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A Proposed Solution to the Problem of Construction Industry Overruns: Lean Construction Techniques and Linear Programming

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Abstract

Background: This paper will suggest that combined strategy of Lean Construction techniques with Linear Programming as a possible solution to the problem of overruns in construction work. It will seek to examine how a combination of Lean Construction techniques and a base software model of Linear Programming can apply to a construction project at the initial and intermediate planning stage to overcome challenges related to project overruns. Based on a literature review and data collection it will investigate if the combination of Lean Construction techniques and Linear Programming could result in time and cost assurances in a construction project**. Objective:** To investigate to what extent a combination strategy of Lean Construction principles and Linear Programming could help solve the problem of overruns in time and costs in construction. **Analysis:** The research work deals with the application of lean construction principles such as Last planner system Just in time etc. at the first part of the project and then the second part introduces formation of linear programming model base on the output of first part. The collective result of the combination is then measured. **Expected Findings:** Time and Cost overrun can be easily overcome through applying the combination of Lean construction techniques, and linear programming was implemented. Project planning and scheduling can be improved in the early phase of the project, which helps to avoid delays and failure of project occurring at a later stage.**Improvement:** The combination of both is never used in the construction industry so far, so this project gives initial strategy to do so for small scale construction project first, and after successful implementation, it can be applied to the large scale construction project.

Keywords: Lean Construction, Linear Programming, Planning and Scheduling, Time Cost Trade–Off

1. Introduction

From the days of early industrialization, the construction industry has suffered from overruns in both time and cost. One famous example included the Sydney Opera House, which was estimated to cost USD$7 million but ended up costing USD$102 million, and while the original project duration was approximated at four years, it took more than ten years to complete. The project started without final drawings from architect and later on government changed the scope and withheld the payments of the architect in the middle of execution. The overrun was mainly because of improper coordination between designer and government, lack of planning at an early stage and political influence[1].

Huang studied one of the longest construction delays in South Asia. He found that the Sino Iron mine (located on the west coast of Australia and solely Chinese owned) was started in 2006 and completed three years later than scheduled. The initial estimated cost of the project was USD$2.5 billion, but on completion, it was found to be USD$8 billion. The primary reason behind the overrun is said to be contractor's lack of international experience (Particularly in the mining industry), failure in corporate management and government administration and proce-

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dures. The project was completed on time if the contractor had done the ground testing of Australian construction industry[2]. Another example is the Wembley Stadium in the UK, which according to the Comptroller and Auditor General's report was delayed initially by two years and by a further year, and the final cost was twice as much as the original budget. Poor and less experience project management by Wembley National Stadium Limited (WNSL) leads to failure of the project. In the early stage of Planning, cost and duration were falsely estimated and at the time of execution poor quality management was maintained. WNSL is still suffering from massive loss instead of profit as the loan amount is huge and the stadium does not host the predicted number of events.

According to Chidambaram, the delays may occur due to some of the following: changes to the scope of works, the struggle to use local standards to reach global levels, unavailability of workers, breach of contract between contractor and client, fluctuation of material price, financial and political interference. To get a better understanding of this, the overruns needs to be analyzed using both qualitative and quantitative approaches so that effective solutions can be found[3].

When looking at the risks associated with delays in the global construction market, it is important to examine its complete scenario, to identify, analyze and evaluate them sufficiently.

2. This Study is Divided as Follow

The introduction offers an overview of the construction market and identifies the problem of overruns.

The *first* part suggests a strategy for dealing with it, which is the combination of Lean Construction and Linear Programming.

The *second* part states the research questions.

Part three discusses traditional approaches of Lean Construction and Linear Programming.

Part four proposes a methodology to investigate the research questions.

Part five offers a proposed plan of study for achieving the research questions.

The conclusion section suggests expected outcomes and conclusions through the utilization of Lean Construction and Linear Programming in construction project management.

3. Introduction to the Problem of Overruns

The construction sector in every country makes a significant contribution to GDP, and as much as one-third of a nation's population depends on it. For example, in India, the construction industry is expected to reach USD$1 trillion by 2025 making India the third largest construction giant in Asia, unless it is struck by the plight of overruns (Global Construction Perspective, 2012)

In the UK, statistics reveal that for every GBP£1 spent on construction, at least 90% remains in the UK, the industry nearly employs 10 % of the population, and it remains one of the largest players.

