WASTE MANAGEMENT OF AN INDUSTRIAL PRODUCT USING LEAN MANUFACTURING

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ABSTRACT

The presence and development of the organization at the level of employing equipment and available resources faces significant challenges for managing waste from lean perspective for both industry and service systems. There is also a greater aspect and need to manage lean waste as it may reduce resource consumption.

Al-Kufa / Iraq cement plant is employed as a case study, and evaluation of the relationship between lean management of the inventory, transportation and production is conducted. In this research, lean waste ,and 3R (Reduce, Reuse, and Recycle) were employed for quantification. Analytical Hierarchy Process (AHP) is used to quantify these variables. Results were generated using Minitab software Version 17. Lean management contributes to reduce waste by 55%, while the lowest contribution was to recycle waste by 18%.

Keywords: Waste Management, 3R, Reduce, Reuse, Recycling.

INTRODUCTION

Quicker and cheaper product/process are no more two successful measurements to manufacture product or assessing actual manufacturing operation. Different successful parameters like materials are employed in manufacturing and generated wastes during product life cycle and their handling approach [Anastas P. T.,2003].

"Lean" manufacturing is the system that reduces waste as any activity that does not add value to the final product, cost, reduction , flexibility and focuses on processes improvements through the reduction or elimination of the all wastes [Anand G.,2008]. From lean, manufacturing perspective, the major manufacturing wastes are transportation and unnecessary inventory that should be reduced [3].. The lean customer is satisfied by fulfilling cost and time minimization, whereas the green customer is satisfied when the manufactures purchased assistance to them being further environmentally favorable [Duarte S.,2011].

LITERATURE SURVEY

The following literature review reveals lean management in manufacturing, waste management, and related aspects.

Babu et al. (2009) defined waste minimization as the continuous application of a systematic approach to reduce the generation of waste for electroplating industrial wastes minimization in Malaysia. They improved housekeeping, changing technological process ,changing product, changing input material, recycling chemicals and raw materials. Their results indicated that recovering by-product and reducing input to process were good and successful waste minimization method.

Khalil et al. (2013) described work undertaken to implement lean practices in the continuous process for cement production in Turkey. Their work aim is to overcome this obstacle by

ISSN: 2307-3721, e ISSN: 2307-3713
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producing a tool, which can be used to easily visualize the benefits of adopting lean practices without requiring disruption to the production environment. As they use process mapping, computational simulation and Taguchi method for design of experiments. They succeeded in declaring that lean philosophy is not limited to specific industry. Their results shown how lean changes could produce significant positive benefits to key performance, measures and were validated by industry experts.

Udai et al. (2016) undertake lean practices in the continuous processes represented by cement production in India as one of the industries with largest inventories and WIP. Their aim to overcome this obstacle by producing a tool which can be used to easily visualize the benefits of adopting lean practices without requiring disruption to the production environment. They used Trend chart to show before and after WIP reduction. Their results shown reduction WIP for the rest of Cement production line demonstrating the potential efficiency could be, made by implementing lean in the cement industry.

Abdillah et al. (2018) Served this research to reduce waste in the industry of manufacturing companies that produce electronic goods in North Sumatra, and they categorized value-added work and which work has no added value. They used value stream mapping to visualize the real state of the production process and determine the classification of value added activity and non-value added activity. Their results obtained the efficiency of the process cycle and total estimation of the improvement of the lead time.

RESEARCH OBJECTIVES

The aim of this research is to:

1. Propose a methodology of the waste management throughout lean manufacturing activities.
2. Assess criteria of lean waste through employing alternatives 3R waste management hierarchy utilizing from AHP technique in order to select the best alternative that contributes to minimize lean waste.

METHODOLOGY

In order to manage waste throughout lean perspective and according to literature survey a developed methodology is presented. The objective of the methodology is to minimize waste and effective resource consumption. This research is the first to provide evaluation integrative framework to assess an organization's waste reduction in terms of lean-management implementation. The bold blocks indicates the aspect that is considered in this research. Different non value added activities are employed to quantify lean manufacturing system. one relevant statistical tool, and one technique are employed. lean management will be achieved throughout employing three upper phases of the management hierarchy (Reduce,, Reuse, and Recycling) utilizing priorities that contribute in best management of waste and effective resource consumption as identified below in Figure 1.

Lean Management

Lean Management is an effectiveness founded system on improving flow to reduce the waste and utilize techniques to develop management system through right or modification pre-presenting ideas. This management system aims to preserve soft manufacturing flow by constantly determining and eliminating waste causing in rising value of actions in the manufacturing process [Haiyan W.,2011]. Where it creates a firm able to preserve market competition through improving its efficiency for best, on time delivery, minimum cost of lean management, quality and removal of waste (every action that does not insert value to product) [Chahal V.,2012].

