Simulating The Impact Of The Material Flow In The Jordanian Construction Supply Chain And Its Impact On Project Performance

Dr. Ghaith Al-Werikat

Abstract: With the new developments and challenges within the construction industry, improving the construction supply chain is becoming a major concern to both governments and industries. Improving the construction supply chain helps in improving the quality of construction projects, reducing cost, wastes, delays and other disruptions. This paper discusses the analysis of material flow in the construction supply chain. The methodology consisted of preliminary investigations, survey and simulation development to analyse the extent of impact that material flow has on construction projects in Jordan. Both the main survey and the investigations revealed that material flow delays, are caused mainly by 3 types of delays; late delivery, wrong specification and material damaged on site. The highest impact regarding late deliveries was scaffolding with a 16% probability of occurrence, a 2-day delay on the activity's duration. Concrete ranked highest regarding wrong specification with a 19% probability of occurrence, an 8-day delay the activity's duration. Regarding materials damaged on site, bricks ranked highest with a 9% probability of occurrence, a 3-day delay on the duration. The simulation results exhibited a delay of 50% on the projects duration and a probability of a delay occurring is 9.2%.

Index Terms: Construction supply chain, project management, material management, project delays, project performance and material flow

1 Introduction

ACCORDING to a report from the Department of Statistics (2013) the construction industry in Jordan grew by 9.6% compared to 2012 due to reasons including: political instability in neighbouring regions, security of investment, and low rates of interest. Additionally, the cost of construction materials and land increases in Amman have resulted in the capital's new housing developments being pressed (Ministry of Housing and Reconstruction, 2013) therefore project cost controls are required. Jordan's long-term plan, Jordan 2025 (2015), expects the construction sector GDP contribution to reach a 6% target by 2025. Delays are an event or act that requires additional time to complete a task. (Graham 2014). Even with the technological advancements nowadays, delays in construction projects are common and construction projects remain to suffer from time overruns. (Warne 2011). Delays can occur for many reasons such as: design changes, weather conditions, labour shortage, equipment failure, material shortage etc. moreover, Xu and Wang (2014) contributed that delays are connected and usually a delay in an activity results in delays in dependent activities which results in time overruns. Construction 2025; (Department for Business, Innovation & Skills, 2013) reflects the aims of the UK construction industry in 2025. The report reveals that through improved control of the supply chain flows in construction projects, delays and extra costs can be avoided whilst the level of quality increased. Many researchers have studied construction projects delays. Table 1 illustrates their findings. Nowadays, governments and construction corporations have been looking for ways to transform the industry by reducing delays, cost overruns and quality.

Successful transformation requires better management and control over the construction supply chain. (Department for Business, Innovation & Skills, 2013). Most conducted research has analysed construction project delays in general. Debatably, this paper is one of the first attempts to quantify the impact of the material flow within the construction supply chain on construction projects performance.

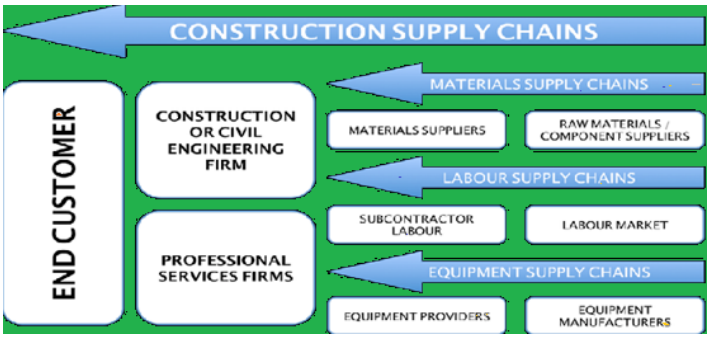

Fig. 1. *The Myriad of Construction Supply Chains (Cox et al., 2006)*

Cox and Ireland (2002) contributed that the main flows in the construction supply chain includes: equipment, labour and material (Figure 1).

