Employing 3R Techniques in Managing Cement Industry Waste

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Abstract

Waste management conserves human health, ownership, environment, and keeps valuable natural resources. Lean-green waste of an organization’s operations can be decreased through implementation 3R (Reduce, Reuse, and Recycling) techniques by reduction of manufacturing system wastes. This research aims to integrate lean-green waste of the manufacturing system throughout employing 3R techniques and weighted properties method in order to manage waste. Al-Kufa cement plant is employed as a case study. Results are generated using Edraw Max Version 7 and Excel. Overall results show reduce technique of lean-green waste management has major contribution of 55 % and recycling technique has minor contribution 18 %. Defects waste has major integration of lean-green waste, while air emissions waste has minor integration of lean-green waste.

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

الخلاصة

إدارة الضياعات تحافظ على صحة الإنسان، حق الملكية، البيئة، وعلى الموارد الطبيعية القيمة. يمكن الحد من الضياعات الرشيقة–الخضراء لعمليات المنظمة من خلال تنفيذ تقنيات 3R (الحد، إعادة الاستخدام، وإعادة التدوير) عن طريق الحد من ضياعات نظام التصنيع. يهدف هذا البحث إلى تكامل الضياعات الرشيقة–الخضراء لنظام التصنيع من خلال استخدام تقنيات 3R وطريقة الخواص الموزونة لغرض إدارة الضياعات. تم توظيف مصنع سمنت الكوفة كدراسة حالة. تم توليد النتائج باستخدام برنامج Edraw-Max الإصدار ٧ وبرنامج Excel. تساهم الادارة الرشيقة–الخضراء للحد من الضياعات بنسبة كبيرة قدرها ٥٥ %، واقل مساهمة كانت لإعادة تدوير الضياعات قدرها ١٨ %. تتضمن العيوب تكاملا كبيراً للضياعات الرشيقة–الخضراء، في حين أن الانبعاثات الهوائية تنطوي على تكامل طفيف للضياعات الرشيقة–الخضراء.

الكلمات المفتاحية: ادارة الضياعات، 3R ، الحد، اعادة الاستخدام، اعادة التدوير.

1. Introduction

Anything else which is not adding any value to the product is considered as waste as per lean concept. Inventories of raw materials, work in process inventories, inventories of finished product, overproduction, waiting of equipment ,waiting of human resources, space occupied by unused equipment and materials, excess used of materials etc. are the waste as per lean concept **(Suresh, 2014)**. Green waste is defined as an unnecessary use of resources or a substance released to the air, water, or land that could harm human health or the environment. When organizations use resources to provide products or services to their customers it leads to creation of environmental wastes **(EPA, 2014)**. Lean-green manufacturing means manufacturing without Waste, pollution and optimum use of natural resources (**Suresh, 2014**).The production of waste and its disposal through end-of-pipe means (e.g., landfill, incineration or off-site treatment) is an increasingly undesirable outcome for firms and their stakeholders. Landfill disposal generates costs for the firm in transport and disposal fees. It also represents an opportunity cost owing to the loss of material that has potential reuse value. Waste reduction, rather than waste disposal, offers a range of benefits to a firm's environmental and financial performance (**King, and Lenox, 2001**). Reducing waste in processes or reusing waste or recycling waste as raw material can reduce costs for firms **(Doonan *et.al.*,2005).** From time the production of waste to its final disposal is known as waste management **(Sivakumaran, 2015).** The aim of this research is to study the effect of 3R (Reduce, Reuse, and Recycling) techniques to manage of lean-green waste. Assessment of manufacturing system activities on lean-green waste integration is employed through 3R techniques and weighted property technique. The next paragraph presents theoretical background, global interest in employing 3R techniques in managing waste, processing activities, and relative integration technique, and performance indicators. This paragraph is followed by data collected from Al-Kufa Cement plant is employed as case study. These data are further analyzed, different lean-green waste are employed to quantify 3R Techniques throughout different processing activities. The last paragraph is summarizing conclusions; also recommendations for future work are reported.

