An Intelligent Decision Support System for SMED and Its Application in Textile Industry

Onur Dogan, Ufuk Cebeci and M. Kursat Oksuz
Department of Industrial Engineering
Istanbul Technical University
Macka, 34367, Turkey
odogan@itu.edu.tr, cebeciu@itu.edu.tr, mkoksuz@itu.edu.tr

Abstract

The new trend is to avoid high-volume batch-and-queue manufacturing to produce small batches with short lead-time due to fluctuation in customer demands. However, producing more products at small batches results in more changeovers. Thus, a rapid changeover provides to be able to manufacture small quantities of the large diversity of customer demands. One of the most common method for changeover time reduction is Single Minute Exchange of Dies (SMED) which is a technique of Lean Manufacturing. The developed prototype intelligent SMED decision support methodology uses the expertise of different experts, professionals and scientific papers. Intelligent system approach for SMED has two main functions. First one is gathering data that the system asks some questions to the user to obtain the facts of the company and the second one is intelligent recommendations. According to "the facts" and "inference engine", the system manages the SMED application and can give some suggestions. The methodology has forward chaining mechanism and 90 rules. One of the original aspects of the system is starting the methodology with the vision of the firm and strategy. If the strategy is proper for the firm, the system may continue, if not, suggest another strategy such as outsourcing or investment in production technology.

Keywords
SMED, Changeover time reduction, Reduction of setup time, Intelligent systems, Decision support systems,

1. Introduction

Today more investment or having enough experience is not sufficient for companies to provide a competitive advantage. The way to come to the fore in this competition is based on optimum control of existing workforce, machine, material and processes. In the globalizing world, the way of establishing this mechanism on robust mean depends on effective use of information.

Lean manufacturing is an approach aimed at cleansing all wastes that is causing burden. Lean manufacturing system aims to meet customer demands with least amount of source, in the shortest time, with the cheapest cost and without an error. In other words, it enables just in time and high variety manufacturing in small lots with zero defects.

One of the popular approaches for productivity is to manufacture small sizes with short lead-time for rapidly meeting to changes in the customer demands (Sullivan, et al., 2002). Customers want to product range only as their needs according to high quality, affordable price and quick delivery principles. The SMED methodology helps to meet customer needs with less wastage (Shingo 1996). Setup times may be too long. If the machine is a bottleneck one, setup time will be more important. Decreasing the setup time provides that firms produce more products at smaller batch sizes results in more changeovers (Goubergen and Landeghem, 2002). The quick changeover capability eliminates this disadvantage.

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Goubergen and Landeghem (2002) classifies three main reasons that why shorter setup time is needed: to increase *flexibility* to meet increasing product diversity and decreasing customer demands; to increase *capacity bottlenecks* in order to maximize line availability for production; to decrease *lower cost* by total productivity maintenance.

Although a great number of companies have initiated the SMED, some studies fail on implementation. The expert knowledge is necessary for some SMED applications. Therefore, a knowledge based intelligent SMED methodology is applied in this study. The proposed methodology can reduce the burden of supervisors and improve effectiveness significantly.

1.1. Intelligent Decision Support Systems

Decisions making by managers in firms are critical for successful of the firm. Accurate, on time and the shortest decisions sustain firms in competitions environment. Decision Support Systems (DSS), in general meaning, are a computer based information systems that they generate and evaluate effective alternatives about decision, which is necessary to solve problem by understanding and using available data. The DSS help to compensate lack of knowledge of managers. Intelligent Decision Support Systems (iDSS) are interactive computer-based systems that use data, expert knowledge and models for supporting DMs in organizations to solve semi structured problems by incorporating artificial intelligence techniques (Sarma, 1994).

There are a number of decision support and intelligent systems in practice such as expert systems and knowledge-based information systems. Expert systems (ES) are an artificial intelligence based systems that converts the knowledge of an expert in a specific subject into a software code. The application of ES in the textile industry can help firms (Metaxiotis, 2004) to decrease setup time by identifying activities that are more appropriate and devise more efficient and objective planning in their production (Ford & Rager, 1995). Knowledge-based systems (KBS) are systems that uses artificial intelligence or expert system techniques in problem solving processes. It incorporates a store (database) of expert knowledge with couplings and linkages designed to facilitate its retrieval in response to specific queries, or to transfer expertise from one domain of knowledge to another (Laudon & Laudon, 2002). In a textile, KBS can diagnose manufacturing problems (Hussain & Shamey, 2005).

