Environmental Technology & Science Journal
Vol. 10 Issue 2 December 2019

Optimal Frame Rates Determination for Effective Monitoring of Construction Site Operations using Time-Lapse Movies

Ali, A.A[1] & Idowu, F.A[2]
Ahmadu Bello University, Zaria, Department of Quantity surveying
aaabdu2000@yahoo.com and idowufaruq@gmail.com

Time-lapse movie has become more effective, efficient and less time consuming in monitoring labourers' operations, when compared with video recording, yet different frame rate is required for effective monitoring of individual labourers' activities of construction operations. However, to allow for accurate observation of Labourers' operation using time-lapse movies the frame rate must be lowered from the standard 30fps (frames per second) because some amount of detail is always lost in the interval between two consecutive frames in a time-lapse movie. This study aimed at determining an optimum frame for monitoring Labourers' activities and processes. The research obtained construction video on an ongoing job site of a three bedroom bungalow residential building (as a case study) on foundation base. It was manually constructed with the participation of unskilled labour and the videos were converted to 15 different time-lapse frame using *Adobe premiere pro* (a video and picture editing software), then the 15 time lapse movie was shown to eleven construction professionals along with a closed ended questionnaire. The research analysis conclude that the dry mixing process in time-lapse movie can be observed with frame rate of 3-seconds with accuracy level of 100%, for the wet mixing process, the time-lapse movies can be accurately monitored at a level of 100% with a frame rate of 2-seconds and the casting of concrete can be observed with a level of accuracy of 100% with a frame rate of 2-seconds. However, the number of Labourers' pouring measured fine aggregate (sand) with wheel barrow attained a maximum accuracy through different average point at 40-seconds, the number of labourers involved in dry mixing and wet mixing achieved a maximum accuracy at 1-minute and 30-seconds respectively. Further study should be conducted on optimal frame rate for monitoring material's using time-lapse movies

Keywords: Adobe premiere pro, Labourers' Activities, Labourers'operation, Time-lapse movie

Introduction

Monitoring and tracking the performance of construction projects plays a major role in achieving this goal (determining an optimum frame for monitoring Labourers' activities and processes. The research obtained construction video on an ongoing job site of a three bedroom bungalow), but is often a difficult and complicated task due to the constantly changing job site environment. Although construction site control in the majority of the construction industry is still mostly a manual task using visual inspection and paper based checklists, project participants such as Owners, Architects, Contractors, and Subcontractors increasingly rely on using technologies to update data when collecting site performance information (Bohn, 2009). In recent years, advanced approaches to progress monitoring have been studied to replace traditional methods of collecting and managing spatial data. Images from digital cameras or video cameras are generally used to monitor project progress (Nuri *et al.*, 2008).

Institution of Civil Engineers (2011) defined Time-lapse photography as a wonderful way of capturing a record of construction activities. It is a way of speeding up the actual events by capturing short duration video clips, or still images at regular intervals, and then combining them to form a movie. This means recording images at a frame rate lower than the standard 30fps (frames per second) established by the National Standard Television Committee. A movie so recorded is said to be in time-lapse mode. In this way, one can watch a ten-hour movie recorded at 1fps in just 20 minutes. Since the time of the Gilbereths, photographic analysis has been increasingly employed to address various site related issues. The usefulness of photographic information and the various methods of analysing them have been widely reported in the literature (Ibrahim & Kaka, 2008). In construction, Time-lapse photography are being applied in several different ways; a site record (Weather, Progress, Plant, Labour, Materials), Performance review of the activity for continuous improvement (Management and Health and Safety), Planning tool during preparation for similar activities in the future, Marketing material for bids, and for demonstrating ones contracting abilities to potential clients, Supporting material for convincing statutory bodies and affected parties (e.g. highway, planning, rail, waterways, property owners, the public) about one's ability to perform an innovative construction technique, A Promotional tool for use at exhibitions, careers fairs, trade shows and on websites, An Educational tool (Construction Technique, Management and Health & Safety) for practicing engineers and students, A realism tool and for demonstrating the complexities of construction processes to the public (Institution of Civil Engineers (ICE), 2011). However, time-lapse movie requires less storage memory as photographs will be deleted after the selection of required one, but also a lot of detail is also deleted thereby reducing the level of information (Ibrahim & Chindo, 2012). A lot of viewing time is also saved as a one-day work can be viewed in just a few minutes as only a small number of pictures are kept. Ibrahim et al. (2012) stated that construction professionals have been using time-lapse movies in monitoring construction operations. However, there is an issue that needs to be addressed in the use of time-lapse videos. This relates to the fact that lowering the frame rate during recording has an implication for the amount of detail that can be observed from the time-lapse video. This is particularly so because some amount of detail is always not recorded within the interval between any two consecutive frames. The frame rate therefore has an effect on the level of accuracy in interpreting time-lapse videos. This situation raises a question regarding the optimum frame rate required for the observation of various construction operations.

