ENHANCING SUSTAINABILITY OF CONSTRUCTION PROJECTS THROUGH WASTE MINIMIZATION

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Abstract: Construction activity is a critical indicator of development. As developmental activities in emerging countries are increasing, the construction industry is being viewed with increased interest as an area which needs sustainable practices. The construction industry uses 55% of the wood cut for non-fuel uses and 40 % of the world's energy and a large proportion of the material manufactured can be traced to buildings and their construction. To make construction sustainable, all of its stages from conception to deconstruction need to be considered with the viewpoint of waste minimization. This paper looks at the execution stage of a construction project and seeks to identify the sources of waste generation at the planning and execution stage. A detailed field study and subsequent root cause analysis of the execution planning process has been done to identify the factors that lead to erratic and variable execution performance and thus create waste in the form of inventory and rework. An attempt has been made to study, categorize and quantify waste related to MEP works on building sites which typically account for about 40% of the project construction cost. The studies have incorporated expert views, interviews with on-site personnel, study of documents and actual field sampling. Based on the observations, multiple solution concepts has been proposed. The proposed solutions aim at reducing the generation of waste through better execution planning and control.

Keywords: Waste minimization, planning & execution, MEP

1. Introduction

The Conseil International du Batiment (CIB) defines sustainable construction as "… creating and operating a healthy built environment based on resource efficiency and ecological design." Huovila & Koskela (1998) identified energy efficiency, non-toxics, recyclability, preserving property value, flexibility, long service life, use of local resources, information dissemination, use of by-products and efficient mobility as the important sustainability criteria for the built environment.

The construction industry warrants a special focus from the standpoint of sustainability considering the nature of its material and energy inputs.. The construction industry uses 55% of the wood cut for non-fuel uses and 40 % of the world's energy and material consumption can be related to buildings and their construction. 54% of energy consumption in the U.S. is directly or indirectly related to buildings and their construction. Nearly one-quarter of all ozone-depleting chlorofluorocarbons (CFCs) are emitted by building air conditioners and the processes used to manufacture building materials. Also, construction and demolition waste has typically accounted for almost 65% of Hong Kong's and about 50% of UK's landfills at the peak of construction activity.

Construction waste is thus a major area of concern. The Indian construction industry is unique due to its labour intensive nature and consequent aversion towards mechanization and automation. Despite the booming size of the Indian construction industry, the issue of sustainability is still not being given due consideration.

The objective of the research study was to analyze at the project and execution planning process and its influence on the level of waste generation. This is based on the premise that poor planning and coordination results in poor procurement schedules, rework and improper waste management, which leads to the generation of waste. The study specifically focuses on Indian building sites to find the impact and root causes of planning inefficiencies. As MEP works typically account for about 40% of the project cost on modern building sites, the study also attempts to analyze, categorize and quantify

MEP waste on the projects. Based on the findings from the study, solution concepts that would help in making the construction process more sustainable are proposed.

2. Literature survey

Abundant literature exists in the field of construction and demolition (C&D) waste. Numerous studies have looked at quantifying and analyzing the nature of construction waste generated in construction in various parts of the world. Studies by Apotheker (1990), Craven et al (1994), Ferguson et al (1995) and Stokoe et al (1999) have quantified C&D waste in numerous countries and found it to be a significant impediment to sustainability. Concrete and mortar have been identified as the major components of C&D waste. Also, the presence of materials such as asbestos and Volatile Organic Compounds (VOCs) in C&D waste makes it extremely hazardous. Studies also document and suggest the various strategies that have been devised to manage the generation, handling and recycling of C&D waste. But relatively little work has been done to study the causes of waste generation and to quantify the details.

Bossink & Brouwers (1996) found that the amount of construction waste depends on the construction techniques employed, work procedures and common practices. They also identified the sources and causes of C&D waste which, among other factors, included (a) error in contract documents (b) lack of knowledge of construction methods (c) improper material handling (d) improper planning of material procurement and (e) damage caused by subsequent trades. Esin & Cosgun (2006) found that change in specifications due to change in end user requirements generated a significant amount of waste. This leads to the conclusion that poor project and execution planning contributes significantly towards C&D waste.