1.2. Reducing Changeover Time: The SMED Approach

Changeover time is defined as the period between the last good product from previous production order leaving the machine and the first good product coming out from the following production order (Coimbra, 2009). SMED is one of the methodologies that is utilized to reduce setup times and rapidly response customer requirements (Desai and Warkhedkar, 2011).

Shigeo Shingo (1989), a Japanese Industrial Engineer developed the SMED methodology. It makes possible to perform change operations under 10 minutes (single digit) that the methodology is named SMED. The main goal of SMED is to determine and reduce the time wasted while performing many activities to exchange of dies. The steps of a classic changeover activities are shown in Table 1.

Table 1. Portion of basic setup steps before SMED implementation (Shingo, 1996)

Steps in setup	**Proportion of setup time before SMED**
Preparation, after-process adjustments, checking of materials and tools	30%
Mounting and removing blades, tools, and parts	5%
Measurements, settings, and calibrations	15%
Trial runs and adjustments	50%

At the Stage 1 of the SMED, Shingo (1996) separates operation as internal, which are performed while the machine is offline and external activities that are performed while the machine is running (Figure 1). Then, at the Stage 2, via standardizing important function, internal activities are converted to external activities since they decelerate the production. At the Stage 3, all aspects of the set-up operation are focused on streamlining by using multiple operators working parallel. In the literature, stages can be seen as four steps. At the beginning of the SMED, a preliminary stage where shows current setup procedure, in other words, the internal and external setup conditions are not distinguished is included.

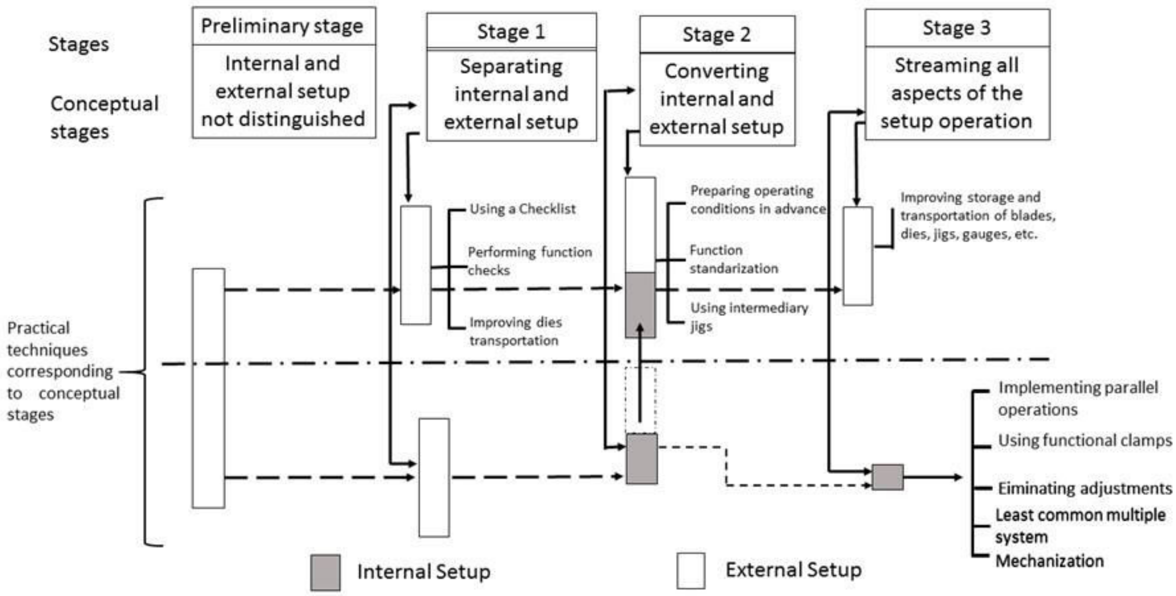

Figure 1. SMED: Conceptual Stages and Practical Techniques (Shingo, 1989)

2. Literature Review

The SMED methodology was developed by Shigeo Shingo (1989), who is a Japanese Industrial Engineer. There are several applications of the SMED methodology in different industries. Cakmakci (2009) implemented process capability analysis technique for the automotive industry to investigate the relation between the SMED methodology and equipment design. The author stated that the reduction of setup times improve both manufacturing processes and equipment design. Almomani et. al., (2013) proposed a systematic approach for the setup time reduction by incorporating the SMED methodology with Multiple Criteria Decision-Making Techniques (MCDM) which are Analytical Hierarchy Process (AHP), Preference Selection Index (PSI) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). The methodology was implemented in a PVC industry and it was stated that the productivity and flexibility of the facility is increased by applying the proposed methodology.

