International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 6 (2018) pp. 4593-4598


# Lean Design Strategy of Waste Minimization in Construction Industries

**J Prakash Arul Jose[1], P Rajesh Prasanna[2], Fleming Prakash[3]**

*[1]Research Scholar, Civil Engineering, Bharath University, Chennai, 600073, India.*
*[2]Professor, Civil Engineering, Anna University, Trichy, 24, India.*
*[3]UG Student, Civil Engineering, PSG College of Technology, Coimbatore, 641004, India.*
*prakasharuljose11@gmail.com, rajeshprasanna71@yahoo.com, fleming14c432@gmail.com*

**Abstract**

Construction waste minimization is practised, for the system to be economical and feasible, irrespective of the construction methodology. This paper would be the answer for wastage problems that are common in construction sectors. On reviewing the reliability and accuracy over both the construction and demolition waste, a management scheme is proposed in accordance with lean construction concept. In lean design, last planner system is implemented to identify the confronting problems, where resource management and scheduling are the key concepts that are focussed on. Hence this proves to be an ideal approach in dealing with waste minimization and productivity enhancement by the analysis of the percent of planned complete.

**Keywords:** Construction methodology, Construction-demolition waste management, Lean design, Percent of planned complete, Last planner system.

## INTRODUCTION

Construction industry consumes natural resources to an unbounded exempt. It also generates large amount of construction waste which causes significant impacts on the environment. So construction manufacturers give more importance in recycling and reusing of the waste generated. The main causes of waste generation are:

- Lack of waste management plans
- Poor supervision and attitude of workers
- Inaccuracy in quantity surveys
- Complications in order-taking
- Issues in material storage
- Inferior quality of materials
- Poor materials handling

Construction waste includes soil and aggregate, sand, cement, bricks, concrete, gypsum board, metal, ceramics, tiles, wood etc. The advantage of using recycled waste materials includes, the enabling of recovery metabolism and thereby, protect the environment and natural resources. It also aids in cost reduction, benefit to industry and economy and reduction of space requirement for landfill uses.

[1] By using life cycle analysis, resource consumption was evaluated which integrates the ecological footprint indicator in the construction techniques. It is required to determine the building construction and then to calculate the methodology, so that the impacts that are produced by the industry could be defined. This method is applicable to both resources and waste generation in construction industry, but it is difficult to describe the eco-efficiency index to assess the efficiency of the ecological footprint indicator. [2] Minimisation of waste at the design stage is an essential one. It focuses on some significant indicators like large-panel metal frameworks, pre-fabricated components, molecular design, waste reduction investment and economic incentive for waste minimisation. Presentation of potential design strategy in waste reduction should have been made clearer. [3, 4] proposed to identify the construction waste and then to express the physical waste generated. Finally the waste management plan was applied. If the implemented waste plan management was successfully capable to solve the issues, then this process would have been really reliable.

[5] proposed the construction and demolition waste management to maximise the waste reduction along with recycling procedures and to minimise the construction waste disposal by life-cycle analysis. Due to its reduced accuracy it seems to be complicated in dealing with the sustainability index. [6] Rock materials and sand are the main sources of the raw construction material. In order to protect natural resources, country's economy and to minimise waste disposal, the recycled aggregates are used as an alternate for natural aggregates in concrete construction. [7, 8] Unavailability of policy, standards or specification acts as a barrier, which limits the usage of recycled aggregates. [9] presented a field scale methodology for developing a generalised waste management plan. The waste management plan is applied to city, regional or country level. This methodology is also used to estimate the total waste generation rates at a larger scale to develop more effective waste reduction strategy. No quantification methodology can fulfil all of the potential scenarios and so an appropriate methodology should be generated. [10] discussed the causes of problems in construction industry and proposed a strategy that could mitigate the problem. It has also evaluated economic feasibility of waste minimisation in terms of cost savings. An appropriate methodology is recommended to do significant cost savings. [11] presented a new plan to quantify the waste generated at new residential constructions. In previous published research works, there is an existence of 1-10% of mean deviation between the models predicted and the data's collected. But in the proposed model the maximum deviation is found to be -38.48% in volume and -15.97% in weight. This model is an important tool for construction companies to optimize construction and demolition waste management.

