ON THE USE OF BUILDING INFORMATION MODELING IN INFRASTRUCTURE BRIDGES

Mohamed Marzouk, Associate Professor, mm_marzouk@yahoo.com
Mohamed Hisham, Graduate Student, mohamed1984_h@hotmail.com
Construction Engineering and Management Program, Nile University, Egypt
Sabri Ismail, Executive Director, sabri@bimengineering.com
BIM Engineering Solutions, Egypt
Mohamed Youssef, Manager – Arab Contractors, cvmamy@gmail.com
Omar Seif, Senior Engineer, eng.omar.seif@gmail.com
Institute for Construction Engineering and Management, The Arab Contractors (OSMAN AHMED OSMAN & Co.), Egypt

ABSTRACT

This paper describes the requirements for applying Integrated Design and Delivery Solutions (IDDS) in bridges' projects in EGYPT to overcome the problems arising from applying the traditional engineering and delivery methods and processes. These requirements are: forming a new delivery model; building an integrated team; changes in contracts and roles of project parties; implementation of new technologies as Building Information Modeling (BIM); and changes and requirements for people, organizations, and educational resources. The paper describes how to successfully implement Building Information Modeling on bridges' projects by forming Building Information Modeling execution plan which requires four steps which are: identifying high value BIM uses during project planning, design, construction and operational phases; designing the BIM execution process by creating process maps; defining the BIM deliverables in a form of information exchanges; and developing the infrastructure needed to support the implementation.

Keywords: Integrated Design and Delivery Solutions, Building Information Modeling, Bridges' projects

1. INTRODUCTION

Bridges have great importance in EGYPT because of the presence of river Nile of length 1500 km which divides EGYPT into three regions which are: eastern region, western region, and Delta. Bridges are the structures that connect these three regions together. Also the importance of bridges in EGYPT arises from the large number of residents which leads to traffic problems which can't be solved without bridges. Despite the importance of bridges, the bridges' engineering and delivery methods in EGYPT are very complex and always associated with problems and disputes between all parties related to the engineering and the delivery methods, and this leads to the delay of the delivery of the bridge, reduction of quality, and extra payments. A new integrated approach is required to overcome these problems, and this is achieved by applying Integrated Design and Delivery Solutions (IDDS) which is provided by the adoption of Integrated Project Delivery (IPD) with Building Information Modeling (BIM) using people with enhanced skills and specific cultures. There are three classifications for integration which are: vertical integration; horizontal integration; and temporal integration. Vertical integration is sharing information and knowledge between phases of a project lifecycle. Horizontal integration is sharing information and knowledge between disciplines working within one project phase. Temporal integration is sharing information and knowledge between projects. IDDS role is to achieve integration with its three classifications.

To achieve better integrated approach, implementation of Building Information Modeling (BIM) must be planned. This planning enables the most efficient use of BIM capabilities and allows all parties to know their role in BIM implementation. The BIM plan is formed by the BIM planning team and it acts as a baseline for BIM implementation in a project, so by monitoring the performance against this plan it is easier to take suitable corrective actions.

2. INTEGRATED PROJECT DELIVERY (IPD)

Integrated Project Delivery (IPD) is a project delivery approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to reduce waste and optimize efficiency through all phases of design, fabrication and construction (AIA California Council 2007-a & b). Integrated Project Delivery (IPD) strategy depends on sharing knowledge and experiences beginning from the early phases of the project life cycle by the early involvement of all project parties and completing through the project life cycle. In IPD, all project parties share risks and rewards, and they have open and equal access to information (Tatum 2009). The idea of IPD is to create a project team whose concern is the best delivery of the project as the defined requirements within the limited time and the defined budget.