2. Theoretical Background

The approach was based on the "waste management hierarchy" practices that refer to the idea that preventing, reusing, reducing, recycling or recovering waste is preferable to disposal. Following practices are used for this purpose in an order of avoid reduce, reuse, recycle, recovery, and disposal as figure (١) (**Sivakumaran, 2015**). In general, actions higher up the hierarchy can reduce the costs at a lower level, and environmental impact is generally reduced at higher levels. However, relative costs can vary significantly depending on factors such as disposal and transport costs **(EPA Victoria, 2014)** . The waste management hierarchy is the internationally accepted policy for waste management practice, and emphasizes reducing waste at the source **(Waste, 2011).**

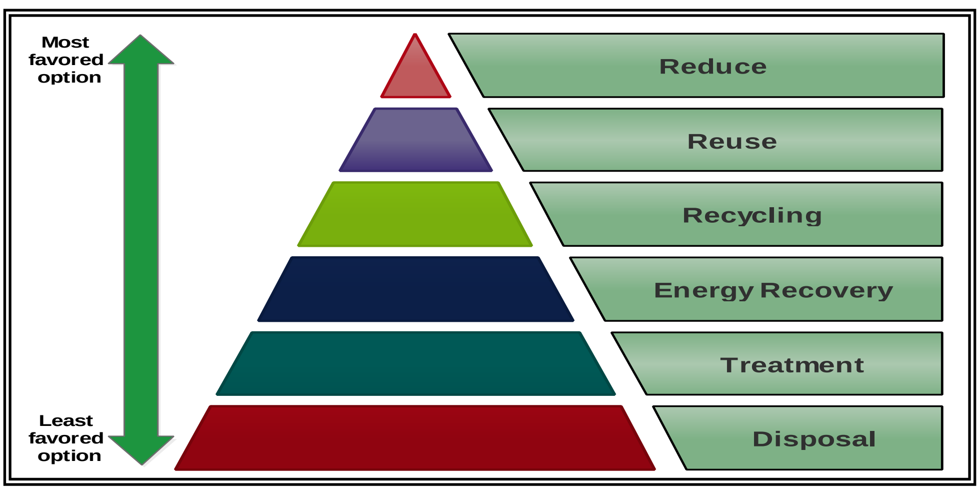

Figure (١) The Waste Management Hierarchy (Keith.2007)

In waste hierarchy, Reduce represents those activities that prevent or reduce the amount of waste generated. This will allow for the most efficient use of resources, reduce the impact on health and the environment and lower disposal costs (**EPA, 2014**). Reuse means any operation by which products or components that are not waste are used again for the same purpose for which they were conceived. "Preparing for re-use" means checking, cleaning or repairing recovery operations, by which products that have become waste are prepared so that they can be re-used without any other pre-processing **(Jacqueline, 2009)** . Recycling means any recovery operations by which waste materials are reprocessed into products, materials whether for the original or other purposes. It includes reprocessing organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations **(UN-Habitat, 2009)**.

3. Literature survey

Many researchers reveal their interest in lean-green waste management throughout utilizing of waste mangement hierarchy by employing different techniques that assess waste management.

(Staniskis *et.al.*, 2005) implied that the largest quantity of solid industrial wastes. Their results show (about 75%) is decreased by on-site recycling

(Field and Sroufe, 2007) clamied that efficient reduce, reuse and recycle of paper waste are fulfilled with the backup of related equipment and utilize of expert personnel; the opposite is right, shortage of instruments for waste crushing.

(Babu *et.al.*, 2009) defined waste minimization as the continuous application of a systematic approach to reducing the generation of waste at source. This definition contains source reduction and on–site recycling. Techniques of waste minimization practice by industries include source reduction and recycling techniques. 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 the waste minimization method with good successful results in their study which was regarding the electroplating industrial wastes minimization in Malaysia.

(Agamuthu *et.al.*, 2011) shown that so far about 95 percent of the waste is directly disposed in landfills. This action will not only create environmental problems, but it also leads to unsustainable management. The main factor in the weak implementation of 3R is the lack of a specific policy and focus on construction waste management.

(Dan *et.al.*, 2012) stated that the 3R (Reduction, Reuse, Recovery) hierarchy is a strategic approach to solid waste management. 3R practices comprise different measures and skillful techniques to reduce the volume of discarded waste materials.

(Rao and Prabhakar, 2013) defined waste reduction as the considerable reduction of waste by implementing four strategies are Source reduction, using recyclable material, good management, control practicing and waste segregation.

(Kenneth *et.al.*, 2015) stated that application of the 3Rs (Reduce, Reuse and Recycle) policy directory in a deprived municipality in Ghana and point on beneficial studies for other municipalities displaying similar situations. They concluded that, the 3Rs paradigm is a beneficial strategy for efficient and active management of solid waste because it abides to the principles of fulfilling sustainable environment.