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TABLE 1
Summary of previous studies of the causes of construction projects delays

RESEARCHER	COUNTRY	DELAYS MAJOR FACTORS
AL-MOMANI (2000)	JORDAN	POOR DESIGN, WEATHER CONDITIONS, LATE DELIVERIES, DESIGN CHANGES.
KOUSHKI ET AL. (2005)	KUWAIT	CHANGING ORDERS, WEATHER CONDITIONS, CLIENT'S FINANCIAL PROBLEMS AND CLIENT UNFAMILIARITY WITH THE CONSTRUCTION PROCESS.
FRAIDI AND EL-SAYEGH (2005)	UNITED ARAB EMIRATES (UAE)	SLOW PLANS APPROVALS, POOR EARLY PLANNING, LABOURS SHORTAGE, POOR MANAGEMENT ON SITE, LOW LABOURS PRODUCTIVITY, CLIENT'S SLOW DECISION TAKING AND CHANGE IN DESIGN.
ASSAF AND AL-HEJJI (2006)	SAUDI ARABIA	PAYMENTS, ARCHITECTURE DELAYS, MATERIALS PROBLEMS, LABOUR SHORTAGE, POOR MANAGEMENT, DESIGN ERRORS AND GOVERNMENTAL APPROVALS
G. SWEIS ET AL. (2008)	JORDAN	LABOUR SHORTAGE, UNQUALIFIED LABOURS, MATERIAL SHORTAGE, PROBLEMS AND SHORTAGE OF EQUIPMENT AND FINANCIAL DIFFICULTIES
TUMI (2009)	LIBYA	DESIGN CHANGES, MATERIAL SHORTAGE, POOR MANAGEMENT AND FINANCIAL DIFFICULTIES
KIKWASI (2012)	TANZANIA	PAYMENTS DELAYS, DESIGN CHANGES, POOR MANAGEMENT, INFORMATION DELAYS, FINANCIAL DIFFICULTIES AND DISAGREEMENTS BETWEEN CONTRACTORS AND SUB-CONTRACTORS
KUMAR (2016)	INDIA	POOR MANAGEMENT AND INADEQUATE CONTRACTORS WORK
BEKR (2016)	JORDAN	POOR PLANNING, MATERIAL SHORTAGE, EQUIPMENT SHORTAGE, LABOUR SHORTAGE AND POOR PLANNING AND MANAGEMENT

Managing the material flow is important in the construction project life cycle. Donyavi and Flanagan (2009) stated that there are five categories in the process of managing materials and failure to address them may result in some problems and delays. The categories are: Specification and measurement, the purchasing and procurement process, transportation to site, order checking, offloading and on site storing, financial and administrative payment process, material use on site and wastes removing. Another concern is inaccurate material planning which may lead to the following risks: contract overrun time and not being able to meet the contracts obligation to submit the project at the agreed time to the client due to the lack of materials, over ordering materials may tie up the contractor's finances as it has cash flow implications and on the other hand, the over ordered materials may disrupt the construction site and take additional storage place that can be used for other activities. (Sears 2015)

2 PROBLEM STATEMENT

Despite many researchers contributing that material management has an impact on projects performance (Gulghane and Khandve, 2015; Barry et al. 2014; Alanjari et al. 2014; Aziz, 2013; Sardroud, 2012), so far no research has been conducted to analyse the impact of material flow on projects performance in separation to the other elements of the construction supply chain has been conducted. This opens an opportunity to conduct a research. The main intention of this research is to analyse the extent to which material flow impacts construction projects performance in terms of delays.

3 RESEARCH DESIGN AND METHODOLOGY

Preliminary investigations, survey and simulation scenarios development were adopted in this research as explained next

3.1 The preliminary investigations

Over the period of 3 months, site visits were conducted at two residential housing projects, both of which were located in Amman, Jordan. The construction work was being carried out by two independent contractors. Useful information was obtained by observations to general project meetings, projects documents and suppliers documents. Material flow related delays were observed on sites including: random delivery times, wrong specifications/ quantity, damaged materials.