IPD provides great benefits to all project parties. For owners, it allows early and open sharing of project knowledge streamlines project communications and allows owners to effectively balance project options to meet their business enterprise goals. Integrated delivery strengthens the project team's understanding of the owner's desired outcomes, thus improving the team's ability to control costs and manage the budget, all of which increase the likelihood that project goals, including schedule, life cycle costs, quality and sustainability, will be achieved. For contractors, the integrated delivery process allows contractors to contribute their expertise in construction techniques early in the design process, resulting in improved project quality and financial performance during the construction phase. The contractor's participation during the design phase provides the opportunity for strong pre-construction planning, more timely and informed understanding of the design, anticipating and resolving design-related issues, visualizing construction sequencing prior to construction start, and improving cost control and budget management, all of which increase the likelihood that project goals, including schedule, life cycle costs, quality and sustainability, will be achieved. For designers, the integrated delivery process allows the designer to benefit from the early contribution of contractors' expertise during the design phase, such as accurate budget estimates to inform design decisions and the pre-construction resolution of design-related issues resulting in improved project quality and financial performance. The IPD process increases the level of effort during early design phases, resulting in reduced documentation time, and improved cost control and budget management, all of which increase the likelihood that project goals, including schedule, life cycle costs, quality and sustainability, will be achieved.

3. BUILDING INFORMATION MODELING (BIM)

A Building Information Model (BIM) is a digital representation of physical and functional characteristics of a facility. As such, it serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its lifecycle from inception onward. A basic premise of BIM is collaboration by different stakeholders at different phases of the life cycle of a facility to insert, extract, update or modify information in the BIM to support and reflect the roles of that stakeholder. The BIM is a shared digital representation founded on open standards for interoperability (NIBS 2007). Building Information Modeling provides great benefits to all project parties. For the designer, BIM eases the creation of different design alternatives, and the designer can make any modifications to the design in a very short time and with minimal effort. For the contractor, BIM reduces the site errors because of the early coordination between models and the better project visualization. For the owner, an integrated Building Information Model is created at the end of the project construction. This model contains all information about the project, the contractors who worked in the project, the RFIs, and project photos at different phases during construction. This model serves the owner in the operation and maintenance stage. Building Information Modeling allows teams in different regions and countries to work together to create designs, solve problems, and complete projects faster.

The adoption of Integrated Project Delivery (IPD) with Building Information Modeling (BIM) using people with enhanced skills and specific cultures provides Integrated Design and Delivery solutions (IDDS). IDDS is a priority theme developed by a working group organized by CIB. The group's white paper describes a vision of exemplary IDDS and its main elements including collaborative processes, enhanced skills, integrated information and automation systems, and knowledge management. Tatum (2009) discussed the vision of organization culture and structure for IDDS, and the project roles and actions for IDDS. The role of IPD is to make early communication between project parties, while the role of BIM is to facilitate this communication. Adoption of IPD with BIM facilitates identification and understanding of various design goals and it provides a mechanism to realize those goals. A design team whose participants are brought together early and are all working with BIM are better able to visualize problems, analyze potential points of conflict, provide creative solutions, and ultimately minimize design errors. The integrated processes have many requirements and need a paradigm shift in the design and the engineering processes. The requirements for adopting IDDS are: Forming an integrated team which consists of representatives from all project parties; Implementation of new technologies as Building Information Modeling; and Skills of using new technologies and the ability to work in an integrated team. Many changes are required to allow applying IDDS, these changes are: new delivery model and contract forms, new roles for project parties, new engineering education system, and changes in people and organizations' cultures.

4. PROPOSED IDDS IN BRIDGES PROJECTS

The problems arising out of the traditional approaches are: time consumed in transferring data between applications and between project parties; limited access to information across functional stakeholder areas; errors associated with manual data re-entry; difficult coordination; and no support for production (Chen et al. 2006). In order to reach a new integrated approach that helps in overcoming the problems in the current traditional approaches, IDDS must be applied .IDDS need many changes and requirements. This paper presents the changes and requirements needed by IDDS in bridges' projects, and it focuses on the method of BIM implementation on bridges' projects. The changes and requirements are described in below sub-sections.