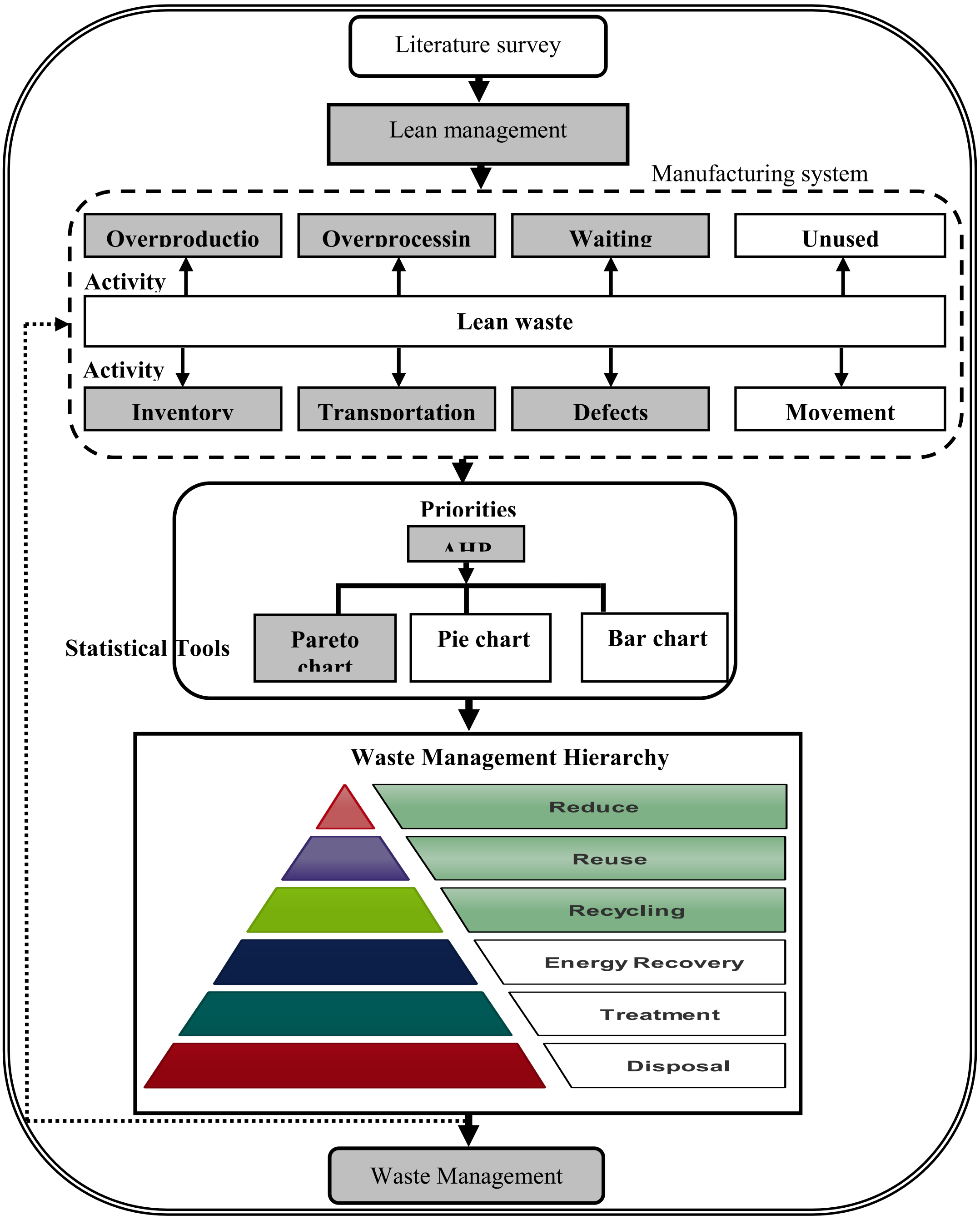

Figure 1. Developed Methodology of Managing Waste Through Lean Manufacturing [Researcher]

Main benefits of lean management systems are: i) Total waste minimization, ii) Improve productivity, iii) Minimize cost, iv) Minimize defects, and v) Improve total quality. [Dušan S.,2014],

A lean management has impact onto environmental system positively [Franchetti M.,2009]. Environmental impacts of an organization's operations can be decreased through lean implementation by reduction of manufacturing wastes such as defects. Defective products and their environmental effects related with material and manufacturing utilized can be

ISSN: 2307-3721, e ISSN: 2307-3713
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limited by defect elimination [Mitch K.,2006]. Table 1. Illustrates environmental impacts associated with eight types of manufacturing waste [Hines P.,2008].

