Development of a Progress Management System Integrated with the Quality Inspection Process: Case of a nuclear power plant construction project in Korea

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Abstract
In this paper, the authors present the concept of a progress management system that synchronizes the quality inspection process with integrated cost-schedule information in construction projects. In general, construction progress has been measured using subjective judgments by field managers or extensively processed cost data. A practical progress management system should be able to maintain and provide objective and reliable progress data on time without extra data processing. The quality inspection process can produce appropriate data for this purpose. However, in conventional construction management practices, progress measurement and quality inspection have been separated. In order to design and implement a system that synchronizes them, the available information that can be provided from current processes were identified and connected using the following steps: 1) analyzing the quality inspection process, 2) identifying the means for measuring progress, 3) determining identical elements in various schedules, and 4) linking quality inspection lots to the means for measuring progress. An on-line system was developed and applied to a nuclear power plant construction project in Korea. The results from operating it show that the conflicts in progress determination between clients and contractors were reduced, and the costs and time for administrative tasks involving the processing of progress management and quality inspection data were saved.

Keywords: information systems (IS); progress; quality; cost-schedule integration

1. Introduction
A comprehensive and systematic approach to progress monitoring is crucial to the identification of discrepancies between planned and actual schedules and costs (Lee and Peña-Mora, 2006). To this end, precise information concerning progress should be obtained in a timely manner. This approach also provides useful objective data to determine payments to contractors. However, there is no authorized method for measuring progress. Furthermore, its process may vary according to the nature of the contracts between clients and contractors. In general, the criteria for measuring progress are agreed upon between the parties and include cost or time proportion, milestones, and earned value. One challenge to be faced is that clients and contractors may disagree on the progress, particularly if it is measured by means of a site supervisor's subjective opinion. For this reason, an objective and reasonable method for measuring progress is required.

Several researchers have proposed methodologies for accurate progress measurement, in particular, those based on the integration of cost and schedule data. Eldin (1989) proposed a practical procedure for evaluating work progress in a quantitative manner by employing the WBS and earned value. Yang et al. (2007) attempted to calculate a budgeted cost work schedule by allocating the project budget into a work-packaging model. Chou et al. (2010) developed a management information system that provided an objective measure of completed work by integrating an earned value analysis and database management system based on a multiple criteria decision-making process.

However, only a few researches have considered the interrelationship between quality management and progress measurement, even though it is also a major management area in a construction project. In previous studies, only the cost and time data of activities that are assumed to meet quality standards have been considered. However, in real world projects, activities may be reworked according to quality inspection results. Thus, the schedule is delayed and the progress assessment has to be modified. For this reason, progress measurement should be accompanied by an assessment of the quality of the work (Boukamp and Akinci, 2007). In terms of measuring the progress in real world practice, making an informational link to the quality management area can reduce the efforts to collect data to measure progress.

An environment to facilitate the approach mentioned above has been cultivated owing to the increasing focus on quality inspection. For instance, almost all construction companies have acquired ISO 9000/9001 certification, which applies to the quality control processes of construction projects. Basically, quality assurance involves quality inspection, and it is particularly essential in complex public-lead projects requiring a high standard of quality such as a nuclear power plant. Quality inspections take place with the completion of fieldwork at construction sites. Therefore, the integration of these two procedures could be an efficient means of obtaining objective data concerning progress in real time, by eliminating any additional workload for collecting progress data.
This research aims to implement a progress measurement system integrated with a quality inspection process. To explain the concept and details of its implementation, the authors begin by reviewing previous studies and current trends in progress and quality management practices. On the basis of this review, a means to connect the two processes is identified. The concept is further developed into to-be processes, and a data structure is designed. An implemented system in use is explained with screenshots. The benefits of the system are validated by applying it to a nuclear power plant construction project in Korea.

2. Progress and Quality Management and its Integration

Lukas (2008) categorized progress measurement techniques, as shown in Table 1. The "units completed" technique is the most objective because real measurements are made of all the works completed against the total works to be completed. This technique is generally adopted in Korea to measure progress and determine payments to contractors. The ratio of the completed quantities against the total planned quantities is calculated using individual items on a contractual bill of quantities (BOQ) (Yang et al., 2007). However, this may cause an additional workload. Moder et al. (1983) suggested that collecting actual data on site and processing it to measure progress should be carried out with a limited amount of time and effort. Ghanem (2006) also mentioned that the "units completed" technique requires much time and effort for the measurement work itself, making it impossible to deliver just-in-time information concerning progress.