[12] used system dynamics approach for construction and demolition waste management in terms of cost-benefit analysis. It focussed on the dynamics and interrelationships of the construction and demolition waste management activities throughout the cycle. The casual loop diagram and stock-flow diagram are used to handle the construction and demolition waste management process. A conceptual model of the construction and demolition waste chain is also produced. Simulation results revealed that the current regulation is not-effective for promoting construction and demolition waste management practices. [13] has analysed the challenges of building information modelling in construction fields. [14] presented a review of zero-waste concept. The zero-waste concept stimulates optimum production and consumption, recycling and resource recovery. This study is used to develop national zero-waste guidelines. Overarching and guiding principles are recommended for zero waste development. [15] introduced an optimization model for construction and demolition waste management. This model focussed on the basic principle on waste reduction, reusing and recycling strategies. It produced data including transportation rates and resale value of recyclable materials based on revenue generation in the practice of recycling wastes. It is used to estimate the investment and quantity of raw materials accurately. A mathematical model was used to estimate the maximum revenue from demolition waste. Minor deviation occurred due to efflorescence, rusting and adulteration of mixed earth with Reinforced Cement Concrete (RCC). [16, 17] identified the key wastes and the sources affecting the construction process using questionnaire based survey. Last Planner System (LPS) is used to identify the problems and to make better assignments through continuous learning. The Percent of Planned Complete (PPC) analysis is also done. While implementing LPS, the process like scheduling and resource management should have been given importance.

[18] discussed construction and demolition waste treatment. Resource-efficient design was employed in areas where the construction waste is more. [19] focussed on the influence of contractors' attitudes and behaviours towards waste management in construction industry. A structured questionnaire survey was done. A logistic regression analysis was used to study the relationship between the factors affecting attitude and behaviour towards waste management that includes construction-related education among employees, contractor experience, source-reduction measures, re-use of materials and waste-disposal. A purposive stratified random sampling methodology was used. The result of this study is not compared directly with available studies on household attitudes and behaviours regarding waste management. [20] explained the importance of recycling wastes and the problems in construction industry. This study was used to explore the existing waste recycling methods by telephonic-interview of recyclers and by visiting construction and demolition sites. It also aims to improve the current status in recycling markets.

The existing waste recycling methods did not encourage the recycling parties and pointed out the difficulties from various directions. Hence in these scenarios, the proposed paper focussed on a new construction methodology in terms of waste reduction which also enables the project to be financially and technically feasible.

## METHODOLOGY

### Lean construction concept

In this paper, a Lean Construction (LC) concept is used. This LC technique improves the construction project by reducing the waste of resources and at the same time it increases the productivity and secures a healthy and safer environment. The core concept of lean production is to enable the flow of valuable steps and eliminate the non-value steps. Lean production management leads to revolution in manufacturing design, supply and assembly. The benefit of incorporating lean construction in construction process is to reduce the construction cost by using precise materials and to diminish the amount of waste generation. In addition, by having a proper strategic planning, the construction period will be shortened. Moreover, the productivity, profitability and job satisfaction of the clients are greatly enhanced by the use of lean construction technique.