3.2 Survey

The main aim of the survey was to gather data required to develop the simulation scenario. The questionnaires aimed to get a wide response from professionals, engineers, consultants and management members of the construction industry in Jordan. Figure 2 represents the questionnaire respondents

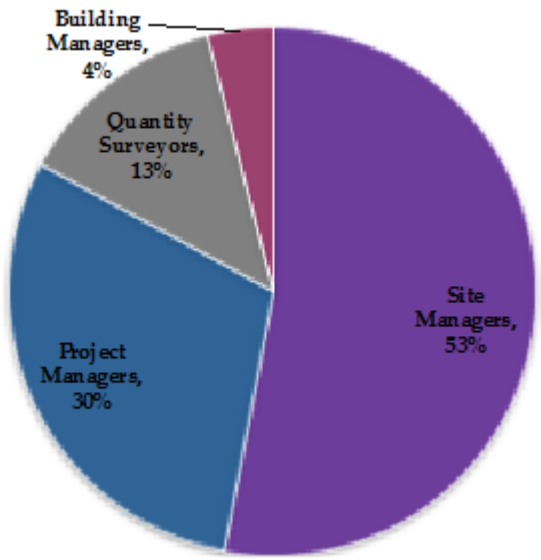

Fig. 2. *Survey Respondents.*

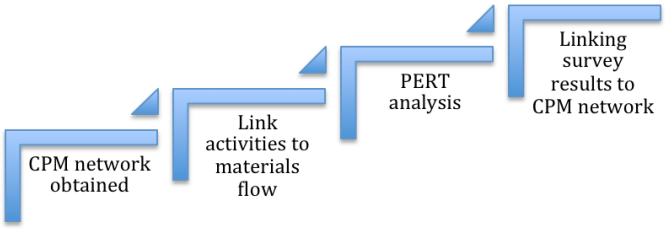

Fig. 3. *Simulation Scenario Development*

The questionnaire helped in getting the respondents to identify delays related to the material flow. the questionnaire included the following questions; (1) Do you receive the ordered material on time? If not, please specify the material, the potential delay in days and the probability of that occurring. (2) Do you receive the exact material which you ordered? If not, please specify the material, the potential delay in days to exchange the material and the probability of that occurring (3) Does any of the material get damaged whilst on site? If so, please specify the material, the potential delay in days to exchange the material and the probability of that occurring.

3.3 Simulation Scenario Development

The critical path network obtained from the skeleton level of a typical medium scale residential housing project, one of the construction projects visited, was analysed for activities relating to the material flow on MS-project 2007 software. To investigate and quantify the effect of material flow on the residential housing project, a comparison of the most likely versus the most pessimistic activity durations was conducted. Figure 3 illustrates the steps in developing the simulation scenario. The following equation clarifies the process of calculating delays in the simulation scenario.

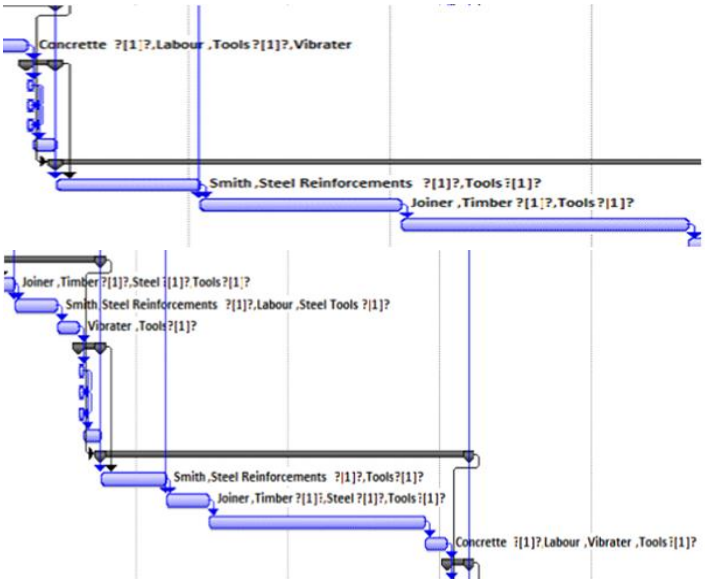

Fig. 4. *Examples from the Simulation Results*

TABLE 2
Comparison Of Scenarios: Actual Versus Material Flow Delay

Scenario	*Duration (Days)*	*Delay (Days)*	*Delay (%)*
Actual	*135*	*0*	*0*
Material Delay	*263*	*125*	*90%*