However, since 2012, Europe has seen a downward turn, and there has been a decline in construction investment (Appendix A, Figure A1 and Graph) which continued into 2013 (Deloitte, 2012). Further evidence from the European Union shows a decrease in construction investment by 9.9%, 3.2%, 0.2%, and 2.8%, in Greece, Spain, and Slovenia respectively.

In addition to this, the European Commission forecasts did not anticipate positive growth rates for these countries until 2014 and still it is very much same for various economic and political reasons. However, interestingly, Denmark, Estonia and Lithuania indicated signs of recovery, which are being attributed to proper management, resource leveling, project strategy, newly developed policies and formats of work. Indeed, Denmark and Lithuania have shown significant comparative increases from the construction sector in its GDP contribution when compared with previous years.

Figure A2 (Appendix A) revealed that although in 2011 and 2012, both Germany and France continued to be the largest construction markets in the EU, it was with lesser investment than prior years due to the global recession. While it is notable that Western European countries have healthy construction markets, there is also data (Global Construction Survey, 2013, p.12-15) which suggests that they suffer from weak civil engineering, wrong design, improper management systems, insufficient resources, and so on. In addition to this, there is the risk of overruns due to poor analysis, improper cost estimates, failed contractor and client relationships, and other contingencies like weak management overseeing implementation and execution. Some of the key factors

which can save overruns according to[4] are: 1. Accurate estimates at the initial level, 2. An improved labor productivity index and 3. A higher additional contingencies estimate. Strategies like Six Sigma, successfully reviewed for timely completion of the project in different conditions with little modification.

A report by the UK National Audit Office, "Modernizing Construction, "noted that 70% of government departmental and related projects were delivered late. The delays were due to both external (macro) and internal (micro) factors. Domestic issues such as those mentioned in Figure A3 (Appendix- A) could be resolved by meetings between the contractor, client, and consultant. External factors, however, were more complicated to solve as they included aspects such as project financing, change in scope of works, land acquisition and progress of civil work[5].

In[6] noted that the South East Asian region is also plagued by issues of overrun and 30 % of total construction projects are either extended by time and budget or fail altogether. 87 Vietnamese construction firms are surveyed to know the causes of overrun. The reasons for the increase in budgeted costs include inflation in material prices, wrong methods of quantity surveying, and hikes in labor costs due to inflation and changes in the environmental conditions. A project in African and Asian continent faces the above causes mainly. Similarly, the delays in time are among other things due to weak labor outputs, improper or insufficient coordination, and material shortages. For wide base transactions there are always up and downs, including improper material procurement, unequal resource allocation, malpractices and wrong approaches such as unbalanced bidding and bias to selective subcontractors. Al-Sweet noted that it was important to work on such factors to try and curtail the effects of extended time and costs. The construction market in Gaza strip is unbalanced as the love for money (greed) is excessive in this region[7].

In addition to this, the construction sector faces skill shortages. Constructions delays are often accompanied by or as a consequence of changes in initial design, resource deficiency and allocation, and lack of timely decision making, amongst other reasons (Department of business innovation and skill, 2013, p.15). For example, Figure A2, (Appendix-A) shows that the investment and production decrease over the course of time and cost overruns delay project completion. Delays take place due to political pressure, government policies, basic infrastructure needs (which influences the investment), and client and contractor understanding, and the degree of output and skills of the labour force which affects completion and delivery. Indeed, it can be argued that some of the primary reasons for the decline in construction investment in Europe between 2009 to 2012 are a lack of managerial capacity, deficient proper execution, and an overall shortage of skilled workers.

However, it would be too simplistic to extrapolate the European situation to other parts of the world. Factors causing project overruns are very similar and yet different, depending where the construction is located. But generally speaking, external causes of project delays can be listed as follows:

- Economic;
- Technical;
- Environment; and
- Regulatory.

Under the economic reasons, the following can be included: project funding, resources for procurement, and scarcity of funds. The lack of these create a time lag in scheduled work, increases in time and cost, and ultimately result in project abandonment or failure[8].

The client, Quantity Surveyor, Architect and other famous people involved in construction activities in Nigeria are interviewed and below results were found.

Technical causes include a skills and knowledge deficiency about design, incorrect quantity surveys, and deviation from the original.

The environmental reasons refer to extreme climate changes (arid, windy, snowy), and remote geographical locations with inadequate infrastructure, which impacts the budget. These factors can alter the face of the project by introducing overrun issues[9].