### Last planner system of lean construction

To attain waste reduction, an instant growth in productivity and a reduction in unpredictability of lean goals during every part of a social process must be enhanced. This increases the reliability of commitments of the team members and thus creates a mutual attempt plan. As a key concept of LC, only smaller number of accidents will occur and it will increase the safety in workplaces. The principal schedule to synergise the LC concept is at the construction and pre-construction stages. Both of this process are critical due to the removal of construction waste during construction and examination of material, equipment and labour service throughout the pre-construction process. The lean production concept has been identified as a clever stratagem in designing, controlling and improving construction processes. This also improves planning process and safety management in order to consider hazard rates and their counter measures. The benefits gained from LC concept compete with other approaches by its effective use of resources, cost reduction, quality improvement and by its immediate response. Key reported barriers of adopting other techniques include

(i) Lack of lean awareness amongst workers and management.
(ii) Current financial crisis.
(iii) Inadequate training and high cost.
(iv) Work pressure and fear of failing in the implementation.
(v) Multi-cultural workforce and language barrier.
(vi) Workers attitude and resistance to change.

The advantages of lean techniques include

i) Generation of a smooth work flow without waste
ii) Reduction of wastes generated from the project activities

iii) Increasing the profit and the market share iv) Improving the safety and workers morale
iv) Increasing team empowerment
v) Improving customer satisfaction
vi) Delivering the projects at the stipulated time.

**Classification of Construction waste through lean construction approach**

Construction waste is classified on the basis of different features such as quantity, type, etc. Excess materials, delays, defects and rework are the most common wastes.The non-physical wastes from the construction processes is the basis of waste concept from lean construction approach. Actually the lean construction concept recompense special attention to construction process waste, which is further divided into two main categories i) waste due to nature of processes ii) waste due to non-value adding work. The wastes mentioned in construction process category are not entirely due to nature of process or due to non-value adding works. The classification based on lean construction approach was given in figure A1.

**Lean Construction Key Performance Indicators (LC-KPIs)**

The Lean Construction Key Performance Indicators (LC-KPIs) are revealed in terms of five important aspects. They are quality, speed, cost, waste and value indices.

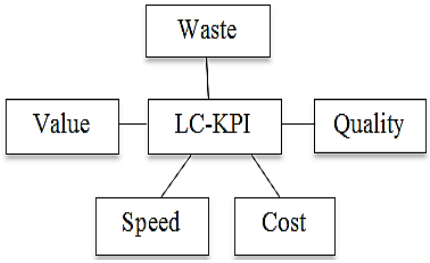


**Figure 1.** LC-KPIs

The explanation for the proposed five LC-KPIs as given in figure 1 is as follows.

a. Sigma Rating (SR): The degree of excellence i.e. the quality of work is measured to highlight the complementary function of sigma and lean methods through sigma rating. The SR value thus obtained is compared with benchmark value of sigma rating to conclude whether DMAIC (Define, Measure, Analyze, Improve and Control) sigma betterment survey is required or not.
b. The key aspects in LC are the speed of the project and the efficacy of the cost. The representative measures in the Earned Value Management System (EVMS) are the schedule performance index and the cost performance index are the representative measures in the Earned Value Management System (EVMS). EVMS is a technique which relates the project resources to schedule and technical performance in the project status.
c. The value and waste indices are necessary to measure the real impact of embracing the lean techniques in the construction process. Lean construction techniques translate the floor into low inventorying levels, less material waste and low impartation and the motility of labour and material in addition to less shortcoming and plan effectiveness and higher cost.

**Lean supply**

Supply concerns to the hand-off between a supplier and a customer. Supply constitutes three flows inorder to stress the flow in the transformation flow value. The basic concept depicting supply chain is given in figure 2.

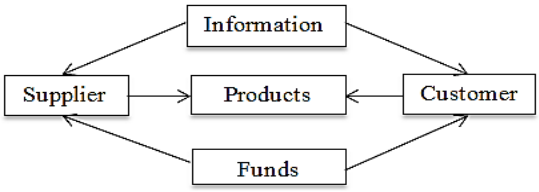


**Figure 2.** Flow supply

The flows comprised by the supply are as follows:

i) a bi-directional exchange of information

ii) a uni-directional flow of goods or services from the supplier to the customer.

iii) a uni-directional flow of funds between the customer and the supplier.

