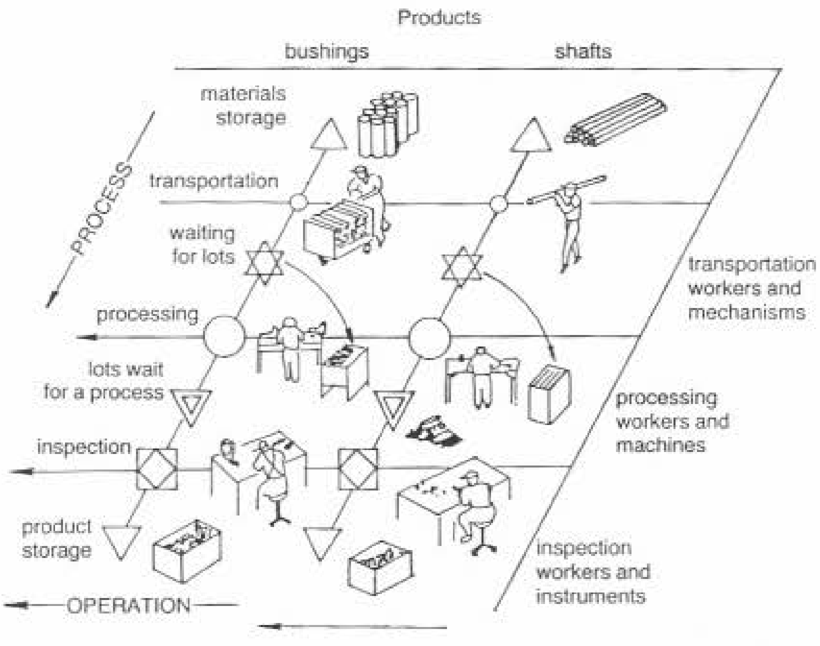

Figure 1. Structure of Production [11, page:6]

As it is stated by Shingo [11], production is the network of processes and operations, with one or more operations corresponding to each step in the process. A *process* can be described as a continuous flow by which raw materials are converted into finished goods. An *operation*, by contrast, is any action performed by man, machine, or equipment on raw materials, intermediate, or finished products. Although processes differ from industry to industry and from factory to factory, each phase of the manufacturing processes are similar to each other, like; *work, inspection, transportation, and storage*, and have corresponding operations [11, pp:5-19]. That is, there are work operations, inspection operations, transportation operations and storage operations. Each of these operations, furthermore, has four subcategories: *setup, essential, auxiliary*, and *margin allowance*. Therefore, there are setup, essential, auxiliary, and margin allowance operations related to work, inspection, transportation, and storage, such as; processing operation setups, inspection operation setups, transportation operation setups, or storage operation setups. Consequently, it can be stated that; production activities include processes and operations, and setups are comprised in each type of these operations.

Another subject which may help us to realize the fundamentals of SMED system is understanding the concept and procedures of the traditional setup operations. In today's world, diversified, low-volume production is considered to be the greatest challenge in manufacturing [11]. To overcome the problems posed by diversified production, some companies have adopted methods such as simply producing only a few kinds of products and try to stimulate a sufficient demand for them. Volkswagen [11, pp:12-13] is a case in point. For a long time, Volkswagen manufactured only one type of car, the famous "bug." In today's world of highly competitive markets and diversified demand, this strategy has met with limited success. Actually, Volkswagen has had to develop a full line of products. Especially for the automotive industry, it is becoming increasingly difficult to slow the pace of diversification as it attempts to stimulate new demand with frequent model changes. And as production diversifies, the quantity of each model will certainly decrease.

Although numerous setup operations might be required in a diversified production system, when we look at the problem from the traditional point of view; several possibilities arise when the problem is taken in terms of the setup itself [11, page:13];

- *Common setup elements*: Although the products may differ, the dimensions of the tools and parts used in processing may remain constant. In situations like this, setup problems are considerably reduced.

- *Similar setup elements*: Although the products differ, the basic shape, for example, the chuck remains constant. If it is still round, and only the diameter differs, then the only setup change required is adjusting the dimension of the dimension of the chuck claws. A setup in this kind of situation is extremely simple.