Over the years, research has attempted to analyze the problems and challenges associated with the project planning process. Collingridge et al (1994) predicted that technologies with high capital intensity, large unit size, long lead time, and high infrastructural requirements are susceptible to large schedule delays. Goldratt (1997) identified three basic reasons why even well-planned projects run into problems which are:

1. Activity level contingencies: Unduly large amount of safety built into individual activities
2. Student syndrome: Tendency to delay the application of peak effort to the last possible moment
3. Multitasking: Tendency to distribute available resources over multiple concomitant activities

Xiao & Proverbs (2002) evaluated and compared the construction time performance of construction contractors in Japan, the United States of America and the United Kingdom. They concluded that while Japanese construction contractors achieved superior levels of time performance through detailed planning & by working more closely with subcontractors, contractors in the US and UK suffered because of less intensive schedule planning & monitoring, adversarial relationships & lack of pragmatic thinking. Kar (2009) reports lack of advance planning, a holistic approach, inconsistency in monitoring and follow-up, coordination and communication lapses and absence of a methodical approach as major causes of project failures in developing countries.

Koskela (1992) proposed new concept of waste as incident of material losses and the execution of unnecessary works, which generate additional costs but do not add value to the product. Only processing activities were assumed as value adding activities. Hence target for continuous improvement can be achieved by eliminating / reducing the share of non value adding activities and increasing the efficiency of value adding activities.

The most classical waste categorization according to lean production philosophy was given by Ohno (1988) which has been quoted by Formoso et al. (1999) and Koskela (2000). Following is the 7 wastes proposed by Ohno, of which the first five refer to flow of material and the last two is due to work of men: (a) Waste of overproduction (b) Waste of correction (c) Waste of material movement (d) Waste of processing (e) Waste of inventory (f) Waste of waiting (g) Waste of motion.

Instead of classifying waste of productive time, Serpell et al. (1995) have classified these wastes in relation to work categories. There are three types of work categories as proposed:

1. Productive work (value-adding activities)
2. Contributory work (non value-adding activities but essential for conversion process)
3. Non-contributory work (non value-adding activities)

Result of research studies carried out on Brazilian building construction projects by Formoso et al. (2002) indicates that the amount of material waste is very high and there is a large variability in waste incident across different projects. Research conducted in Netherland by Bossink and Brouwers (1998) indicated material waste in range of 1 - 10% in weight of the purchased amount of materials. The main causes of waste were identified as upstream process, such as design and material supply, as well as poor handling of materials in transportation and storage. Garas et al. (2001) conducted research in the Egyptian construction industry to find out the causes of the waste present. The study indicated that late information and changes to design were the most fundamental causes of material waste.

A general frame work for construction improvement and waste reduction was developed by Serpell and Alarcon (1998) which has been successfully applied to several construction sites in Chile. An analysis of the relationship between buffers (inventory) and construction labour performance done by Horman and Thomos (2005) in Brazil shows that some buffers helps in achieving the best labour performance in construction operations.

Although past work has addressed the issue of waste due to inadequate planning, no formal study has identified the factors and investigated root causes relevant to the Indian industry and quantified the levels of waste.

3. Methodology

The data for the study to identify the factors related to inadequate planning in the Indian construction industry was collected through a variety of methods. Site visits were made to multiple Indian building projects in various stages of completion. Interviews and meetings were held with the project managers, planning staff, section in-charges and execution engineers of the sites. Foremen, supervisors and workers were interviewed to get a clear perspective of project execution at the operational level. Project BoQs and contract documents were studied. The project planning and execution planning documents like construction schedules, monthly reports, Daily Progress Reports, Minutes of Meetings, catch-up schedules, method statements, clearance certificates and other formats were studied to understand the existent project planning, control and monitoring mechanisms. The observations were then collated and a root cause analysis was done.
A model to quantify the levels of waste was developed with the help of literature survey. Empirical formulae were used to measure the cost of waste due to labour inefficiency, material scrap and excess inventory. Tour based work sampling (Liou and Borcherding 1985) was conducted to get the problem areas related to workers inefficiencies. Crew work sampling was then done to get to know the actual problems associated with those areas. All activities were listed and categorized in three categories as value added, non-value added and non-value added but required. Finally modified work sampling was done for all processes to measure time spent by labourers in these work categories. Store records like material request forms, material receipt & issue details, inventory ledgers were and cost statements were studied to analyze the material handling and management at the sites.