Regulatory causes include failure of adequate and appropriate management controls, lack of oversight in monitoring and scheduling of project, delayed timely completion at initial stages, and lack of strategy in planning to curtail time and cost consumptions[10].

4. The Consequences of these are as Follows

Firstly, insufficient funds extend the project duration and cost.

Secondly, changes in design lead to the evolution of project execution and changes in the budgeted cost.

Thirdly, the initial climatic conditions and project review are set to achieve required goals. These must be considered by other change and not doing this could cost the project dearly, including project delays and failure.

One suggested solution is to use the combined strategy of Linear Programming and Lean Construction, and this forms the basis of this study investigation. The next section discusses this briefly.

Part One: Linear Programming and Lean Construction

As mentioned above, construction project work is affected by factors of time, cost, quality, and scope. Globally, the construction industry has been subjected to time and cost overruns for many decades and accordingly it is critical to establish the root causes of these overruns and find solutions. The bottom of the pyramid of any construction project is filled with risk its assessment and evaluation[11] and these must be borne in mind when seeking explanations and providing justified solutions. Linear Programming and Lean Constructions are two vital components of construction work and are offered here as solutions to the problem of overruns in time and budget.

Linear can be defined as "straight" or as a task with one objective. Therefore laying down all related factors successively is known as "Linear Programming."

Effective resource allocation to make a project more cost and time effective is one of the best tools used by the global construction sector. It can be defined as a maximizing or a minimizing the formed linear function on its constraints. Traditional scheduling methods like Critical Path Method (CPM) and Programme Evaluation Review Technique (PERT) have their pros and cons. CPM does not set resources and resource allocation whereas PERT fails to calculate cost analysis as the method is time oriented.

Linear functioning of a construction project is developed along the concepts of "line of balanced and linear scheduling" instead of regular schedule, and it can lead to timely completion[12]. About the construction sector, it refers to the strategic management of the workforce to control costs and the progress of the project[13]. Explains how Constraint Programming (CP) can be used as a searching algorithm for Linear programming model formulation. The model is formed as per objective function, and the algorithm helps to choose critical resources. Finally, the model gives a better way of resource utilization which later supports improved work efficiency.

Lean in the context of construction work refers to reduction or elimination. It can also refer to a sway from existing practice of work towards a new era of construction. The major project constraints are time, cost and quality. Over the past few decades, it has been observed that speeding up the progress of work to complete it in the stipulated time, leads to a related project cost increase. Similarly, attempts to reduce the cost leads to a similar compromise with output. Lean Construction does not suggest a strategy which is fast and cheap, on the contrary, it provides an opportunity to think smart[14]. A construction project involves different activities and with related several resources[15]. Studied the development fuzzy logic network to resolve the issue of time and cost overrun by preparing schedules. The network uses sensitivity analysis as resources are a constraint and compare between manual scheduling, CPM scheduling and Primavera planning and scheduling. Activities with small float and large resources should be considered as priority to stop the delay

Linear Programming can be defined as a stage by stage process where limited resources are allocated in an optimum way to each activity so that output becomes worthy. Linear describes and refers to sequential patterns of activities and programming indicates planning of those activities in a straight manner. When all activities and resources comply with project constraints the mathematical equation can be called a "Linear Programming model".

It is suggested that this model can lead to a reduction in time and cost with useful results.

Having provided a brief background of the sector, identified the problem of overruns and suggested a strategic solution, the next section briefly mentions the three research questions centered on the present investigation.

5. Part Two: The Research Questions

- How can Lean Construction techniques be used in small scale organizations?
- How can the Linear Programming model be conceptualized for construction projects?
- How can the combination of Lean Construction and Linear Programming be used as a strategy to solve the problem of overruns in construction projects?

Part Three: Traditional Approaches of Lean Construction and Linear Programming

According to EUROSTAT (2010), construction outputs continue to decline in Europe. The output in the EU of small and medium scale industries fell by 1.6% in the third quarter of 2009 compared with the previous quarter; employment decreased by 9.8% in the construction industry falling by over the third quarter when compared to a year earlier. One of the main reasons was delays in completion of projects. Several academics in this area[16,17] suggest different strategies for solving time and cost overrun issues such as project management techniques, Lean Construction principles, and Linear Programming. If nature of work and scope of the new project is similar then analysis of delays made on schedule, resources, and manpower in past project can be use as a fact sheet for a new project by which Management Information System (MIS) is prepared. MIS is majorly used for project monitoring and control. Last Planner and linear programming also gives the privilege to monitor and schedule the project activities[18].