Although it is possible to reduce setup difficulties by focusing on common and similar setup elements, by classifying these elements, and by choosing the right machine for each task, the number of the setups will remain the same. These kind of traditional techniques are not enough for small-lot production, where; once an operation begins to develop momentum, with the change, production has to move on to the next one. At this point, the following strategies should be considered [11, page:13];

* Improve the operations to eliminate the need for guesswork as much as possible.
* Simplify operations through division of labor and attempt to minimize the effects of shifting work rhythms.

Approaching the setup problem from this point of view leads us to the *SMED system*, which is explained by its developer Shigeo Shingo [11] to be a scientific method for setup time reduction that can be applied in any factory, to any machine.

Before presenting the key concepts underlying the SMED system, I'd like to summarize the basic steps in the traditional setup process so as to denote the contributions of SMED system to the setup procedures. In contrary to the common thoughts that the setup procedures are infinitely varied; depending on the type of equipment being used and the type of operation, in fact, all setup procedures comprise a sequence of steps [11, pp:26-27]:

1- Preparation, after-process adjustment, checking of materials, tools, etc.

2- Mounting and removing blades, tools, parts, etc.

3- Measurements, settings, and calibrations.

4- Trial runs and adjustments.

Operation	Proportion of time
Preparation, after-process adjustment, and checking of raw material, blades, dies, jigs, gauges, etc.	30%
Mounting and removing blades, etc.	5%
Centering, dimensioning and setting of other conditions	15%
Trial runs and adjustments	50%

Figure 2. Steps in the Setup Process [11, page:27]

Also it should not be forgotten that the greatest difficulties in a set up operation lie in adjusting the equipment correctly. The large proportion of time associated with trial runs derives from these adjustment problems (Figure: 2). To make the trial runs and adjustments easier, the most effective approach is to increase the precision of the preceding measurements and calibrations .

Shingo [11] states the conceptual stages of the SMED system, which brings enormous advancements to the traditional setup process, as:

1) Preliminary Stage:

In traditional setup operations the internal and external setup conditions are not distinguished; what could be done externally is done as internal setup, causing the machines to remain idle for extended periods. What is meant by *internal setup* (IED) operations are the tasks which can only be performed when the machine is stopped; such as inserting or removing a die. In contrast to the internal setup operations, *external setup* (OED) operations are the ones which can be performed while the machine is running, such as transporting the dies to and from storage.

Shingo [11, pp: 28-29] states that actual shop floor conditions should be studied in great detail in planning how to implement SMED system and also describes some of the approaches such as:

A *continuous production analysis* performed with a stopwatch is probably the best approach, although it takes a great deal of time and requires great skill.

Another possibility is to use a *work sampling study*, where there is a great deal of repetition.

A third useful approach is to study actual conditions on the shop floor by *interviewing workers*.

Another method is to *videotape* the entire setup operation. This method is found to be extremely effective if the tape is shown to the workers immediately after the setup has been completed. Giving workers the opportunity to air their views is found to result in useful insights [2].

2) Stage 1: Separating Internal and External Setup

Distinguishing between internal and external setup is stated to be the most important step in implementing SMED. It is commonly believed that preparation of parts, maintenance and so forth should not be done while the machines are stopped. Shingo comes up with the idea that if a scientific effort to treat as much of the setup operation as possible as external setup is put forward, then the time needed for internal setup - performed while the machine is off - can usually be cut some 30%-50%. Shingo indicates [8, pp:291-303] that; mastering the distinction between internal and external setup is the passport to achieving SMED.

3) Stage 2: Converting Internal to External Setup

The second stage involves two important notions;

* Re-examining operations to see whether any steps are wrongly assumed to be internal,
* Finding ways to convert these steps to external setup.

According to Shingo [11, pp: 36-51], operations that are now performed as internal setups can often be converted to external setups by re-examining their true functions. It is extremely important to adopt new perspectives that are not bound by old habits.

4) Stage 3: Streamlining All Aspects of the Setup Operation

Although the single-minute range can occasionally be reached by converting to external setup, this is not true in the majority of cases. Shingo [11] says that this is the reason to make a collective effort to streamline each elemental internal and external setup operation. Thus, stage 3 calls for a detailed analysis of each elemental operation.