(Ruisheng *et.al.*, 2015) proposed methodology to adopt and streamline of metal stamped parts production in Singapore (a case study). Their methodology which aims to integrate metrics derived from lean and green implementation, an easy-to-track metric called Carbon-value efficiency,. Their results show that Carbon-value efficiency can be improved by 36.3%, lead time by 64.7% and reduction in Carbon footprint by 29.9%.

(Alain *et.al.*,2016) Conducted a quantitative study of lean-green integration concentrated on waste reducing techniques in manufacturing operations. They utilized design of experiments tool to measure the effect of the Lean/3R (Reduction, Reuse, Recovery) matrix is made. Their outcomes asserted the effect of the 3R hierarchy on advance plan to decrease waste (+1.64 respecting measured amount into case study 1 and +1.43 respecting measured amount into case study 2). Further, the outcomes of this research illustrate that join of two techniques may improve the performance of waste advance plan in manufacturing (+2.80 respecting measured amount into case study 1 and +1.60 respecting measured amount into case study 2).

Weighted property method is very useful when there are a lot of important requirements to compare , evaluate and give how the main requirements are considered and should be independent to each other. This method shows each requirement is assigned to a certain weight under quantitative analysis using digital logical method. In order to evaluate weighting factor, the values for relative importance of that property are summed up to acquire positive decision. The weighting factor (α) is obtained by dividing the positive decision for each goal by the total number of positive decisions**.** Ranking was given according to which requirement has more priority **(Suresh, 2015).**

From Equation (1) yields the dimensionless scaled goal amount for the goal where a minimum amount is desired. While equation (2) yields the dimensionless scaled goal value for the goal where a maximum amount is desired. The total of multiplied scaled factors and weighting factors appears the performance index that calculates according to equation (3) **(Anojkumar, 2014).**

$$\textbf{Scaled Property } (\beta) = \frac{\textbf{Minimum value in the list}}{\textbf{Numerical value of the property}} \times 100 \qquad \textbf{(1)}$$

$$\textbf{Scaled Property } (\beta) = \frac{\textbf{Numerical value of the property}}{\textbf{Maximum value in the list}} \times 100 \qquad \textbf{(2)}$$

$$\textbf{Performance index } (\gamma) = \Sigma\, (\beta \times \alpha) \qquad \textbf{(3)}$$

4. Case Study

There are (21) factories of Cement in Iraq, of production approximately (12 million) Tons in 2015 year, while the local demand is (18) million Tons per year. AL-Kufa Cement Plant is one of these plants that produce different types of Cement such as ordinary, sulphate resistant (currently is producing sulphate resistant) throughout wet process as this plant suffers from different waste types, therefore manufacturing system activities are considered. 3R techniques used as the goal of research methodology is lean-green waste management. Flow diagram of AL- Kufa Cement plant wet process are shown in Figure (2).

