ISFOR 2017 International Symposium on New Horizons in Forestry
18-20 October 2017 | Isparta - Turkey
Poster presentation

The effects of lean manufacturing set-up time reduction efforts on productivity in North America's secondary wood products industry

Sevtap Erdogan[1,*], Enis Küçük[2]

[1] Faculty of Forestry, Department of Forest Industry Machinery and Business Administration, Kastamonu University, Kastamonu, Turkey
[2] Faculty of Forestry, Department of Forest Industry Machinery and Business Administration, Artvin Coruh University, Artvin, Turkey
[*] Corresponding author: serdogan@kastamonu.edu.tr

Abstract: Since lean manufacturing's emergence onto the world stage in the 1970s and in its later evolutions, many industries and companies of different sizes and specializations have tried to adapt lean tools and techniques with varying success. Most often, lean manufacturing has been concentrated in large manufacturing firms. Yet, lean manufacturing tools and techniques are also suited for small enterprises. This study investigated how a firm's productivity is affected by lean set-up time reduction efforts needed to achieve "one-piece flow" in secondary wood products manufacturing facilities on four woodworking machines (moulder, shaper, table saw, and band saw) based on firm size. As part of this study, surveys were administered to firms in North America's secondary wood manufacturing industry which had adopting lean manufacturing from 2015 to 2015. This ten-year period was chosen since some of the companies involved might not have undertaken any set-up improvement activities on their woodworking machines in recent years. This survey targets industries which widely use moulders, band saws, table saws, shapers, and require frequent changes in set-up of these machines. Thus, the survey looks at members in the wood products manufacturing and furniture manufacturing as identified by the U.S. Census Bureau. Survey questions asked about the company's set up times and experience with lean to the hypothesis that smaller firms would achieve lower productivity gains through set-up time reduction than larger firms. Both small and large firms surveyed reported productivity gains from reduced set-up times, with several companies citing productivity improvements over 15 percent. In addition to firm size, results are broken down as they related moulders, band saws, table saws, and shapers. However, the sample size of responses was small such that no statistically significant difference could be found. This study adds to the research around how lean manufacturing has been applied across the wood products industry by firm size by providing a unique survey instrument and by highlighting initial findings into this subject.
Keywords: Lean manufacturing, Set-up time, Productivity, Wood products industry, Survey

1. Introduction

To better compete in today's global economy, manufacturing firms seek to decrease the time needed for setting up their manufacturing machinery. Set-up time refers to the amount of time between the production of the last time and the production of the first good item after set-up of a new production batch (Trevino et al., 1993). Set-up time can be affected either internal or external set-up activities. Internal set-up means the activities and time it takes to stop a machine, while external set-up time means set-up time spent on activities performed while the machine continues its production run (Cakmakci, 2009; Monden, 2011). Some set-up efforts aim to change internal set-up to external set-up activities. Monden (2011) highlights the improvements achieved when changing internal set-up activities to external set-up activities, a machine can continue producing during the time that was switched from internal to external set-up activities. For example, liners/spacers can be used to standardize the die heights of a punch press or a molding machine to eliminate stroke adjustment so that the process can continue to produce without stopping the machine (See Figure 1).

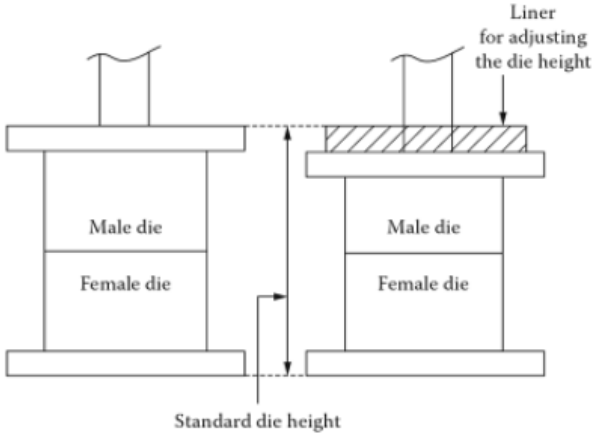

Figure 1**:** Using a liner to standardize die height (source: Monden 2011).