Argues[19] that lean principle for construction ought to be used to some extent, but to what degree is still a topic of debate and depends on funds, flexibility, quality and management of labor. In the context of the UK construction market, all the principles of Lean Construction are taken for granted including Just In Time (JIT), Last Planner System, and Total Quality Management. However these are limited to a particular scope and it is worth calculating to what extent the Time Management, Last Planner System (LPS) and local optimization of Lean Principles (LP) are practical.

6. The Workability of LP Principles Depends on at upon

a. The skill of workers in the execution of the project and,

b. Coordination of stakeholders at the managerial end.

LP, LPS, JIT and Six Sigma are the continued improvement and suitable project delivery techniques. Just in Time is adopted for inventory control and procurement handling which often supports to cost reduction by monitoring material resources. On the other hand Last Planner system target project as whole and monitor both labour and material resources. JIT fails if the supplier is unable to deliver on schedule time and this can bring the project delays[20].

Studied[21] the effect of Six Sigma for integrated project delivery. The first Approach of Six Sigma was developed and implemented by Motorola for product manufacturing. The framework consists of Define, Measure, Analyze, Improve and Control (DMAIC) and every project concern is run through above process. Six Sigma is said to be an updated version of Total Quality Management as the working principles are same in both the methods. Six Sigma is supposed to be a timely project delivery tool among many and it can only be suited to the particular type of business problem while fruitless for other problems. In the same context, Last Planner System deals with both planning and execution related issues and accommodates problems ranging from foreperson training to stakeholder's involvement.

Explains[22] some talented drivers in implementing Last planner system in United Kingdom road transport project. The project report was prepared for government officials to receive the funds for the project. Drivers are known as factors occurring in a natural state or human induced state while implementing LPS, which deviates the project performance. This can be bifurcated as Internal and external. Internal drivers (human Induced): 1. Owner client demand, 2. The desire to reduce variation and waste, and 3. The desire to improve communication within the project team. The external drivers (Natural) can be earthquake, flood, drought or any other natural calamity causing time money and manpower loss.

Human induced drivers are solved by supply chain management, employee training and the push from client and owner. In the context of Natural drivers managers ask to make an innovation deal as per situation such as Storm-water can be used for specific construction activities which reduce the excess flooding because of rain. In the case of drought, activities which required less water are executed first and simultaneously another arrangement can be made. In the occurrence of another natural calamity, the project schedule is revised as the master plan and reverse plan work on the principle of bit by bit completion. Schedules are prepared as per availability of time cost and manpower. No one can stop the natural phenomena but can find a way out.

According to[23] waste can be reduced or prevent by applying lean construction principles. Their Study focuses on customer value, value stream improvement of workflow and establishes pull. Project manager, contractors, site engineers and labours are interviewed to know their awareness about lean construction principles. One

fourth of total was acutely aware of LC, so a questionnaire is made which includes factors influencing implementation of lean construction and circulated for comments. Variability reduction and continues improvement top the list and this concerns can overcome by Last Planner System.

In construction sector climate, environment, and natural phenomena plays a vital role in the timely completion of the project[24]. Look for the time and cost overrun issue in Iranian construction industry and come up with the solution of using risk management concept in project life cycle. A quantitative method of fuzzy Analytic Hierarchy Process (AHP) can be used to determine and manage the risks associated with the project. AHP is very similar to Linear Programming model as both the methods run for objective function with constraints and limitations. All project risks are listed down first and then a hierarchical structure is a formed with decision criteria. AHP output gives the priority risk factor according to their weight and then project manager can solve those issues. "Project management" followed by "financial risk" were said to be the biggest risk in Iranian construction industry.

Explains[25] a case study where research team works at the project in collaboration with Lean Construction Institute and find out how lean can be implement, loopholes in implementation, factors to take care while implementing lean and every individual's approach towards lean implementation. The study shows delays were resolved by the Last Planner System and recommended the introduction of a new theory to overcome its shortcomings. In other words, the scope and extent of LPS can be determined by nature and complexity of the project and the problem can be resolved by a combined strategy of Lean Construction and LP.

Linear Programming models are widely used in construction industry for resource allocation and leveling, cash flow management, scheduling and networking of activities. The cash flow management deals with credits available, solving issues regarding payment delay and budget constraints. According to[26], the Linear Programming model prepared for cash flow management is first tested with Lean Construction principles and the output from it is used as an input to the LP model. However, there was a need for a strategy, which could be combined with Lean Construction principles to fill in the gaps in the theory.