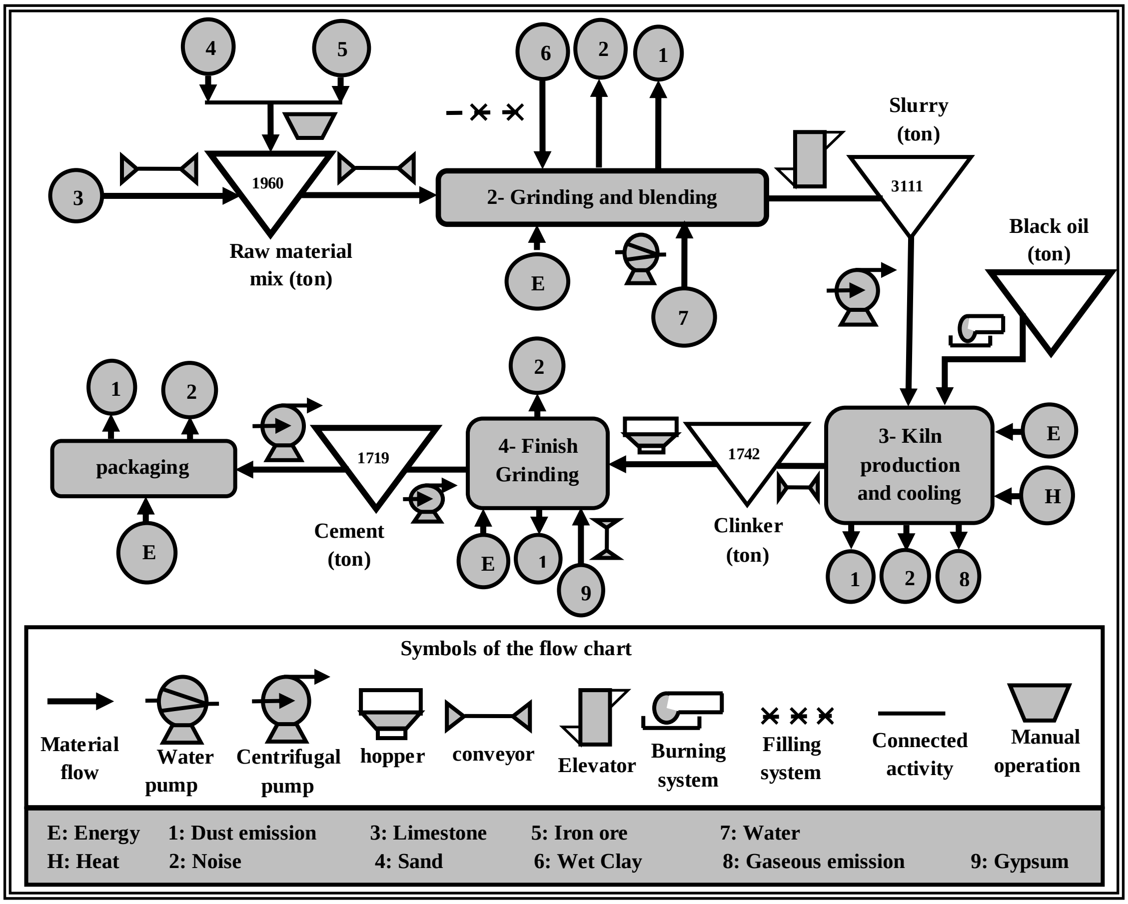

Figure (2) Flow Chart of AL-Kufa Wet Cement Manufacturing

5. Data collection, Anylsis and Discussion

Rely on how each of lean-green wastes through cement manufacturing processes responds to each technique of waste management hierarchy, three waste management techniques were determined to make decision are Reduce, Reuse, and Recycling. As well as, eight wastes are related to lean-green wastes in Al-Kufa cement plant as shown in tables (1),(2),and (3) respectively. Effect of 3R techniques are ranked where 1 is for negative effect, 3 for moderate effect, and 5 for positive effect as shown in table (4).

Table (1) Lean-Green Waste Reduce Technique

Technique	Reduce			
process / Waste	Grinding and Blending	Kiln Production and Cooling	Finish Grinding	Packaging
Overproduction	Reduce solid waste as raw mix inventory leads to decrease overproduction	Reduce solid waste as Slurry inventory leads to decrease overproduction	Reduce solid waste as Clinker inventory leads to decrease overproduction	Reduce solid waste as Cement inventory leads to decrease overproduction
Overprocessing	Actual slurry production has moderate effect onto Overprocessing	Actual clinker production has moderate effect onto Overprocessing	Actual cement production leads to increase Overprocessing	Actual Cement Packaging leads to decrease Overprocessing

Defects	Control on quality of input materials lead to decrease defects	Control on variability of temperature inside Kiln leads to decrease defects	Keeping on designed mixture ratio between clinker and gypsum leads to decrease defects	Control onto moisture of Cement has moderate effect onto defects
Waiting	Reduce bottlenecks due to break of grinding balls leads to decrease waiting	Reduce the sudden electric shutdown leads to decrease waiting	Replace grinding objects (steel balls) has moderate effect onto waiting	Reduce change over time has moderate effect onto waiting
Inventory	Reduce lead time (used or actual time and waste time) leads to decrease inventory	Reduce lead time (used or actual time and waste time) leads to decrease inventory	Reduce lead time (used or actual time and waste time) leads to decrease inventory	Reduce lead time (used or actual time and waste time) has moderate effect onto inventory
Transportation	Utilizing of needed time or effective time leads to decrease transportation	Utilizing of needed time or effective time leads to decrease transportation	Utilizing of needed time or effective time leads to decrease transportation	Utilizing of needed time or effective time has moderate effect onto transportation
Air emissions	-----	-----	-----	-----
Physical waste	Use water sprayers leads to decrease physical waste	-----	Use water sprayers has moderate effect onto physical waste	-----