In construction, the most common applications of time-lapse are in dispute resolution, accident investigation, education, quality assurance, productivity measurement, communication of design intent, animation of the virtual world, site security, planning and scheduling, and teaching and learning of construction operations (Ibrahim & Kaka, 2008).

Since early 1900's, construction professionals have been using construction photographs or movies for documentation and analysis of construction activities (Everett *et al.*, 1998). The motion study of bricklayers by (Gilbreth 1909, cited in Ibrahim & Kaka, 2008) demonstrated a good example of utilizing motion pictures for studying workers activities. Gilbreth photographed the progress of work on the Augustus Lowell Laboratory of Electrical Engineering for the Massachusetts Institute of Technology in order to explain the detail work procedure of the project and improve a bricklaying process. Everett *et al.* (1998) emphasised the use of time-lapse in the monitoring of entire construction operations. They concluded that this approach can be of great benefit in documenting actual project progress and the recordings can be used in the resolution of claims and disputes, for education, public relations, fund raising, and it provides managers with remote access to project progress. Everett *et al.* (1998, cited in Yun-yi, 2010) reported that the information retrieved from time-lapse videos in two construction projects has succeeded in resolving construction claims and disputes. In their case study of an earthmoving project, the time-lapse images with a 4-second time interval allowed the project manager to reduce the excavation cost by viewing the images to investigate the actual amount of scooped earth excavated by the end-loader and dumped into the trucks, instead of calculating the amount of excavated earth from the number of trucks which were not fully loaded. The other time-lapse video tape recording showed that the delayed progress of an earth retention wall construction was due to an inefficient and inappropriate operation sequence. Therefore, the owner was able to successfully refuse the schedule extension proposed by the contractor. Abeid and Arditi (2002) recommend recording the operation at 1fps (frames per minute) and playing back time-lapse movies at lower frame rates depending on the need. Their study recognises that the observation of different operations requires different amount of detail and hence, different frame rates. But it fails to come up with the best frame rate required for the accurate observation of each operation. Kang and Choi (2005) opined that the observation error rates of most workers increased rapidly until the 60-second interval; but their increment is quite consistent. Thus, it may be possible to predict the confidence level by utilizing time-lapsed photo sets up to 60 second interval if more investigation will be implemented for various activities. Enabling construction professionals to predict the level of confidence in utilizing time-lapsed photo set may promote the use of webcam for monitoring construction operations. Considering that the error rate of 60 second interval photo sets was marked less than 30% for all sites, time-lapsed photo set with less than 60-second interval may be utilized for monitoring construction operations and evaluating productivity with 70% of confidence level (Kang & Choi, 2005). Ibrahim *et al.* (2012) researched further into the optimum frame rate for mortar mixing and block handling activities; he established the best frame rate at which these activities are to be observed. He suggested that a 50-second frame rate is appropriate for the observation of the measure of sand used in mixing mortar, a 20-second frame rate for the accurate identification of the number of cement bags used. The author further suggested a 5-minute frame rate for keeping accurate track of the number of labourers in mixing mortar and a 2-second frame rate for the accurate tracking of number of blocks offloaded or damaged.

Although several researches have established frame rate at which some construction operations should be recorded, it is necessary to understand that a generally applicable genuine and general frame rate for construction cannot be ascertained if the frame rate of all the respective activities are not first established. Therefore, this study seeks to establish an optimum frame rate for monitoring manual concrete construction activities and processes which include dry mixing, wet mixing and casting.