Activities pessimistic duration = pessimistic duration + highest pessimistic potential delay form main survey

4 Analysis and Discussion

The simulation results presented in Table 2 indicate that the project was delayed by 50% of its duration. That huge impact reveals the importance of managing the material flow as it can lead to overrun costs and delays. Moreover, the results of the main survey suggested, the average probability of the material flow delay's occurrence is 9.2%. Figure 4 displays examples from the simulation scenario. The main survey results suggest that material flow delays can be the result of three main sources: late delivery, wrong specifications or quantity, and damaged materials on site as can be seen in Figure 5. The results suggest that the highest problem in materials flow is materials delivered with wrong quantity or specifications which can be due to a problem in the supplier's company and/or the contractor's company. Using shared applications and IT software can help to ensure the right quality and quantity has been ordered and processed from both parties.

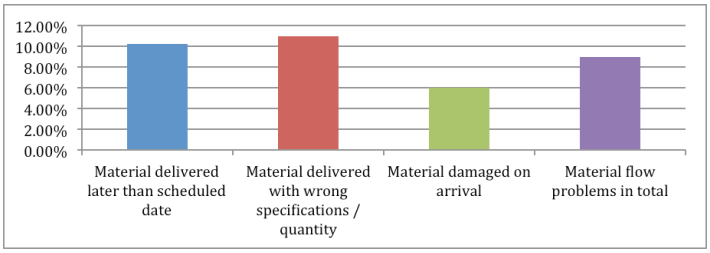

Fig. 5. *Main Survey results: Sources of Material Flow Delays and their Probability of Occurrence*

Moreover, the results from the simulation scenario and the main survey suggest that material flow plays a major role in project delays thus impacting on project activities causing delays and additional costs. In addition, materials cost is an important aspect to discuss as it represents a percentage of the total project cost and may cause financial disruptions to the material flow in the project. Accurate material planning plays a major role in projects success. Consequently, the distribution, transportation, handling of materials and consumption monitoring should be managed and planned accurately by an experienced and competent staff member. Other problems that may disrupt the process of material flow in the construction industry are:

1. Late material orders result in project delays
2. Random times of material deliveries results in interrupting works and causing delays.
3. Lost or damaged material because it was stolen or kept in insecure storage places.

This discussion suggests that the Jordanian construction industry has some problems regarding materials management. Failure to deal with this crucial element of the construction chain may result in delays and additional costs. The following presents possible solutions for material delay problems:

1. **Initiation of long-term relationships between contractors and suppliers**. Supply chain partnerships have proved important in the manufacturing industry and have resulted in many gains such as: shorter product development, inventory reductions, improved delivery service, increased market share and improved quality. This can open an opportunity for the construction industry to gain from the manufacturing industry experience. (Dornfeld 2012).
2. **Supplier early involvement with the contractor in the design stage.** Giving suppliers the opportunity to discuss the different aspects in the design stage of a project may help the main contractor in improving the projects plan in terms of available material, specifications and other issues from the supplier's perspective. Moreover, the early involvement of suppliers helps in increasing their awareness to the problems that can be a result of the material flow process, delivery and material planning issues. Figure 6 represents the most pessimistic material delays, was used in developing the simulation scenario, based on the main survey results.
3. **Enhancing communication channels with suppliers**. The use of information technology can help both suppliers and contractors to place an order, check it, trace it and pay for it. Using a shared system or application between suppliers and contractors can help them both to make sure that all information regarding orders is shared accurately between them and can help in avoiding any problems in orders. As an example, Electronic document management (EDM) is an information system that can be used.