2. APPLICATIONS OF *SMED* METHODS:

In traditional setup operations, several kinds of waste recur [11, pp:33-113]; while the finished goods are transported to storage or the next batch of raw materials is moved from stock after the previous lot has been completed; the machine has been turned off which results in the loss of valuable time. Another example [11, pp:43-45] is the time lost while removing a defective part, which is the result of the delivery of blades, dies, etc., after the initial setup has begun, and, discovering the defective part only after several test runs. As it can be seen from this example; with the transportation of raw materials or finished goods, waste can occur after processing,while the machine is still turned off, as the parts that are no longer needed are transported to the tool room. Many examples can be declared where shortages, mistakes, inadequate verification of equipment, or similar problems may occur in setup operations.

Shingo [see 8,9,11,12, among all] proposes numerous, practical SMED techniques to deal with these problems. I find it useful to state some of them here so as to indicate some sample applications of SMED system:

- **Using a checklist:** Make a checklist of all parts and steps required in an operation. This list may include: names; specifications; numbers of blades, dies, and other items; pressure, temperature, and other settings; numeric values for all measurements and dimensions.

- **Performing Function Checks:** In addition to a checklist for the parts, it is necessary to perform function checks in the course of external setup, as the part checklist does not tell whether the parts are in perfect working order.

- **Improving Transportation of Dies and Other Parts:** Moving the parts from storage to the machines, and then returning them to storage, once a lot is finished, is an external setup procedure, in which, either the operator moves the parts himself while the machine is running automatically or another worker is assigned to the task of transportation.

- **Preparing Operating Conditions in Advance:** In converting internal setup operations to external operations, the first step is to prepare operating conditions beforehand. Shingo [11, pp: 52-113] gives many sample applications of this, such as: preheating the mold in die-casting machines; which results in cutting the internal setup time by about thirty minutes. Second example; cutting centering grooves on the case pattern which eliminates the center marking operation, indicating the item's position in advance.

- **Function Standardization:** Instead of shape standardization which is wasteful, because it makes the dies become larger to accommodate the largest size needed and costs rise because of unnecessary material usage; functional standardization can be used where the parts, whose functions are necessary from the standpoint of setup operations, are standardized.

- **Radical Improvements in External Setup Operations:** Improvements in the storage and transportation of parts and tools can contribute to streamlining operations.

- **Radical Improvements in Internal Setup Operations:** Implementation of parallel operations, which means utilizing more than one worker in setup operations; using functional clamps which is an attachment device to hold objects in place with minimal effort; using one turn attachments; securing objects with single-motion methods such as magnetism and vacuum suction; eliminating the adjustments by fixing numerical settings and using imaginary center lines and reference planes, can be given as examples of techniques developed to improve the internal setup operations.

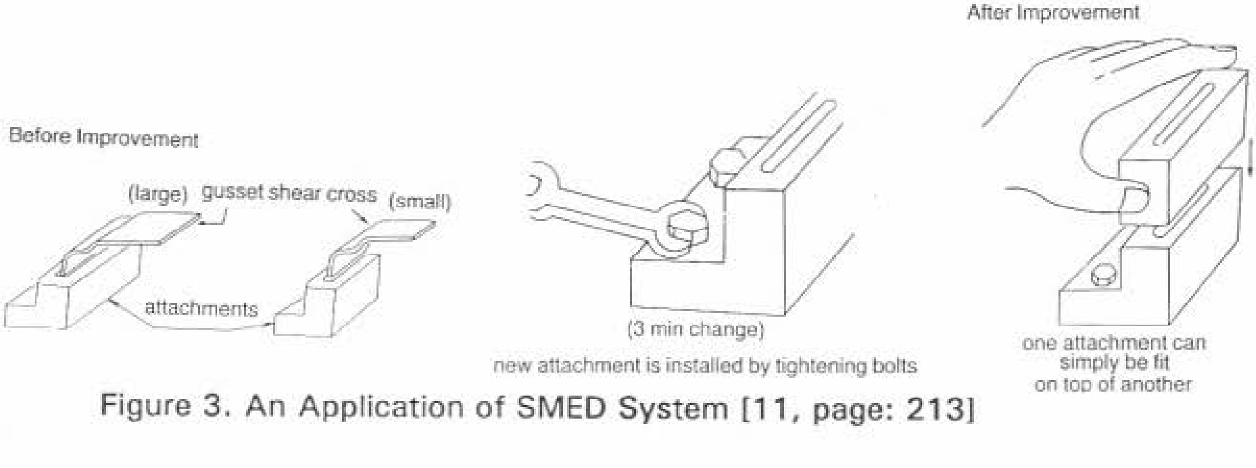

Figure 3. An Application of SMED System [11, page: 213]