Table 1. Impact of Lean Wastes Minimization on Environmental Performance [Hines P.,2008]

Waste type	Examples	Enviromental impact	Benefit of reduction waste
Overproduction	Manufacturing items for which there are no orders.	- More raw materials consumed in making the unneeded products - Extra products may spoil or become obsolete requiring disposal.	If organizations do not overproduce they consume fewer raw materials, use less energy to operate, eliminate the risk associated with not selling the excess inventory and eventually disposing of it as waste.
Overprocessing (Complexity)	More parts, process steps or time than necessary to meet customer needs.	- More parts and raw materials consumed per unit of production - Unnecessary processing increases waste energy use and emissions.	Improving processing to what is needed allows organizations to cut down on waste and lower their environmental impact.
Waiting	Stock-outs lot processing delays, equipment downtime, capacity bottlenecks.	- Potential material spoilage or component damage causing waste - Wasted energy from heating, cooling and lighting during production downtime.	Reducing waiting can cut down on production downtime which means organizations have less wasted energy.
Inventory	Excess raw materials, work-in-process (WIP) or finished goods.	- More packaging to store WIP. - Waste from deterioration or damage to stored WIP. - More materials needed to replace damaged WIP. - More energy used to heat, cool and light inventory space.	Having less product inventory sitting around organizations can use their plant space more efficiently. Saving heating and cooling demands, also consuming less packaging and raw materials. Lower levels of inventory, also reduce the risk of waste due to obsolescence and undiscovered defects.
Transportation	Carrying long distances transport.	- More energy for transportation possible emissions from transportation.	Minimizing transportation reduces the energy used and the costs associated with the product.
Movement	Human motions that are unnecessary or straining.	- More space required for work-in process (WIP) movement increasing lighting, heating, cooling demand, and energy consumption. - More packaging required to protect components during movement.	Reducing any effort of lifting things unnecessarily or the need to walk excessive distance back and forth (to find tools or complete a task) means organization will use less energy.
Defects	Scrap, rework, replacement production, inspection.	- Raw materials consumed in making defective products - Defective components require recycling or disposal - More space required for rework and repair, increasing energy use for heating, cooling and lighting.	Minimizing product defects means organizations are using fewer raw materials to manufacture products, i.e. less energy consumption.
Unused creativity	Lost time, ideas, skills, improvements, suggestions from employees.	Fewer researchers suggestions of pollution prevention and waste minimization opportunities.	The opportunities to drive out waste, increase profitability, sustainable growth and value creation.

Analytic Hierarchy Process

Numerous approaches to evaluate the priority values of the comparative matrix are suggested and the efficiency relatively estimated. AHP (Analytic Hierarchy Process) is one of the ways for deciding among the complex criteria structure in different levels. Its inclusive roadmap is determined to cooperate with the axiomatic, the rationalistic and irrationality to produce multiple goals, and certain and non-certain criteria of each alternative [Ming C. L.,2010]. The verbal judgments made by the decision maker are interpreted into numbers as utilized in Table 2.

Table 2. AHP fundamental scale [Ming C. L.,2010]

Intensity of Importance	Definition
1	Equal Important
3	Somewhat more important
5	Much more important
7	Very much more
9	Absolutely more important
2,4,6, 8	Intermediate values

Statistical Tools

Usually, Pareto diagrams reveal that 80% of the effect is attributed to 20% of the causes. Pie chart is a circular statistical graphic which is divided into slices to illustrate numerical proportion. While Bar chart is employed to illustrate effect into data, compare various kinds of data and compare data gathered at various periods [Carvalho H.,2009].

Waste Management

Managing of waste comprises from treating and elimination of waste materials and their causing output. Analysis of the whole inflow through the assembly of human actions can assist solution of major issues with managing waste [Jacqueline V.,2009]. From the time of production of waste to its final disposal is known as waste management. The technique based on "waste management hierarchy" is shown in Figure 2. These techniques that refer to the idea of preventing, reusing, reducing, recycling or recovering waste are preferable to disposal [Sivakumaran S.,2015]. Techniques of upper hierarchy can minimize costs to the minimum, and environmental effect is in any event decreased at upper levels. moreover, proportional costs can change considerably relying on parameters such as elimination and transportation costs [EPA Victoria,2014].