Based on the studies conducted, a techno managerial solution concept was developed. The Theory of Constraints was used to develop a new execution planning logic. A simulation model was developed in STROBOSCOPE using Microsoft Visio, to replicate FPS process as practiced at various sites. This model was tested using work sampling data collected at site and through questionnaires. Four ways to minimize waste were suggested and implemented through simulation and results were discussed.

4. Study of the planning process

4.1 Definitions
It is worthwhile to define the terms project planning and execution planning at this stage. These are explained below.

1. ***Project planning***
    a. Focuses on overall scheduling for a project, to meet broad targets of cost, time, quality and safety
    b. Considers only precedence relationships, as resource and information availability data may be both unavailable and irrelevant at this stage
    c. Is relevant at senior management level
    d. Has limitations with respect to execution planning
2. ***Execution planning***
    a. Focuses on scheduling at activity level, to provide a realistic execution plan
    b. Should consider both precedence and resource/information constraints
    c. Needs to study and factor actual field conditions
    d. Is more relevant to the operational level task force

Ideally, a robust execution plan depends on, and is to be derived from a robust project plan. While the project plan provides the broad framework for project execution, the execution plan uses this framework to work out the details of execution and presents an executable plan to the field level operational force, taking into account all realtime project constraints and conditions. So, there should be a tight correspondence between a project plan and an execution plan.

4.2 Observations
4.2.1 The execution planning process
Based on the observations made during the course of the present study, the problems in the execution planning process were identified (Table 1).T As a result of these problems, the planning process tends to be more reactive than proactive, this frequently leads to cost and time overruns. Thus, there is a large amount of variability in the construction process which is not factored into planning. This variability can only be reduced if a structured planning process with a sound tracking and feedback structure is implemented.

Table 1: Problems existent in the Execution Planning Process

Problem	Elucidation
Inadequately detailed project master schedule	• Too broad • No logical precedence linking
Insufficient schedule interaction	Inconsistent interaction between Master Construction Schedule (MCS) and package schedules
Discontinuous schedule updation	• Deviations with project progress, the large number of activities and the complex interrelationships. • Lack of manpower trained to work on packages like MSP and Primavera
Inadequate detailing of execution plan	• Only dates, no quantities • Co-ordination aspects not considered • Inaccurate duration estimation
Insufficiently developed coordination planning mechanism	• Critical for finishing and services • Co-ordination drawings prepared to resolve spatial conflicts • The sequence in which various trades have to enter and work in an area is done through verbal meetings
Inadequate project monitoring systems wrt activities	Cost implications of activity crashing and delays due to coordination problems, material unavailability etc. not captured easily.

Apart from the flawed planning process, problems were also found during execution. Interviews to execution engineer, foremen and workers gave insights to some problems associated with execution which were responsible for delayed project completion. These problems were playing crucial role in variable project duration. Some of the problems associated with execution, observed during work sampling are listed in Table 2.

Table 2: Observed Problems in the Execution Process

Problem	Manifestation
Design Problems	• Lack of co-ordination b/w structural and services drawings • Frequent Changes in design during construction • Delay due to drawings / finalization of interiors • Level difference due to mistake in drawing / execution
Execution Problems	• Co-ordination with other services • Co-operation of specialized agency to the engineer. • Damages to the fixtures holes due to civil works (plastering) • Clearance from other departments (present at all sites) • Use of superseded drawings • Space constraints • Structural accuracy of constructed structure
Material Problems	Material procurement, Storage and Shifting
Manpower Problems	Lack of skilled Manpower & Contractor

Based on the findings of the field study, a root cause analysis of the execution planning mechanism in Indian construction projects was done the results are presented in Figure 1 in the form of a fishbone diagram.

A more detailed study on quantifying the waste due to MEP processes was then carried out. It was found that many of the issues faced in executing MEP was similar to general construction.