Table (2) Lean-Green Waste Reuse Technique

Technique	**Reuse**			
process / Waste	**Grinding and Blending**	**Kiln Production and Cooling**	**Finish Grinding**	**Packaging**
Overproduction	Reuse solid waste of slurry as raw material has moderate effect onto overproduction	Reuse solid waste as semi-finished product leads to increase overproduction	Reuse solid waste as finished product has moderate effect onto overproduction	------
Overprocessing	Reuse solid waste as raw material leads to increase Overprocessing	Reuse solid waste as semi-finished inventory leads to increase Overprocessing	Reuse solid waste as finished inventory leads to increase Overprocessing	Reuse solid waste of Cement as Packaged product has moderate effect onto Overprocessing
Defects	Reuse reject rate as raw material leads to moderate effect onto defects	Reuse reject rate as semi-finished product leads to moderate effect onto defects	-----	-----
waiting	Reuse raw mix leads to moderate effect onto waiting	Reuse slurry leads to increase waiting	Reuse clinker leads to increase waiting	Reuse Cement leads to moderate effect onto waiting

inventory	Reuse solid waste as raw material inventory has moderate effect onto inventory	Ruse solide waste as semi-finished product leads to increase inventory	Reuse solid waste as finished product has moderate effect onto inventory	-----
Transportation	Reuse solid waste as raw material leads to increase lead time onto transportation	Reuse solid waste as semi-finished product leads increase lead time onto transportation	Reuse solid waste as finished product has moderate effect onto lead time transportation	-----
Air emissions	-----	-----	Reuse solid waste as finished product has moderate effect onto air emissions	Reuse solid waste as packaged product has moderate effect onto air emissions
Physical waste	Reuse solide waste as raw material has moderate effect onto physical waste	-----	Reuse solide waste as finished product has moderate effect onto physical waste	Reuse solide waste as packaged product has moderate effect onto physical waste

Table (3) Lean-Green Waste Recycling Technique

Technique	**Recycling**			
Waste \ process	**Grinding and Blending**	**Kiln Production and Cooling**	**Finish Grinding**	**Packaging**
Overproduction	-----	-----	Recycling solide waste solide waste as semi-finished product leads to increase overproduction	Recycling solide waste as semi-finished product leads to increase overproduction
Overprocessing	-----	-----	Recycling solide waste as semi-finished product leads to increase Overprocessing	Recycling solide waste as Packaged Product leads to increase Overprocessing
Defects	Recycling reject rate as raw material leads to decrease defects	-----	Recycling reject rate as semi-finished product leads to decrease defects	Recycling reject rate as semi-finished product leads to decrease defects
waiting	-----	-----	Recycling solide waste as semi-finished inventory leads to increase waiting	Recycling solide waste as semi-finished inventory has moderate effect onto waiting

inventory	-----	-----	Recycling solide waste of inventory as semi-finished product leads to increase inventory	Recycling solide waste of inventory as semi-finished product leads to increase inventory
Transportation	-----	-----	-----	Recycling solide waste as semi-finished inventory has moderate effect onto transportation
Air emissions	-----	-----	Recycling solide waste as semi-finished product leads to increase air emission	Recycling solide waste as semi-finished product leads to increase air emission
Physical waste	-----	-----	Recycling solid waste as semi-finished product has moderate effect onto physical waste	Recycling solid waste as a semi-finished product has moderate effect onto physical waste

Table (4) Ranked Actions of 3R Techniques

Technique	**Reduce**				**Total**	**Percent**
Process / Waste	**Grinding and Blending**	**Kiln Production and Cooling**	**Finish Grinding**	**Packaging**		
Overproduction	5	5	5	5	20	18.18
Overprocessing	3	3	1	5	12	10.91
Defects	5	5	5	3	18	16.36
Waiting	5	5	3	3	16	14.55
Inventory	5	5	5	3	18	16.36
Transportation	5	5	5	3	18	16.36
Air emissions	-	-	-	-	-	-
Physical waste	5	-	3	-	8	7.28
Total	33	28	27	22	110	100
Weighting factor	30	25.45	24.55	20	100	
Positive decisions	1	2	3	4	4	
Technique	**Reuse**				**Total**	**Percent**
Overproduction	3	1	3	-	7	12.96
Overprocessing	1	1	1	3	6	11.11
Defects	3	3	-	-	6	11.11
Waiting	3	1	1	3	8	14.82
Inventory	3	1	3	-	7	12.96
Transportation	1	1	3	-	5	9.26
Air emissions	-	-	3	3	6	11.11
Physical waste	3	-	3	3	9	16.67
Total	17	8	17	12	54	100

