A STUDY ON THE IMPACTS OF SCHEDULE COMPRESSION TECHNIQUES ON CONSTRUCTION PROJECTS IN SRI LANKA

Jallini Theivendran* and Sachie Gunatilake
Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

Construction delay is considered to be one of the recurring problems in the construction industry and it has an adverse effect on project success in terms of time, cost and quality. Previous researchers have stressed the importance of early identification of construction delays and have suggested major delay-reducing remedies. Among this, 'Compressing Schedule' is a commonly used method to expedite the construction process. The consequences of schedule compression can be troublesome if productivity and quality of the project are sacrificed for the sake of remaining ahead of schedule. Therefore, this research was carried out to identify the impacts of schedule compression techniques on projects and suggest the strategies to be followed to overcome those negative impacts. A questionnaire survey and ten semi-structured interviews were conducted with Sri Lankan construction contractors. Altogether, 11 number of schedule compression techniques were found to be commonly used in the Sri Lankan context. Additional cost, quality issues, productivity problems, conflicts, coordination problems and abortive works were highlighted as the recurring negative impacts. In order to mitigate the impacts, the research has stressed and recommended strategies for each technique.

Keywords: *Construction Delay; Impacts; Mitigation Strategies; Schedule Compression.*

1. INTRODUCTION

Timely completion is important for all construction projects due to the monetary effects associated with a project's completion date. However, in practice it is challenging to achieve both time and cost aspects together (Bandara, 2012). According to Ssemwogerere (2011), construction delays can result in serious financial loses to contractors such as additional overhead costs incurred beyond the originally planned project costs. Furthermore, it affects clients with significant financial difficulties and economic risks such as loss of market opportunities and high interest rates. Subsequently reducing both construction projects' cost and time is a prime problem in today's market-driven economy. Achieving these two objectives simultaneously is desirable, but often it must rank according to the importance: one before the other (Mubarak, 2010).

If any construction delays are encountered where the contractor is culpable, then the contractor needs to take all necessary steps to accelerate the project (Firth, 2011). In order to meet these requirements, the normal construction work schedule needs to be compressed with the help of schedule compression. Schedule compression is an effort to reduce project durations for early delivery, or to recover the occurred delays (Mubarak, 2010). Schedule compression is usually performed in the construction industry by means of schedule compression techniques. Even though, past researchers in other countries have identified a variety of schedule compression techniques, very few studies can be found that compare impacts of each technique. In fact, the effects of each technique such as; imposing extra cost, risk of changes and rework are inherently different (Hazini *et al.*, 2013). Currently, there is inadequate knowledge for selecting schedule compression techniques to be employed and mitigating the potential negative outcomes of schedule compression techniques.

* Corresponding Author: E-mail - jallini@gmail.com

As stated by Hazini *et al.* (2013) determining the best technique in compressing project schedules has always been a challenge. In particular, some techniques will impact more on the project while others will impact little. Therefore, when it is needed to compress a construction schedule, the management team should select a method that minimises the impacts on the project. Therefore, the aim of this research is to identify the impacts of schedule compression techniques used in construction projects in Sri Lanka. The following sections in the paper discuss the concept of schedule compression and its necessity for construction projects, the techniques used to compress schedules in construction projects, the identified impacts associated with most commonly used compression techniques on construction projects as well as strategies to overcome these impacts.

2. LITERATURE REVIEW

2.1. WHAT IS SCHEDULE COMPRESSION?

When a construction project falls behind schedule, in order to reduce the damages and bring the project back on schedule, the contractor's rate of performing the remaining activities must be increased: i.e. in other words, stated that the contractor's individual schedule need to be compressed (Mansur, 2004). This compression process is referred to as "Schedule Compression" or "Accelerating a Project" (Mansur, 2004; Moselhi and Esfahan, 2013; Mubarak, 2010). According to Mansur *et al.*, (2003) schedule compression can be said of as the shortening, squeezing or compaction of the project schedule. Similarly, Thomas (2000) also define schedule compression as having more work to perform in the same period of time or having a shorter period of time to perform the same amount of work. According to Baker (1991), schedule compression may be carried out to serve one of three purposes: reducing total design-construct time from that considered normal; accelerating a schedule for owner convenience; and recovering lost time after falling behind schedule.