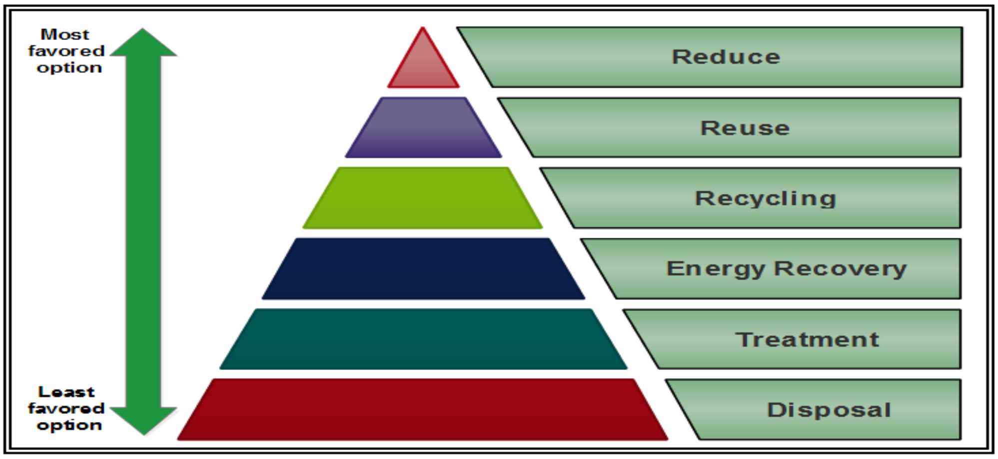

Figure 2. The Waste Management Hierarchy [Keith W.,2007]

Source Reduction (Prevention)

Source reduction is used to reduce the waste generation. Its procedures are possessed before a material or output be wasted. This decreases [Wikipedia ,2015]

i. Waste quantity across the reuse of output.
ii. The passive results of production waste onto human health and ecosystem.
iii. Existence hurtful matters at materials as well as outputs.

Successful industrial examinations assist to achieve waste prevention, effective utilization of industrial resources. This requires system planning and overall effort of the organization. Reduction can be done from domestic level to mass industrial setups. In manufacturing and retail the changes in the method and practice of production, input substitution, process technology, equipment change, on site/off site recovery, reuse, recycling, redesign and reformulation, reduction of packaging are common. Excess outer coverings and packets can be avoided during the production or they are collected from customers during retail [Babu B. R.,2009].

Reuse

Reuse is the work or technique of employing waste another time as raw material, semi-finished product or finished product. Readiness into reuse interests testing cleaning or reforming recovering processes, and the outputs which became wasted can be reused without the need for different manufacturing operations [Jacqueline V.,2009].

Recycling

It is a recovery process through which waste substances are reprocessed into output material, as major or different objectives. Recycling comprises remanufacturing of essential substances without energy recovery and remanufacturing of materials which can be utilized like fuels and in manufacturing processes [UN-Habitat,2009].

Case Study: (AL- Kufa Cement Manufacturing Plant)

The cement industry is distinguished by intense energy and raw materials, considerable Work-In-Process (WIP) inventories, rising breakdown levels, and the necessity to increment the productivity so as to meet big demands.

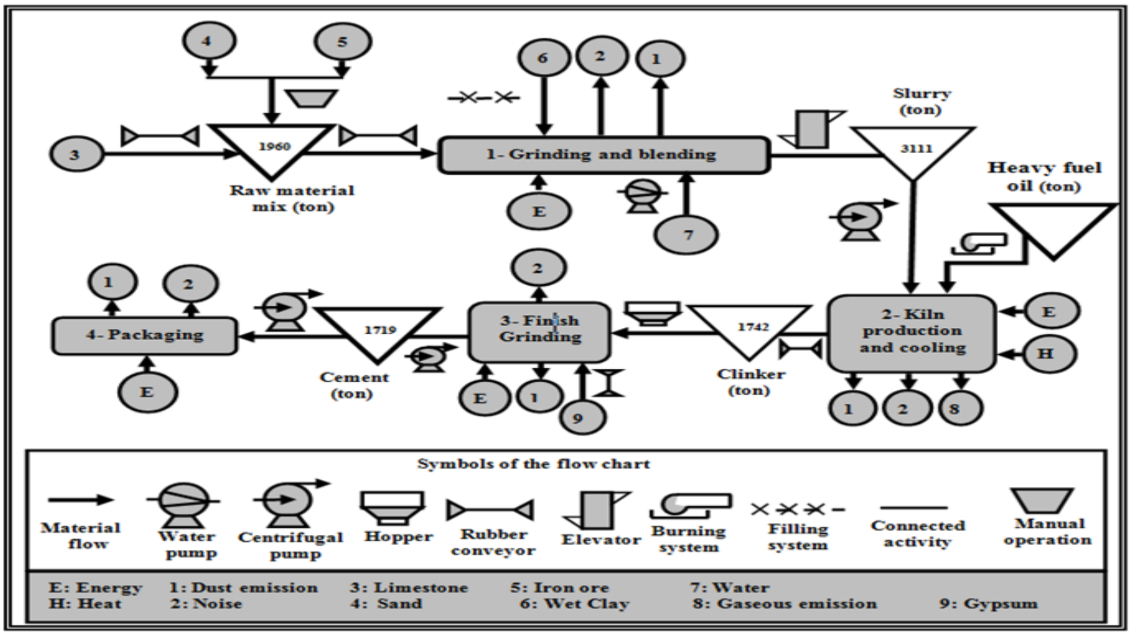

Figure 3. Flow Chart of AL-Kufa Cement Manufacturing System (Wet Process)

