Improving productivity of solid waste recycling centres through lean implementation: a comparative analysis based on value stream mapping

Guilherme Luz Tortorella
Federal University of Santa Catarina/Santa Catarina, Brazil
g.tortorella@ufsc.br

Lucila M. S. Campos
Federal University of Santa Catarina/Santa Catarina, Brazil
lucila.campos@ufsc.br

Glauco Garcia Martins Pereira da Silva
Federal University of Santa Catarina/Santa Catarina, Brazil
glauco.silva@ufsc.br

Abstract

This paper aims at reporting a comparative analysis of lean implementation for productivity improvement in five recycling centres that sort MSW in Brazil. Since their labour is composed by poor communities' members, cultural and social characteristics represent an incremental challenge for lean implementation.

Keywords: Community Recycling Centres; Municipal Solid Waste; Lean Production; Productivity.

INTRODUCTION

Solid waste management has been an integral part of every human society (Shekdar, 2009) and is one of the most challenging issues in urban cities, which are facing serious pollutions problems due to the generation of huge amount of solid waste (Kumar, et al., 2009). The influence of improper management practices for municipal solid waste (MSW) has attracted the attention of various entities, professionals and researchers in recent years (Mondelli et al., 2007; Taylan et al., 2008; Parrot et al., 2009), since these can cause serious threats to the public health and environment. MSW is the most complex solid waste stream, as opposed to more homogeneous waste streams resulting from industrial or agricultural activities (Troschinetz and Mihelcic, 2009). According to the Brazilian Institute for Geography and Statistics (IBGE, 2002), Brazil produces about 125,281 tons of MSW per day, 30.5% of which are disposed off in garbage dumps, 22.3% in controlled dumps and 47.1% in sanitary landfills. Although, the selectiveness of garbage disposal has improved in recent years, 63.6% of Brazilian towns still dispose off their solid waste in dumps.

Furthermore, Nunes et al. (2007) report on their study that the majority of recycling centres in Brazil are badly administered by public authorities and their viability depend on continuity of operation and reaching expected production volumes. According to Krook and Eklund (2010b) there is a lack of affordable and accurate monitoring for providing the recycling centres with the necessary facts for improving waste. Javied et al. (2014) also mention that, among several critical success factors for improving efficiency at recycling centres, four main points are worth noticing: (i) proper funding for MSW management system, (ii) awareness and training of workers and people, (iii) increased pay of workers and related staff and (iv) proper production practices for daily activities' demand. Thus, as the trend towards recycling grows, so does the need for increasing the effectiveness of recycling centres (Hemphala et al., 2010). One way of doing this is to adapt ideas, theories, strategies, philosophies, and principles from the area of operations management (Sundin et al., 2011), such as lean manufacturing (Liker, 2004), to enhance the performance and efficiency of recycling centres.

Lean manufacturing is widely adopted and is claimed to increase productivity, decrease lead time and costs and enhance quality, through a systematic reduction of waste (Womack and Jones, 1996). Nevertheless, it is important to distinguish the meaning of the word 'waste' in lean manufacturing context, in which it refers to losses in productive systems such as overproduction, waiting and transportation (Ohno, 1988); from its meaning in the environmental and recycling context. Previous studies (Sundin et al., 2011; Krook and Eklund, 2010a and 2010b) have presented initiatives to adapt such industrial production practices into recycling centres systems.

Thus, this paper aims at reporting a comparative analysis of value stream mapping implementation for productivity improvement in solid waste recycling centres. The study is carried out in five recycling centres that sort the MSW of Porto Alegre, one of the main cities in the Southern region of Brazil. Besides the environmental benefits, such centres are managed by community cooperatives and the more productive they are the higher income of their workers will be. None of them has had previous experience with any of the lean manufacturing practices. Therefore, they present a huge potential for productivity improvement in their production systems. Further, since all of them present their labour composed by poor communities members, cultural and social characteristics may be an incremental challenge for a lean implementation.

The contribution of this article is two-fold. First, it contributes to the existing body of literature on solid waste management systems by integrating lean manufacturing practices into the continuous improvement of recycling centres' production systems. Second, the article presents a complementary approach to a relatively recent research trend that comprises lean and green practices (Dües et al., 2013) or lean manufacturing expertise and green operations systems (Bergmiller and McCright, 2009), which is commonly called as 'lean and green systems'. Specific studies in this research area are still scarce (Hemphala et al., 2010), and this paper enables a broader perspective about this subject.