3. EFFECTS OF *SMED* SYSTEM:

In addition to its most significant effect; which is the time reduction in the setup operations, SMED causes many other direct and indirect impacts on manufacturing related operations. Some of them can be summarized as [8, pp: 357-369]:

- **Stockless Production:**

It is known that inventories tend to disappear when high-diversity, low-volume orders are dealt with by means of high-diversity, small-lot production. However, having both high-diversity and small-lot production at hand, leads to an increase in the number of setup operations. SMED system offers the solution to this problem, while providing the minimal inventory levels. Moreover, following effects can be expected related to this;

* Increase in the capital turnover rates.
* More efficient use of the plant space as a result of the stock reductions.
* Increase in productivity due to the elimination of the stock handling operations.
* Unusable stock arising from model changeovers or mistaken estimates of demand is eliminated.
* No more loss of goods through deterioration.
* The ability to mix production of various types of goods leads to further inventory reductions.

- **Increased Machine Work Rates and Productive Capacity:**

As the setup times are reduced, the work rates of machines will increase resulting in a rise in the productivity level.

- **Elimination of Setup Errors:**

As the trial runs are eliminated, setup errors are reduced.

- **Improved Quality:**

As the operating conditions are fully regulated in advance, quality of production improves.

- Increased Safety:

Simpler setups result in safer operations.

- Simplified Housekeeping:

Standardization reduces the number of tools required and those that are still needed can be organized more functionally.

- Lowered Expenses:

Investment efficiency is increased by achieving possible increases in productivity at, relatively, little costs.

- Operator Preference:

As the tooling changes become quicker and easier, there is no longer any reason to avoid them.

- Lower Skill Level Requirements:

As the tooling changes get easier, the need for skilled workers decreases.

- Reduced Production Time:

As the production takes place in small-lots, and waiting for processes and lots are eliminated, production periods tend to get shorter drastically.

- Increased Production Flexibility:

In addition to shortening production times, the adoption of SMED facilitates product changeovers, thereby making it possible to respond rapidly to changes in demand, and substantially increasing manufacturing flexibility.

- Elimination of Conceptual Blind Spots:

As the generally accepted concepts are changed in conjunction with the improvements, people will start to question all the concrete ideas and try to eliminate all kinds of conceptual blind spots instead of sticking to them.

- New Attitudes:

As the people start to see; the things that are thought to be impossible are turning out to be possible, there occurs a revolution in the minds of people and their perceptions tend to change.

- **Revolutionized Production Methods:**

Since the markets are becoming more and more competitive, and large-lot, mass production is abandoned as a result of diverse demand, SMED system comes up to be the only effective solution of the huge flexibility required in this diversified production.

PART B.

1. PRINCIPLES OF *JIT* MANUFACTURING:

The just-in-time concept, which appears to be the core of Japanese production management and productivity improvement, can be summarized as [7]; "Produce and deliver finished goods just in time to be sold, subassemblies just in time to be assembled into finished goods, fabricated parts just in time to go into subassemblies, and purchased materials just in time to be transformed into fabricated parts."

The JIT ideal is for all materials to be in active use as elements of work in process, never at rest collecting carrying charges. As Schonberger [9, pp: 15-16] states, JIT is a hand-to-mouth mode of operation, with production and delivery quantities approaching one single unit, that is piece by piece production and material movement.

Vollmann, *et al.* [13, pp:67-76], indicates the basic action programs included in JIT as:

1) Reduction of setup times and lot sizes:

This is necessary to make all of the products constantly. It's also consistent with reducing inventory levels. Setup times can typically be reduced by using SMED techniques some of which are summarized above.