Research Methods

In order to identify an optimum frame rates for monitoring labour's activities with the use of time-lapse movies, labour's activities and processes were recorded on an ongoing job site using a portable digital camera. The video gotten were then imported into *Adobe premiere Pro CC*, which is a picture and video editing software, the video was then converted to still pictures by exporting the videos in TIFF format and saved into the respective folders at 29.97fps (29.97 frames per seconds). The still images created were converted manually. Each time interval to be considered was converted into seconds (multiply minutes by 60), and multiply by the frame rate (frames per second (fps)) intended for the final video playback. This gives the total number of photos required to be taken during the whole event. The pictures selected manually were then saved into different folders from 5-minutes to 1-minute, 50-seconds to 10-seconds and 5-seconds to 1-seconds which make a total of 15 different time-lapse movies. The still pictures in the TIFF format was then imported into the software as a sequence image at the converted frame at its original frame rate of 29.97fps (29.97 frames per seconds) and further exported in AVI video format into a frame of 24fps (24 frames per second) by this a 17.01 minute was converted into 0.20 minutes (20 seconds). The same approach was done for additional 14 different time-lapse movies of 5-1 minute's interval and 50, 40, 30, 20, 10, 5, 4, 3, 2, 1 second.

In order to determine the level of accuracy of interpreting job site situation a structured questionnaire was used with closed-ended questions based on the 15 time-lapse movies generated which was administered to eleven (11) construction professionals working on the site. The usage of material and workers' activity in each video were evaluated. The response was ranked such that 5 (most accurate) is the highest score and 1 (less accurate) is the lowest score. Supposing the number of wheel barrow measure of fine aggregate used was 2, the respondent who choose 1 and 3 as the number of wheel barrow measure of fine aggregate used were ranked 4 (non-accurate by 1) as they are close to 2, if 4-wheel barrow measure was used it was ranked 2, and if 5-wheel barrow it was ranked 1. The 15 different frames were observed in order from 5-minute interval to 1 second interval in order to receive an unbiased response from the respondent (Ibrahim et al., 2002). The summation of the point assigned to each and every frame will be the total score of that time-lapse movie.

The Table 1 shows responses of five different respondents in 5-minutes time-lapse movie on the number of labourers involved in the pouring of wheel barrow measured. All the responses of the five respondents were computed and the average score was 4.2. Four respondents out of five were of the opinion that the number of labourers involved in pouring sand with wheel barrow can be observed with an accuracy level of 5 (most accurate) and the only one respondent was of the opinion that the number of labourers involved can be observed at an accuracy level of 1 (non-accurate). The average score of the entire 5 respondents was computed and the same procedure was done to all 15 time-lapse movies for the labour activities.

The Table 2 shows summary of the average of all the 5 respondent used on each question for the time-lapse movies, from 5-minute to 1 second for all the processes of concrete construction which include the Dry mixing, wet mixing and Casting which concerns the labour activities.

Table 1: Respondent Response on Labours' Activities

S/NO	Question/Responses	5 mints Av.	4 mints Av	3 mints Av	2 mints Av.	1 mints Av.	50-mints Av.	40-mints Av.	30-sec. Av.	20-sec. Av.	10-sec. Av.	5-sec. Av.	4-sec. Av.	3-sec. Av.	2-sec. Av.	1-sec. Av.
1	How many labourers did you see carrying out that operation?	4.2	3.2	4.6	4.8	4.6	4.8	5	5	5	5	5	5	5	5	5
2	How many labourers were involved in dry mixing of concrete?	3.4	3.6	4.4	4.8	5	5	5	5	5	5	5	5	5	5	5
3	How many labourers were involved in wet mixing of concrete?	3	4.4	4	3.8	3.6	3.4	4	5	5	5	5	5	5	5	5
4	How many times was bucket use in placing of the concrete?	1	1	1	1	1	1	1	1	1.2	1.6	2.8	4	4.6	5	5
5	How many times was head pan use in placing of the concrete?	1.2	1	1	1	1	1	1	1	1	1.4	3	4.2	4.8	5	5

Table 2: Scores of 5 respondents on 5 minutes' interval time-lapse movie of labourers involved in pouring measured sand with wheel barrow

Respondent	The video shows labourers pouring sand with wheel barrow. How many labourers did you see carrying out that operation?
1	5
2	5
3	5
4	5
5	1
Average score	**4.2**

Figure 1 shows the average score of the numbers of labourers involved in the pouring of wheel barrow measured of sand at 5-minute time-lapse frame was 4.2, the score then fell to 3.2 at 4-minute frame, at 3-minute the score rose 4.6, it then further increase to 4.8 at 2-minute. At 1-minute the score fell to 4.6 and then further rose to back to 4.8 at 50-second time-lapse interval, the average score then obtained a maximum score of 5 (most accurate) at 40-second which was maintained through to 1-seconds time-lapse frame. Therefore, the numbers of labourers involved in the pouring of wheel barrow measure of sand can be observed at a degree of accuracy of 40-second time-lapse movie frame rate.