Weighting factor	31.48	14.82	31.48	22.22	100	
Positive decisions	1	3	1	2	4	
Technique	**Recycling**				**Total**	**Percent**
Overproduction	-	-	1	1	2	5.56
Overprocessing	-	-	1	1	2	5.56
Defects	5	-	5	5	15	41.66
Waiting	-	-	1	3	4	11.11
Inventory	-	-	1	1	2	5.56
Transportation	-	-	-	3	3	8.33
Air emissions	-	-	1	1	2	5.56
Physical waste	-	-	3	3	6	16.66
Total	5	-	13	18	36	100
Weighting factor	13.89	-	36.11	50	100	
Positive decisions	3	-	2	1	4	

6. Integration Lean-Green Management

From table (4), the waste management alternatives are evaluated with respect to their difficulty from the lean-green integration perspective in achieving the goal that is waste management as shown in table (6.5). The individual and overall integration of lean-green management is calculated as in table (5).

Table (5) Individual and Overall Integration of Lean-Green Waste Management

Criteria / Goals	3R Waste Management Techniques: Reduce	Reuse	Recycling	Total	Weighting factor %
Overproduction	20	7	2	29	14.50
Weighting factor %	10.00	3.50	1.00	14.50	
Overprocessing	12	6	2	20	10.00
Weighting factor %	6.00	3.00	1.00	10.00	
Defects	18	6	15	39	19.50
Weighting factor %	9.00	3.00	7.50	19.50	
Waiting	16	8	4	28	14.00
Weighting factor %	8.00	4.00	2.00	14.00	
Inventory	18	7	2	27	13.50
Weighting factor %	9.00	3.50	1.00	13.50	
Transportation	18	5	3	26	13.00
Weighting factor %	9.00	2.50	1.50	13.00	
Air emissions	-	6	2	8	4.00
Weighting factor %	0	3.00	1.00	4.00	
Physical waste	8	9	6	23	11.50
Weighting factor %	4.00	4.50	3.00	11.50	
Total	110	54	36	200	100

From table (5), bar chart is used to evaluate individual lean-green integration to manage waste through 3R (Reduce ,Reuse, Recycling) in which defects waste has major contribution of 19.50 % while of air emissions waste have major contribution of 4 % as shown in figure (3).

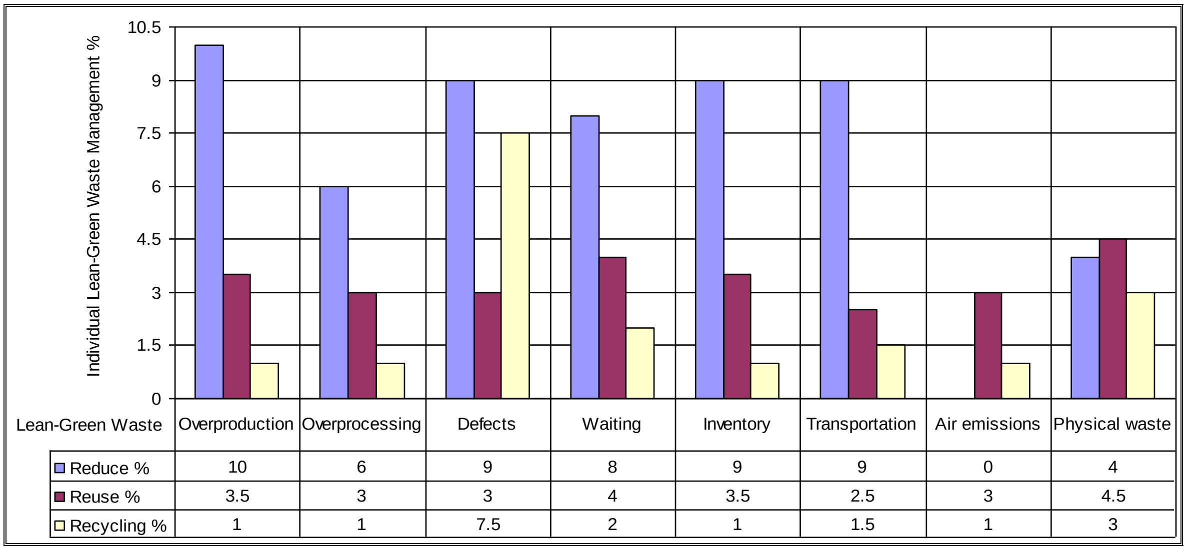

Figure (3) Individual Lean-Green Management of Each Muda

From table (5) Pie chart is used to evaluate overall lean-green integration in which reduce of lean-green waste management has major contribution of 55 % and recycling has minor contribution of 18 % as shown in figure (4).