The "representative quantities" technique was developed as an alternative to the "units completed" technique, where the progress is determined by measuring the critical works completed or the resources input to do so. In the context of this technique, Jung (2007) presented the concept and implementation of Standard Progress Measurement Packages (SPMPs). This approach can be useful in that the measurement efficiency increases without sacrificing the accuracy of the progress measurement. However, no consideration was given to integration with the quality management area. As to the quality management area, a couple of researches introduced mobile quality inspection solutions. Chin (2004) attempted to integrate the schedule and quality using multimedia, but no quantitative relationship between progress and quality was clarified.

No explicit approach for the quantitative integration of quality and progress (i.e., cost and schedule) has been presented. According to a preliminary investigation on conventional projects in Korea, no formal interaction between the quality and progress management areas has yet been observed, as presented in Fig.1.

3. Systems Analysis and Design

3.1 Concept of System and Field Investigation

Fig.2. shows the conceptual model of a progress measurement system integrated with a quality inspection process. The model consists of four main components: 1) the quality inspection process, 2) the means for progress measurement, 3) a hierarchical structure of construction schedules, and 4) quality inspection lots linked to the means for measuring the progress. The distinctive concept is to find a correlation between the activities and quality inspection by means of inspection lots containing quantities of work.

3.2 Quality Inspection Process with Master Data

In order to present a practical approach, the as-is processes of quality inspection and progress measurement in a nuclear power plant construction project were analyzed by one of the authors. The client's in-house professionals responsible for the quality and schedule management in the fields of civil, architectural, mechanical, and electrical engineering were involved in this analysis. The analyzed processes are explained in the following sections.

Fig.3. shows a conventional inspection process using IDEF0 modeling notation. The quality inspection process consists of the following steps: an Inspection and Test Plan (ITP), work notification, Inspection Reporting (IR) after the inspection and test on work preparation, work in process, and work completed. At each step, corresponding documents are produced, shared, and confirmed by practitioners responsible for quality management from various organizations such as clients, contractors, and external authorities.

The inspection phases, inspection items, and documents attached to inspection reports are the master data used in the quality inspection process. Table 2. shows an example of the
The master data can be predefined according to work type from the Work Plan Procedure (called WPP hereafter), Quality Control Instruction (called QCI hereafter), and special/general specifications, as presented in Fig.4.

### 3.3 Means for Measuring Progress: Resource Estimates

In general, the progress is measured on the basis of the contractual BOQ. Individual items in the BOQ describe a resource or work with its quantity. In this research, BOQ items are defined as "Resource Estimates" (hereafter, REs) in that they play the role of the means for measuring progress. REs are subdivided into the primary REs, which are directly measured to determine the progress, and secondary REs, which are subordinate to one of the primary REs. Secondary REs are automatically measured by measuring the primary REs, which means the advantage of the "representative quantities" technique is available. The cardinality between the primary and secondary REs should be kept at 1:N.

An example of defining primary and secondary REs from the BOQ is presented in Table 3. In this example, two BOQ items involving plywood forms "under 15th floor" and "above 16th floor" are defined separately as independent primary REs, while another BOQ item "plywood form rent fee" is defined as a secondary RE and split into one "under 15th floor" and another "above 16th floor". This is a decomposition case, where one BOQ item is defined as multiple secondary REs to be subordinate to different primary REs. In order to enable REs to act as a means of measuring the progress, these should be connected to elements at a proper level of the schedule. The details will be explained in the next section.

### 3.4 Unit for Progress Planning and Measurement: Activities of hierarchical schedule

The progress measurement should treat both the cost and time aspects. Measuring progress based on quantities of BOQ items can fulfill the cost aspect. Progress should also be measured against its planned schedule considering the time aspect. To this end, activities concerning the schedules at various levels need to be aggregated into the entire project level and disaggregated to the bottom level for progress planning and measurement. A hierarchical structure with a Work Breakdown Structure (called WBS hereafter) is introduced to this end. The framework for defining the levels of a schedule in construction projects can be outlined as follows: a summary schedule covering the entire project and major events or milestones; a main schedule for project headquarters to control the overall time and costs under the conditions of the contract; and a detail schedule for fieldwork describing the works to be specifically completed during relatively short periods. According to the hierarchy mentioned above, activities concerning the main schedule can be identified as front-end units for progress planning based on the following rationale:

1. The main schedule is set up in an initial stage of the project, covering the whole period of the construction project.
2. In general, the main schedule is composed using a network scheduling technique such as PERT/CPM, by which the start and finish dates of activities are automatically calculated. As a consequence, the planned progress is also updated automatically, along with the results of rescheduling when the main schedule is changed.
3. Most contracts specify the main schedule as the...
In this study, an inspection lot is defined as the entire quantity of REs, whose size is determined according to the concept of "inspection lot," as described in Fig.9. An inspection lot is generally used in the manufacturing industry as a quality inspection unit, referring to a partial quantity of the entire inspected product. For this reason, this research proposes a guideline to use "work types" from WPP/QCI when the practitioners organize the activities on the detail schedule. Regarding the hierarchy of the main and detail schedules, this guideline will be convenient to group similar work types or compose an independent sequence of works from the bottom level to upper level of the schedules.

In general, BOQ items are placed under their relevant chapters, which are classified according to various aspects such as the product (i.e., area, zone, facility, component, etc.) and/or process (i.e., earthwork, steel/concrete structural work, exterior/interior work, mechanical/electrical work, etc.). While organizing the BOQ chapters, the items can be linked to the "work type groups" and "work types" of WPP/QCI. Consequently, REs can be distributed to the main schedule efficiently. To this end, the main schedule and detail schedule should be prepared by selecting the "work type group" and "work type" from the standardized library, as described in Fig.8.

3.5 Quality Inspection Lots Linked to Means for Measuring Progress

The proposed quality inspection process is closely linked to the activities of the detail schedule. However, in the real world, diverse processes are used to plan and prepare for quality inspection. For this reason, this research introduces the concept of "inspection lot," as described in Fig.9. An inspection lot is generally used in the manufacturing industry as a quality inspection unit, referring to a partial quantity of the entire inspected product.

In this study, an inspection lot is defined as the entire quantity of REs, whose size is determined according to the quality inspection cycle per "work type". Inspection lots are not only assigned to the activities of the detail schedule, but also to the quality inspection documents such as ITP and IR. In addition, inspection lots include quantities of REs that

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**Table 3. Example of Primary and Secondary Resource Estimates from BOQ**

| Item                  | Spec.          | Quantity | Unit | Class              | Resource Estimate                 | Quantity | Reference | Remarks            |
|-----------------------|----------------|----------|------|--------------------|-----------------------------------|----------|-----------|--------------------|
| Plywood Form          | Under 15th Floor | 14736    | M2   | P                  | [REP3010] Plywood Form (Under 15th Floor) | 14736    | -         |                    |
| Plywood Form          | Above 16th Floor | 8846     | M2   | P                  | [REP3020] Plywood Form (Above 16th Floor) | 8846     | -         |                    |
| Plywood Form          | Rent Fee       | 23582    | M2   | S                  | [RES3011] Plywood Form Rent Fee (Under 15th Floor) | 14736    | [REP3010] | Split for dependency on Primary Resource Estimate |
|                       |                |          |      | S                  | [RES3021] Plywood Form Rent Fee (Above 16th Floor) | 8846     | [REP3020] |                    |
| Steel Bar HD13        |                | 1488     | TON  | P                  | [REP3060] Steel Bar HD13          | 1488     | -         |                    |
| Steel Bar HD16        |                | 450      | TON  | P                  | [REP3070] Steel Bar HD16         | 450      | -         |                    |
| Rebar                 | Under 15th Floor | 2404    | TON  | P                  | [REP3100] Rebar (Under 15th Floor) | 2404     | -         |                    |
|                       | Above 16th Floor | 367     | TON  | P                  | [REP3110] Rebar (Above 16th Floor) | 367      | -         |                    |
| Concrete Placement    | Under 15th Floor | 17061   | M3   | P                  | [REP3120] Concrete Placement (Under 15th Floor) | 17061    | -         |                    |
|                       | Above 16th Floor | 9021    | M3   | P                  | [REP3140] Concrete Placement (Above 16th Floor) | 9021     | -         |                    |

P in class: Primary Resource Estimate
S in class: Secondary Resource Estimate

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Fig.5. Progress Planning by Distributing REs on Main Schedule communication medium between the client and contractor(s) in relation to the schedule, progress, and payments.

Considering the real world practices stated above, the planned progress on the main schedule is set up by distributing the primary REs to the activities of the main schedule, as shown in Fig.5.