One of the ways of setup time reduction is transferring the classical production environment to cell formation. Ohta and Nakamura (2002) proposed a new cell formation by using a grouping method to reduce setup time between machines in the same cell. Besides, Azizi and Manoharan (2015) suggested implementation of Value Stream Mapping (VSM) method to improve the efficiency in Small Medium Enterprise (SME) by eliminating non-value added activities. The first stage of the proposed methodology is to analyze the production waste in current state map, and then to use the Kaizen activity with SMED to effectively support future state for process improvement of the action plan.

Ferradás and Salonitis (2013) proposed a tailored SMED methodology for an automotive supplier and applied in one of his welding cells. The proposed method consists of five stages and the implementation of the method resulted in 33% reduction of the changeover time of the welding cell. Karasu et. al., (2014) proposed Taguchi experimental design to the trial runs phase of a changeover operation to get the parameters that gives the first correct product. The proposed methodology applied in a plastic injection unit of an LCD-TV factory and 30% improvement was obtained according to the results.

Recently, Rosa et. al., (2017) applied the SMED methodology in association with the other Lean Techniques such as visual management and 5S for an assembly line at the automotive sector. The authors stated that the stoppage time on the assembly line related with the setups was reduced by at least 58.3% by implementing this method. Brito et. al., (2017) combined the SMED methodology and ergonomics for a turning production of a metallurgical factory to reduce setup times and to improve ergonomic conditions. The authors stated that the setup time was reduced 46% and the musculoskeletal disorder (MSD) risk decreased by using the proposed methodology. Boran and Ekincioğlu (2017) integrated the Muscle Fatigue Assessment (MFA) and the grey-based Taguchi method with the SMED methodology to evaluate the ergonomic risks in setup activities. The proposed method was implemented in a factory producing aluminum profiles and better results in setup time were achieved using this method compared to the conventional SMED methodology. Braglia et al., (2017) proposed a novel SMED method integrated with a 5-whys analysis method to reduce overall changeover duration. The method applied for a screen printing machine and significant improvements were achieved. Similarly, Ahmad and Soberi (2018) used the cause and effect and 5-whys analysis integrated with the SMED. They introduced four standard strategies and priorities sequence to improve the conventional SMED method and conducted a case study to show effectiveness of the proposed method. Lozano et al., (2017) applied the SMED methodology especially for the food industry. They proposed to measure the results of the SMED technique using the mean time between failures (MTBF) and mean time to repair such failure (MTTR) along with indicators such as global efficiency (GE) and overall equipment effectiveness (OEE). Lastly, Saravanan et al., (2018) implemented the SMED methodology in the manufacturing system of injection moulding facility to reduce the change over time. The total change over time was reduced by about 67.72% after implementing the SMED, thus production losses are reduced and the productivity increased.

3. The Developed Intelligent Decision Support Approach

The Intelligent SMED (iSMED) approach has some rules. They are "IF... THEN..." type rules. The proposed methodology works on two stages. First, it decides whether the SMED should apply. In the second stage, it orientates user for a successful SMED application.

In the first stage of the model, if the firm is not ready for SMED or lean manufacturing applications, the methodology suggests to continue after the company is ready for SMED. If the firm is ready for lean manufacturing or SMED then bottleneck machine is suggested by the methodology. But the company may select a different machine for SMED. In our case study, the bottleneck machine with one of the highest setup times is selected to apply the SMED.