It has been noted that construction industries globally currently deal with delays which caused by workforce management, quality production, financial status scheduling, networking, and nature and scope of the project. It is argued here that a majority of the overruns in planning and scheduling can be solved by utilization of Lean Construction principles in combination with Linear Programming to overcome issues of resource allocation, optimization of activities and implementation[27].

Studies show that Linear Programming is widely used to determine and resolve project delays. The major areas of research on the LP model are: 1. Strategic investment in construction workforce[28], 2. Construction time-cost trade-off problem is solving[29] and 3. Scheduling and crashing of individual activity for success[30]. The literature includes the shortcomings of Lean Construction principles and suggests that these can be fulfilled by Linear Programming theory. Investing manpower plays a vital role when resources are limited so a precise resource leveling can be done on Micro-Soft Project (MSP) to reduce project duration. Also, planning and scheduling of each project activity on MSP gives optimum results when performed with linear programming model.

Studies on the use of Lean Construction principles firstly fail to set benchmarks on to what extent these can be used efficiently and secondly, suggesting that the application of the same theory would be broadly applicable to all situations cannot be said to be useful as there are a variety of causes for overruns and delays. Therefore, this remains a topic of doubt.

The LP model successfully uses resource leveling, which involves regression analysis, for cost crashing, which takes correlation analysis into account but in spite of this, it still has shortcomings like manual error, workforce management and so on.

The simplex method is one of the traditional methods of linear programming in which objective function is set for optimality with decision constraints[31]. Explains how linear programming can help to solve the issue of smooth reservoir operation and discuss the difference between available LP solver in the market for ex. MS Solver, LINDO, MATLAB and GAMS. Practical problems in the water resource management such as Human need of water, the agricultural need for water and industrial need are modelled as a linear programming model. Developing a model, a solution of model and validation of solution are the necessary steps in LP. Available Solvers in the market such as LINDO and MATLAB performs linear as well as nonlinear programming activities. LINDO is straightforward and user-friendly as the specification of the type of problem is not needed. Different mathematical

functions, statistical calculation, and probability can be done in the solver, but sometimes it becomes complicated for the large-scale project when constraints are more, so a better version of it is required. Mathematical Language of Technical Computing (MATLAB) is suitable for the large scale complex project as it gives a unique toolbox of functioning. It gives a more accurate result for correlation constraints and project factors. MATLAB is the simplest computer language available in the market, but LP in this solver is done for large scale project. MS Excel Solver is the most efficient technical computing language for medium and small scale industry as most of the time LP model is single objective with fewer constraints.

7. What this Paper is Proposing is Entirely New, and this is its Unique Contribution

The combination of Lean Construction principles and Linear Programming has never been used in the construction sector. This thesis will argue that Lean Principles can fill in the loop holes of Linear Programming by management and execution whereas Linear Programming can resolve the issue of the extent by forming a Linear Programming Model.

The issue of the overrun was globally recognized in the late 1990's. Acharya investigated construction in India and found that the public sector plays a vital role in the industry and time, and cost overruns have been affecting this sector for decades. Construction delays are complex, costly and risky and hence the delays need to be analyzed[32]. Analyze them where the 30 delay factors are considered first, 12 most significant and six less significant. Conclusion reveals that unavailability of construction material and climatic conditions are the significant delays causing factors. Apart from this, contractors approach and skills also decide the rapid project progress status.

There are research papers, which address overruns from different perspectives using various methodologies. For instance[33], suggest the effective use of project monitoring and assurance of resources (funds, labour, material, machinery, etc.) for solving delays. While 34 refers to improved procurement methods, specification writing, and early involvement of the contractor.

The concept of Linear Programming has also been investigated[25] suggested effective resource management and optimization of labour work force through utilization of the Linear Programming model. The LPS and JIT techniques were recommended by others[29] for master plan preparation, workforce management and maximization of profit through waste minimization[34] researched overruns and found that it was caused by less efficient working and resulted in less output from resources. Some of his arguments and research are discussed briefly here.