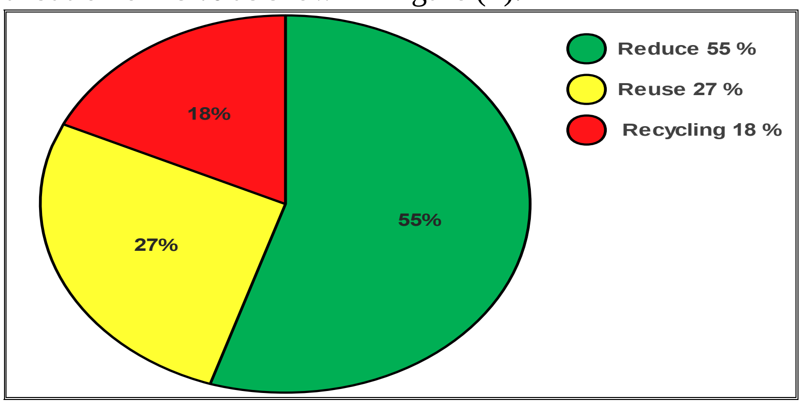

Figure (4) Overall Integration of Lean-Green Waste Management

From equations (1),(2), and (3) respectively, scaled amounts of the goals are utilized on account of further dependable comparison of the goals with various identities of measurements. Table (6) yields performance indexes is utilized in integration of lean-green waste management of Cement manufacturing.

Table (6) 3 R Waste Management Integrated

Technique / Goals	3R Waste Management Techniques												Performance index %	
	Reduce				Reuse				Recycling					
	Min.		Max.		Min.		Max.		Min.		Max.		Min.	Max.
Overproduction	5	20	5	100	1	100	3	100	1	100	1	20	31.90	31.90
Overprocessing	1	100	5	100	1	100	3	100	1	100	1	20	30.00	22.00
Defects	3	33	5	100	3	33	3	100	5	20	5	100	16.77	58.50
Waiting	3	33	5	100	1	100	3	100	1	100	3	60	32.62	36.40
Inventory	3	33	5	100	1	100	3	100	1	100	1	20	31.46	29.70
Transportation	3	33	5	100	1	100	3	100	3	33	3	60	21.58	33.80
Air emissions	-	-	-	100	3	33	3	100	1	100	1	20	5.32	8.80
Physical waste	3	33	5	100	3	33	3	100	3	33	3	60	11.39	29.90

These results that scheduled in table (6) of maximum and minimum 3R (Reduce, Reuse, Recycling) objectives are calculated utilizing the equation (3) of Weighted Property Method (WPM) in which defects waste has major integration of 3R waste management techniques , while air emissions waste has minor integration of these techniques.

1- For Minimum Value of defects waste:-

$$WPI\ \% = 33 \times 0.195 + 33 \times 0.195 + 20 \times 0.195 = 16.77\ \%$$

2- For Maximum Value of defects waste:-

$$WPI\ \% = 100 \times 0.195 + 100 \times 0.195 + 100 \times 0.195 = 58.50\ \%$$

7. Conclusions and Further Recommendations

1- Individual results show reduce technique to manage of lean-green waste integration throughout grinding and blending process has major contribution of 30 %, while reuse teqniques throughout grinding and blending and finish grinding processes has major contribution of each one 31.48 %, whereas recycling teqniques throughout packaging major contribution of 50%.

2- Overall results illustrate reduce of lean-green waste management has major contribution of 55 % and recycling has minor contribution of 18 %. Defects waste has major integration of lean-green waste, while air emissions waste has minor integration of lean-green waste.

3- Implementation 3R (Reduce, Reuse and Recycling) teqniques of waste management in other industries and further researches, other waste management techniques such as recovery and treatment should be employed later to assess and manage different aspects of lean-green waste integration.