Contractor and client usually aim to establish the delicate balance between the overall cost of a project and its duration. As such, contractor may want to compress or accelerate the schedule of a construction project because of below reasons (Mubarak, 2010);

1. The contractor's normal finish date in the planned schedule does not meet the imposed finish date of the contract
2. After starting construction and completing a percentage of work, the contractor realizes that the project is behind schedule. Contractor needs to compress the remainder schedule to avoid finishing late get out of liquidated damages
3. In some cases, the contractor may have a benefit from early completion
4. When economy is well, starting another job earlier making more profit to the contractor. This time frame may require the contractor to compress the current project to free certain resources for the new project

Client, on the other hand, may order accelerated delivery of their under-construction projects because of (Esfahan, 2011);

1. Monetary considerations such as project financing e.g. to meet prescribed fiscal requirements,
2. To minimise the effects of change orders on project schedules,
3. To recover from delays for which they were the main source such as late delivery of material and/or equipment,
4. To minimise project total cost, because of stockholder pressure and
5. Simply because of their desire to complete the project earlier to address market demands in case of the development of a new product or service by the owners‟ organisation that needs to get to market as soon as possible due to rising loss-of-opportunity costs

In compressing a project, the critical work must be performed more quickly, and/or the sequences must be changed to allow more of the critical work to occur at the same time (Trauner *et al.*, 2009). Previous studies have identified several techniques of compressing a schedule, which provides a practical and usable catalogue of techniques used effectively for compressing a schedule in the construction industry. Figure 1 depicts the schedule compression techniques identified through the literature review categorised into five main groups.

Schedule compression can be fulfilling the urgent need. However, the consequences of schedule compression can be troublesome if productivity and quality of the project are sacrificed for the sake of remaining ahead of schedule (Nepal *et al.*, 2006). It is, therefore, important to counteract and/or minimise the effects of schedule compression on construction performance by adopting sound and proper strategies.

3. RESEARCH METHOD

The aim of this study was to carry out an in depth investigation on the impacts of the schedule compression techniques on construction projects. A questionnaire survey was carried out among the building construction contractors to identify the commonly used schedule compression techniques. The questionnaires were distributed to a random sample of 45 contractors, who are handling schedule compression in Sri Lankan construction industry. The respondents were required to indicate the usage of each technique based on a six point Likert scale. 38 responses were obtained resulting in a 84% response rate. One sample t-test was used for the questionnaire survey analysis and to find out the significant schedule compression techniques that are most commonly practiced in the industry.

In order to identify the impacts and mitigating strategies of the most commonly used compression techniques 10 semi structured interviews were conducted among Sri Lankan contractors. The interviews were digitally recorded (with permission), transcribed and was coded under the principles of qualitative content analysis.