BACKGROUND

The main principles that characterize LM (lean manufacturing) have been defined similarly by different studies. Womack and Jones (1996), for example, define LM as a superior way to manufacture products using fewer resources to generate greater value to customers. For Lewis (2000), LM is an integrated set of activities designed to achieve high-volume production using minimal inventories of raw materials, work-in-process, and finished goods. More recent studies usually define lean as a management system formed by two levels of abstraction: principles and practices (Hines et al., 2004; Shah and Ward, 2007; Pettersen, 2009). The principles represent the ideals and laws of the system, such as encouraging employees' participation in continuous improvement activities, eliminating waste, producing according to the pull of the customer, and continuous flow production (Marodin and Saurin, 2013; Liker, 2004). These practices operationalize the principles and some of the most well-known are the use of kanbans, cellular manufacturing, and value stream mapping (Shah and Ward, 2003; Pettersen, 2009; Rother and Shook, 1999).

Many western companies unsuccessfully tried to import Japanese manufacturing techniques to their production systems. However, existent socio-cultural factors involved in the change process were neglected, which led to limited benefits (Longoni et al., 2013). Further, the understanding of the company's current context is fundamental for the appropriate LM implementation (Pavnascar et al., 2003). According to contingency arguments, organizations should use LM practices that are effective in their context (Anvari et al., 2011). Therefore, the contingency approach assumes that it is the contextual variables that, in the long run, determine the organizational responses in the LM implementation (Desai, 2011).

One of the most implemented lean practice is the Value Stream Mapping (VSM). The purpose of VSM is to minimize waste that prevents a smooth, continuous flow of product and information throughout a value stream (Jimmerson et al., 2005). A value stream displays the set of activities involved in creating a product or providing a service, and their relative importance (Braglia et al., 2006). However, practitioners should be aware of some important distinctions between contexts when applying VSM (Shah and Ward, 2003). In addition to materials and information flow, other types of flow may also be important to external and internal customers: such as warranty service, quality information, and maintenance and revision procedures. While manufacturing typically consists of linear flows of material and information, processes within other contexts may flow in linear, parallel, or even reverse direction (Larson, 2013).

Generally, VSM is performed in the following manner: (i) select a product family, (ii) create a current state map, (iii) create a future state map using lean practices, (iv) create an implementation plan for the future state, and (v) implement the future state through structured continuous improvement activities (Duggan, 2012; Rother and Shook, 1999). Further, VSM are preferably created through gemba walks, in which a multifunctional team walks the value stream in order to identify in-loco the processes steps and their characteristics and data, such as cycle time, changeover time, number of operators, inventory amounts, etc. (Vindoh et al., 2011; Bertolini et al., 2013).

METHOD

There are 7 steps to the research method adopted in this paper. The method aims at applying VSM in five recycling centres in order to identify improvement opportunities for productivity enhancement in each case, and assumes no previous knowledge on the tool.

In step 1 we propose an extensive data collection with emphasis to the type of organisation targeted in the study. Such data enable the identification of current context of each one of the recycling centres, in addition to common difficulties faced by those during their daily operational tasks. Step 2 is carried out analysing products and services offered by each centre and their production processes. The aim is to determine families of products/services, such that items in a family present similar processing needs. Grouping of items in families will simplify the task in Step 3. Another objective in Step 2 is to stratify total production mix in terms of percentage participation of product/service families. The steps of the method to follow should be first implemented for the product/service family with greatest impact on total demand.

In step 3 the improvement team will draw the current state map for each centre. As mentioned above, such task will be initially carried out for the highest priority product/service family. The current value stream is drawn starting from the downstream to upstream processes, as follows: (i) shipping, (ii) weighting, (iii) housing, (iv) pressing, (v) sorting, and (vi) supplying of sorting. Such approach allows to walk the value stream from the customer (internal or external) perspective, and enables the assessment of process operations with respect to waste, supporting the improvement team on the task of determining how operations add value to products (Vinodh et al., 2011), which is the core of Step 4. Clear identification of waste, either in material or information flows, in the current state is vitally important to search for performance improvement opportunities in the future state (Herrmann et al., 2008). One way to prioritize such opportunities is measuring the impact of waste reduction on the average production lead time of the product/service family under analysis (Duggan, 2012).