Benefits of reduced set-up time include increased flexibility and capacity; reduced lead-time, batch sizes, inventory, and waste; and improved customer responsiveness (McIntosh et al., 2007; Wadhwa, 2012; Zammori et al., 2011). These advantages can help companies increase their competitiveness including an ability to diversify their product lines and/or increase their production capacity.

According to Enginarlar (2003), increasing production capacity is the main goal of set-up time reduction efforts. By minimizing set-up time, machine downtime is decreased and more products can be produced, so as to minimize any losses in production capacity.

Reducing set-up time is one component of "Lean" manufacturing strategies. Here "Lean" can be defined as making manufacturing and other systems more effective and more efficient (Womack et al., 1990). Lean manufacturing techniques were first widely used in Toyota Motor Company's invention of the Toyota Production System (TPS) for its automobiles in the 1950s. The driving force behind Lean is the desire to increase productivity and reduce costs by eliminating unnecessary tasks from work areas (Monden, 2011). As mentioned, start-up reduction activities are one tool used as part of Lean manufacturing techniques. While other manufacturing industries have successfully adopted Lean methods through set-up time reduction, the implementation of Lean techniques in other industries needs further exploration. One of these industries is the wood products industry.

Still, a small number of studies have examined the wood products manufacturing area. Fricke (2010) analyzed on lean manufacturing in Virginia's wood products industry. More recently, Erdogan (2015) used original survey data research the use of Lean tools by the wood products industry in the U.S. This study seeks to expand these efforts by focusing the investigation within the U.S. secondary wood products industry and firms' ability to successfully implement set-up time reduction efforts. The secondary wood products industry is especially suited for the study of set-up time efforts because manufacturing facilities in this industry produce various types of products on the same equipment and therefore require frequent set-ups for the production of new products.

Specifically, this study examines these set-up time efforts on four common basic woodworking machines in the secondary wood products manufacturing firms: band saw, moulder, table saw, and shaper. Advanced machines such as CNC (computer numerical control) wood routers, are not of primary interest in this study due to their complexity and the variability in set-up requirements. This variety makes it difficult to compare the set-up time reduction performance on CNC-routers between different facilities.

With these considerations in mind, in addition to exploring the use of Lean techniques in another objective of this study is to investigate how a firm's productivity is affected by set-up time reduction efforts as related to firm size. As many small manufacturing firms have a limited financial and other resources, and may lack certain expertise among its small staff, this study will examine whether small firms achieve lower productivity gains through set-up time reduction than do large firms. Another objective of this study is to examine how any productivity changes vary by the type of wood products manufacturing equipment used.

2. Material and methods

The primary methods of this study for gaining insights into common set-up time activities in the wood products industry was a web-based survey among readers of one of the leading wood products industry trade magazines. The results of this study were used to describe current trends and successes of set-up time improvement efforts among secondary wood manufacturing firms in North America from 2005 to 2015. This ten-year was chosen to increase the number of usable responses from the survey and help highlight trends and successful practices in set-up time reduction efforts in the industry.

This survey targets members in the wood products manufacturing (NAICS 321) and furniture manufacturing (NAICS 337) industry segments, as defined by the U.S. Census Bureau (2012). However, not all the sub-categories of these two industries are within the scope of this study. For example, sawmills (NAICS 321113), wood preservation (NAICS 321114), and metal household furniture manufacturing (NAICS 337124) manufactures, among others, are of no interest to this study.

Possible respondents from the U.S. wood products industry were identified by consulting the trade publication FDM&CM (http://www.fdmcdigital.com/). The decision to cooperate with a trade magazine allowed access to the magazine's wide network of industry professionals, with the hope that this would increase the number of survey responses for this study. Obtaining a higher survey response rate can be important because it increases the statistical validity of the findings of the study by collecting expanding the population from which data are drawn from (Great Book n.d.; UMEX 2002).