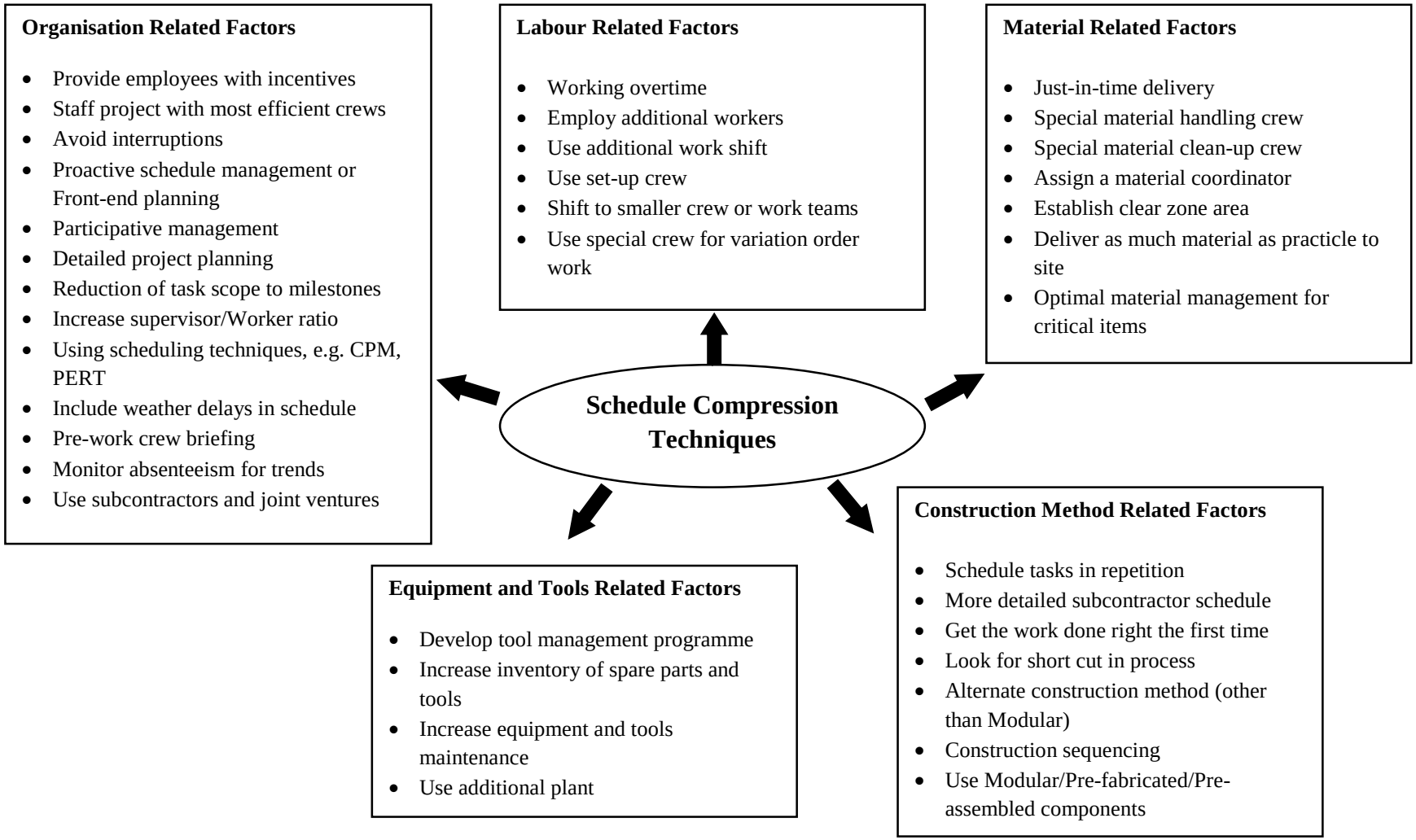

Figure 1: Schedule Compression Techniques

4. RESEARCH FINDINGS

Following sections discuss research findings of the study under the broad headings of commonly used schedule compression techniques in the Sri Lankan construction industry, the impacts of the commonly used schedule compression techniques and the strategies to mitigate the negative impacts of schedule compression techniques.

4.1. MOST COMMONLY USED SCHEDULE COMPRESSION TECHNIQUES IN SRI LANKAN CONTEXT

According to the t-test, the population mean μo was considered as "3" which is used as the test value for the analysis. The critical t value is 1.6871 when the degrees of freedom (tn-1) is 37 and the probability level (α) equals to 0.05. Based on the critical t-value, the null hypothesis is rejected when the tested t-value exceeds 1.6871. In order to find the significant items, the techniques which has got the greater t-value than critical t-value was selected. That means, the null hypothesis is rejected and the alternative hypothesis is accepted. Based on the rejection, the significant schedule compression techniques were identified and ranked as given in Table 1.

Table 1: Identification of Significant Schedule Compression Techniques

Item No.	Schedule Compression Technique	t value	Sig. (2-tailed)/ P-value	Mean	Rank	Std. Deviation
	Labour Related Factors					
L1	Working overtime	4.603	0.000	3.842	2	1.128
L2	Employ additional workers	2.758	0.009	3.474	7	1.059
	Material Related Factors					
M1	Optimal material management for critical items	2.546	0.015	3.447	8	1.083
	Construction Method Related Factors					
CM1	More detailed subcontractor schedule	3.656	0.001	3.579	4	0.976
CM2	Construction sequencing	3.221	0.003	3.553	5	1.058
	Equipment and Tools Related Factors					
	-					
	Organisation Related Factors					
O1	Provide employees with incentives	1.720	0.094	3.290	11	1.037
O2	Staff project with most efficient crews	3.239	0.003	3.500	6	0.952
O3	Participative management	2.309	0.027	3.395	9	1.054
O4	Detailed project planning	7.544	0.000	4.079	1	0.882
O5	Increase supervisor/Worker ratio	2.086	0.044	3.316	10	0.933
O6	Use subcontractors and joint ventures	3.774	0.001	3.684	3	1.118

As indicated in Table 1, out of the techniques identified through the literature review (see Figure 1), 11 were found to be commonly used in the Sri Lankan context. These include two labour related, one material related, two construction method related and six organisation related factors. No techniques emerged as significant from the equipment and tools related category shown in Figure 1. These techniques are explained in detail in the following section along with their impacts on projects.