Step 5 consists of drawing the future state map for each studied recycling centre. Designing the future state allows the clear definition of improvement opportunities that lead to waste elimination, iterative improvement, and sustained benefits (Womack and Jones, 1996). Waste elimination becomes easier when problems are identified using a team-based, systemic approach rather than the narrow scope of an individual or isolated department (Miller et al., 2010).

Once reaching the process' future state, several inferences on ways to improve value addition are likely to be outlined based on practical experience. Further, this information allows comparing the obtained results in order to highlight achievements and share best practices among recycling centres. However, in the comparison carried out in step 6, it is worth noticing the existent contextual factors in each case study, so the differences and limitations among them are taken into account. Our proposed method closes with Step 7, in which lessons learned during the value stream analysis and future developments are proposed. In addition, this is when the organisations are ready to adopt yokoten, i.e. a process in which learning is shared throughout the organisation by adapting best practices and improvement ideas to problems arising in other areas or departments (Azevedo et al., 2012; Liker, 2004).

RESULTS

Solid waste collection in Porto Alegre involves 150 neighbourhoods, with a population of more than 1.3 million. More than 60 tons of solid waste are collected per day and distributed to eighteen recycling centres, in which only 18% of total solid waste generated in the city is recycled. The collection and distribution of the solid waste are performed by DMLU (Department of Urban Sanitation), while the recycling centres are managed by cooperatives, whose members are mostly poor and not part of the mainstream economy. In these centres, the solid waste is separated, appraised, stored, and commercialized. The profit remains with the cooperatives, making it an important income source (about R$ 812/person/month) for more than 500 workers, who present an average monthly productivity of 1.9 ton per person (DMLU, 2013). These recycling centres must be designed to minimize process lead time and maximize the output rate. Another design parameter is sorting quality; it must be easy to discard the waste in the correct waste fraction container. The importance of this is highlighted by Krook and Eklund (2010a and 2010b).

The main data was collected through observations, questionnaires and interviews with workers at the five recycling centres. This data collection was conducted during March and December 2014 during different days of the week. Also, additional data was gathered at the DMLU in order to complement initial information. There are many categories of MSW such as food waste, rubbish, commercial waste, institutional waste, street sweeping waste, industrial waste, construction and demolition waste, and sanitation waste. Plastic, paper, cans and dry waste together comprise the largest amount of MSW (from 60 to 85% of total material) and, in terms of revenue, these materials represent from 75 to 90% of total monthly income. Besides its financial and productive significance, these materials present the same process flow, which enables the characterization of a major product family. Thus, given its importance, this value stream was selected to be mapped its current state in all recycling centres, considering both information and materials flow.

In Step 3, the value stream's current state was mapped and analyzed by the improvement team. Participants brainstormed ideas and identified specific steps in the process that could be eliminated (such that waste could be minimized) or consolidated (such that value could be maximized). To complete the drawing of the current state map six 4-hour meetings were carried out, in addition to several gemba walks in the recycling centres' shop floor to visualize the processes in loco. Table 1 depicts the current state characteristics of the five studied RCs, displaying information emerged from the current state map analysis.

Table 1 – Comparison of current state characteristics of studied recycling centres

Current state indicators	**RC1**	**RC2**	**RC3**	**RC4**	**RC5**
Lead time	7.4 days	12.4 days	13.6 days	13.4 days	6.1 days
Process time	86.4 minutes	134 minutes	179 minutes	168 minutes	145 minutes
Number of scheduling points	9	10	12	7	5
Number of involved personnel	100	30	35	28	22
Monthly commercialized waste/person	1.6 ton	2.1 ton	1.4 ton	1.4 ton	2.4 ton
Monthly income/person	US$ 200	US$ 234	US$ 177	US$ 169	US$ 370
% of rejected material	66%	34%	53%	20%	28%
MSW sorting type	2 Conveyors (28m) with 28 workers each	12 Individual Workbenches	4 tables with 4 workers each	4 tables with 4 workers each	1 conveyor (11m) with 12 workers
Does it sort medical waste?	Yes (21%)	No	No	No	No

Participants faced some difficulties while performing the current state analysis. The first one was related to processes data. System information was inexistent and several processes were informally performed. Moreover, cycle times were extremely sensitive to workers' expertise and commitment, imposing difficulties in the analysis of current data. Prior to the current state mapping RCs used to estimate cycle times based on past experience; the same applied to the definition of the centres' production capacity, which was estimated from past performance knowledge. Thus, part of the improvement team was given the task of random sampling processes' cycle times in order to provide more reliable information for the value stream analysis. The lack of quality control of sorted materials by the RCs was also viewed as another opportunity for improvement during mapping. Finally, two additional improvement opportunities were considered noteworthy; they were related to: (i) the lack of process indicators and formal process management routines, and (ii) unbalancing of labour distribution (and therefore production capacity) across workstations.