The survey gathers information related to the objective the study, basic company information, set-up time reduction efforts, and General Questions. The web-based survey conducted was accessible online for 73 days (October 06, 2015 – December 17, 2015). During this (approximately) two and a half months surveying period, 24 completed responses were received. 23 of these responses were considered valid and analyzed.

3. Results and discussion

3.1. Respondent characteristics

Respondents held a variety of positions within manufacturing firms (Table 1). The largest categories of respondents were plant managers (8) and owners (7). Additional responses came from continuios improement staff, production managers, along with one CEO and one process engineering manager.

Table 1: The statistics on respondents' job descriptions.

Job Descriptions	Number of Participants
Plant Manager	8
Continuous Improvement Person	4
Operations / Production Manager	2
Owner	7
Process Engineering Manager	1
Pres/CEO	1
TOTAL	23

When asked about the main product produced by their facilities, six respondents indicated that they are Wood Kitchen Cabinet and Countertop Manufacturers (NAICS 33711), followed by four Household, Institutional Furniture Manufacturer (NAICS 33712), four Millwork Manufacturers (NAICS 32191), and one Office Furniture (including Fixtures) Manufacturer (NAICS 3372). Additionally, eight respondents selected Other product types manufacturing (Table 2). Respondents who selected the Other product types manufacturing specified their main product types one of the following:

- Store fixtures,
- All of the above (note: means all the standardized answers of the question),
- Custom cabinets, furniture, millwork,
- Wood moulding,
- Cabinet Components,
- Custom wood products to customer specs,
- POP display, and
- Custom AV related furniture.

Table 2: Main product category produced in respondents' facilities.

The main product category		Number of Response
Millwork		4
Wood Kitchen Cabinet and Countertop Manufacturing		6
Household, Institutional Furniture Manufacturing		4
Office Furniture (Including Fixtures) Manufacturing		1
Other		8
Other	1. All of the above 2. Store fixtures 3. Custom cabinets, furniture, millwork 4. Wood moulding 5. Cabinet Components 6. Custom wood products to customer specs 7. POP display 8. Custom AV related furniture	
Total		23

In addition to a geograpically diverse group of U.S. companies, one respondent indicated that their wood products manufacturing firm was from Canada (Table 3).

Table 3: Locations of the facilities of respondents.

	States/Province	Number of Facilities
United States	CA California	2
	GA Georgia	1
	IL Illinois	1
	IN Indiana	1
	ME Maine	1
	MN Minnesota	2
	NC North Carolina	3
	NE Nebraska	1
	NJ New Jersey	1
	NY New York	2
	OH Ohio	2
	PA Pennsylvania	2
	TX Texas	1
	VA Virginia	1
	WA Washington	1
	Total	22
Canada	AB Alberta	1
	Total (USA & CANADA)	23

The survey also asked respondents to specify the employment sizes of their manufacturing facilities. Of those surveyed, 14 firms indicated that they employeed between 1 and 19 employees, 6 facilities with between 20 and 99 employees, 2 facilities with betwen 100 and 499 employees and one facility with 500 or more employees (Table 3).

Table 4: Employement sizes in facilities of respondents.

Employment Size	Number of Facilities
1 to 19 employees	14
20 to 99 employees	6
100 to 499 employees	2
500 or more employees	1
Total	23

Firms surveyed used a variety of manufacutring machines, but the most common were the table saw (15), followed by moulder (11). In contrast few respondents reported using shapers (2) and or band saws (2) (Figure 2).