ISSN: 2307-3721, e ISSN: 2307-3713

The operation of transportation determines the efficiency of moving products. The activities of manufacturing plant suffer from producing different waste types such as, time, cost, defects, air emission, inefficiency transportation, and solid waste. The activities of inventory, transportation and manufacturing are considered. Structural components flow diagram of AL-Kufa cement plant as shown in Figure 3. The production of limestone, the raw materials are reduced ratio of 0.5 % and produced ratio of 99.5 %. During the production of clinker, the slurry is reduced of 44% and produced ratio of 56%. Finally, during the production of one ton of sulphate resisting cement, the amount of clinker and gypsum reduced ratio of 1.3% and produced ratio of 98.7 % as output of finish grinding as shown in Figure 4.

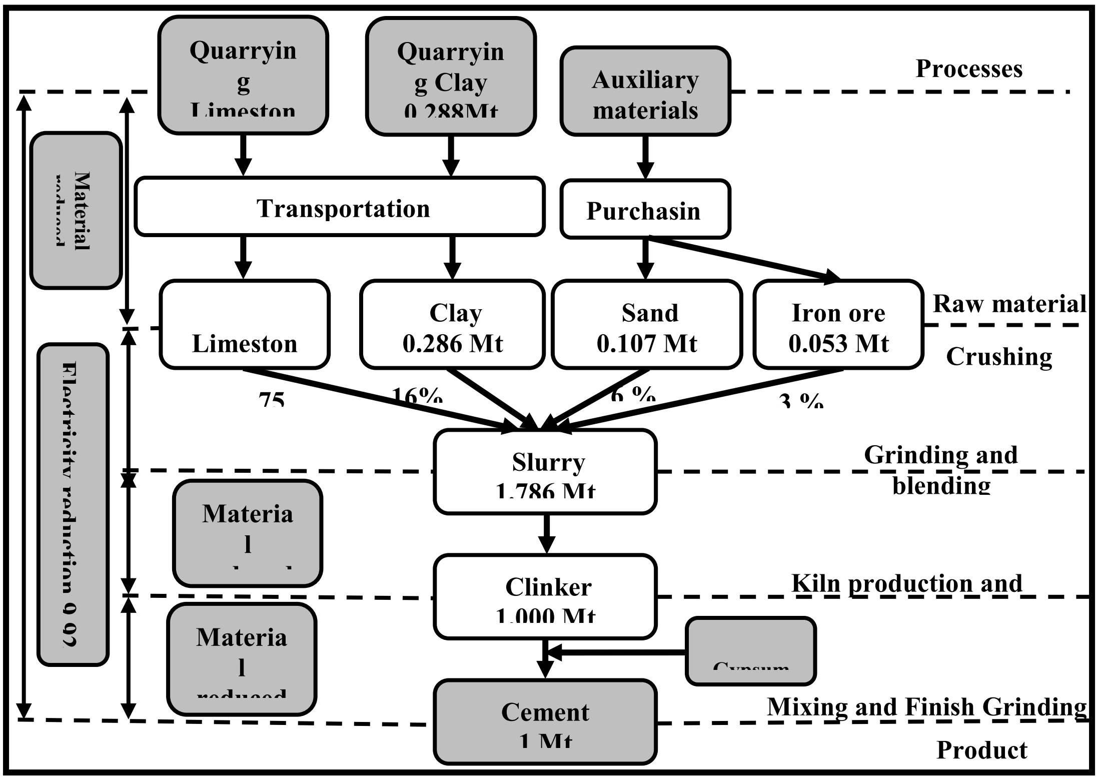

Figure 4. Material Flow Balance Diagram for Production 1 ton of Sulphate Resisting Cement [151]

3R (Reduce, Reuse and Recycling)

Rely on the local situations, three waste management techniques were determined as decision making alternatives (A) are reduce (A_1) , reuse (A_2), and recycling (A_3) from more to less important according to hierarchy waste management . As well as, six criteria are related to lean waste in Al-Kufa cement plant as shown in Figure 5.