4.1 Forming a new delivery model

In the new approach, all project parties are considered as one team. As the design build model, the new delivery model depends on early involvement of all project parties but it differs from the design build in the level of the owner involvement after the end of the design phase. In design-build projects, the owner usually participates through completion of the design and then seeks to minimize input and involvement to protect the clear silos of responsibility and risk (AIA California Council 2007-a). The new model requires the owner to increase participation through the construction phase, and to share risks with the other parties.

4.2 Building an integrated team

Building an integrated team that is committed to collaborative processes and is capable of working together effectively is the key to success of the new integrated approach. The integrated team consists of representatives from all project parties. It can be divided into smaller teams that contain also representatives from all project parties such as the BIM planning and execution team. All teams have one goal which is delivering the project to meet the time, budget, and quality requirements. The culture of the integrated team is to solve problems instead of blaming and transferring risks and responsibilities.

4.3 Changing project parties roles

In the new contract, the new roles of parties must be defined. For owners, they must define obviously the project requirements and goals from the beginning, they have to share risks and remove any barriers through all the project phases. For the designers, they have the same old role of gathering and processing information to create a unique physical solution in understandable manner, but the tools used to achieve these services are changed. The designers also will be the leaders of all teams by organizing these teams, enabling communication over vast distances, and developing a bridge model, analyze it, and reevaluate the design in short times. The contractors will share experience in the design, and help in defining specifications, they are responsible for the construction activities to be executed within defined time, defined budget, and defined quality.

4.4 Organizations changes

Designers, contractors, and firms need new skills and knowledge to participate in collaborative efforts. It is no longer enough for the designer to be skilled in analysis, and the contractor to be skilled in performing shop drawings and site work, but they both need to learn how to use BIM to facilitate communication and information sharing, and to achieve high performance. The new technology as BIM must be taught in engineering schools and universities where there must be an increase in the learning through collaboration and evaluating students based on their group and individual work together. The management of any firm has to be committed to the integrated idea and provide the needed support, and this is achieved by joining the sponsoring organizations and by explaining the benefits of the new approach to various consultants, contractors, and to its employees. The management of firm has to provide training for its employees to create capacity building.

4.5 Implementation of BIM

BIM has great effect on the improvements of the three main concerns of bridges stakeholders which are quality, schedule, and cost. BIM is needed for bridges projects since it creates consistency in information in different phases from design to maintenance. It assists in choosing the suitable construction method and site layout, and it allows early and digital fabrication of structural elements. To successfully implement BIM on a project, a detailed and comprehensive planning must be performed. The plans should be documented into a BIM Project execution Plan to ensure that all parties are clearly aware of the opportunities and responsibilities associated with the incorporation of BIM into the project workflow. The BIM Project Execution Plan should define the appropriate uses for BIM on the project (e.g., cost estimating, and design coordination), along with a detailed design of the process for executing BIM throughout the project lifecycle. Once the plan is created, it can be followed and the progress against this plan is monitored to gain the maximum benefits from BIM implementation. To develop the BIM Plan, a planning team should be assembled in the early stages of a project. This team should consist of representatives from all the primary project team members including the owner, designers, contractors, prime specialty contractors, and facility manager. It is very important for the owner as well as all primary team members to fully support the planning process. For the initial goal setting meetings, key decision makers should be represented from each of the organizations so that the overall goals and vision for implementation on the project are clearly defined for further planning initiatives. Once this initial goal setting is complete, then the detailed implementation processes and information exchanges can be developed and implemented by the lead BIM coordinators for each of the parties. The BIM Plan for the project cannot be developed in isolation (CIC 2009). No single party within the project team can adequately outline the execution plan. In order to have a successful project using BIM, full coordination and collaboration by all parties is an absolute necessity. The planning team should conduct a series of planning meetings to develop the execution plan.