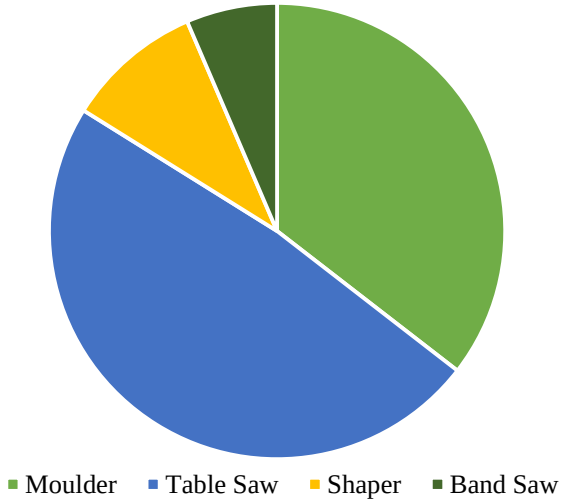

Figure 2: Numbers of specified machine types.

3.2. Set-up time

The survey gathered information on what activities wer most time-consuming and impeded set-up reduction efforts. Four of the 11 (36%) answers relating to the moulder were *Mounting and adjusting cutterheads (knives, cutter etc.)*, qhilw for table saws seven of the 13 (54%) answers chose *Mounting and adjusting a circular saw or a combination cutter.* Of thethe four different types of woodworking machines specified in this study (moulder, table saw, shaper, band saw), respondents indicated that *Mounting and adjusting* is the most time consuming activity during their set-up for 13 out of a total of 28 machines (Table 5). One possible reason for this being the most commonly reported *Mounting* time consuming set-up activity may be related to qualifications of the employees and the condition of the machines used and their level of technology.

Table 5: The most time consuming areas for their machine set-ups in respondents' facilities.

The most time consuming activity	Moulder	Table saw	Shaper	Band saw	Total
Adjusting cutting depths and widths	2	2	2	0	6
Cleaning activities	1	1	0	0	2
Mounting and adjusting cutterheads	4	7	1	1	13
Searching for tools and equipment while doing set-up	1	1	0	0	2
Trial runs	2	2	0	0	4
Other	1	0	0	0	1
Total	11	13	3	1	28

When participants were asked if they do have a machine that creates a production bottleneck in their facilities, seven respondents (44%) answered *Yes* while nine respondents (56%) answered *No.* Such bottlenecks hinder set-up time reduction, and therefore can affect productivity. Follow up questions gathered information on bottleneck machines, reasons for bottlenecks, and solutions for the specified bottleneck (Table 6).

Table 6: Bottleneck machines, reason for and solution to the specified bottleneck.

Bottleneck Machine	Reason	Solution
Drum Sander	Set up time required	Not specified
Ripsaw	Machine failures	Manufacturer engineered better parts
Door and panel clamp machines	Glue drying	Fans, and leave gaps between products for air flow
Moulder	Production needs	Overtime
Auto Drilling	Set up time required	SMED set-up reduction
Costa Sander	Speed of the machine	Purchased another machine
CNC	Speed of the machine	Highly scheduling issues, obtained second CNC

3.3. Set-up Time Reduction efforts

Respondents reported a variety of beneficial set-up time reduction efforts. The most frequently cited results were in the areas of *New equipment technology* (28%), followed by *Moving internal activities into external ones* (16%) and Searching for tools and equipment while doing set-up (16%). Table 7 outlines the full range of responses for what respondents found most rewarding in their set-up reduction efforts.

Table 7: The most rewarding set-up time reduction effort in respondents' companies.

The Most Rewarding Set-Up Time Reduction Effort	Number of Responses
Moving internal activities into external ones	4
Adjusting cutting depth and width	3
Searching for tools and equipment while doing set-up	4
Cleaning activities	3
Mounting a blade in a machine	1
New equipment technology	7
Other	3
Total	25

For moulders, only one out of a total of 11 respondents indicated that they had no set-up time improvement, while all the other respondents indicated that they achieved some set-up time improvement in their facilities because of their set-up time reduction efforts. Set-up time improvements raned from a 0 to 4.9% reduction in time for in three facilities, 5 to 9.9 % reduction in four facilities of respondents, and more than 15 % reduction in three facilities responding. When respondents were asked about how they would rank the productivity gains (increasing throughput) related to the set-up time improvement on their moulder, seven respondents rated the gain as *Little,* while another four respondent rated the gains as *A lot.* All respondents who undertook set-up time reduction efforts on their moulders therefore reported improved productivity throughput.