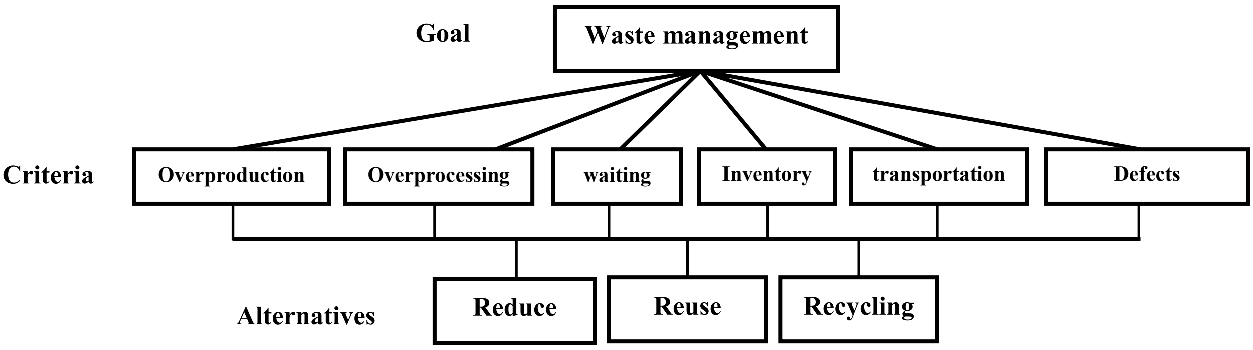

Figure 5. Decision hierarchy

Alternatives of waste management will be compared with respect to six lean manufacturing waste as shown in Tables (3,4).After that the Table 3. Translates its decisions into the analytical hierarchy matrix.

Table 3. Alternatives waste management compared with respect to lean waste

Alternative Criteria	Reduce		Reuse		Recycling	
Overproduction	Production according to right quantity of product. Less consumption of raw material.		Reuse extra production as inventory between work stations. Reuse solid waste.		Introduction recycling of obsolete materials needing disposal. Recycling solid waste.	
Weights	**1**	**1**	**7**	**2**	**3**	**1**
Over processing	Increase machine efficiency. Quality of entered material.		Utilization of generated heat in heating of water boilers. Reuse dust.		Recycling participated dust as inventory . Recycling heat as energy.	
Weights	1	1	9	4	2	1
waiting	Controlling faults through proper maintenance reduces downtime. Reduce cycle time.		Reuse returned material from manufacturing. Reuse returned transportation activities.		Recycling returned material from manufacturing . Recycling returned transportation activities.	
Weights	**7**	**2**	**1**	**1**	**1**	**5**
inventory	Optimum utilization of material. Control on inventory .		Reuse participated finish grinding. Reuse cement through packaging.		Recycling participated of finish grinding. Recycling packaging as semi-	
Weights	**9**	**5**	**1**	**1**	**1**	**2**
Transportation	Converge distances between manufacturing processes. Update of transportation activities.		Reuse solid waste produced from rotary kiln as clinker inventory. Reuse gas emissions as moving energy inside kiln.		Recycling solid waste produced from rotary kiln as raw material inventory. Recycling gas emissions as energy to rotate turbines.	
Weights	**1**	**1**	**7**	**4**	**2**	**1**
Defects	Continuous maintenance of machines. Quality of incoming materials.		Reuse reject as raw material. Reuse reject as semi-finished product.		Recycling reject as raw material. Recycling semi-finished product.	
Weights	**5**	**2**	**1**	**1**	**1**	**3**

Table 4. Priorities of lean-green Matrix

Overproduction	Reduce	Reuse	Recycling	Priority
Reduce	1	1/7	1/3	0.100
Reuse	7	1	2	0.600
Recycling	3	1/2	1	0.300
Over processing				
Reduce	1	1/9	1/2	0.080
Reuse	9	1	4	0.720
Recycling	2	1/4	1	0.200
waiting				
Reduce	1	7	2	0.591
Reuse	1/7	1	1/5	0.076
Recycling	1/2	5	1	0.333
inventory				
Reduce	1	9	5	0.761
Reuse	1/9	1	1/2	0.081
Recycling	1/5	2	1	0.158
Transportation				
Reduce	1	1/7	1/2	0.098
Reuse	7	1	4	0.714
Recycling	2	1/4	1	0.188
Defects				
Reduce	1	5	2	0.581
Reuse	1/5	1	1/3	0.110
Recycling	1/2	3	1	0.309

After evaluation the green alternatives respective to their intensity in managing the lean waste as criteria. The lean waste must evaluate respective to their significance in achieving the goal that is waste management as shown in Table 5. The matrix of resulting priorities of lean waste as criteria is shown in Table 6.