4.2. THE IMPACTS OF THE MOST COMMONLY USED SCHEDULE COMPRESSION TECHNIQUES

Through the qualitative content analysis and cognitive mapping, the problems and impacts associated with these 11 most commonly used schedule compression techniques were identified. These are discussed in detail under each technique below.

Detailed Project Planning

When contractor follows the initial detailed plan, the disruptions will lead to delays in construction projects. According to the respondents, delay in material delivery, restrictions in obtaining utility connections, major variation, unforeseen situation, non-availability of resources subcontractors issues create disruptions to the project. Hence this situation may require the contractor to redo the scheduling process for the rest of the project. The idea behind this planning is looking into the remaining portion of the project as a new project and planning for this portion to meet the original schedule. Due to these issues detailed project planning is subjected to generate negative impacts to the project. If the new schedule is prepared based on the previous data, it will not match the future events. Preparation of a new schedule creates practical issues and quality problems. For instance, in order to cope up with the schedule the contractor may assign less skilled workers to the project without any evaluation. As a result of poor performance of unskilled workers, quality issues may be created in the project. Further it incurs additional cost to the contractor.

Working Overtime

Workers are instructed to work on overtime during the construction period to increase the rate of progress and minimise the delays. However the worker's additional overtime period impacts the project negatively when the overtime is extended to long term. Based on the responses, the negative effects are misuse the overtime, increase in cost, loss of productivity, health and safety problems and lower quality.

Use Subcontractors and Joint Ventures

Usage of subcontractors and joint ventures is one of the schedule compression techniques which is used for the purpose of fair sharing of responsibilities and risks among the project contributors while reducing the workload of main contractor. Even though it is beneficial for the main contractor due to increased resources, there are several negative effects as well. Employing subcontractors and joint ventures is a different issue. Though the work has been subcontracted it should be supervised properly as the workers may not have the adequate skill and also it will help to avoid conflicts between subcontractors. Further, the respondent suggested that contractor need to arrange advance payment for the subcontractors. Therefore the contractor should be capable in financial wise. In addition to the advance payment, the contractor has to bear some administrative cost to monitor or supervise the subcontracting work. Moreover the contractor is in a position to arrange additional facilities for the subcontractor such as accommodation to workers.

At the same time, as one respondent stated "the performance of the subcontractor is questionable all the time". Sometimes the subcontractors who have given the performance bond may not work properly. In such occasions, the subcontract may need to be terminated or replaced by another subcontractor. Managing subcontractors is also a difficult task. As pointed out by a respondent, every subcontractor has their own working style. Most of the time it deviates from the main contractor's sequence of work leading to coordination problems between main contractor and subcontractor.

More Detailed Subcontractor Schedule

Subcontractors' works are detailed and scheduled in all construction project to achieve the better coordination among subcontractors. Scheduling subcontractors' works help to maintain a baseline for all the subcontractor activities and avoid delays in main contractor's works. Preparation of a subcontractor schedule is a difficult task for the main contractor. As the greater amount of subcontractors, the coordination of all individual subcontractor schedules to the main contractor schedule is a challenging task. Moreover, the subcontractors generally directly coordinate with the main contractor rather than among them. Accordingly, if the main contractor needs to complete a unit of work, he needs to face a situation of lesser coordination among subcontractors.

Moreover, the existing subcontractor schedule will get affected when additional subcontractors are coming into project. Due to the urgency the main contractor put additional subcontractors to the project without any evaluation. Hence it will create different skill levels between existing workers and new workers. Due to the detailing of subcontractor schedule, the one work will be divided among subcontractors in order to expedite the work. For an example; if two subcontractors are asked to work on one concrete slab, it will create conflicts between subcontractors so as to cover up higher amount of work than the other person in order to receive a higher payment.

Construction Sequencing

Due to the disruptions to the project, the existing sequence cannot be followed in construction projects. Therefore, the contractor in a position to shifts and shuffle certain activities to cover up the schedule compression period. Due to this re-sequencing, the contractor faces the negative impacts which are risk of further delays, abortive works, resource idling and increase in cost. For instance, respondents noted that re-sequencing will delay the pre-planned activities and increase the project overheads for the additional facilities like storage.

Staff Project with Most Efficient Crews

Employees with higher efficiency level are always required for the project. Though it is beneficial to speed up the work but finding out an efficient crew is a challenging thing. Under the schedule compression period, it is impractical to evaluate the efficiency level of each worker. At the same time, there is no gauge to measure the efficiency. Some negative impacts of this technique were identified such as; retention of efficient workers, lack of performance capacity and cost. In addition, assigning a large amount of work for the efficient crew will create a situation of losing the efficient crew owing to physical and mental stress.