In Step 5 of the research method, the improvement team drew the value streams' future state map. The resulting improvements are depicted in Table 2; its construction demanded six additional 4-hour meetings, which took place in a two-month timeframe. Some objectives and assumptions were set before drawing the future state map. First, a six-month implementation horizon was targeted for the future state map, so that team members could reasonably work on the proposed improvements without losing focus of daily activities yet not losing the improvement momentum created so far. Second, improvement ideas that demanded capital expenditure should be limited, since the study was carried out in cooperatives supported by local government with limited budget. Improvements demanding acquisition of additional instruments, new machines or costly layout changes should be initially disregarded.

Table 2 – Processes' improvement opportunities for future state maps

Process	Improvement opportunities	Observation
Supply of sorting	1-Sizing the receiving inventory to keep an uninterrupted flow between waste delivery.	Applied to all RCs
	2-Using gravity to facilitate receiving process.	
	3-Using visual management at receiving in order to allow supervisor's anticipation before running out of material.	
	4-Including work station responsible for tearing bags and removing their content before the conveyor	At RC1 and RC5
	5-Removal of glass and other dangerous materials that can harm the sorting or damage the conveyor	
Sorting	6-Reduce number of shared jerricans to allocate sorted waste	
	7-Added secondary sorting to reduce number of different jerricans in sorting area and operation cycle time	At RC2 and RC5
	8-Increase conveyor rhythm to archive *takt*	At RC1 and RC5
	9-Adequacy of conveyor length and number of workers to improve work balancing	
	10-Balancing workload and defining cycle times	Applied to all RCs
Transportation	11-Review of batch sizes and packaging for transportation	Applied to all RCs
	12-Implementing visual management for stock before pressing	
Pressing	13-Reducing batch size for pressing	Applied to all RCs
	14-Improving pressing change over	
	15-Defining standardized work for workers procedure	
Housing/storage	16-Implementing visual management for finished goods	Applied to all RCs

Several improvement actions were elicited towards the desired future state; they are displayed according to processes in Table 2. Among the opportunities, 16 main actions were defined, with major attention to sorting process due to its specificities. It is worthy to notice that, regardless the process and RCs' characteristics, a few actions were commonly applied. For instance, the implementation of visual management, review packaging and batch sizes and balance workload among processes were the main improvement deployment for almost all RCs. No actions were addressed to improve information flow with customers and suppliers, since it was understood that it belongs to local government's scope. Further, MSW distribution to RCs and delivery of finished goods to customers remain the same way as current state, since the improvement horizon was six-month implementation and these improvements demand a longer time. Thus, future state analysis focused on improving productivity, lead time and quality through simplification and standardization of internal processes. Table 3 depicts future state results for each RC after implementation of identified improvements.

Table 3 – Future state results for each recycling centre

Future state (6 months) indicators	RC1	RC2	RC3	RC4	RC5
Lead time	1.3 days	3.4 days	6.2 days	4.1 days	1.4 days
Process time	56 minutes	88 minutes	82 minutes	87 minutes	120 minutes
Number of scheduling points	1	1	1	1	1
Number of involved personnel	100	39	44	40	40
Monthly commercialized waste/person	3.4 ton	4.3 ton	2.1 ton	2.3 ton	5.2 ton
Monthly income/person	US$ 419	US$ 530	US$ 276	US$ 288	US$ 792
% of rejected material	37%	20%	20%	20%	20%
Improvements in sorting resources	2 Conveyors (28m) with 36 workers each	17 Workbenches	5 tables with 6 workers each	5 tables with 6 workers each	1 Conveyor (20m) with 22 workers