Figure 2 demonstrates that flows are sledding directly from the supplier to the customer and back, nevertheless flows can also take place in an indirect manner. More precisely, supply is concerned to the operation resulting in the conveying of goods and services to the sites. The implemention of lean production principles and techniques to supplier-consumer relationships, across organizational boundaries leads to attaining lean supply. The linkage of suppliers and customers through various flows are referred to as supply chain. To integrate the functions, goals and objectives of logistics, procurement and production, the supply-chain management field has been emerged.

**Lean supply chain**

Lean supply chains are designed by keeping the following value-adding tasks in mind.

i) physical movement of products
ii) change in unit of hand-off
iii) short-term storage to enable synchronization
iv) presuming information at the right time

Lean supply aims at opportunities for modularization, utilizing standard materials and ingredients, early assembly, in order to invalidate the matching problems and the consequence of merge bias downstream. Lean supply also

aims to contemporize transportation speed adjustment and supplier and customer production inorder to balance the supply and demand.

### Lean design

Design includes not only product design, but also process design. Product design describes what is to be produced and used, while process design describes how to produce it or use it. Designing provides information to distinguish positive and negative reiteration and also to reduce negative iteration. The challenges of lean design includes i) governing the time and cost, and the target of the waste reduction of the project objectives without reduction in the value ii) producing, evaluating and recognizing alignment between causes, ideas and criteria; the necessity for transferring a project from project definition into proper design iii) capturing and producing accessible design reasoning of a facility iv) reducing the utility loss, the project proceed through its stages. Lean Project Delivery System is represented in figure A2.

### Benefits of lean design

The value generation and waste reduction is improved by acquiring a lean design approach. Value is produced for the identification, inspiration and clarification for stakeholder purposes by a set-based strategy. Waste is minimized by the superior product design of the lean approach. The advantages of product design are i) can be more economically and satisfactorily manipulated and retained ii) They are easily, securely and quickly built to a greater extent iii) They are easily unchanged and produces environmental damage to a lesser extent throughout apprehension and demolition

## RESULTS AND DISCUSSION

The efficiency of the construction industry is increased by means of proper planning and control. The dynamic processes in lean construction are planning and control. Planning points out the criteria and develop strategies so as to reach the project objectives while control confirms the events of the planned sequence. If the planned sequences are not convenient re-planning has to be done. One of the best known lean techniques is the Last Planner System (LPS). It is an important tool for construction management process and a monitor for planning efficiency inorder to assist the smooth workflow variations, reducing the uncertainties plaguing in construction processes and development of foresight. It also consists of work flow control and production unit control.

Work flow control is accomplished through look-ahead process, while production unit control is accomplished through weekly work planning. The lean production management is devoted to minimize and to regulate variability and unpredictability in the implementation of the project plans. The potential variability is eliminated by the removal of the constraints. The implementation of the entire Lean Project Delivery System (LPDS) is achieved through shielding production. The production management assures that the work is done in a regular sequence and rate for the responsible releasement to the customer. The works are reviewed on weekly basis so that any change in design indices are done at the earliest which also prevents restructuring of the entire work. Figure 3 indicates the change of PPC of the project after the implementation of the last planner system. It shows that the productivity of the project has been enhanced to 86% due to the improvement in work flow reliability.

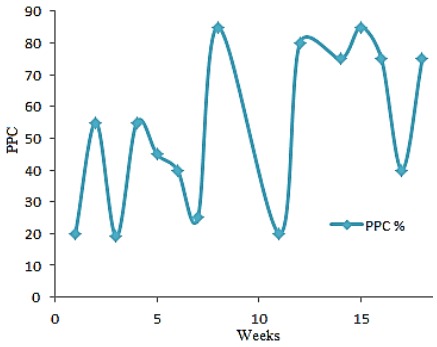


**Figure 3.** PPC improvement with Last planner implementation

Figure 3 is uneven, where at the initial stage, PPC seems to be regular till the 5th week and then rises to the peak point. This is due to the implementation of last planner system. After this rising, it again falls back to the previous level. This fall back was related to the payment shortage and lack of labour. When these shortcomings were removed, PPC went higher, improving the rate and preventing the reoccurring of the existed limitations.