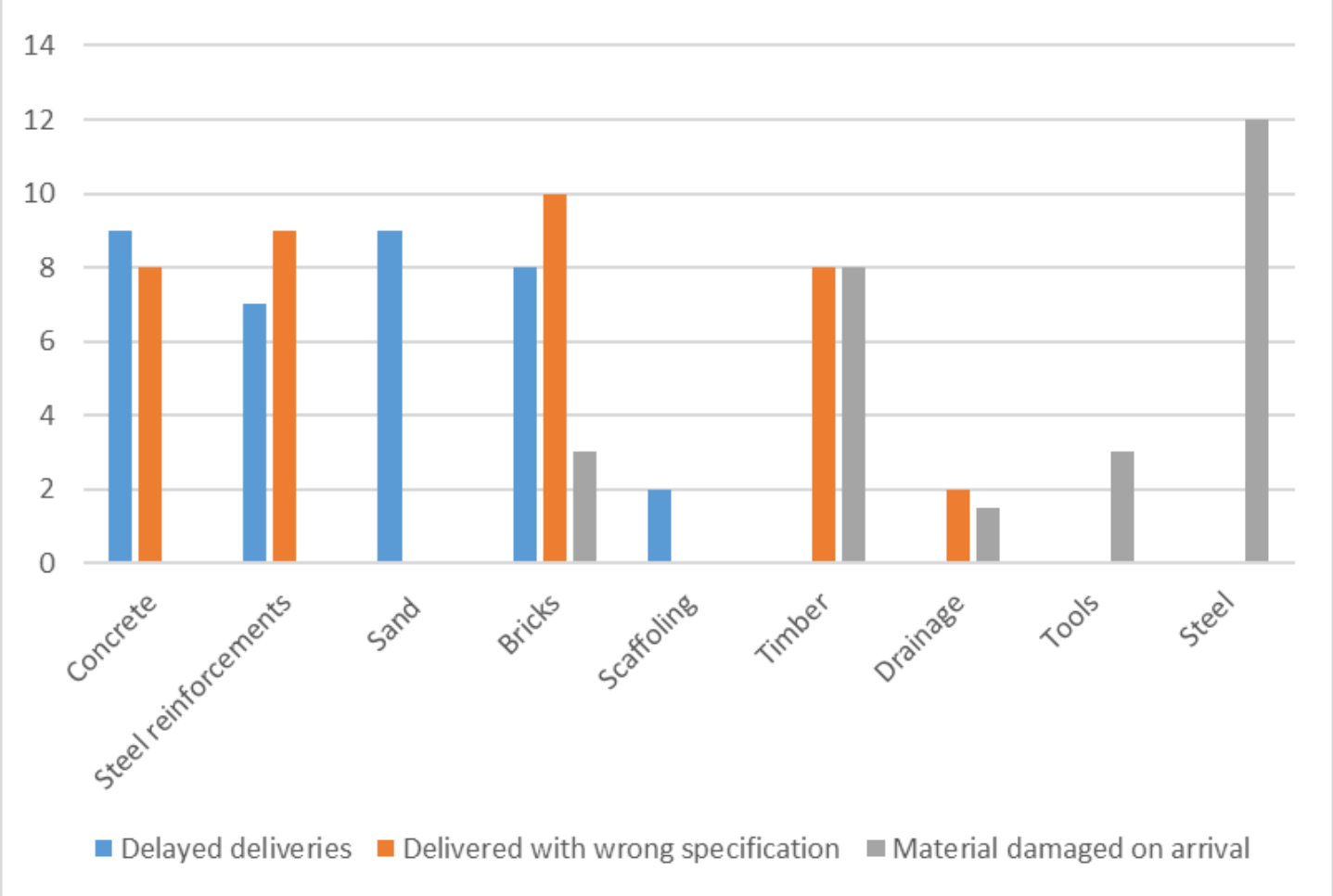

Fig. 6. *Simulation Results Demonstrating the Impact of Material Delays in Days: The most pessimistic material delays based on the main survey results.*

6 CONCLUSION

Material flow delays inevitably affect costs and impact hugely other activities therefore, it is vital to address such issues. A good contractor/supplier relationship may help overcome some problems, especially in the early stages of the project. This could help to inform the supplier as to the material specification and quantity well in advance of requiring the material. Managing the material whilst on site is another area of concern and was a cause of damage to material and/or lost/stolen material. These issues lead to a shortage which in turn causes delays and indeed has cost implications. Moreover, the use of technology between supply chain partners helps in overcoming purchasing and potential problems regarding the materials flow which all helps achieve increased efficiency in management and control of the construction supply chain.

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