2) A "no defects" goal in manufacturing:

Another principle of JIT manufacturing is improving quality through process improvement. This can be handled by engaging in programs of quality awareness and statistical process control. Quality improvement has taken many forms. Two critical aspects for JIT are *Total Preventive or Productive Maintenance (TPM)* and *poka-yoke*. The focus of TPM is to apply the same diligence of product quality approaches to equipment and process quality. Poka-yoke, which means mistakeproof operations , intends to guarantee quality by building checking operations into processes so that the quality of every part is evaluated as it is created. This also ensures low cost since the cost of finding defects is lowest when they are found at the same time they are made.

3) Focus on continual improvement:

Continual improvement concept, basically stands for making thousands of small improvements in methods, processes, and products in a never-ending quest for excellence.

4) Cellular manufacturing:

JIT firms tend to group their equipment for cellular manufacturing; a group of machines manufactures a particular set of parts. The equipment layout minimizes both travel distances and inventories between machines. Cells are designed in U-shape to increase worker interactions and reduce material handling. Basically, this is an effort to involve workers and use their knowledge to a greater extent.

2. RELATIONSHIP BETWEEN *SMED* AND *JIT*:

In the above paragraphs I tried to explain; what SMED system is, what the cornerstones of JIT are, and also; what the common overlaps between these are. In this section, I will try to point out the interrelation between these concepts.

As it has been stated by Schonberger [8], cutting the lot sizes is the main idea underlying JIT concept. It is obvious that when we order in larger lots, the average inventory gets larger, and as a result we pay more inventory carrying charges ; which are the interest costs on capital tied up in inventory plus the physical holding costs, such as warehouse rent and warehouse workers' wages. Therefore, if we want to cut carrying costs, we should order smaller quantities more often. But more frequent ordering costs has its costs, too. Every time we reorder a component part, there is a setup cost. Setting up the equipment to run a particular component part often involves moving heavy dies into place and making numerous adjustments. Then a trial piece is run off, and an inspector checks it. This "first-piece inspection" often reveals a defect. This results in more adjustments and more trials where it sometimes takes hours before the settings seem right and production proceeds.

The labor involved in setup plus the scrapped parts and overhead costs, obviously result in an increase in the setup cost [9, pp: 18-24]. The manufacturing superintendent wants to hold down setup costs by setting up less often and making parts in larger quantities. A classic conflict shapes up: Finance wants to hold down carrying costs by small, frequent runs; manufacturing wants to hold down setup costs while avoiding production stoppages, by long, infrequent runs. The solution to this is the economically correct lot size, which is not so big as to incur an excessive setup cost, not so small as to incur an excessive setup cost. The compromise quantity is known as the *economic order quantity* (EOQ), or economic lot size or run size.

Also this can be explained using figure 4 [9, page: 19]; The upward-slanting carrying cost line reflects the rising cost of larger lots; the downward-curving setup cost line reflects the falling cost of making parts less often, in larger lots. The sum of the two costs is the total cost curve, which bottoms out at the economically correct lot size, the EOQ.

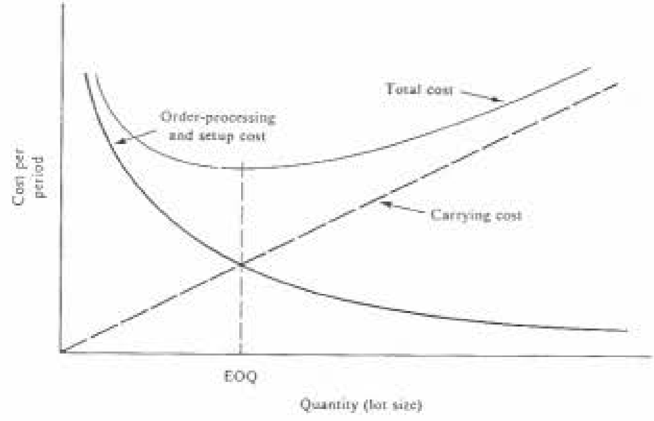

Figure 4. Setup Cost and Economic Order Quantity (EOQ) [9, page: 19]

Schonberger [9] indicates that the Japanese techniques also bring a new viewpoint to the approved EOQ concept, discarding some part of the EOQ training, providing such reasons;

1. Carrying cost and setup cost are only the obvious costs. Quality, scrap, worker motivation and responsibility, and manufacturing productivity are also significantly affected by manufacturing lot sizes.