Figure 2 indicates the numbers of labourers involved in dry mixing at 5-minute photoset interval the average score was 3.4, which then rose to a score of 3.6 at 4-minute, at 3-minute the score further increased to 4.4, the average score then rose to 4.8 at 2-minute interval. It then attained a maximum score of 5 (most accurate) at 1-minute time-lapse movie frame rate which was retained till 1-seconds. This implies that for the numbers of labourers involved in dry mixing can be monitored with a level of accuracy of 1-minute time-lapse movie frame rate.

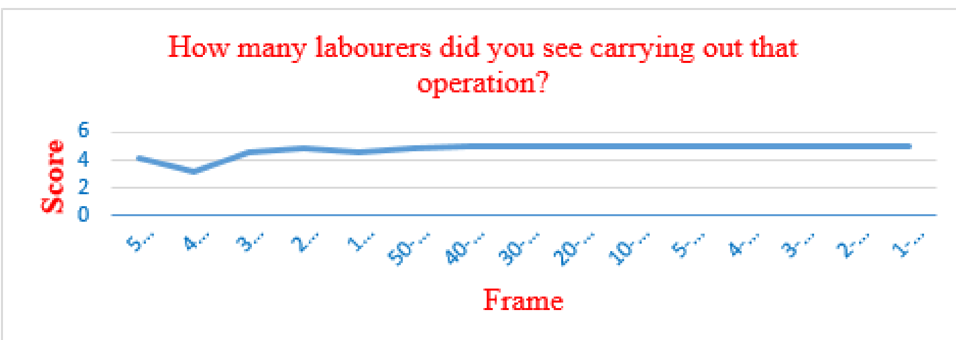

Figure 1: The numbers of labourers involved in pouring of wheel barrow measure of fine aggregate (sand).

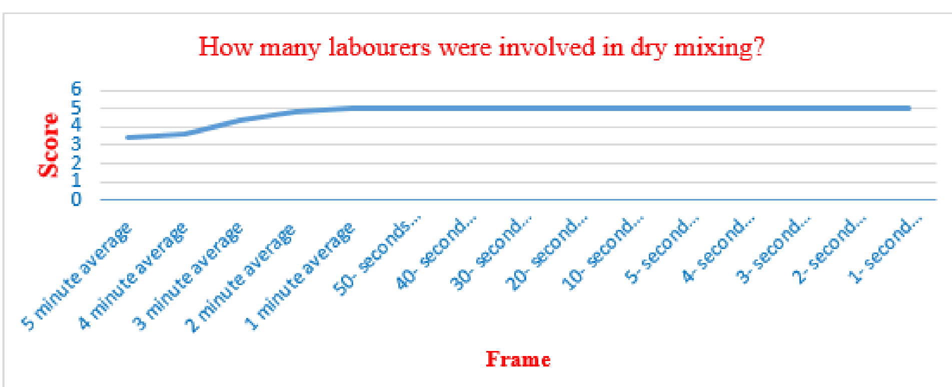

Figure 2: The numbers of labourers involved in dry mixing

As shown on Figure 3, the numbers of labourers involved in wet mixing of concrete was scored 3 (accurate) at 5-minute time interval, it then rose to the score of 4.4 at 4-minute, at 3-minute the score fell to 4 (very accurate) and fell to the score 3.8 at 2-minute. The score further fell to the score of 3.6 at 1-minute and fell to 3.4 at 50-seconds time interval, it then rose to the score of 4 at 40-seconds, and attained a maximum score of 5 (most accurate) at 30-seconds, the score was then maintained to 1-second. Hence, the numbers of labourers involved in wet mixing of concrete can be observed with the degree of accuracy of 30-seconds time-lapse frame rate.

Figure 4 reports on the count of the numbers of times was bucket use in placing of the concrete, at 5-minute the average score was 1(non-accurate) which was then maintained to 30-seconds time-lapse frame, the score at 20-seconds then rose to 1.2, at 10-seconds the score increased to 1.6, which further rose to the score 2.8 at 5-seconds time interval, the score the increased to 4 at 4-seconds and further rose to the score of 4.6 at 3-seconds. At 2-seconds it reached a peak score of 5 (most accurate) which is the maximum score and it was maintained at 1-seconds photoset time interval. It means for the number of times bucket was used in placing of the concrete can be studied with a level of accuracy of 2-seconds time-lapse movies frame rate.