5. Assessment and quantification of MEP waste

Execution problems associated with manpower was assessed by conducting work sampling. Activities performed by workers were categorized under Value Added, Non-value Added and Non-value Added but Required. Modified Crew Work Sampling (Liou & Borcherding 1985) was done to assess worker efficiency for all major processes of MEP.

Waste was measured for labour and material in terms of cost using empirical formulae. Cost of labour inefficiency represents the costs spend on labourers for their NVA and NVAR works. Material waste is a measure of cost of material scrap and cost of excess inventories. Cost of excess inventories is the loss of opportunities of interests on the investments which are kept excess in store.

Figure 2 represents the waste in percentage of total project cost

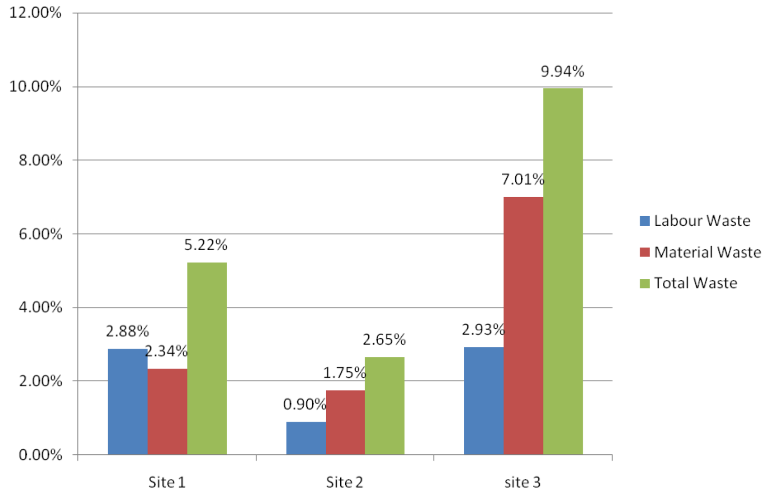

Figure 2: MEP Waste as percentage of Project Cost

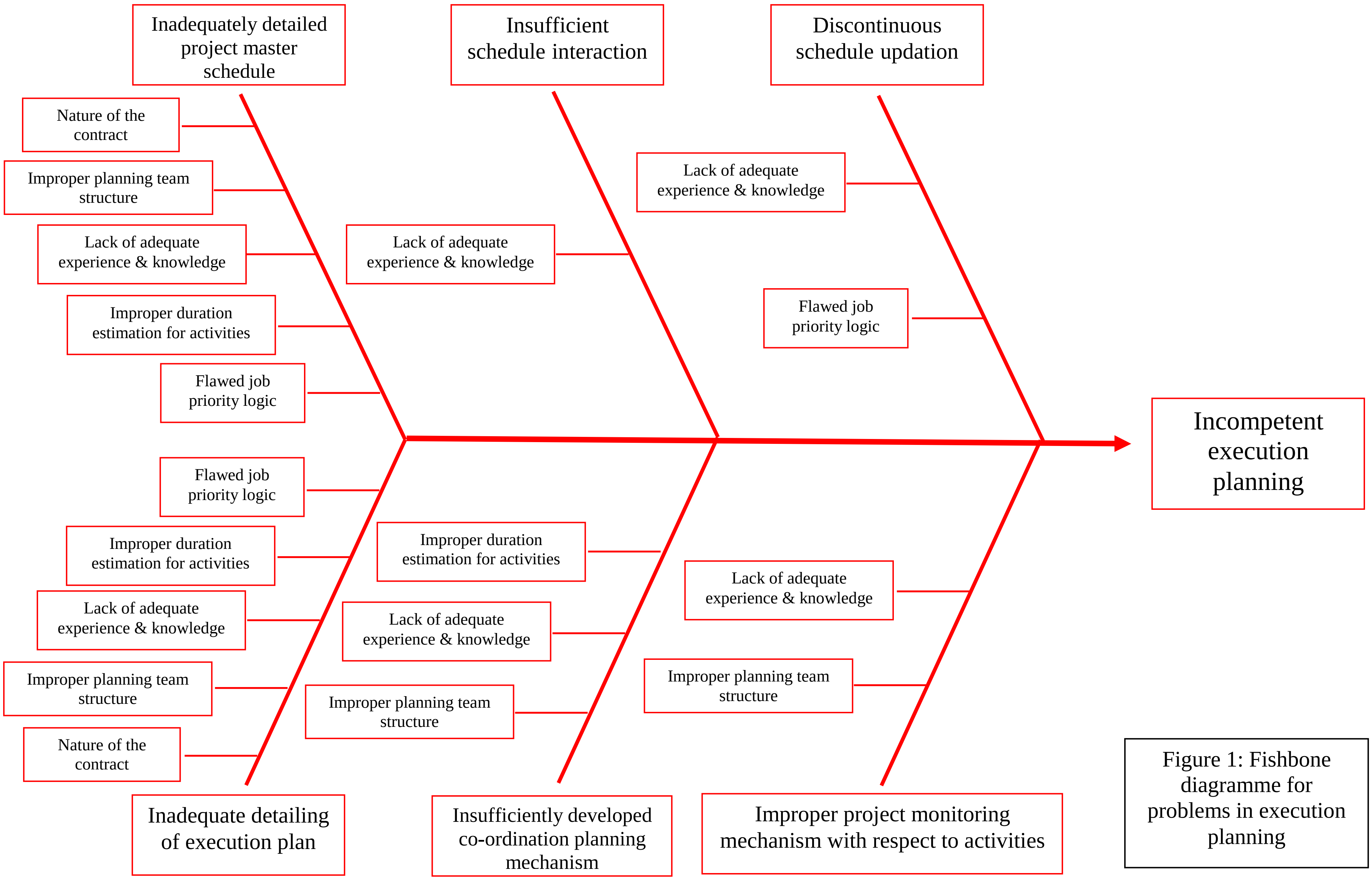

Figure 1: Fishbone diagramme for problems in execution planning

Though MEP execution is not labour intensive, cost of labour inefficiency was almost 3% of the project cost which is alarming. Direct cost may be small but improving productivity could decrease project duration marginally and would have more benefits. Large portion of material waste was found due to excess inventory at site. Excess inventory was attributed to the fact that material was procured in bulk if it was to be imported, or to achieve price advantage from the vendor.

6. Root Cause Analysis

As the study analyzed and concluded, the major reasons directly or indirectly causing these improprieties can be categorized as shown in Table 3.

Table 3: Roots Causes behind Problems in the Execution Planning Process

Root cause	Elucidation
The nature of the contract	• LSTK or BOT contracts – milestone based • This is reflected in the detailing of the MCS