DISCUSSION

Our results denote some interesting points with regards to the productive systems of solid waste recycling centres. First, despite a careful sample selection process in order to ensure the uniformity of characteristics among the studied RCs, some contextual variables presented differences that may influence the results. For instance, size of the RC, which can be compared based on the number of involved personnel, vary from 22 at RC5 to 100 at RC1. A few studies (Dora et al., 2013; Ates, 2004) state that the larger the size of the plant the worse the information flows, which negatively affects the production scheduling process. However, RC1, which is the largest recycling centre, currently presents nine scheduling points, as shown in Table 2, while others that are smaller present ten or twelve such as RC2 and RC3, respectively. Further, large size also implies the availability of human resources that facilitate adoption and implementation of change management practices (Foster et al., 2007; Herron and Braiden, 2006). Nevertheless, our findings show that smaller centres have presented significant changes with adoption of lean practices, such as RC5 and RC2, whose productivity improvements were approximately 112% and 105%, respectively, comparing current and future states. Thus, although literature evidences that contextual variables impact the adoption and implementation of lean practices in solid waste recycling centres (Hemphala et al., 2010), results indicate that the direction of the effect is not always as predicted.

Secondly, the current state results indicate the existence of a significant amount of waste incorrectly sorted, which in turn influences the environmental and productivity performance of the waste management system as a whole (Wilson et al., 2006). Due to its heterogenic line of business, the waste sector involves several agents with varying incentives for sorting waste. For instance, two of the RCs presented more than 50% of rejected material and only one achieved the target of 20% of rejected material established by the municipal legislation (DMLU, 2013). However, future state achievements show the percentage of rejected material of four RCs aligned with the target. RC1 presents a particular contextual variable, which may justify its result of 37% of rejected material. Among all RCs, RC1 is the only one that receives and sorts medical waste (21% of total material) due to agreements with local hospitals. This kind of waste usually presents a more problematic and specific materials for manual sorting than domestic waste, which, consequently, affects the quality of sorting (Krook and Eklund, 2010a). Krook and Eklund (2010b) also mention that this problem could possibly be addressed by product design limiting the extensive mixture of different materials in products and enhancing the ability for dismantling. Thus, the waste origin may influence the quality of sorting at RC1, and, although its productivity has already increased, it could potentially be enhanced without such issues.

More specifically, regarding the implementation process of lean practices (e.g. VSM) in recycling centres it is worthy to note a few points. In general, solid waste recycling centres are often poorly run and operate to low standards. However, there are some main differences between recycling centres and an ordinary industrial production system. For example, it is the function of the recycling centres to receive and take care of visitors' waste, characterizing a push system, while industrial production systems normally order the incoming material from their suppliers, denoting a pull system. Thus, some lean principles such as "let the customer pull value from the producer" (Slack et al., 2010) needed to be adapted to this scenario based on municipal arrangements with DMLU and the future productivity planned for each centre in order to review and establish new patterns of MSW collection frequency and distribution quantities. Such outcome corroborates to the contingency approach, in which organisations should use and adapt lean practices and principles that are effective in their context (Anvari et al., 2011; Desai, 2011). As a consequence, the adoption of a "best practice" approach becomes brittle, since the diversity of as its major theme of study the identification of the best practices associated with alleviating these problems.

Finally, a recycling centre can be viewed as a combination of a service and a production operation (Sundin et al., 2011). While it is supposed to perform an environmental role through the sorting and compacting of MSW in order to become raw material for other businesses, it contributes as a socio-economic service. Specific socio-economic conditions prevail in many economically developing countries, including rapid population growth, migration to urban areas, lack of sufficient funds and affordable services, poor equipment and infrastructure and generally a low-skilled labour force (Parrot et al., 2009). The promotion and development of recycling centres is a means of upgrading living and working conditions of rag pickers and other marginalized groups (Sharholy et al., 2008). Such service can be denoted by the increase in the number of involved personnel from the current to future state. Considering the five studied RCs, despite the obtained productivity improvements, 48 people were added to the centres, resulting in an increase of 22% in employment opportunities. Moreover, the average monthly income per person presented a significant increase that varied from 56% to 126%, at RC3 and RC2 respectively. Therefore, not only the employment level has improved but also the financial condition of these workers has increased, contributing to a local socio-economic inclusion.

CONCLUSIONS

MSW management is a major problem in most economically developing countries. This research suggests two major findings. First, while VSM theory brings valuable information to managers and facilitators, the most important benefit comes from actually applying the tool. During the mapping process insights grow, paradigms are shifted, and consensus is built. Not only the mapping activity leads to better and leaner processes, but also brings consensus that enables and enhances lean implementation in contexts other than manufacturing.