8. References

Agamuthu P., Chenayah S., Hamid F. S., And Victor D., 2011 , “3R Related Polices For Sustainable Waste Management In Malaysia,” Proceeding Conferences Of Innovation and Sustainability Transitions in Asia, Kuala Lumpur, Malaysia.

Alain Fercoq, Samir Lamouri, Valentina Carbone, 2016 ,”Lean/Green integration focused on waste reduction” Journal of Cleaner Production,Vol.137,pp.567-578.

Anojkumar L., Ilangkumaran M., Kirubakaran B., Arulmuruga L., Mohamed Hassan S., Lokesh S. ,2014,”**A** Novel Method For Material Selection In Industrial Applications**”**, International Research Journal of Engineering and Technology, Vol.3,No.11,pp.439-443.

aste Economics Team, 2011 ,” The Economics of Waste and Waste Policy”, Published by the Department for Environment, Food and Rural Affairs, London.

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, Vol.27,No. 3,pp.155-177.

Dan Azimi Jibrila, J., Bin Sipan, I., Sapric, M., Aliyu Shikad, S., Abdullah, M.-I., 2012 ,” 3R's Critical Success Factor in Solid Waste Management System for Higher Educational Institutions, Proceedings of the sixty five International Congress on Interdisciplinary Business and Social Sciences, Malaysia,pp.626-631.

Doonan, J., Lanoie, P., Laplante, B., 2005," Determinants of Environmental Performance in the Canadian Pulp and Paper Industry: An Assessment From Inside the Industry. Ecol. Econ.,Vol.55,No, 1,pp.73-84.

EPE Victoria, 2014 ," Your Environment,Waste Management Hierarchy", Available From: http://www.epa.vic.gov.au/yourenvironment/waste.

Field J., and Sroufe R., 2007 ,"The Use of Recycled Materials in Manufacturing: Implications for Supply Chain Management and Operations Strategy", International Journal of Production Journal of Environment Pollution and Human Health , Vol.45, No18-19,pp. 4439-4463.

Jacqueline Vaughn, 2009 ,"Waste Management Reference Handbook "Santa Barbara, California Denver,Colorado Oxford,England,ABC-Colio,Inc.

Keith Waldron, 2007 ,"Handbook Of Waste Management and Co-Product Recovery in Food Processing", Published by Woodhead Publishing Limited, Abington Hall, Abington Cambridge CB21 6AH. England.

Kenneth Peprah, Samuel Twumasi Amoah, Godwin Thomas Wedam Achana, 2015 , "Assessing '3Rs' Model in Relation to Municipal Solid Waste Management in Ghana", Department Of Environment and Resource Studies, University For Development Studies, World Environment, Ghana,Vol.5,No.3,pp.112-120.

King, A.-A., Lenox, M.-J., 2001 ," Lean and Green? An Empirical Examination of The Relationship Between Lean Production and Environmental Performance", Prod. Oper. Manag. Vol.10,No.3, pp.244-256.

Rao, L. N., and Prabhakar, G. , 2013 ," Waste Minimization in the Chemical Process Industries-A Review" Journal of Chemical, Biological and Physical Sciences, an International Peer Review E-3 Journal of Sciences, Vol. 3, No. 2,pp. 1594-1601.

Ruisheng Ng, Jonathan Sze Choong Low, Bin Song, 2015 , "Integrating and Implementing Lean and Green Practices Based on Proposition of Carbon-Value Efficiency Metric", Journal of Cleaner Production.,Vol95,pp.242-255.

Sivakumaran Sivaramanan, 2015 ,"Principles of Waste Management Techniques", Published On Research Gate.

Staniskis J. K., Stasiskiene Z., 2005 ," Industrial Waste Minimization- Experience From Lithuania" Waste Manage. Res.,Vol.23, No.4.,pp.282-290.

Suresh Prasad, S.K. Sharma, 2014 ," Studies Linking Lean Manufacturing Methodology With Green Manufacturing" Journal Of Energy Research And Environmental Technology, Vol.1, No. 1; pp. 34-37.

Suresh Talur, Kiran Kumar.P, T. Madhusudhan, 2015" Selection of Material by Weighted Property Method for Savonius Vertical Axis Wind Turbine Rotor Blade" International Research Journal of Engineering and Technology,Vol.6,No.1,pp.439-443.

U.S. Environmental Protection Agency (EPA), 2014 ,"Total Productive maintenance(TPM)",http://www.epa.gov/lean/thinking/tpm.htm#implications.

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