Improper planning team structure	• Top-down scheduling • Inputs from site staff not fully utilized
Lack of adequate knowledge experience	• Significant problem for finishing and services • Use of thumb rules – risky approach
Improper duration estimation for activities	• Lack of experience, absence of benchmarks • Imposition of forced completion dates
Flawed job priority logic	• Traditional emphasis on progress reporting • Commercial considerations override technical considerations • Client imposed handover dates

While doing work sampling many issues were observed which were causing inefficiency to workmen. These problems were analyzed in detail to get the root causes. Table 3 represents the root cause analysis of execution problems observed.

Table 4: Root Causes behind Observed Execution Problems

Problem	Root Cause
Idle and Waiting Time	• Inappropriate crew size • Poor assignment of work • Unavailability of interdependent team mates
No contact	• Lengthy process of material issue • Labour used for arranging snacks
Poor housekeeping	• Lack of control of site engineers over workers • Lack of knowledge towards ill effects of poor housekeeping
Late Start of work	• Lack of management commitment
Same crew working at different levels	• Competition among crew to get more work • Management wish to allot similar works
Lack of co-ordination	• Poor scheduling • Unavailability of all details from beginning

7. Results and Discussion

The field studies conducted in some building construction sites in India helped understand the process of execution planning and its influence on sustainable practices. The study to assess and quantify of MEP waste found that the total MEP waste was 9.94% of the total Project Cost, which is a significant and alarming fraction. The root causes behind the existent problems with project execution were also identified.