5. BRIDGE INFORMATION MODELING PROJECT EXECUTION PLAN

To develop BrIM plan, four steps are required according to Building Information Modeling Execution Planning Guide by CIC research group. The first step is to determine the goals for BrIM implementation and to determine the appropriate BrIM uses in bridges' projects that could achieve these goals. After several interviews with designers and contractors working in bridge design and construction, twelve goals were identified and twelve Bridge Information Modeling uses were found to be appropriate to achieve these goals. The identified goals and uses are shown in Table 1. After identifying the goals and the uses, the next step is to develop process maps for these uses. Two types of process maps are to be developed, the first type is the overview process map and the second type is the detailed process map.

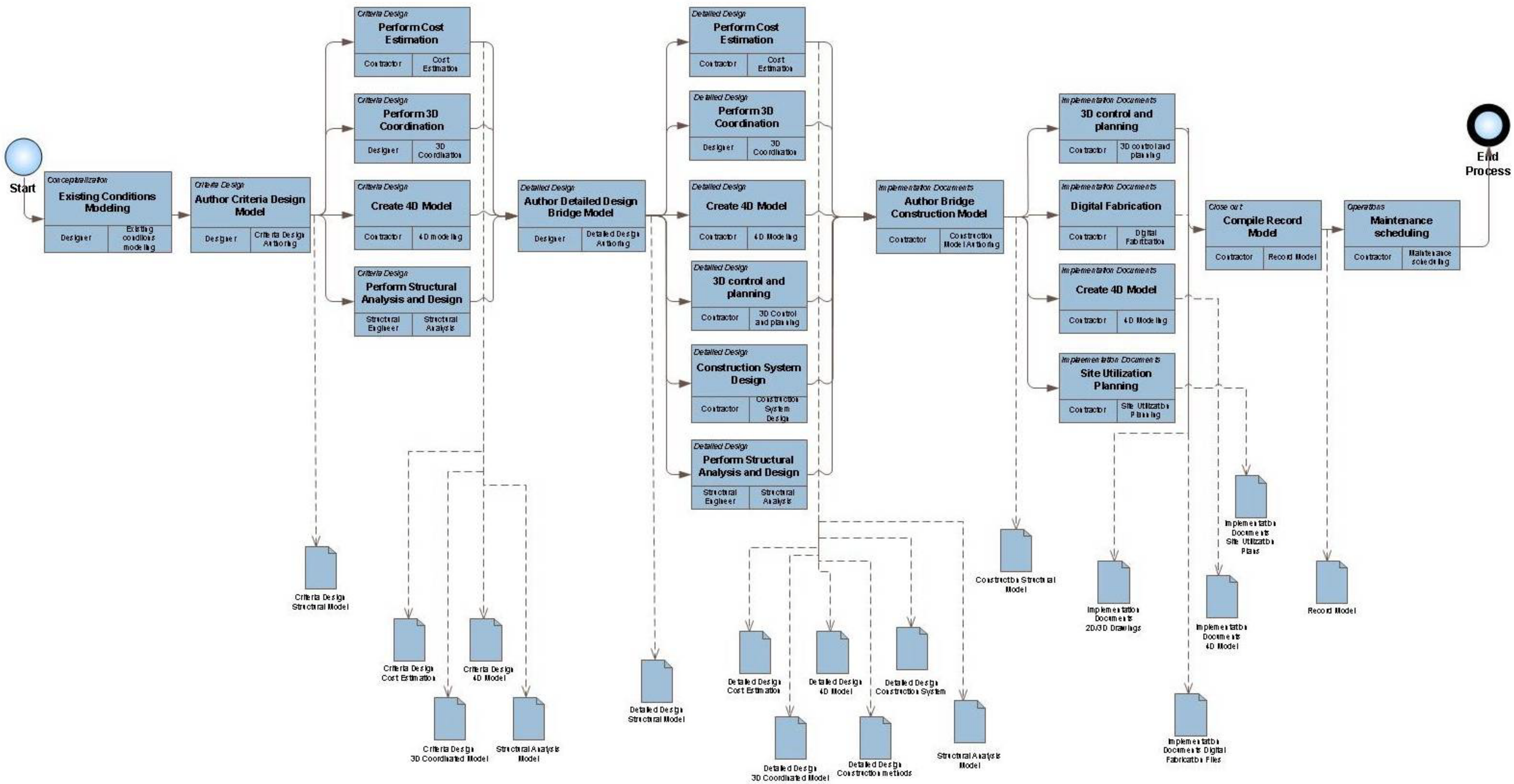

Figure 1: Proposed map for BrIM uses

The overview process map for the BrIM uses is developed by placing uses in a map as processes. These uses are arranged according to the project sequence and phases. It is required to identify the responsible party for establishing each use, the detailed process map for achieving each use, and the project phase of establishing each use. The BrIM Overview Map includes the critical information exchanges which are either internal to a particular process, or shared between processes and responsible parties. These information exchanges are the BrIM deliverables. The proposed overview map was developed based on the project phases identified for the Integrated Project Delivery (IPD) approaches which are described before. The proposed overview map for BrIM uses is shown in Figure 1. A detailed BrIM Use Process Map must be created for each identified BrIM Use to clearly define the sequence of the various processes to be performed within that BrIM Use.

Table 1: The identified goals and BrIM uses (CIC 2009)

Goal description	**Potential BIM uses**
Obtaining existing location information	Existing conditions modeling
Decrease the design time and make different design alternatives easily	Structural analysis
Increase effectiveness of Design	Design Authoring, 3D Coordination
Coordinate the bridge with the existing roads and conditions	3D Coordination
Obtaining accurate and quick cost estimation for bridge components	Cost Estimation
Increasing constructability and safety awareness	Construction system design
Identifying schedule and sequencing and increase productivity	4D Modeling
Maximize fabrication productivity and minimize tolerances	Digital fabrication
Identifying space conflicts, and planning the delivery of materials and the temporary facilities	Site utilization planning
Decrease site errors and increase communication between staff	3D Control and Planning