Table 5. Lean waste compared respective to achieving waste management

	Waste management	Weight				
Overproduction	Plant does not overproduce and consume lower raw materials, semi-finished materials, employ minimum energy to run, disposing of extra inventory, and less cost	1	1	1	1	1
Overprocessing	Increase processing efficiency and effectiveness permit plant to reduction downtime , lead time, less material consumption , manufacturing cost. and their environmental impact.	3	2	3	3	2
Waiting	Reduction waiting means plant produce less waste time, minimum production downtime, less energy waste, reject and saving cost.	3	1	3	5	3
Inventory	plant has less inventory , spaces more efficiently. and lower waste because of obsolescence and undiscovered rejects. Saving heating and cooling requests.	5	1	1	2	1
Transportation	Plant become less utilized energy and the costs related to output. less excessive distance and idle time. Increase Speed production.	5	1	1	1	1
Defects	Less defects means plant uses lower raw materials to processing, less energy consumption. space to storage, lead time and cost.	3	1	1	2	2

ISSN: 2307-3721, e ISSN: 2307-3713
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Table 6. Priorities of lean and waste management Matrix

Criteria	Overproduction	Over processing	Waiting	Inventory	Transportation	Defects
Overproduction	1	1/3	1/3	1/5	1/5	1/3
Over processing	3	1	2	3	3	2
Waiting	3	1/2	1	3	5	3
Inventory	5	1/3	1/3	1	2	1/2
Transportation	5	1/3	1/5	1/2	1	1/2
Defects	3	1/3	1/3	2	2	1
Priority	0.055	0.295	0.275	0.127	0.100	0.148

Priorities of waste management

From priorities of the lean waste as criteria are known respective to waste management, and the priorities of the green alternatives respective to lean waste. The global priority of lean management is calculated and scheduled in Table 7.

Table 7. 3R management of lean waste

Alternatives Criteria	Reduce	Reuse	Recycling	Total
Over production	0.006	0.033	0.016	0.055
Over processing	0.024	0.212	0.059	0.295
Waiting	0.162	0.021	0.092	0.275
Inventory	0.097	0.010	0.020	0.127
Transportation	0.010	0.071	0.019	0.100
Defects	0.086	0.016	0.046	0.148
Waste management	0.385	0.363	0.252	1.00

From table 7. Pareto chart is used to evaluate lean criteria to manage waste through alternatives that are named 3R (Reduce ,Reuse, Recycling) in which Reduce has major contribution of 38.5 % as shown in Figure 6.

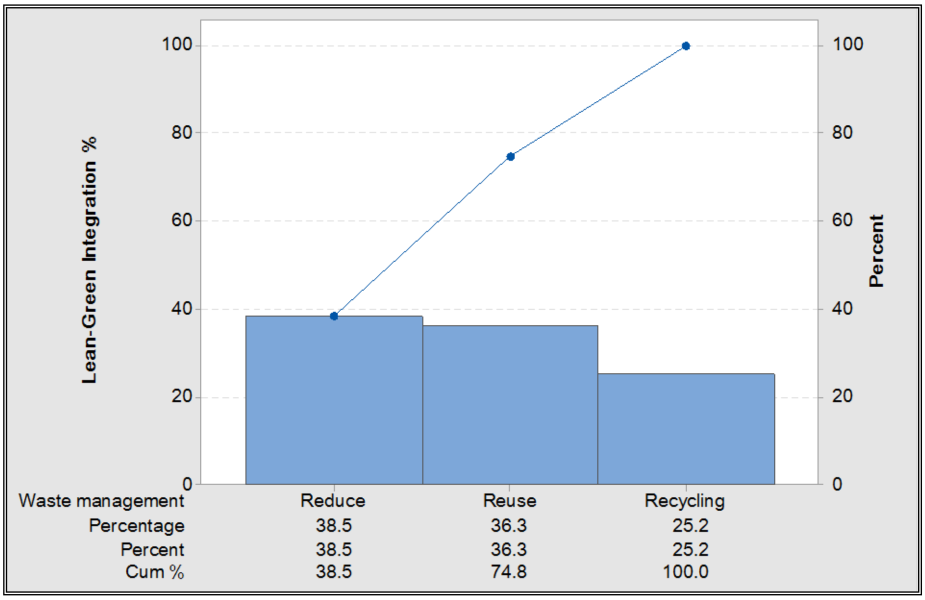

Figure 6. Integration of Lean-green management

ISSN: 2307-3721, e ISSN: 2307-3713

CONCLUSIONS

From this work the followings are concluded and recommended:

1. Lean manufacturing is a catalyst to minimize lean waste due to its impact on the activities of manufacturing system.
2. A methodology is developed for lean management throughout manufacturing activities. AL-Kufa cement plant is employed as a case study to investigate the developed methodology.
3. Through AHP technique, The Reduce alternative can contribute to manage major lean waste of 55 % and the Recycling alternative has minor contribution of 18 %.
4. Defects are the major waste that can be managed through lean manufacturing.
5. Employ different stages of waste management hierarchy in other industries and further researches.