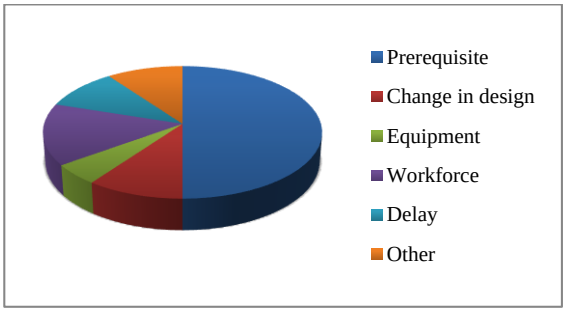


**Figure 4.** Reason behind the rise and drop of PPC

The ratio in relation to the prior condition of the workflow as in figure 4 accounts higher among other factors of design change, device error or work delay. Inadequate labour and construction materials were also experienced in the area where the work is manifested. Planning and scheduling techniques were improved after the consideration of all the reasonable factors. Rework due to the failure of the initial plan was also minimized due to the development of last planner system in the project.

The influence of PPC on productivity is illustrated in figure 5. In customary project management, the variability is found to

be independent on management action so that the trade-off is fixed at an exact point of time and cost.

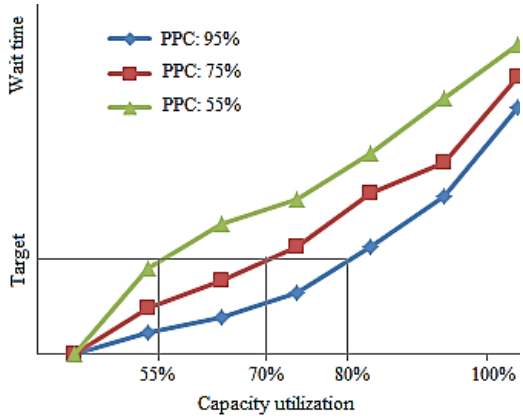


**Figure 5.** Improving the trade-off between time and cost by increasing the work flow variability.

55% of PPC corresponds to 55% of utilization rate. Increasing PPC to 75% increased the utilization rate to 70% and so the productivity improvement is high. The pace of completion can be increased without increasing the labour cost. While increasing PPC from 55% to 75%, greater improvements in productivity is observed and further increasing the percent plan leads to 80% of capacity utilization.

## CONCLUSION

This research focuses on the minimization of waste generation. Upon comparing several methods, the proposed method based on lean design results in better performance, where the increased values prove that this proposed strategy is productive and the trade-off between time and cost has been enhanced by increasing the work flow variability. Design of last planner system in lean design assists in waste management at the construction site besides keeping check of other factors that makes the productivity getting lowered.

## REFERENCES

[1] Jaime Solis-Guzman, Madelyn Marrero and Antonio Ramirez-de-Arellano, Methodology for Determining the Ecological Footprint of the Construction of Residential Buildings in Andalusia, Ecological Indicators, Vol. 25, 2012, pp. 239–249, http://dx.doi.org/10.1016/j.ecolind.2012.10.008.

[2] Waldo Galle, Mieke Vandenbroucke and Niels De Temmerman, Life Cycle Costing as an Early Stage Feasibility Analysis: The Adaptable Transformation of Willy Van Der Meeren's Student Residences, Procedia: Economics and Finance, Vol. 21, 2015, pp. 14-22, http://dx.doi.org/10.1016/S2212-5671(15)00145-8.

[3] Sasitharan Nagapan, Smail Abdul Rahman, Ade Asmi, and Nur Fadhilah Adnan, Study of Site's Construction Waste in Batu Pahat, Johor, Procedia Engineering, Vol. 53, 2013, pp. 99-103, http://dx.doi.org/10.1016/j.proeng.2013.02.015.