Increase the efficiency of the future activities related to the bridge	Record Model
Plan maintenance activities and evaluate different maintenance approaches	Maintenance scheduling, Record Model

All the information exchanges identified in BrIM overview map must be detailed by choosing a model element breakdown structure for the project then Identifying the Information Requirements for each Exchange (Output & Input). Figure 2 shows the model breakdown structure for a bridge and the information requirements for the output information of Authoring construction model, and for the input information of 3D control and planning and site utilization. The information level of detail is divided into three levels which are:

- Level A which represents accurate size and location.
- Level B which represents general size and location.
- Level C which represents schematic size and location.

It is important to be mentioned that the level of details of the output information must be higher than or equal the level of details of the input information.

BIM Use Title			Authoring Construction Model		3D control and planning		Site utilization	
Project phase			Implementation Documents		Implementation Documents		Implementation Documents	
Type of information flow (output/input)			Output		Input		Input	
Model Element Breakdown			Info	Resp. Party	Info	Resp. Party	Info	Resp. Party
A	SUBSTRUCTURE							
		Foundations	A	Contractor	A	Contractor	B	Contractor
		Abutment	A	Contractor	A	Contractor	B	Contractor
		piers	A	Contractor	A	Contractor	B	Contractor
B	SUPERSTRUCTURE							
		Deck	A	Contractor	A	Contractor	B	Contractor
		Parapet	A	Contractor	A	Contractor	B	Contractor
		Miscelaneous details	A	Contractor	A	Contractor	C	Contractor
		Lighting posts	A	Contractor	A	Contractor	C	Contractor

Figure 2: Model breakdown structure for a bridge and information requirements

The last step in developing the BrIM project execution plan is developing the infrastructure needed to support the BrIM implementation. This includes:

- Fulfillment all the technology infrastructure needs, and this is done by the team that should determine the requirements for hardware, software, and computer networks for the project.
- Identifying the methods to ensure model accuracy and comprehensiveness. The BrIM planning team should reach an agreement on how the model is created, organized, communicated and controlled. Items to consider include: Reference model files to a common origin so that they are easy to integrate, defining a file naming structure for all designers, trades and subcontractors, and defining an agreement on model accuracy and tolerances.
- Developing electronic and meeting communication procedures, and this is done by the BrIM planning team.