For table saws, 11 of the 13 respondents (85%) using such machines reported that that their set-up time improvement efforts resulted in reduced time, while two respondents reported no reductions. Of those indicating reduced set-up time, set-up time improvement ratings ranged from 0 to 4.9% set-up time reduction in six facilities, 5 to 9.9 % in two facilities, and, more than 15 % in three facilities. When respondents were asked how they would rank the productivity gains based on the set-up time improvement achieved on their table saw (twelve responses were obtained), two respondents indicated *None* was achieved, while four respondents responded that *Little* improvement was gained, while another four respondents indicated that *Some* improvement was achieved and two respondents rated their improvement as *A lot*. Overall, a majority of respondents concerning their table saw set-up time reduction efforts (ten out of total twelve responses) indicated productivity improvements (in terms of increasing output) related with the set-up time improvement efforts on their table saws.

3.4. Productivity improvements

For shapers, all three firms using shapers participants indicated their firms achieved at least some reductions in start-up time. Two out of the total of three respondents rated the set-up time *improvement between 5 and 9.9% while the other respondent rated their firm's improvement as more than 15%.* When respondents were asked to rate the productivity improvement achieved, one respondent indicated that *Some* productivity was gained while another two respondents indicated that *A lot* of productivity improvement was achieved.

Finally, for bands saws, one of the two respondents rated their set-up improvement as *None* while the other respondent rated their set-up time improvement result as *More than 15%.* When respondents were asked to rate the productivity improvement depending on the set-up time improvement achieved on their band saw, the respondent who acheived set-up time reducdtions answered *A lot.*

Respondents using molders ranked the productivity improvement (in terms of increasing throughput) from reducing set-up time as either *Little* (64%) or *A lot* (*36%*). When respondents answerd which moulder's set-up requirements had been reduced, the most common answer was *Searching for tools and equipment while doing set-up* (four answers), followed by *Mounting and adjusting cutterheads* (three responses), *Converting internal set-up time to external set-up time (three responses), Adjusting cutting depths and widths* (two responses), *Cleaning activities* (two responses), and *Other*.

For respondents using the table saw, four ranked their productivity improvement from decreased set-up times responded either *Little* (27%) or *Some* (27%) while two participants responded *None* (13%) and another two responded *A lot* (*13%*). When asked about the single most important outcome from reducing the set-up time for the table saw, five participants (39%) answered *Increasing productivity/capacity*, followed by two participants (15%) citing *More frequent set-ups/improve flexibility*, two participants chose (15%) *Reduced batch sizes*, one participant (8%) *Reduced maintenance due to shorter cycles*, one participant selected (8%) *Improved responsiveness to customer demands*, while two participants (15%) selected *Othe*r. One of the *Other* respondents elaborated: "We run all parts on a nested based CNC now. much faster" while the other one did not specified any response."

Two-thirds of respondents using a shaper in their firm ranked the resulting change in productivity (increasing throughput) from set-up time improvements as either *A lot*. The other third of respondents reported Some productivity improvements. When participants were asked in which area set-up time has been reduced, the most frequent response was Adjusting cutting depth and width (two answers) while the other participant indicated *Mounting and adjusting a cutterhead*.

For those respondents using band saws, when asked how they ranked the productivity increases achieved from reduced set-up time for their bandsaws, one participant answered *A lot* while the other respondent did not provide an answer. When participants asked which activity most reduced set-up time, one respondent wrote "Fixturing for cutting different components" while the other respondent did not provide an answer.