The decision made at the end of the first stage is whether SMED should be applied or not. If applying the SMED is final decision then the second stage starts (Figure 2). The database of intelligent system includes some facts about the firm such as below:

- Does the firm have an ERP? , if yes, the ERP modules used effectively in manufacturing, data of dies and machines for. Before steps of the setup are defined, if the tools required for exchanging are untidy, after they are organized using 5S rules. Through the fact database, activities are separated as internal and external. Internal activities are converted as far as possible to external. Then, by using multiple operators working parallel, time of both internal and external activities are reduced. Again, the setup time is measured and if it is in acceptable level, SMED stops.

We benefit from different resources such as scientific articles, books, expert knowledge and lessons learnt from industrial case studies. The structure of the intelligent model can be shown in Figure 2.

4. Industrial Application

As a case study, a firm in the textile industry is chosen. The company specializes in design and manufacturing the components of the window blind and shade systems, by using plastic and metal mould manufacture, assembly line and plastic injection machines. The iSMED was decided to apply to five different injection machines. The machines are active with the codes E23, E24, E25, E26 and E27. After applying Pareto Analysis, machine E23 is selected, because the most important bottleneck is machine E23. The E23 has biggest set-up time in the high volume production line; "foot for roller blind" which has the most sales volume.

Table 2 shows three kind of process times, which is injection, pressing and packing for roller blind resulting in a bottleneck operation.

Table 2: Process Time of Roller Blind RB Foot

Product Name	**Injection**	**Pressing**	**Packing**
R.B. Foot	10 sec.	2 sec.	1,2 sec