Second, the adoption of traditional manufacturing production management practices (such as visual management and work design) in a recycling centre may characterize an important contribution to the area. As stated by Sundin et al. (2011), the studied context usually presents certain reluctance in adopting formal controlling and management practices. The justification for that is twofold. First, personnel training in recycling centres (whenever it exists) is usually task focused and does not emphasize the development of managerial skills. Due to their socio-economic condition, labour force usually comes without technical background and low educational level, which hinders the implementation of more complex management practices.

Implementing lean management approaches reinforce the need for re-orientation of solid waste management systems regarding scope and strategic positioning. The evolutionary process of transferring the lean team-based approach to solid waste management systems may enable that re-orientation. However, existing practices discourage the establishment of a transparency culture, where abnormalities and problems could be identified by anyone. That may limit the improvement potential and problem solving capability, which is one major principle in a lean system. Thus, further studies are needed to better understand the barriers and policies within different recycling centres. That would enable a proper adaptation of lean principles and maximize their acceptance by recycling centres.

References

Anvari, A. et al., 2011. A proposed dynamics model for a lean roadmap. *African J of Bus Manag* 5 (16), 6727-6737.

Ates, H., 2004. Management as an agent of cultural change in the Turkish public sector. *Journal of Public Administration Research and Theory* 14 (1), 33-58.

Azevedo, S., Carvalho, H., Duarte, S., Machado, V., 2012. Influence of Green and lean upstream supply chain management practices on business sustainability. *IEEE Transactions on Engineering Management* 59 (4), 753-765.

Bergmiller, G., McCright, P., 2009. Are lean and green programs synergistic? *Proceedings of the 2009 Industrial Engineering Research Conference.*

Bertolini, M., Braglia, M., Romagnoli, G., Zammori, F. 2013. Extending value stream mapping: the syncro-MRP case. *International Journal of Production Research* 51 (18), 5199-5519.

Braglia, M., Carmignani, G., Zammori, F., 2006. A new value stream mapping approach for complex production systems. *International Journal of Production Research* 44 (18), 3929-3952.

Desai, V., 2011. Learning to learn from failures: the impact of operating experience on railroad accident responses. Ind and Corp Change 20 (2), 1-28.

DMLU, 2013. *Planilha de informações básicas das UTs para reajuste de convênio*. Fórum de Catadores de Porto Alegre.

Dora, M. et al. 2013. Operational performance and critical success factors of lean manufacturing in European food processing SMEs. *Trends in Food Science & Technology* 20, 1-9.

Dües, C., Tan, K., Lim, M., 2013. Green as the new Lean: how to use Lean practices as a catalyst to greening your supply chain. *Journal of Cleaner Production* 40, 93-100.

Duggan, K., 2012. *Creating mixed model value streams: practical lean techniques for building to demand*. CRC Press.

Foster, S., Hawking, P., Zhu, C., 2007. The human side of ERP implementations: can change management really make a difference? *Int Fed for Info Proc* 254, 239-249.

Hemphala, H., Kihlstedt, A., Eklund, J., 2010. Vision ergonomics at recycling centres. *Applied Ergonomics* 41, 368-375.

Herrmann, C., Thiede, S., Stehr, J., Bergmann, L., 2008. An environmental perspective on lean production. *Proceedings of the 41st CIRP Conference on Manufacturing Systems*.

Herron, C., Braiden, P., 2006. A methodology for developing sustainable quantifiable productivity improvement in manufacturing companies. *Int J of Prod Eco* 104, 143-153.

Hines, P., Holweg, M. and Rich, N., 2004. Learning to evolve: A review of contemporary lean thinking. *International Journal of Operations and Production Management* 24 (10), 994-1011.

IBGE, 2002. Pesquisa nacional de saneamento básico 2000. *Instituto Brasileiro de Geografia e Estatística, Rio de Janeiro-RJ, Brazil*. Available at: http://www.ibge.gov.br (Acessed on 03.30.2015).

Javied, S., Hanan, F., Munawar, S., Qasim, M., Anees, M., Ghani, M., Azad, A., Khalid, M., Ullah, I., Ansar, A., 2014. Management of municipal solid waste generated in eight cities of Pakistan. *International Journal of Scientific & Engineering Research* 5 (12), 1186-1192.