3.5. Limitationsand suggestions for future research

Although only a limited number of participants participated in the survey (twenty-three participants), respondents were mostly employees in the targeted job positions (plant or production managers, continuous improvement persons), assuring that the responses obtained have been given by knowledgeable professionals. Thus, despite the low response rate, the findings from this study can be considered relevant. However, the conclusions drawn from this study only apply to the facilities of the survey participants and they do not represent the general North American secondary wood manufacturing population or subscribers of FDM&CM. Similary, the low response meant the study was unable to test the relationship between set-up time improvements and firm size with statistical reliability or validity.

Future reserach could expand upon this study's investigation of Lean tequniques such as start-up time reduciton in the wood products industry by seeking to answer some of the following questions: 1) To what extent do secondary wood manufacturing firms use other Lean techniques beyond those related to start-up time? If so, which other techniques? 2) Do companies provide appropriate training to their employees to improve implementation of Lean techniques in their facility? If so, what is the type and content of such training? 3) How have bottleneck and other oproblems affected wod products manufacturing firms' production, and how have they worked to solve bottleneck issues? In addition to these questions, future reserach may benefit from comparisions between the production of similar versus different types of wood products.

4. Conclusions

This study is among a small but growing body of research aiming to understand the application of Lean techniques to the wood products industry and its production processes. Specifically, this study focused set-up time reduction efforts and the benefits obtained thorough these reduction efforts in North American enterprises. Even though comparatively few responses were collected, too few for most rigorous statistical tests to be conducted, the survey responses gathered still provided valuable insights. For instance, respondents indicated that Lean techniques aimed at reducing set-up time can be successfully implemented in the wood products industry. Respondents cited up to 15% savings time and higher for certain pieces of equipment. Survey respondents also highlighted also improved productivity (as measured by throughput) as a result of set-up time reduction activities. As this study shows, the large majority of secondary wood products manufacturers experienced considerable benefits from their set-up time reduction efforts, including increasing productivity and capacity, among other improvements.

References

Cakmakci, M., 2009. Process improvement: performance analysis of the setup time reduction-SMED in the automobile industry. The International Journal of Advanced Manufacturing Technology, 41(1-2):168-179.

Enginarlar, E., 2003. Lean buffering in production systems: A quantitative approach. PhDDissertation, University of Michigan, Ann Arbor, MI, USA.

Erdogan, S., 2015. Development of a tool to measure the effectiveness of kaizen events within the wood products industry. M.S. Dissertation, Virginia Polytechnic Institute and State University, Blacksburg, VA, USA.

Fricke, C. F., 2010. Lean management awareness, implementation status, and need for implementation support in Virginia's wood industry. M.S. Dissertation, Virginia Polytechnic Institute and State University, Blacksburg, VA, USA.

Great Book, n.d.. Determining Statistical Confidence in a Survey, http://www.greatbrook.com/survey_statistical_ confidence.htm, Accessed: 12.03.2015.

McIntosh, R., Owen, G., Culley, S., & Mileham, T., 2007. Changeover Improvement: Reinterpreting Shingo's "SMED" Methodology. Engineering Management, 54(1): 98-111.

Monden, Y., 2011. Toyota production system: an integrated approach to just-in-time. CRC Press, Boca Raton, FL.

Trevino, J., Hurley, B. J., & Friedrich, W., 1993. A mathematical model for the economic Justification of setup time reduction. International Journal of Production Research, 31(1): 191-202.

Wadhwa, R. S., 2012. Flexibility in manufacturing automation: A living lab case study of Norwegian metalcasting SMEs. Journal of Manufacturing Systems, 31(4): 444-454

University of Wisconsin-Extension (UMEX), 2002. Additional PD&E Resources Quick Tips Numerical List, http://www.uwex.edu/ces/pdande/resources/quicktipsnumerical.html, Accessed: 10.12.2015.

Zammori, F., Braglia, M., & Frosolini, M., 2011. A measurement method of routing flexibility in manufacturing systems. International Journal of Industrial Engineering Computations, 2(3): 593-616.