Employ Additional Workers

Employing additional workers is another schedule compression technique which is used to increase the number of workers on the job to finish the work in a shorter time period. Contractor can use this technique freely when market situations and budget permits. Based on the responses, the impacts are; quality issues, additional facilities, labour idling, conflicts between workers, not giving expected outcome, difficulties in supervision and increases in cost.

Optimal Material Management for Critical Items

Certain items of construction material should be designated as critical to assure their optimal management during delays in order to avoid wastages. For that, there should be a certain management control in the stores. Then the contractor needs to follow a certain procedure when ordering materials to the site. The optimal material management plan needs to be flexible so as to be adjusted based on site requirements. Otherwise, it can result in delays in ordering and material delivery to the site. If there is any delay in material delivery it will create an idling situation at the site. If the time is short, then the contractor may need to arrange more suppliers to procure materials resulting in increased costs.

Participative Management

Participative management has identified that no manager can be a fountain of all knowledge. It insists to tap the ideas of those closest to the work; i.e. the individual worker as they may have the best idea of all for performing the work in the shortest and most cost-effective time. According to the respondents, training programmes for junior staff, weekly or monthly management level meetings and senior management site visits are some of the techniques used to practice participative management. Some of the negative impacts that are resulted due to this are conflicts between parties, multi-point responsibility and indirect increase time.

Increase Supervisor to Worker Ratio

Supervisor to worker ratios should be increased with changes in the work force or with changes in the criticality or complexity of the work so as to maintain quality and sufficient control of the work force. The increase in ratio creates negative impacts as increase in cost and division in responsibility.

Provide Employees with Incentives

Incentives have proven to motivate stronger performance when fairly administered. However it impacts the project performance negatively when incentive scheme was not properly implemented resulting in demotivation of employees in other projects and increase in cost.

4.3. STRATEGIES TO MITIGATE THE IMPACTS OF SCHEDULE COMPRESSION TECHNIQUES

The analysis of interview data, further revealed strategies that could be used to mitigate the impacts of the aforementioned negative impacts of the schedule compression techniques (refer Table 2).

In order to avoid the impacts of detailed project planning, an advanced planning should be adhered by the contractor. Such as monthly meetings at the head office and weekly progress review meetings at the site. Due to this top management, project managers, procurement people and other site estimators can be involved to the meeting. From this everyone can discuss about the review of the project, resource availability and availability of subcontractors for the future work. Moreover the impacts can be reduced by proper change in sequence of activities or change in the specification with the approval.

When considering the impacts of working overtime, the target scheme will be a good solution to overcome the negative effects. By giving specific targets based on the programme, workers will get motivated and worked toward the targets. Furthermore the impacts can be reduced by limiting the overtime period maximum up to 5 hours. Additionally shift work can be used put another gang for night works. Therefore always a fresh team will work for the night time. All of these can be possible when there is a proper super supervision

The subcontractors and joint ventures issues can be avoided by the selection of known familiar subcontractor. Further the selection of two subcontractors at a time will create a virtual competition between them. From this arrangement the works can be completed quickly and the absence of one subcontractor will not affect the work. For the more detailed subcontractor schedule, proper coordination and clear demarcation is required. it will be helped to avoid the conflict situation in between subcontractors. Likewise a proper management plan can overcome the impacts of construction sequencing.

The impacts of staff project with most efficient crews can be overcome by introduction of new technologies. Involvement of new technology decreases the requirement of efficient workers. In addition to that recruitment of an additional project manager to the site for a particular period will overcome negative effects. Most important thing is he should be an in house project manager. Otherwise it will increase the cost. With a proper management plan and division of scope will reduce the impacts from employ additional workers to the site.

Table 2: Strategies to Mitigate the Impacts of Schedule Compression Techniques

	Most Commonly Used Schedule Compression Techniques	Effective Strategies
1	Detailed project planning	• Advance planning • Change the sequence of activities • Change the specification with the approval of consultant
2	Working overtime	• Target incentives • Proper plan and supervision • Shift work • Policy on maximum overtime hours
3	Use subcontractors and joint ventures	• Find out the history of subcontractor • Proper negotiation • Familiarity with subcontractor • Assign individual targets and incentives • Select two Subcontractors at a time to create virtual competition