2. Setup cost is real and significant, but not alterable. We are stuck with most carrying costs, but with ingenuity and resolve, setup costs can be driven down. Here, I also would like to present two more graphs by Denis Butt [9, pp: 22-23], who developed a set of graphs exhibiting how the EOQ may be pushed downward -toward one unit- by cutting setup time and cost, so as to point out the significance and relation of setup time and setup cost.

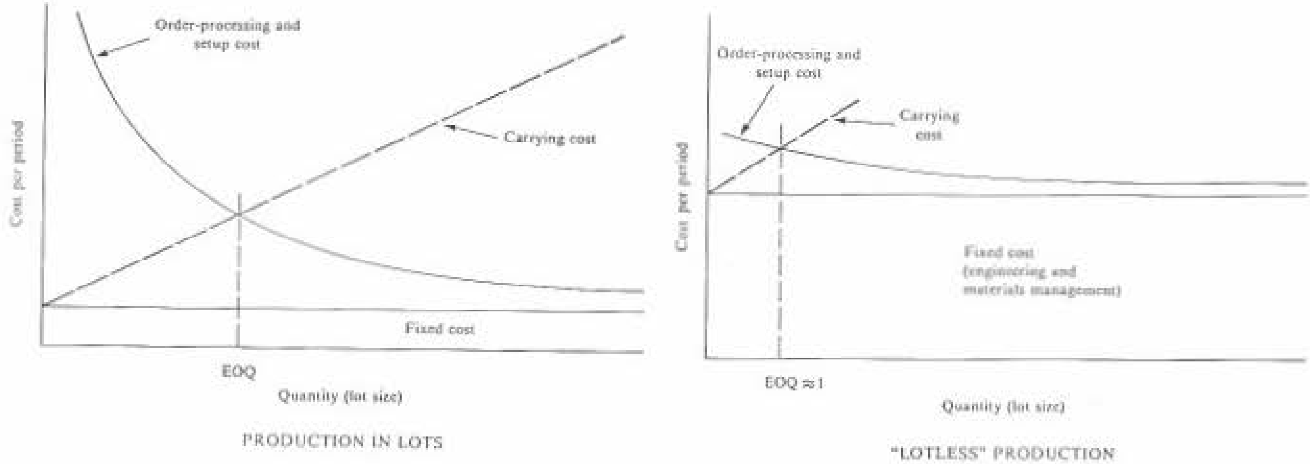

Figure 5. Economic Order Quantity Driven Down by Setup Time and Cost Reductions [9, page: 23]

Also, Shingo [11] demonstrates the interrelation between setup reductions and JIT manufacturing on chart as below;

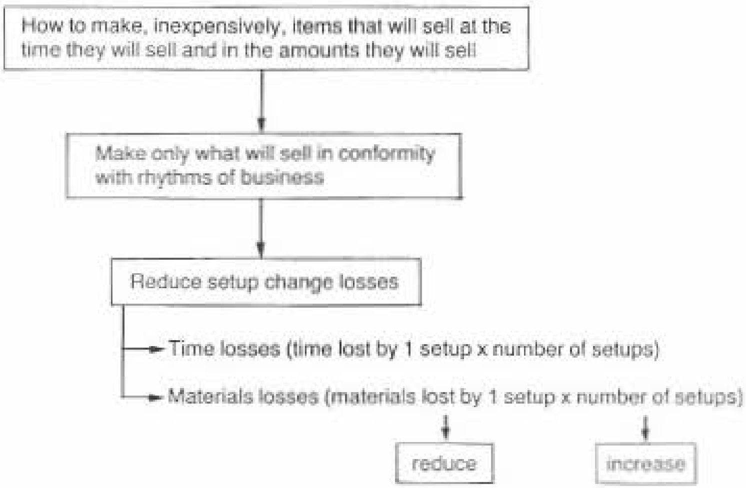

Figure 6. Setup Changes and the Just-In-Time Approach [11, page: 157]

3. IMPLEMENTING *SMED* SYSTEM; CASES:

In this section, I will try to present some examples of SMED implementations in JIT manufacturing environments, and in conjunction with these cases, evaluate the interrelation between these two key concepts.