Suggested[35] that a shortage of funding at initial stages could cause overruns. He investigates 290 large and medium projects in the public sector (1987). Of the total number 186 had cost overruns and 162 had time overruns. The total cost was USD$2 billion. When all the data was compiled, it was found that there was 50% increase in price and 43% increase in time. It is also noted that false estimation of project cost and improper planning could result in delays. He suggested that at the outset of a project a great care should be taken while calculating the expected time and costs, and in order to anticipate all outcomes an effective project manager should have what he called "a wide vision".

Apart from this, Morris pointed out there were natural factors which could cause delays such as climate changes, environmental conditions, political goodwill or otherwise, political turmoil, etc. He argued that with proper planning and effective management project delays could be overcome and a project could be completed in the stipulated time. The overview of the sector allows for further study about overrun and its preventive measures. By using a combination of traditional methods like scheduling, networking and crashing together with the Linear Programming model, it is argued that the overruns problem could be mitigated.

Introduced[36] a new method after carrying out his research. He investigated a construction project which deviated from its schedule and activity crashing had to be done to keep within budget. He noted the crashing of activities while increasing resource use reduced the duration of the project and when a particular event was crashed its cost increased by 20 %. Based on this he developed a model where through activities crashing the final output produced an optimum solution and he did this by solving the overrun constraint on an Excel solver. He formulated the equations to reduce the overall cost of the crashed activities, which satisfied both requirements i.e. reduction in time overrun and reduction in cost overrun.

The present work will try to show that Linear Programming when combined with Lean Construction.

It offers an optimum and practical solution, which could save project costs by 20-30%. This is because crashing and scheduling of activities offer sufficient time to be productive when resources are adequate. Additionally, the crashing of activities controls the duration of time for delivery as its prime objective is to maintain costs. In simple terms, the cost of activity is inversely proportional to its time (Figure A4, Appendix A). The increase in crashing in time will lead to an increase in cost[36].

As shown above, both[35] and[36] offered an explanation and caused for overruns and suggested some preventive measures. Their research indicates that planning, execution and implementation technique, are all critical aspects of construction, and when looking for a successful strategy or method of improvisation to deal with overruns, these must be borne in mind.

[36]studied medium size firms. He investigated the effectiveness of Lean Construction tools and techniques and based on the methods which were initially devised for manufacturing the Lean Construction techniques have been developed. Other research shows that it has not always been successful when utilized on its own. A case in point is the Tower B 2, Brooklyn, New York. This project was expected to get LEED Silver certification and supposed to be world's tallest modular tower. After the implementation of Lean Construction, it was expected to be completed within twenty months instead of thirty, as per the original schedule. However, after twelve months, only 20% project work was executed, and same was forecasted for the coming year[37].

The basic principles include among other things: Last Planner, Increased Visualization, 5S, and First Run studies. Lean techniques deal with the reduction of waste in practical terms[38] and helps solves the problem with Last Planner system[39]. Research indicated that commitment from senior management for implementation of strategies was an important factor in ensuring success. In addition to this, training on Lean Construction principles was another key aspect of implementation and could guarantee the success of the Last Planner.

The Linear Programming model was designed to solve the problem of cost function reduction and profit function for maximization. 37 explain that output of LP model gave optimum results for project completion.

The Last Planner system is a technique that helps organize workflow and addresses project variability in construction. It includes the formation of product design to facilitate improved work flow, and production unit control to the completion of individual assignments at the operational level. The Last Planner is the person or group accountable for operational planning. In this system, various schedules are prepared successively. These include: 1. the master plan with all the activities and specifications, 2. Reverse phase schedules to accommodate changes in the original plan, 3. Progress plans at fixed intervals with statistics of percent complete, and 4. Cost and time-consuming agents are eliminated with pull technique in scheduling and planning, and e. improved communication between stakeholders[40].

Successful implementation of the Last Planner system allows the formulation of a Linear Programming model. The LP model involves data collection of the percentage of how much of a project has been completed, which activities are to be completed, the time and cost of these and their implementation. The Linear Programming provides the opportunity for maximum profit during crashing activities. It provides for activities which need to be crash without affecting the project cost and duration. These activities may be partially completed or yet to be started. The Linear Programming model includes all activities in its modeling if it is implemented at the initiation of the project, but only the completed activities of a partly completed project, when it is implemented later.

To summaries: it was noted through a brief literature review that some of the reasons for construction project overruns are among other things mismatch in planning and scheduling, false estimation, the paucity of material and labor. These causes lead to project delays and failure. Earlier attempts to resolve overruns utilized different Lean Construction principles. These included such as Just in time, last planner system, and Continuous Improvement. Previously, Linear Programming models have been used, but these have errors. Every approach utilized to overcome the challenge of time and cost overruns has built in assumptions and limitations, and these needs to be examined carefully when devising an effective solution. This study will suggest that a combined strategy of Lean Construction and Linear Programming is a practical solution.