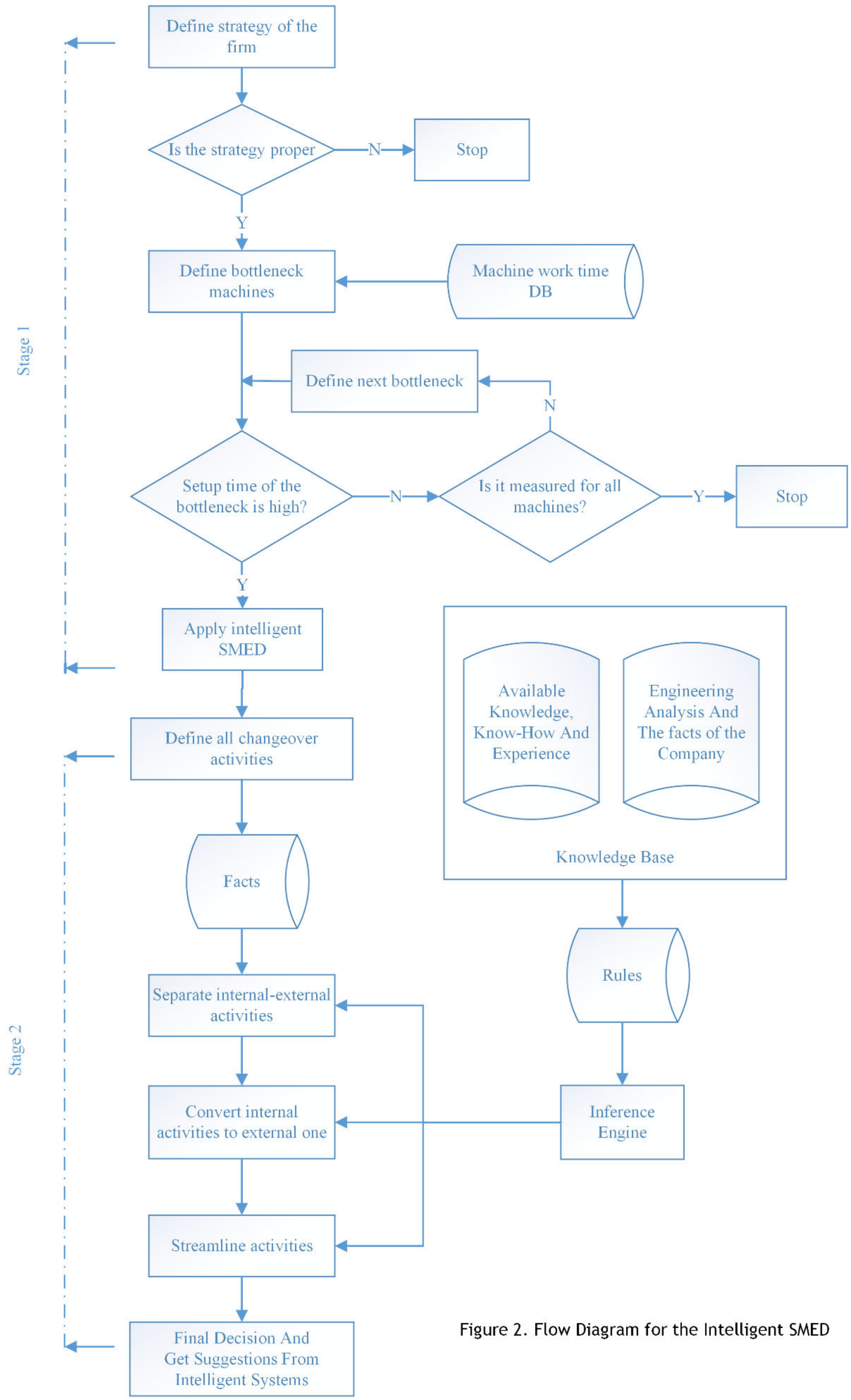

Figure 2. Flow Diagram for the Intelligent SMED

The ideal average setup time should be 30 minutes according to expert experiences. During 22 days, in different periods, observations are made to measure whether setup times are 30 minutes. At the end of the observation, the average of the setup fact time is calculated as 51,82 minutes. Consequently, it is realized that there is deviation from average value. Table 3 demonstrates a part of the observation from 'Machine work time DB'.

The intelligent SMED consists of two main stages and generally continues the following steps:

- The strategy of the company is an important factor for applying the SMED. Therefore, the strategy is an input for the methodology. According to the strategy is proper for the SMED or not, the methodology continues or stops.

Table 3: Setup Time of RB Foot

Production Date	**Code**	**Name**	**Setup Starting**	**Setup Ending**	**Setup Difference**	**Setup Fact Time**
03.01.2017	3DST01KR-0094	R.B. FOOT CREAM	15:00	16:05	00:35	01:05
11.01.2017	3DST01KR-0094	R.B. FOOT CREAM	17:30	18:05	00:05	00:35
30.01.2017	3DST01KR-0094	R.B. FOOT CREAM	15:00	15:30	00:00	00:30
27.03.2017	3DST01KR-0094	R.B. FOOT CREAM	08:00	10:30	02:00	02:30
04.04.2017	3DST01BY-0094	R.B. FOOT WHITE	13:00	13:30	00:00	00:30

Proper strategy means that the firm has lean thinking techniques and infrastructure. In a lean journey, there are many works to apply before SMED.

- If the strategy is proper, then a bottleneck machine is defined for SMED.

As in Table 3, the user enters some values for defining bottleneck machine. These are recorded to 'Machine work time' database and some basic calculations are made. Sometimes there may be more than one bottleneck machine. In such cases, the methodology offers some techniques, such as Pareto Analysis technique, Analytic Hierarchy Process (AHP) technique, etc., to make a decision which bottleneck machine should be select.

Defining bottleneck machine is the end of the first stage. If there is at least one bottleneck machine, methodology starts to apply SMED for defined machine, else stops.

- Defining all changeover activities is the first work in second stage of the methodology.

User defines all elements of changeover. In this stage, also, there are some facts in "Facts" database about changeover of the dies. As examples for facts:

- Activities that must be completed while the equipment is stopped is called "internal activities".
- Activities that must be completed while the equipment is running is called "external activities".
- Human activities mean the operator is doing something and equipment activities mean the equipment is doing something. The human activities are usually easiest to optimize.

The methodology uses data given by user and facts to give advices and directions to user. Rules are found out from knowledge base. The facts and the rules are used for separating internal-external activities, converting internals to externals and streamlining activities. These three steps are similar to classic SMED steps.

As final work, the methodology gives a final decision and suggestions. Therefore, SMED is applied by the help of intelligent system approach.

Some rules used for the iSMED are shown below. The rules can be determined by an expert from industry about the SMED or an academician. If rules are obtained from the academicians, they are shown as a reference and mentioned at the end of the paper in References section.