This study helps us to identify the role of proper planning at the project and execution level in determining the sustainability of construction projects. Thus, this issue needs to be approached in significant detail. Several solution approaches are being considered by the authors. The concept of Critical Chain Project Management has been used to design a new execution planning logic that utilizes realtime field data to come up with realistic execution plans. The potential of Building Information Modelling is being utilized in constructing 4-D simulations of structures which help in better visualization at the planning stage and thus more effective and less variable execution. Simulation packages like Stroboscope have been used to simulate scenarios with improved construction practices with respect to labour and material utilization. Assuming that all the levels of the organization are ready to internalize and utilize the concepts, these can be very effective tools in reducing the levels of waste and making the construction process more sustainable.

References

48. Augenbroe G.L.M, Pearce A.R., "Sustainable Construction in the USA: Perspectives to the year 2010", 2009.
49. Bossink, B.A.G., Brouwers, H. J. H., "Construction waste: Quantification and source evaluation", Journal of Construction Engineering and Management, ASCE, 122(1), 55-60, 1996.
50. Collingridge D. et al, "Inflexibility in the development of North Sea Oil", Technological Forecasting and Social Change, 45(2): 169 – 188, 1994.
51. Esin Tulay, Cosgun Nilay, "A study conducted to reduce construction waste generation in Turkey", Building and Environment, 42: 1667 – 1674, 2006.
52. Formoso, C. T. et al, "Method for waste control in the building industry", Proceedings of the International Group for Lean Construction, 7th Annual Conference, University of California, Berkeley, CA, USA, 235-334, 1999.
53. Formoso, C. T. et al, "Material waste in building industry: Main causes and prevention", Journal of Construction Engineering and Management, ASCE, 128(4), 306-325, 2002.
54. Garas, G. L. et al, "Material waste in Egyptian construction industry", Proceedings, 9th Annual Conference of the International Group of Lean Construction, Singapore, 2001.
55. Goldratt E.M., "Critical Chain", Great Barrington MA, The North River Press, 1997.
56. Goldratt E.M., "The Goal", Great Barrington MA, The North River Press, 1st edition, 1984.
57. Horman, M. J., Thomas, H.R., "Role of inventory buffers in construction labour performance", Journal of Construction Engineering and Management, ASCE, 131(7), 834-843, 2005.
58. Huovila P., Koskela L., "Contributions of the principles of Lean Construction to meet the challenges of sustainable development", Proceedings IGLC '98, 1998.
59. Kar D., "Implementing construction projects on schedule – challenge in a developing economy", Journal of Economics & International Finance, 1(4): 088 – 092, 2009.
60. Koskela, L., "Application of the New Production Philosophy to Construction", Tech. Report No. 72, CIFE, Stanford Univ., California, 1992.
61. Koskela, L., "An exploration towards a production theory and its application to construction", Technical Research Centre of Finland, VIT Publications 408, Finland, 2000.
62. Liou, F. S., Borcherding, J. D., "Work sampling can predict unit rate productivity", Journal of Construction Engineering and Management, 112 (1), 90-103, 1985.
63. Ohno, Taiichi, "Toyota Production System: Beyond Large-Scale Production", Productivity Press, Cambridge, MA. 143 p, 1988.
64. Roodman D.M., Lenssen N., "Worldwatch Paper #124: A Building Revolution: How Ecology and Health Concerns Are Transforming Construction", Worldwatch Institute, 1995.
65. Serpell, A., Alarcon, L. F., "Construction process improvement methodology for construction projects", International Journal of Project Management 16(4), 215-221, 1998.
66. Serpell, A., Venturi, A., and Contreras, J., "Characterization of waste in building construction projects", Proceeding, 3rd Conference of the International Group of Lean Construction, University of New Mexico, Albuquerque, USA, 1995.
67. Shen Li-yin et al, "Benefit analysis on replacing in-situ concreting with precast slabs for temporary construction works in pursuing sustainable construction practice", Resources, Conservation and Recycling, 53: 145 – 148, 2008.
68. Xiao H., Proverbs D., "Construction Time Performance: an evaluation of contractors from Japan, the UK and the US, Engineering", Construction & Architectural Management, 9(2): 81 – 89, 2002.

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