The discussed four steps suite bridges' projects since these projects are complex. These projects need detailed identification of information level of details and responsibilities associated with BIM implementation. As such, great improvement in the project schedule is achieved in addition to a decrease in errors and conflicts.

6. CASE STUDY

This section describes the implementation of Bridge Information Modeling on Abo-Diab Bridge in Al-Buhhayrah governorate, EGYPT. The bridge length is 170 meters and is divided into three parts which are:

- Part 1 between axe 1 and axe 4, the length of this part is 75 meters and is divided into three equal spans. The superstructure is composed of two cast in place concrete box sections.
- Part 2 between axe 4 and axe 5, the length of this part is 45 meters. The superstructure is composed of steel beams and bracings, and concrete deck slab.
- Part 3 between axe 5 and axe 7, the length of this part is 50 meters and is divided into 2 equal spans. The superstructure is the same as part 1.

The bridge 3D model was developed using Tekla structures 15.0 as shown in Figure 3.

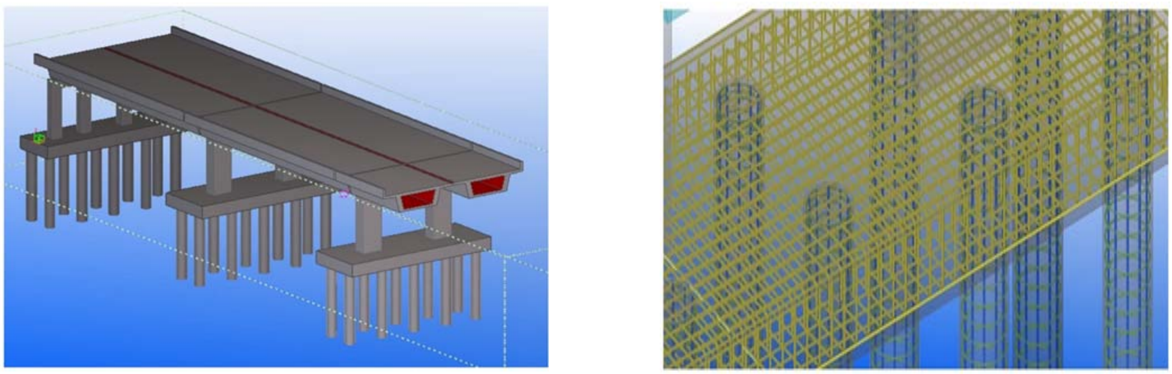

Figure 3: 3D model of the bridge

6.1 Cost Estimation

The cost estimation is done by exporting the quantity takeoff to Microsoft Excel sheet where the unit prices were imported and the cost estimation was done. The quantity takeoff list of the rebar of one pile cap is generated and exported to Microsoft Excel where the rebar unit price is imported and the cost estimation is done (see Figure 4).

6.2 4D modeling

4D modeling was done by linking the 3D model elements to a time schedule of constructing these elements. This is done using Tekla structures 15.0 as shown in Figure 5. Then, it is available to view and visualize what is planned to be constructed at any date imported to the software by the project team to allow more control on the project (see Figure 6). 4D modeling facilitates the prediction of the contractor expenses in certain period by importing the end date of this period to view what is required to be constructed and then exporting the quantity takeoff of the elements required to be constructed to an estimating software or to Microsoft Excel sheet to perform cost estimation as done before for the pile cap rebar.