- If the strategy is proper for the firm, the system may continue, if not, suggest another strategy such as outsourcing or investment in production technology.
- If you do not determine bottleneck machines with value stream mapping technique, by taking into account shifts determine whether there is bottleneck machine.
- If there are too much bottleneck machines, select the most important one by using Pareto Analysis technique.
- If setup time of the selected bottleneck machine is high, apply the SMED to the selected machine.
- If some maintenances can made during setup activities, make them while machine is running and if needed assign to an additional personnel.
- If a part that needs to be exchanged has only 2 sizes, put one fixed on the machine (Goubergen & Landeghem, 2002).
- If one cannot measure, then one will never be able to have a setting 'right from the first time'. Measuring devices should be accurate enough: in one plant there was a very critical setting, the accuracy was in the order of 10ths of a millimeter, but the operators were only using a flexible steel rule to do the setting (Goubergen & Landeghem, 2002).
- If constraint equipment is selected, minimize the potential risk by building temporary stock and otherwise ensuring that unanticipated down time can be tolerated (Lean Production, n.d.).
- If moulds using in changeover process are untidy, place moulds to shelves by planning mould layout and using 5S rules.
- If preliminary is not made, while previous mould is running, bring the new mould near to the machine.

In addition, there are some general advices:

- Use videotaping to observe activities.
- While videotaping the changeover have several observers taking notes. Sometimes the observers will notice things that are missed on the videotape (Lean Production, 2018).
- Only observe, do not interfere in any activities. This makes the changeover normal.

5. Conclusions and Future Research

In this study, a prototype intelligent SMED methodology is developed and applied in a textile firm. The SMED methodology is one of the most important techniques in the lean manufacturing implementation.

Before applying the SMED, bottleneck machines must be determined in the production line of the company. An injection machine in the line is selected and foot of roller blind, which is one of the products that has high sale volume. 22 observations were made and it is seen that average of the setup time is 51.82 minutes. After applying the SMED, company reduces the setup time approximately 73.1 %, from 52 minutes to 14 minutes.

An expert system approach can be used for the application of the SMED as further research. The application can be expanded not only the textile industry but also other manufacturing and service industries. Service industries may include emergency and surgery department of hospitals because time is very important and vital for these departments. An intelligent decision support system software can be developed. Besides, Poka-Yoke (mistake proofing) techniques can be added to the knowledge base of the intelligent system.

References

Ahmad, R., & Soberi, M. S. F., Changeover process improvement based on modified SMED method and other process improvement tools application: an improvement project of 5-axis CNC machine operation in advanced composite manufacturing industry. *The International Journal of Advanced Manufacturing Technology*, 94(1-4), 433-450, 2018.

Almomani, M. A., Aladeemy, M., Abdelhadi, A., and Mumani, A., A proposed approach for setup time reduction through integrating conventional SMED method with multiple criteria decision-making techniques. *Computers & Industrial Engineering*, vol. 66, no. 2, 461-469, 2013.

Azizi, A., Designing a future value stream mapping to reduce lead time using SMED-A case study. *Procedia Manufacturing*, vol. 2, pp. 153-158, 2015.

Boran, S., & Ekincioğlu, C., A novel integrated SMED approach for reducing setup time. *The International Journal of Advanced Manufacturing Technology*, 92(9-12), 3941-3951, 2017.

Braglia, M., Frosolini, M., & Gallo, M., SMED enhanced with 5-Whys Analysis to improve set-upreduction programs: the SWAN approach. *The International Journal of Advanced Manufacturing Technology*, 90(5-8), 1845-1855, 2017.

Brito, M., Ramos, A. L., Carneiro, P., and Gonçalves, M. A., Combining SMED methodology and ergonomics for reduction of setup in a turning production area. *Procedia Manufacturing*, vol. 13, pp. 1112-1119, 2017.

Cakmakci, M., Process improvement: performance analysis of the setup time reduction-SMED in the automobile industry. *The International Journal of Advanced Manufacturing Technology*, vol. 41, no. 1-2, 168-179, 2009

Coimbra, E. A., *Total Flow Management: Achieving Excellence with Kaizen and Lean Supply Chains*, Kaizen Institute, Zug, Switzerland, 2009.

Desai, M. S. and Warkhedkar, R. M., Productivity enhancement by reducing adjustment time and setup change, *International Journal of Mechanical & Industrial Engineering*, vol. 1, no. 1, pp. 7-42, 2011.

Ferradás, P. G., and Salonitis, K., Improving changeover time: a tailored SMED approach for welding cells. *Procedia CIRP*, vol. 7, pp. 598-603, 2013.