REFERENCES

[1]. Abdillah A. N., Ikhsan S. A, Tigor H. N., and Khalida S. I.(2018). Lean Manufacturing Applications in the Manufacturing Industry. MATEC Web of Conferences, published by EDP Sciences.

[2]. Anand G. and Kodali R. (2008). A Conceptual Framework For Lean Supply Chain and its Implementation. *International Journal of Value Chain Management, 2*(3), PP.313-357.

[3]. Anastas P. T., and Zimmerman J. B.,(2003). Design Through the Twelve Principles of Green Engineering. *Environmental Science and Technology, 37*(5), PP. 94-101.

[4]. Babu B. R., Bhanu S. U., and Meera K. S. ,(2009)," Waste Minimization in Electroplating Industries". A Review" *Journal of Environmental Science and Health Part C, 27*(3), PP.155-177.

[5]. Carvalho H., and Cruzmachado V., (2009). *Lean, agile, resilient and green supply chain: a review*. Proceedings of the Third International Conference on Management Science and Engineering Management, Bangkok, Thailand, PP. 3-14.

[6]. Chahal V.,(2012). An Advance Lean Production System In Industry to Improve Flexibility and Quality in Manufacturing by Implementation of FMS and Green Manufacturing. *International Journal of Emerging Technology and Advanced Engineering, Certified Journal,* 2(12), PP.405-408.

[7]. Duarte S., Cabrita R., and Machado V. C.,(2011). *Exploring Lean and Green Supply Chain Performance Using Balanced Scorecard Perspective.* Proceedings of the Second International Conference on Industrial Engineering and Operations Management, Kuala Lumpur, Malaysia PP. 520–525.

[8]. Dušan S., (2014). Innovation Lean Principles in Automotive Green Manufacturing", Acta Logistica. *International Scientific Journal, 1*(4) ,PP. 23-27.

[9]. EPA Victoria, (2014). *Your Environment, Waste Management Hierarchy*. Available ,http://www.epa.vic.gov.au/yourenvironment/waste.

[10]. Franchetti M., Bedal K., Ulloa J., and Grodek S.,(2009). Lean and Green: Industrial Engineering Methods are Natural Stepping Stones to Green Engineering. *Journal Industrial Engineer, 41*(9), PP.24-30.

ISSN: 2307-3721, e ISSN: 2307-3713
www.erint.savap.org.pk

[11]. Haiyan W.,(2011). *Lean and Green Production Development-Examples of Industrial Practices in China and Turkey.* M.Sc. Thesis, School of Innovation, Design and Engineering. Mälardalen University, Sweden.

[12]. Hines P., Found P., Griffith G. and Harrison R.,(2008). *Staying Lean: Thriving, not Just Surviving.* Lean Enterprise Research Centre: Cardiff University, British Library.

[13]. Jacqueline V., (2009). *Waste Management Reference Handbook.* Santa Barbara, California Denver, Colorado Oxford,England, ABC-Colio,Inc.

[14]. Keith W.,(2007). *Handbook of Waste Management and Co-Product Recovery in Food Processing.* Published by Woodhead Publishing Limited, Abington Hall, Abington Cambridge CB21 6AH. England.

[15]. Khalil R. A., Stockton D. J., Tourki T., and Mukhongo L.M, (2013). Implementation of Lean in Continuous Process-Based Industries. *International Journal of Scientific and Engineering Research, 4*(10), PP.723-735.

[16]. Ming C. L. (2010). *The Analytic Hierarchy and the Network Process in Multi-criteria Decision Making: Performance Evaluation and Selecting Key Performance Indicators Based on ANP Model* "Convergence and Hybrid Information Technologies, Marius Crisan, InTech, PP.125-148.

[17]. Mitch K.,(2006). Lean Manufacturing and the Environment. *Association for Manufacturing Excellence, 22*(6), PP.13-18.

[18]. Sivakumaran S.,(2015). *Principles of Waste Management Techniques.* UK: Research Gate.

[19]. Udai S. C., Lalit Y., and Pardeshi R., (2016). Through Lean Manufacturing Techniques Improvement in Production of Cement Plant. *International Journal of Engineering Research and Application, 6*(7), PP. 52-58.

[20]. UN-Habitat,(2009). Solid Waste Management in the World's Cities. Nairobi: United Nations Human Settlements Program (UN-HABITAT).

[21]. Wikipedia, (2015). *Solid Waste Policy in the United States.* Retrieved From, https://en.wikipedia.org/wiki/solid waste policy in the united states.

ISSN: 2307-3721, e ISSN: 2307-3713