- *Toyota Motor Corporation Case:*

When we talk about the implementation of both JIT and SMED, the most significant example that comes to mind is the giant automobile manufacturer; Toyota. As Shingo states [11, pp: 153-172]; resulting from the solid expansion in the business environment surrounding the automobile industry during the uncertain years of 1977-1987, but especially, after the time of second oil crises in 1979, limited customer demand compelled all of the auto manufacturers to firm up their positions in the global small car competition and to switch to a new emphasis on quality. The auto manufacturers were pressed to respond to the changing user requirements, to fulfill demands for quality and performance, and to produce at low prices. As industry competition grew increasingly heated and global, there was no way to survive except by lowering prices; while maintaining or improving quality. Toyota Motor Corporation, as a response to these changes, put its *famous* Toyota Production System into practice, whose basic principle is the elimination of inefficiency. This method, basically, lowers prices and raises business efficiency by approaching an ideal situation pursuing these three characteristics;

* Workers, machines, and objects are combined without waste.
* Workers and machines perform only work that increases value added.
* The time it takes to manufacture goods is the total of processing times.

The purpose of these measures, which rest on the twin cornerstones of JIT production and automation with worker involvement, is to manufacture as inexpensively as possible only goods that will sell, and to manufacture them only when they will sell quickly. The JIT concept of producing items when they are required and in the quantities required, all as inexpensively as possible, can only be done by minimizing inventory, synchronizing the production processes, and producing in a continuous stream with a minimum of work in process. To deal with high-diversity, low-volume production through the JIT approach, a company must abandon large lots in favor of smaller lots along with level production. This can only be achieved by setup time reductions. Toyota Motor Corporation adopted the SMED system in early 1972, succeeded impressively handling a large number, and greater diversity of products with the existing machinery and turned out to be the most competitive automobile manufacturer in the world.

- *Bloomfield Industries Case:*

In another example [2], that is from U.S., Bloomfield Industries (Chicago), a manufacturer of institutional equipment for food preparation and serving; three teams began implementing SMED system by videotaping setups at three large presses which were used to make stainless steel pots. The tape showed that one setup took 332 minutes, of which 286 minutes were devoted to external activities. A second setup took 195 minutes, 110 of which were devoted to external activities. Setup on the third press took 290 minutes, with 205 representing external activities. Much of the external activity involved looking for tools, going back and forth from the die storage area, and waiting for one of the two forklift trucks used to move parts to the 25 machines in the plant. The teams immediately noted some ways to knock off up to 60% of the external time, for example; making sure that every time a tool went into the toolroom it was ground down to a uniform clamp height; finding transport other than the two forklifts to get material to the machines; and moving the die storage area closer to the setup area. In addition to these, machines were designed to be infinitely adjustable to eliminate the trial-run scraps and time losses. Consequently; defect rates and setup times are decreased, resulting in an increase in productivity.

4. CONCLUSION:

In this paper, the main purpose was to point out the influence of SMED system on JIT manufacturing and to come up with concrete data to explain the interrelation between these two concepts. Using the information that has been reached as a result of the literature search pursued, it was concluded that; SMED system was the most effective method in decreasing the setup times, which is closely related to, and in fact most proper way of, decreasing the lot sizes; being the major factor in the JIT manufacturing system. Examples of SMED implementations were used to show; how effective SMED system can be and its impacts on JIT based systems. Also, besides the qualitative approach, quantitative aspects of the close relationship between these two concepts were presented using the information from Schonberger and graphical solutions from Butt. This information was tried to be supported using only two case studies; as a matter of fact, to keep the track by limiting the number of examples although numerous examples could be cited to exhibit the impacts of reducing setup costs; which are directly related to setup time reductions, on decreasing the lot-sizes; which is the key element of JIT concept.

As a result of this research, it has been concluded that;

Although JIT seems to be the key element in effective industrial management, it is an *end*, not a *means*. Its core consists of many practical methods and techniques, among which SMED system has a high significance as it is the most effective tool in reducing the setup times, where it is very critical in lot size reduction and small-lot production which is the major idea underlying the JIT concept.

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