[4] Julie Emerald Jiju, Complications of Construction in Metro based on Planning and Management, Journal of Advances in Civil Engineering, Vol. 1, No. 1, 2015, pp. 18-24 http://dx.doi.org/10.18831/djcivil.org/2015011004 2455-3581.

[5] H.P.Yuan, L.Y.Shen, Jane J.L.Hao and W.S.Lu, Resources, A Model for Cost–Benefit Analysis of Construction and Demolition Waste Management throughout the Waste Chain, Conservation and Recycling, Vol. 55, 2011, pp. 604–612.

[6] Job Thomas and P.M.Wilson, Construction Waste Management in India, American Journal of Engineering Research, Vol. 2, pp. 6-9.

[7] M.Sivaraja, Installation of Durable Runway using Firm Concrete Composite, Journal of Advances in Civil Engineering, Vol. 2, No. 3, 2016, pp. 9-15, http://dx.doi.org/10.18831/djcivil.org/2016031002.

[8] J.Prakash Arul Jose and Fleming Prakash, Construction of Reusable Terrace Roof using Blended Paper Pulp and Silica Aerogel, Journal of Advances in Civil Engineering, Vol. 2, No. 3, 2016, pp. 1-8, http://dx.doi.org/10.18831/djcivil.org/2016031001.

[9] Amal Bakshan, Issam Srour, Ghassan Chehab and Mutasem El-Fadel, A Field Based Methodology for Estimating Waste Generation Rates at Various Stages of Construction Projects, Conservation and Recycling, Vol. 100, 2015, pp. 70-80, http://dx.doi.org/10.1016/j.resconrec.2015.04.002.

[10] Atiq Uz Zaman, A Comprehensive Review of the Development of Zero Waste Management: Lessons Learned and Guidelines, Journal of Cleaner Production, Vol. 91, 2015, pp.12-25, http://dx.doi.org/10.1016/j.jclepro.2014.12.013.

[11] Sallehan Ismail, Kwan Wai Hoe and Mahyuddin Ramli, Sustainable Aggregates: The Potential and Challenge for Natural Resources Conservation, Procedia - Social and Behavioral Sciences, Vol. 101, 2013, pp. 100-109, http://dx.doi.org/10.1016/j.sbspro.2013.07.183.

[12] Zezhou Wu, Ann T.W. Yu, Liyin Shen, Guiwen Liu, Quantifying construction and demolition waste: An analytical review, Waste Management, Vol. 34, 2014, pp. 1683–1692.

[13] P.M.Diaz, Analysis of Benefits, Advantages and Challenges of Building Information Modelling in Construction Industry, Journal of Advances in Civil Engineering, Vol. 2, No. 2, 2016, pp. 1-11, http://dx.doi.org/10.18831/djcivil.org/2016021001.

[14] A.Perera, Fiji towards zero waste: Effectiveness of empowering children and youth of Fiji Islands for integrated waste management, Journal of Solid Waste

Technology & Management, Vol. 42, No. 1, 2016, pp. 982-985.

[15] Sadhan K.Ghosh, H.S.Haldar, S.Chatterjee and P.Ghosh, An Optimization Model on Construction and Demolition Waste Quantification from Building, Procedia Environmental Sciences, Vol. 35, 2016, pp. 279-288, http://dx.doi.org/10.1016/j.proenv.2016.07.008.

[16] Ankit Bhatla, Bulu Pradhan and Jin Ouk Choi, Identifying Wastes in Construction Process and Implementing the Last Planner System in India, KICEM Journal of Construction Engineering and Project Management, Vol. 6, No. 1, 2016, pp. 11-19, http://dx.doi.org/10.6106/JCEPM.2016.6.1.011

[17] R.Pugazhenthi, R.Saravanan and M.Anthony Xavior, A New Heuristic for Modern Manufacturing Environment Scheduling Problems, Journal of Advances in Mechanical Engineering and Science, Vol. 1, No. 1, 2015, pp. 1-11 http://dx.doi.org/10.18831/james.in/2015011001.