Fig.6. explains the sequential details of the progress-planning concept presented in this research. REs are extracted from the BOQ project. The main schedule is developed according to the WBS regarding the summary schedule, site plan, and construction method applied. On the other hand, the primary and secondary REs are extracted from the BOQ. The information about the "work type groups" defined from the Work Plan Procedure (WPP) and Quality Control Instruction (QCI) is linked to the activities of the main schedule and primary REs. Finally, by distributing the primary REs on the main schedule, the planned progress is prepared.

As for measuring the progress, the detail schedule plays the role of a front-end unit. The activities that appear on the detail schedule become direct references to fieldwork, and Inspection and Test Plans (ITPs) are prepared along with activities planning for a specific period (e.g., for the next 2 or 3 months). The activities on the detail schedule should be defined from the activities on the main schedule so that the former can be aggregated into the latter. For this reason, the cardinality between the activities on the main schedule and detail schedule should be kept at 1:N, as shown in Fig.7.

In Fig.7., given that the Inspection and Test Plans (ITPs) are prepared with the detail schedule, the identical "work type" exists in both, and thus integrated progress measurement and quality inspection management is possible. For this reason, this research proposes a guideline to use "work types" from WPP/QCI when the practitioners organize the activities on the detail schedule. Regarding the hierarchy of the main and detail schedules, this guideline will be convenient to group similar work types or compose an independent sequence of works from the bottom level to upper level of the schedules.

In general, BOQ items are placed under their relevant chapters, which are classified according to various aspects such as the product (i.e., area, zone, facility, component, etc.) and/or process (i.e., earthwork, steel/concrete structural work, exterior/interior work, mechanical/electrical work, etc.). While organizing the BOQ chapters, the items can be linked to the "work type groups" and "work types" of WPP/QCI. Consequently, REs can be distributed to the main schedule efficiently. To this end, the main schedule and detail schedule should be prepared by selecting the "work type group" and "work type" from the standardized library, as described in Fig.8.
come from the parent activity in the main schedule, from which activities in the detail schedule are defined. By doing this, the inspection lot plays the role of a medium for linking quality and schedule management.

The number of inspection lots depends on the quality inspection cycle. This varies according to the technical characteristics of the "work type" defined in WPP and QCI or the specifications for exceptional cases. If a quality inspection cycle is defined on the basis of quantity or duration, it will be repeated until approaching their total values. It can also be defined by physical elements such as the facility, equipment, and structural/functional part of a product, which are identified in drawings or specifications. Table 4 shows some examples of defining the inspection lot size per "work type".

While conducting the activities on the detail schedule, the interim progress should be measured and recorded. If the activities on the detail schedule are not directly mapped to individual quality inspections, an inspection cycle based on the lot size may exceed the progress update cycle. For example, if the inspection lot size of excavation work is 1000 m$^3$ according to WPP and QCI, and the amount of work progress is 900 m$^3$, the progress of the activities may not have been updated.

In order to overcome the time gap between the quality inspection cycle and the progress measurement cycle, the inspection lot size needs to be split into several smaller lots, as shown in Fig.10. The initial progress curve in Fig.10(a) is adjusted to form the one in Fig.10(b). However, excessive segmentation of an inspection lot
for exact alignment with the progress measurement cycle may unnecessarily increase the costs of quality inspection. In some cases, provisional quantities of REs should be measured within the total lot size of the inspection lot before quality inspection.

Fig. 11 describes the process used to define inspection lots and distribute REs to them. The general lot size for quality inspection per "work type" or resource is defined in WPP and QCI. According to the inspection lot split concept, the inspection lot sizes from WPP and QCI are adjusted according to the work plan. Afterward, inspection lots are defined for the activities on the detail schedule, followed by determining the progress update rule for an inspection lot with consideration of the work speed and inspection lot size. Finally, quantities of REs from the activities on the main schedule at a higher level are distributed to the inspection lots. Through this process, inspection lots with RE quantities for addressing the progress are prepared to be on the ITPs for quality inspection.

3.6 Quality-progress Integration Process

Fig. 12 illustrates the process for integrating the components presented thus far. An integrated process begins with the definition of master data for quality inspection, including inspection phases and inspection items per "work type" defined in WPP and QCI.

The "work type group" and "work type" information are key elements for linking the schedule activities and quality inspection documents, starting from the ITP. Inspection lots enable individual quality inspections with quantitative information about the progress by holding quantities of REs. By connecting inspection lots to the activities on the detail schedule and ITP, quality inspection and its results have an effect on the progress. Consequently, progress measurement is supported by a formalized quality inspection and interrelated processes for the quality inspection, schedule, and REs. The quality inspection master data enable efficient and error-free document processing in the system.