Figure 5 shows the number of times was head pan use in placing of the concrete scored 1.2 at 5-minute, the score then fell to 1 (non-accurate) at 4-minute which was maintained to 20-seconds time interval. At 10-seconds the score increased to 1.4 and further rose to the score of 3 at 5-seconds, the score then increased to 4.2 at 4-seconds and further rose to 4.8 at 3-seconds. It then attained a maximum average score of 5 at 2-seconds which was then maintained to 1-seconds. This implies that for the number of times head pan was used in casting concrete can be monitored with a degree of accuracy of 2-secconds time-lapse movies frame rate.

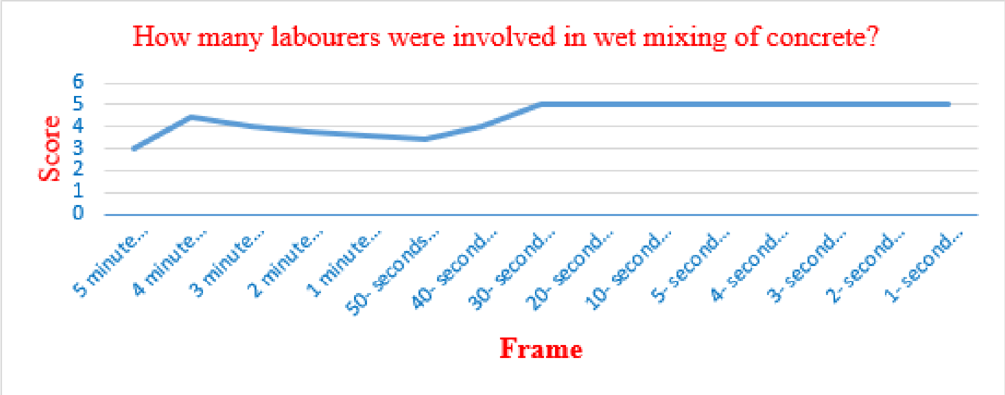

Figure 3: The numbers of labourers involved in wet mixing

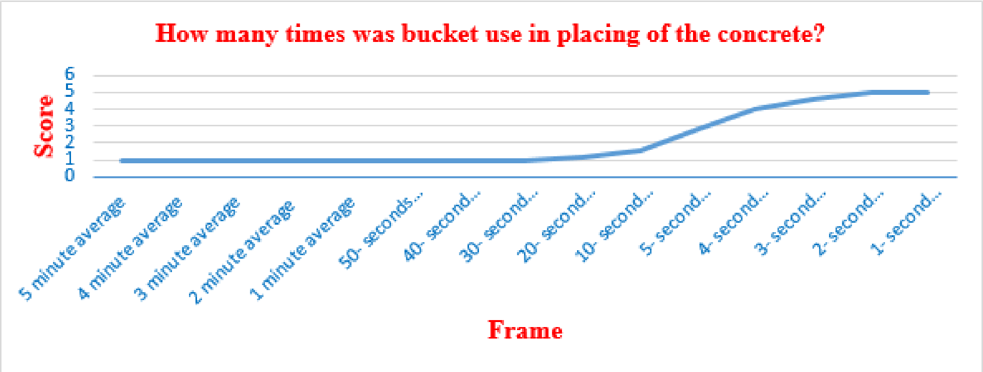

Figure 4: The numbers of times bucket was used in placing concrete

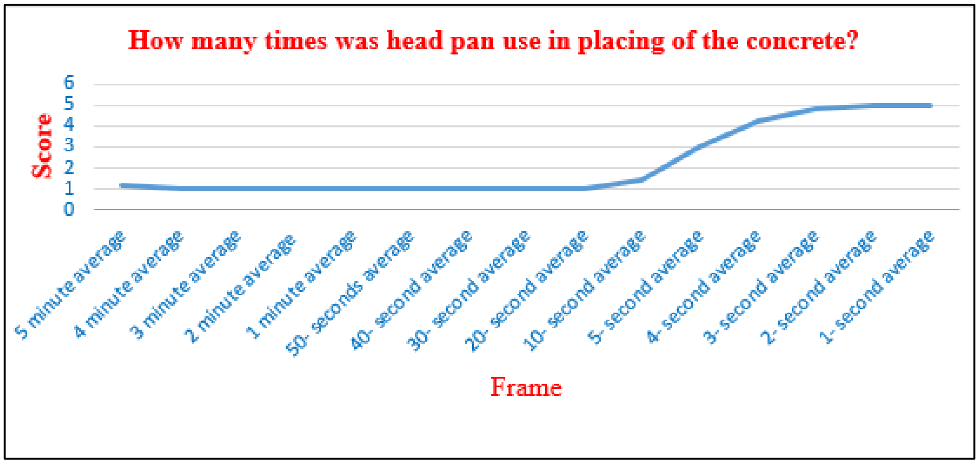

Figure 5: The numbers times head pan was used in placing concrete

Discussion of results

Overall, the results disagree with the allusion by Everett *et al*. (1998) and Abeid and Arditi (2002) that an interval frame rate of 1fps to 5fps may be adequate for the observation of construction operations. Although Kang and Choi (2005) recommended a frame rate of 1fpm for the monitoring of productivity with a 70% level of confidence, the results of this study relate to labourers suggest that labourers can be tracked accurately from a movie recorded at 1 frame in every 5 minutes.

Also, the study of Ibrahim *et al.* (2012), is also different, for keeping accurate track of the number of labourers in mixing mortar, a movie recorded at 1 frame in every 5 minutes is sufficient. As expected, the accurate tracking of number of blocks offloaded or damaged requires a lower frame rate (1 frame in every 2 seconds).

Conclusions

The degree of accuracy observed number of wheel barrow measure of fine aggregate used was a 4-seconds, the number of wheel barrow measure of coarse aggregate used was attained at 4-seconds time-lapse movies. The number of buckets of water used in the mixing of the concrete attained the maximum accuracy level in 2-seconds. The number of labourer pouring measured fine aggregate (sand) with wheel barrow attained a maximum accuracy through different average point at 40-seconds, the number of labourers involved in dry mixing and wet mixing achieved a maximum accuracy at 1-minute and 30-seconds respectively. The number of times bucket was used in casting and head pan used in casting both attained a maximum accuracy from several average at 2-seconds time-lapse movie.