8. Part Four: Proposed Methodology

This research will investigate the use of Lean Construction principles with strategies like Last Planner system, and Just

In Time (Figure A5, Appendix A). It will seek to examine the outline of the process where an expected schedule of the project is prepared by a project manager to manage the workforce. It will rely on the master plan schedule to predict variances, develop contingency plans and devise a new output of schedule which will form the basis of the Linear Programming model. It will suggest a combination of Lean Construction principle and Linear Programming model to solve the problem of project budgeted overruns and delays. It will involve a literature review of the sector and data collection.

The literature view covers most aspects of the Lean Construction principles and Linear Programming. Based on this a case study is identified. Bearing in mind the history of construction projects which is fraught with delays and overruns, the Lean Construction and Linear Programming model is be tested separately and after that in combination.

8.1 Data Collection

This involves the collection of data to determine whether or not Linear Programming can be effectively combined with Lean Construction principles to formulate a successful strategy for solving the problem of construction overruns in time and cost. The data collection focuses mainly on small and medium scale construction industries and those where software applications are have been used for planning.

8.2 Design of the Combination Strategy of Linear Programming Model and Lean Construction

The design of this strategy intends to be linked to Microsoft Project or Primavera. It will prepare a schedule, predict percent project completion, and devise contingency plans.

A Linear Programming model will be developed and implemented for testing. The intention is to use Microsoft Excel solver as a first preference, and LINDO or MATLAB software.

9. Part Five: Proposed Plan of Study

This will be undertaken in the initial stages of the research. The intention is first to study the literature on Lean principles related to overruns and the Linear Programming model in relation to output, Linear Programming regression model to resource allocation, Linear Programming to workforce management and importantly any literature that will contribute to a better understanding of the possible success of the combination of Linear Programming and Lean Construction techniques.

After that the review will investigate effective project management practices, the Last Planner system, JIT, Six Sigma. It will also include:

- Different Lean Construction techniques.
- Possible ways of combining both Lean Construction techniques and Linear Programming.
- Data for preparing for schedules and network diagrams.
- Formulation of Linear Programming equations, to be resolved by Solver.
- Type of project, time required for completion and expected delays, site approval and site details.

The proposed stages for the research:

- *First*: selection of project location and data collection such as normal and crash duration, estimated the cost of project, deadline for completion, etc.
- *Second*: After the successful review on data application of last planner system to project.
- *Third*: Application of LPS includes networking, scheduling and crashing of activities. This can be performed on Microsoft Project.
- *Fourth*: The output of LPS is taken as input for Linear Programming model formation with single or multiple objective function and constraints.
- *Fifth*: Linear Programming model can be run in Microsoft Excel Solver and then the results are validated for optimum solution of the problem.

9.1 Data Collection

The intent is to collect data from South East Europe. This is justified on the basis that Western Europe and some parts of Asia are making sufficient progress in the area of management of construction projects, whereas some countries from South East Europe are struggling with the problem of delays and overruns. It is hoped that this

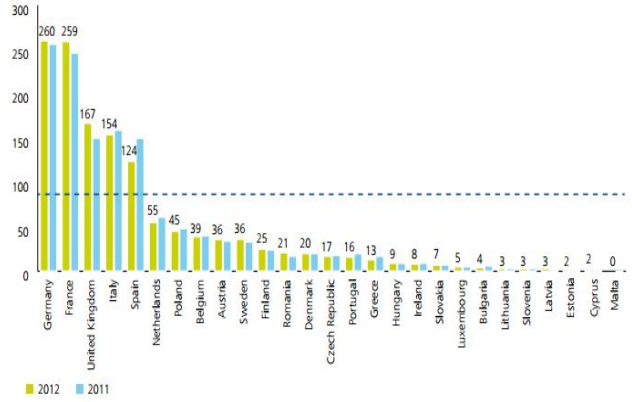

Figure A1: Production index of construction market

(Source: "Adapted from Deloitte, 2013")

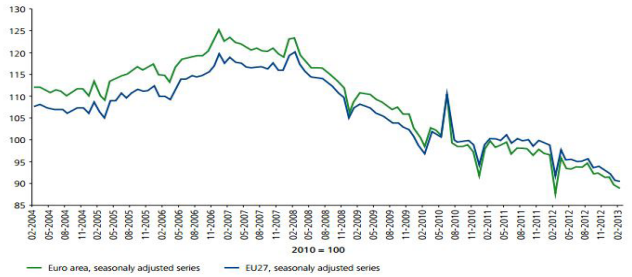

Figure A2: Construction Investment In Europe in 2012 (Euros)

(Source: "Adapted From Deloitte 2013")

research will be used to inform small construction firms to improve their construction management.