4. Quality-progress Integrated Systems

Based on the processes and logics presented in the previous sections, the functions of the information system were developed. The system aims to support the management of nuclear power plant projects in Korea. Because of the high sensitivity of public safety, a nuclear power plant construction project requires strict quality management to ensure that all of the products and work processes on the site meet technical requirements. Additionally, many private contractors participate at various contractual levels, making accurate payments based on their progress critical. For these reasons, such a system is more necessary in this type of project than in others.

The system aimed to not only integrate quality management and progress management but also to reduce the inaccuracy and inefficiency of the conventional management process. In the conventional environment, interim progress was measured by an experienced field manager's subjective judgment. Furthermore, inefficiently, it was based on various unstructured documents and records before reinvestigating completed works. Quality inspection plans were often not consistent with the schedule or work plans, which were modified by design change, adjustments in field conditions...
caused by technical reasons, and so on. Paper-based ITP, work notification, and IR were labor intensive to prepare. In several cases, these had errors or omissions. Moreover, quality inspection documents had to be reprocessed by a human to produce statistical or analytical information. Thus, the proposed system was designed to share information on the quality and schedule on time among the participants responsible for documenting and updating information.

4.1 System in Use

Fig. 13. shows screenshots of the interface windows according to the information flows. The system operation starts from the registration of the master data for quality inspection. On the basis of definitions in WPP and QCI, "work type groups" and their subordinate "work types" are registered as master data in the system. As shown in Fig.13(1), the inspection phases per work type, inspection items per inspection phase, and attached documents in inspection reporting are also registered in the system according to the definitions in WPP and QCI.

Fig. 13(2). shows that REs defined from the contractual BOQ are uploaded and stored in the system. As shown in Fig.13(3), the activities on the main schedule are registered with WBS, and REs are distributed to these. Given that the activities on the detail schedule were registered in the system, Fig.13(4) shows the creation of inspection lots with the distribution of REs from the activities on the main schedule.

An ITP document is created by referring to the activities on the detail schedule. For the sake of the quality inspection master data registered at the start time, the required data for documenting the ITP such as inspection phases and inspection items are defaulted. After assigning inspection lots, the ITP document is followed by an Inspection Report. As shown in Fig.13(5), inputs are made on the inspection phases and items selected in the preceding ITP.

If the results of the inspection conform to the requirements, the quantities of primary REs assigned through inspection lots are accepted as the progress made. On the other hand, if the results do not conform, a non-conformance report (NCR) is produced, where the quantities of primary REs do not reflect the progress. Subsequent to the process described above, the system generates the progress accumulated by individual activities on the main or detail schedule as well as the total progress of the project. It also provides reports on various criteria to check and monitor the status of quality inspection practices and progress trends.

4.2 Validation

An investigation was undertaken in Sep. 2010 to validate the utility and effectiveness of the proposed system after applying it to a nuclear power plant project. The project was located in the southeast seaside area of Korea, and its status was the final construction phase. Interviews with fourteen professionals were conducted, including the managers and engineers for the civil, architectural, mechanical, and electrical departments responsible for quality and schedule management. They had experience on conventional projects in which quality inspection and progress measurement were conducted separately. In order to measure the time and effort required, the participants were asked to perform relevant functions in the systems. In addition to interviews and operation observations, logs that were created in the system were analyzed to measure the performance of these activities after using the system. Table 5. presents the investigation items used to validate the system.

Based on operation observations, the time needed to produce and distribute documents on quality inspections
(i.e., ITP) was 30 minutes per document. The interviewees estimated that, on average, an hour was saved per processing cycle for documenting from the preparation to approval compared to previous projects in which the system was not introduced. When the number of ITP in a nuclear power plant project is around one million, the benefits are significant; however, variances exist depending on the complexity of works. It is estimated that approximately one million man-hours can be saved.

In terms of efficiency, the interviewees responded that there were invisible effects of time and cost saving related to the approval or confirmation of the quality inspection documents. In past projects, they had to move around the site to submit and obtain the documents. They also had to reanalyze existing documents manually for ad-hoc reporting or statistics, because the documents were produced without standardized formats. From the interviewees’ responses above, the authors could conclude that the online processing and sharing of quality inspection documents using related master data improves the accuracy and reusability of data, as well as the productivity and efficiency.

As to the investigation in the progress management area, the interviewees stated that it took about 15 days on average in the past projects to collect data and determine the progress. The records in the system for the current project showed that the progress was determined within 5 days after monthly financial closing and account payable declaration (that is payments to contractors). The system has been updating the progress in its daily site report based on the progress determined by the status of individual inspection lots in ITPs. This means that the progress update cycle is near real-time.