Ford, F. N. and Rager, J., Expert system support in the textile industry: End product production planning decisions, *Expert Systems with Applications*, vol. 9, no. 2, pp. 237-246, 1995.

Goubergen, D. V. and Landeghem, H. V., Rules for integrating fast changeover capabilities into new equipment design, *Robotics and Computer-Integrated Manufacturing*, vol. 18, no. 3, pp. 205-214, 2002.

Hussain, T., Wardman and R. H., Shamey, R., Part 1: Design and development, *A knowledge-based expert system for dyeing of cotton*, vol. 121, no. 1, pp. 53-58, 2005.

Karasu, M. K., Cakmakci, M., Cakiroglu, M. B., Ayva, E., and Demirel-Ortabas, N., Improvement of changeover times via Taguchi empowered SMED/case study on injection molding production. *Measurement*, vol. 47, 741-748, 2014.

Laudon, K. C. and Laudon, J. P., *Essential of management information systems*, Prentice Hall, New Jersey, USA, 2002.

Lean Production, Single-Minute Exchange of Die, Available: http://www.leanproduction.com/smed.html, January 1 2018.

Lozano, J., Saenz-Díez, J. C., Martínez, E., Jiménez, E., & Blanco, J., Methodology to improve machine changeover performance on food industry based on SMED. *The International Journal of Advanced Manufacturing Technology*, 90(9-12), 3607-3618, 2017.

Metaxiotis, K., RECOT: An expert system for the reduction of environmental cost in the textile industry, *Information Management & Computer Security*, vol. 12, no. 3, pp. 218-227, 2004.

Ohta, H. and Nakamura, M., Cell formation with reduction in setup times. *Computers & industrial engineering*, vol. 42 no. 2-4, 317-327, 2002.

Rosa, C., Silva, F. J. G., Ferreira, L. P., and Campilho, R., SMED methodology: The reduction of setup times for Steel Wire-Rope assembly lines in the automotive industry. *Procedia Manufacturing*, vol. 13, pp. 1034-1042, 2017.

Saravanan, V., Nallusamy, S., and Balaji, K., Lead time reduction through execution of lean tool for productivity enhancement in small scale industries. In *International Journal of Engineering Research in Africa* (Vol. 34, pp. 116-127). Trans Tech Publications, 2018.

Sarma, V. Decision-making in complex-systems, *Systemic Practice and Action Research*, vol. 7, no. 4, p. 399–407, 1994.

Shingo, S., *A study of the Toyota production system*, Productivity Press, Cambridge, MA, 1989.

Shingo, S., *Quick Changeover for Operators: THE SMED SYSTEM*, 3rd Edition, Productivity Press Portland, Portland, Oregon, 1996.

Sullivan, W. G., McDonald, T. N. and Van Aken, E. M., Equipment replacement decisions and lean manufacturing, *Robotics and Computer-Integrated Manufacturing*, vol. 18, no. 3, pp. 255-265, 2002.

Biographies

Onur Dogan graduated from the Sakarya University with a Bachelor's Degree in Industrial Engineering in 2010 and received a Master's Degree in Management Engineering from the Istanbul Technical University in 2013. He is a Ph.D. candidate in the same university. He studied on intelligent decision support system, lean manufacturing and quality approaches such as QFD, FMEA or DOE during the master thesis. His PhD research interests include process mining, data mining and customer relationship management.

Ufuk Cebeci graduated from the Istanbul Technical University with a Bachelor's Degree in Industrial Engineering in 1983. He received a Master's Degree in 1986 and a PhD degree in 1993 from the Istanbul Technical University. He is an associated professor in the same university and currently a teaching assistant in the Istanbul Technical University, Department of Industrial Engineering. His research interests include quality systems, lean manufacturing, production planning and control.

M. Kursat Oksuz graduated from the Süleyman Demirel University with a Bachelor's Degree in Industrial Engineering in 2012 and received a Master's Degree in Industrial Engineering from the Istanbul Technical University in 2015. He is a Ph.D. candidate in the same university. He studied on assembly line balancing and lean manufacturing during the master thesis. His PhD research interests include humanitarian logistics, facility location, inventory management, part feeding system and quality management.

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