[18] Muluken Yeheyis, Kasun Hewage, M.Shahria Alam, Cigdem Eskicioglu and Rehan Sadiq, An Overview of Construction and Demolition Waste Management in Canada: A Lifecycle Analysis Approach to Sustainability, Clean Technologies and Environmental Policy, Vol. 15, No. 1, 2013, pp. 81–91, http://dx.doi.org/10.1007/s10098-012-0481-6.

[19] Paola Villoria Saez, Cesar Porras-Amores and Mercedes del Rio Merino, New Quantification Proposal for Construction Waste Generation in New Residential Constructions, Journal of Cleaner Production, Vol. 102, 2015, pp. 58-65, http://dx.doi.org/10.1016/j.jclepro.2015.04.029.

[20] Mansi Jain, Economic Aspects of Construction Waste Materials in Terms of Cost Savings – A Case of Indian Construction Industry, International Journal of Scientific and Research Publications, Vol. 2, No. 10, 2012.

## APPENDIX

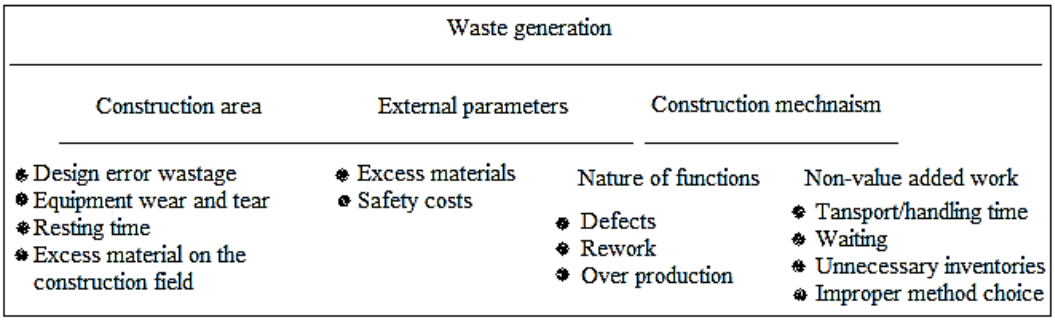


Figure A1.Construction waste classification using lean construction approach

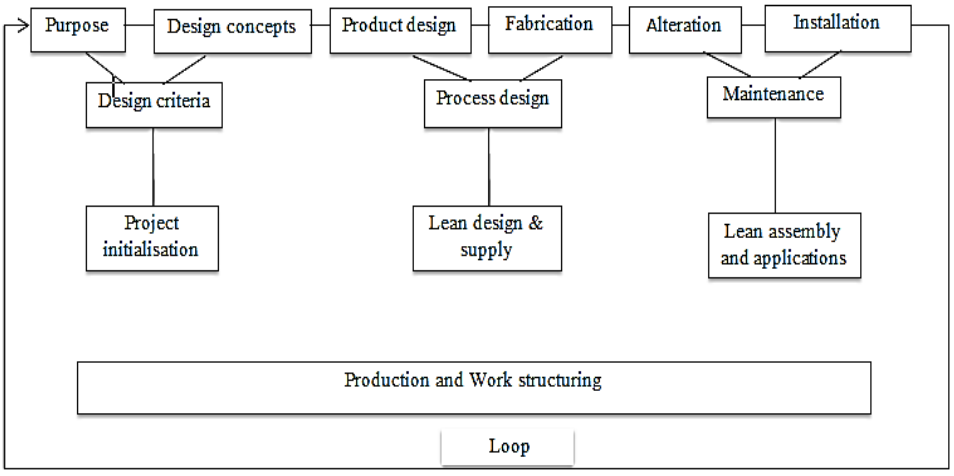


Figure A2.Lean Project Delivery System (LPDS)