9.2 Initial Proposed Timeline for the Research

Before starting the actual quantitative analysis, a through literature review is needed which can take approximately nine months. Once the working alignment is fixed, project selection and project data analysis can be carried out which can take up to six months. The next step is formulation and combination of Lean construction and linear programming model, and it requires almost six months span. Lastly, writing up the dissertation. This is the most important step and hence required nearly fifteen months of duration.

10. Conclusion

Construction projects are complex and need to be completed with maximum profit and minimum waste. It is

Factors, Reasons and Causes of delay	Client	Consultant	Contractor
	Regular interference and poor communication	Incomplete contract documents	Inappropriate organization management
	Variation order and late approval for payment	Incomplete drawings	Lack of technical professional in the organisation
	Late supply of information and late decision making	Poor design management	Unsmooth external and internal communications
	Project objectives are not very clear	Slow response	Lack coordination with sub-contractors
	Nomination of Sub-contractors and suppliers	Delayed approval of drawings and BOQ for construction	Centralization with top management
	Many provisional sums and prime cost	Inadequate duration for inspection	Delayed mobilization
	Duration is not enough for constructing the project	Experience of staff in management and technical inspection	Incompetent contractor staff
	Irregular payments and disturbed cash flow of main contractor	Delay in submittal and approval	Poor planning, scheduling or resource management
	Routine of government authorities and approvals	Poor communication between consultant staff	Poor quality control
	Irregular attending of weekly meetings	Poor quality control	Congested construction site

Figure A3: Internal Causes of Project Delays

(Source: "Adapted From National Audit Office, UK-2014")

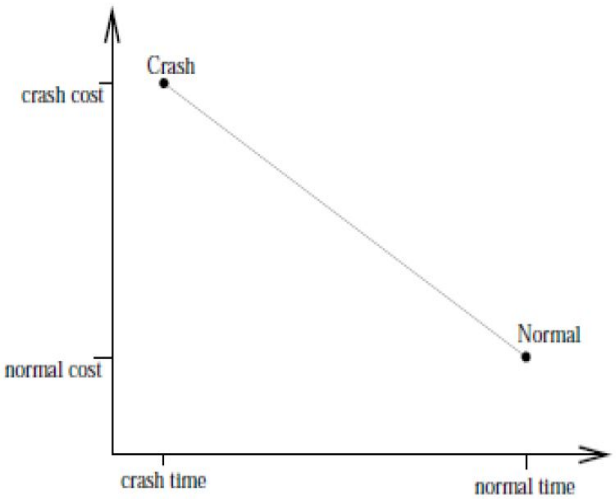

Figure A4: Time and Cost Relationship

(Source: "Adapted From "Time-Cost Analysis", Saleem-2010")

suggested that the efficacious implementation of a combination strategy of Lean Construction techniques and Linear Programming could anticipate the following outcomes:

- Successful project planning and scheduling through using Linear Programming effectively
- Reduction of time and cost through successful application of Lean Construction Techniques at the initial stages of the project
- Development of a model of Linear Programming and Lean Construction Techniques for efficient implementation for small scale industries

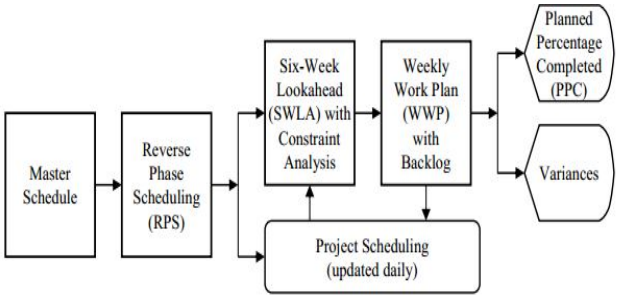

Figure A5: Sequence of last planner process

(Source: "Adapted From "Last Planner System", Saleem-2005")

- Reduction in project overrun and delays with fewer efforts

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