Jimmerson, C., Weber, D., Sobek, D., 2005. Reducing waste and errors: piloting lean principles at Intermountain healthcare. *Joint Commission Journal on Quality and Patient Safety* 31, 249-257.
Krook, J., Eklund, M., 2010a. The strategic role of recycling centres for environmental performance of waste management systems. *Applied Ergonomics* 41 (3), 362-367.
Krook, J., Eklund, M., 2010b. Developing a monitoring method facilitating continual improvements in the sorting of waste at recycling centres. *Waste Management* 30 (1), 32-40.
Kumar, S., Bhattacharyya, J.K., Vaidya, A.N., Chakrabarti, T., Devotta, S., Akolkar, A.B., 2009. Assessment of the status of municipal solid waste management in metro cities, states capitals, class I cities, and class II towns in India: An insight. *Waste Management* 29, 883-895.
Larson, J., 2013. *Management engineering: a guide to best practices for industrial engineering in healthcare*. New York, CRC Press.
Lewis, M., 2000. Lean Production and Sustainable Competitive Advantage. *International Journal of Operations & Production Management* 20 (8), 959–978.
Liker, J., 2004. *The Toyota way: 14 management principles from the world's greatest manufacturer*. McGraw-Hill, New York.
Longoni, A., Pagell, M., Johnston, D., Veltri, A., 2013. When does lean hurt*?. International Journal of Production Research*, 51 (11), 3300-3320.
Marodin, G.A., Saurin, T. A., 2013. Implementing lean production systems: research areas and opportunities for future studies. *International Journal of Production Research* 51 (22), 6663-6680.
Miller, G., Pawloski, J., Standridge, C., 2010. A case study of lean, sustainable manufacturing. *Journal of Industrial Engineering and Management* 3 (1), 11-32.
Mondelli, G., Giacheti, H., Boscov, M., Elis, V., Hamada, J., 2007. Geoenvironmental site investigation using different techniques in a municipal solid waste disposal site in Brazil. *Environmental Geology* 52, 871–887.
Nunes, K., Mahler, C., Valle, R., Neves, C., 2007. Evaluation of investments in recycling centres for construction and demolition wastes in Brazilian municipalities. *Waste Management* 27, 1531-1540.
Ohno, T., 1988. Toyota production system: beyond large scale production. Productivity Press, Cambridge.
Parrot, L., Sotamenou, J., Dia, B.K., 2009. Municiapl solid waste in Africa: Strategies and livelihoods in Yaoundé, Cameroon. *Waste Management* 29, 986-995.
Pavnascar, S., Gershenson, J., Jambekar, A., 2003. Classification Scheme for Lean Manufacturing Tools. *International Journal of Production Research* 13 (41), 3075-3090.
Pettersen, J., 2009. Defining Lean Production: Some Conceptual and Practical Issues. *The TQM Journal* 21 (2), 127-142.
Rother, M., Shook, J., 1999. *Learning to see: mapping the value stream to add value and eliminate waste*. Lean Institute.
Shah, R., Ward, P., 2003. Lean Manufacturing: Context, Practice Bundles, and Performance. *Journal of Operations Management* 21, 129–149.
Shah, R., Ward, P., 2007. Defining and Developing Measures of Lean Production. *Journal of Operations Management* 25, 785–805.
Sharholy, M., Ahmad, K., Mahmood, G., Trivedi, R., 2008. Municipal solid waste management in Indian cities: a review. *Waste Management* 28, 459-467.
Shekdar, A., 2009. Sustainable solid waste management: An integrated approach for Asian countries. Waste Management 29, 1438-1448.
Slack, N., Chambers, S., Johnston, R., 2010. *Operations Management. Sixth Edition*, Financial Times Prentice Hall.
Sundin, E., Bjorkman, M., Eklund, M., Eklund, J., Engkvist, I., 2011. Improving the layout of recycling centres by use of lean production principles. *Waste Management* 31, 1121-1132.
Taylan, V., Dahiya, R.P., Sreekrishnan, T.R., 2008. State of municipal solid waste management in Dehli, the capital of India. *Waste Management* 28, 1276-1287.
Troschinetz, A., Mihelcic, J., 2009. Sustainable recycling of municipal solid waste in developing countries. *Waste Management* 29, 915-923.
Vindoh, S., Arvind, K., Somanaathan, M., 2011. Tools and techniques for enabling sustainability through lean initiatives. *Cleaner Technology Environment Policy* 13, 469-479.
Wilson, D., Velis, C., Cheeseman, C., 2006. Role of informal sector recycling in waste management in developing countries. *Habitat International* 30, 797–808.
Womack, J., Jones, D., 1996. *Lean Thinking: banish waste and create wealth in your corporation*. Simon and Schuster, New York.