Therefore, the dry mixing process in time-lapse movie can be observed with frame rate of 3-seconds with accuracy level of 100%. This is because the number of times fine and coarse aggregate was poured, the number of bags of cement used and the number of labourers involved in both pouring of fine aggregate and dry mixing can be optimally observed at 3-seconds time-lapse movie.

For the wet mixing process, the time-lapse movies can be accurately monitored at a level of 100% with a frame rate of 2-seconds, this is because the number of buckets of water used in the wet mixing and the numbers of labourers involved can be optimally monitored at a time-lapse movie of 2-seconds.

The casting of concrete can be observed with a level of accuracy of 100% with a frame rate of 2-seconds, because the number of times concrete was casted, the number of times bucket and head pan was used can be optimally monitored at a time-lapse frame 2-seconds. However, further study should be carried out on other means/frame rates for determination effective monitoring of construction site operations.

References

Abeid, J. & Arditi, D. (2002). An integrated system controlling construction progress. *Engineering, construction and Architectural management, 10(3)*, 162-171.

Abeid A, J. & Arditi, D. (2002). Time-lapse digital photography applied to project management. *Journal of Construction Engineering and Management*, 128(6), 530-535.

Bohn, J. (2009). Benefits and barriers of construction project monitoring using Hi-resolution automated cameras. *Journal of construction Engineering and Management*, 136(6), 632-640.

Everett, J. G., Halkali, H., & Schlaff, T. G. (1998). Time-Lapse Video Applications for Construction Project Management. *Journal of Construction Engineering and Management,* 124(3), 204-209.

Ibrahim, Y. M. & Kaka A.P. (2008). Review of photographic/imaging Applications in construction. *The Built & Human Environment Review, I*, 99-117.

Ibrahim, Y.M, Ibrahim, A. D. & Chindo, P.G. (2012). Determination of optimum frame rate for observation of construction operations from Time-lapse movies. *Journal of Engineering, project and production management, 2*, 57-65.

ICE, (2011). Time-lapse movie making: production & application to civil engineering. *Journal of Construction Engineering and Management,* 12(2), 74-89

Kang, J. & Choi, J. (2005). Observation error of time-lapsed photos in construction operation monitoring. *Computing in Civil Engineering,* 179(100), ASCE, 1-10.

Nuri, C., Son, H., Kim, C., Kim, C., & Hyoungkwan Kim (2008). Rapid 3d Object Recognition for Automatic Project Progress Monitoring Using a Stereo Vision System" *International Symposium on Automation and Robotics in Construction*, 25th (ISARC) Proceedings. 58-63.

Yun-Yi, S. (2010). *Construction crew productivity monitoring supported by location awareness technologies.* Urbana, Illinois, Champaign: University of Illinios .