	Most Commonly Used Schedule Compression Techniques	Effective Strategies
4	More detailed subcontractor schedule	• Adhere to main contractors schedule • Proper coordination and supervision • Clear demarcation
5	Construction sequencing	• Maintain a proper plan
6	Staff project with most efficient crews	• Mix the best crews with non performing crews • Assign another project manager • Use of new technologies
7	Employ additional workers	• Employ experienced and skilled people • Proper planning • Divide the scope of work
8	Optimal material management for critical items	• Earlier storage • Increase staff in material management • Adhere to certain supplier
9	Participative management	• Participative management with single point responsibility • Control the micro groups
10	Increase supervisor/Worker ratio	• Bring best supervisors to the project • Provide incentives and scope enhancement to existing supervisors
11	Provide employees with incentives	• Provide food • Provide incentives with targets

Impacts of optimal material management for critical items will be decreased by proactive storage. Further the involvement of knowledgeable, enthusiastic, capable and committed material staff will overcome the impacts. Proper knowledge and control on participative management reduces the impacts eventually. The effects of increase in supervisor to worker ratio will be overcome by target and incentives scheme. Moreover, the involvement of masters in supervisor for a certain period will reduce the cost impacts. Instead of providing monetary incentives to employees, the arrangement of giving foods to the site people will motivated them.

5. CONCLUSIONS

Schedule compression is one of the delay minimising methods practiced by the Sri Lankan construction industry. The aim of this research was to identify the impacts of schedule compression techniques used in construction projects. Altogether, 11 techniques were identified as most commonly used in the Sri Lankan context. Even though the construction industry practitioners use the schedule compression techniques to mimimise the delays in construction projects, the techniques on the other hand deliver some negative impacts to the projects. Hence, the commonly practicing techniques have failed to provide an effective delay minimising approach to the Sri Lankan contractors.

The outcomes of the research revealed negative impacts of the schedule compression techniques in the Sri Lankan construction industry. In particular, additional cost, quality issues, productivity problems, conflicts, coordination problems and abortive works were highlighted as the recurring negative impacts. In order to mitigate the impacts, the research has stressed and recommended the strategies for each technique.

6. REFERENCES

Baker, R.D., 1991. *Time-cost relationship in construction.* Thesis (MSc), University of Florida.

Bandara, W.R., 2012. *Crashing applicaton for time cost trade-off in building projects: A case study.* Thesis (BSc). University of Moratuwa.

Esfahan, N., 2011. *Project schedule compression considering multi-objective decision environment.* Thesis (MSc), Concordia University.

Firth, D.S., 2011. *Acceleration* [online]. Available from: http://www.derekfirth.com/uploads/7/7/9/1/7791851/2011_scc_paper_on_acceleration_october_2011.pdf [Accessed 18 April 2014].

Hazini, K., Dehghan, R. and Ruwanpura, J., 2013. A heuristic method to determine optimum degree of activity accelerating and overlapping in schedule compression. *Canadian Journal of Civil Engineering,* 40(4), 382-391.

Mansur, S.A., 2004. *Productivity assessment and schedule compression index for construction project planning.* Thesis (PhD), Universiti Teknologi Malaysia.

Mansur, S.A., Putra, C.W. and Mohamed, A.H., 2003. Productivity assessment and schedule compression index (PASCI) for project planning. In: *5th Asia Pacific Structural Engineering and Construction Conference*, Johor Bahru, Malaysia, 133-147.

Moselhi, O., and Esfahan, N.R., 2013. Project schedule compression: a multi-objective methodology. *Construction Innovation: Information, Process, Management,* 13(4), 374-393.

Mubarak, S., 2010. *Construction project scheduling and control* [online]. Avaailanle from http://www.unimasr.net/ums/upload/files/2011/Mar/UniMasr.com_b22f24e9f6a269f41744453d5ff82d57. pdf [Accessed 10 March 2014].

Nepal, M.P., Park, M., and Son, B., 2006. Effects of schedule pressure on construction performance. *Journal of Construction Engineering and Management,* 132(2), 182-188.

Ssemwogerere, K., 2011. A case for acceleration rather than extension of time on construction projects in Uganda. In: *2nd International Conference on Construction and Project Management,* 192-195.

Thomas, H.R., 2000. Schedule acceleration, work flow, and labour productivity. *Journal of Construction Engineering and Management, 126* (4), 261-267.

Trauner, T.J., Manginelli, W.A., Lowe, J.S., Nagata, M.F. and Furniss, B.J., 2009. *Construction delays-understanding them clearly, analyzing them correctly.* 2nd ed. California: Elsevier Inc.