The interviewees agreed that conflicts in progress determination between the client and contractor(s) were evidently reduced compared with the past projects because they accumulated sources of progress data through the daily quality inspections. That is, there is no room to present different opinions on the progress. The interviewees also stated that the workload for progress determination in the monthly closing period was reduced considerably, even though they could not measure the exact number of man-hours for the task.

The overall evaluation of the system was that it gave a reasonable basis for planning and measuring progress, providing systematic processing and control of quality inspections. Some of the interviewees thought that it took time to become accustomed to the system but this inconvenience could be regarded as mitigated by the effects from the “learning curve”.

5. Conclusion
In this paper, the authors have presented a system that measures the progress of a construction project by means of a quality inspection process synchronized with work planning and execution. To do this, the information that can be extracted from conventional quality inspection and scheduling processes is identified. The authors presented a concept to introduce resource estimates (REs) as a means for measuring progress and to link the progress and quality inspection. To-be process models to implement the concept were presented and a system was implemented using these. This system has been applied to several nuclear power plant construction projects in Korea. An investigation was conducted on one of these to validate the concept. Based on the results of this investigation, the system shortened the time needed to collect data for measuring the progress to within 5 days of the monthly financial closing. The progress in provisional value was updated in near real time along with the results of the quality inspections undertaken, and the conflicts between the client and contractors were significantly reduced. The results also showed that the system contributed to the improvement of accuracy and efficiency in processing quality inspection documents. Predefined master data and the online environment of the system were leveraged to shorten the time needed to produce and distribute documents by one hour. In addition, the system provided the convenience of reusability for various statistics and analyses of accumulated data.

Given that nuclear power plant construction should be managed with sophisticated processes and strict standards to ensure quality, the system was more applicable to this project than to other types of projects. However, this does not mean that the proposed model works only for projects where high quality assurance of the works and outputs are required. Provided that the concept and processes, with adjustments to the level of detail, are applied to projects that require a normal level of quality assurance, the model presented in this study can potentially provide benefits equivalent to cost-schedule and quality integration, as in the case of a nuclear power plant.

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References
1) Boukamp, F., and Akinci, B. (2007) Automated processing of construction specifications to support inspection and quality control. Automation in Construction, 17(1), pp.90-106.
2) Chin, S., Yoon, S., Kim, Y., Ryu, J., Choi, C., and Cho, C. (2005) Real time 4D CAD+RFID for project progress management. Proc., Construction Research Congress 2005, ASCE, Reston, VA, pp.168-172.
3) Eldin, N. N. (1989) Measurement of work progress: Quantitative technique. Journal of Construction Engineering and Management, 115(3), pp.462-474.
4) Chou, J-S., Chen, H-M., Hsu, C-C., and Lin, C-W. (2010) Visualized EVM system for assessing project performance. Automation in construction, 19(5), 5pp.96-607.
5) Lee, S., and Pela-Mora, F. (2006) Visualization of construction progress monitoring. Proc., Joint Int. Conf. on Computing and Decision Making in Civil and Building Engineering, ASCE, Reston, VA, 2527-2533.
6) Modar, J. J., Phillips, C. R., and Davis, E. W. (1983) Management with CPM, PERT, and precedence diagramming, NY: Van Nostrand Reinhold.
7) Poku, S., and Ariditi, D. (2006) Construction scheduling and progress control using geographical information systems. Journal of Computing in Civil Engineering, 20(5), pp.351-360.
8) Yang, Y., Park, C., Kim, J. and Kim, J. (2007) Management of daily progress in a construction project of multiple apartment buildings. Journal of Construction Engineering and Management, 133(3), pp.242-253.
9) Lukas, J. A. (2008) Earned value analysis – Why it doesn’t work. 2008 AACE International Transactions, Toronto, Canada, 29 June – 2 July, EVM.01.01-10.
10) Ghanem, A. G., and AbdellRazig, Y. A. (2006) A Framework for Real-time Construction Project Progress Tracking. Earth & Space, ASCE.
11) Jung, Y., and Kang, S. (2007) Knowledge-Based Standard Progress Measurement for Integrated Cost and Schedule Performance Control. Journal of Construction Engineering and Management, 133(1), pp.10-21.
12) Chin, S., Kim, K., and Kim Y. (2004) A process-based quality management information system. Automation in Construction, 13(3), 241-2.