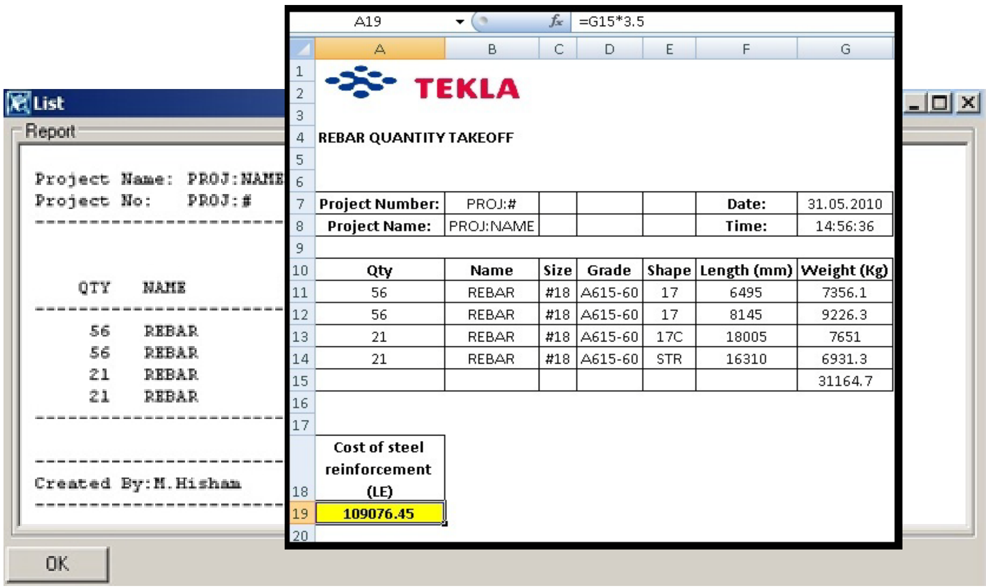

Figure 4: BrIM Cost Estimating

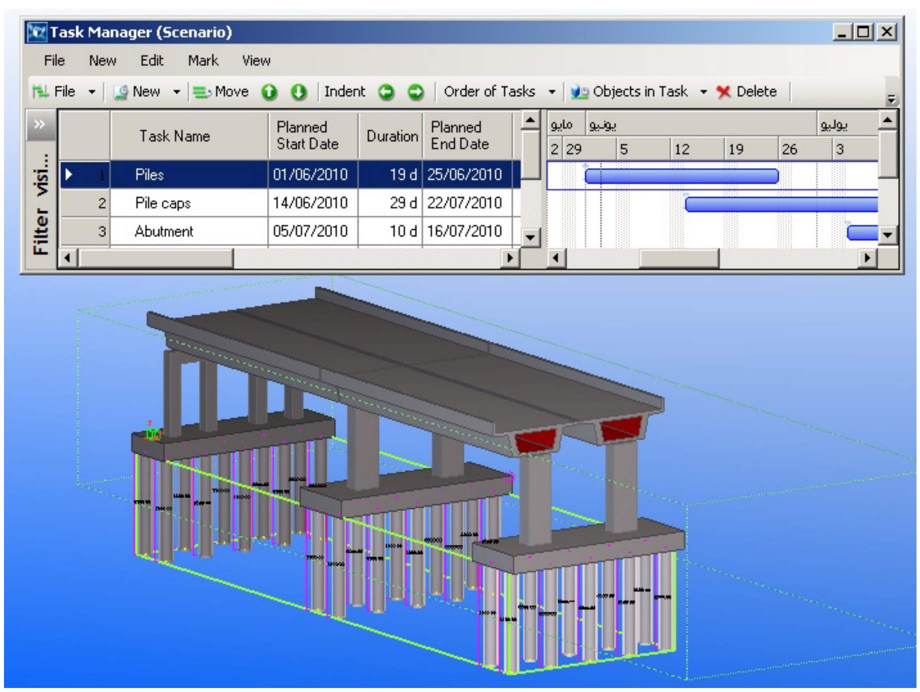

Figure 5: 4D Modeling in BrIM

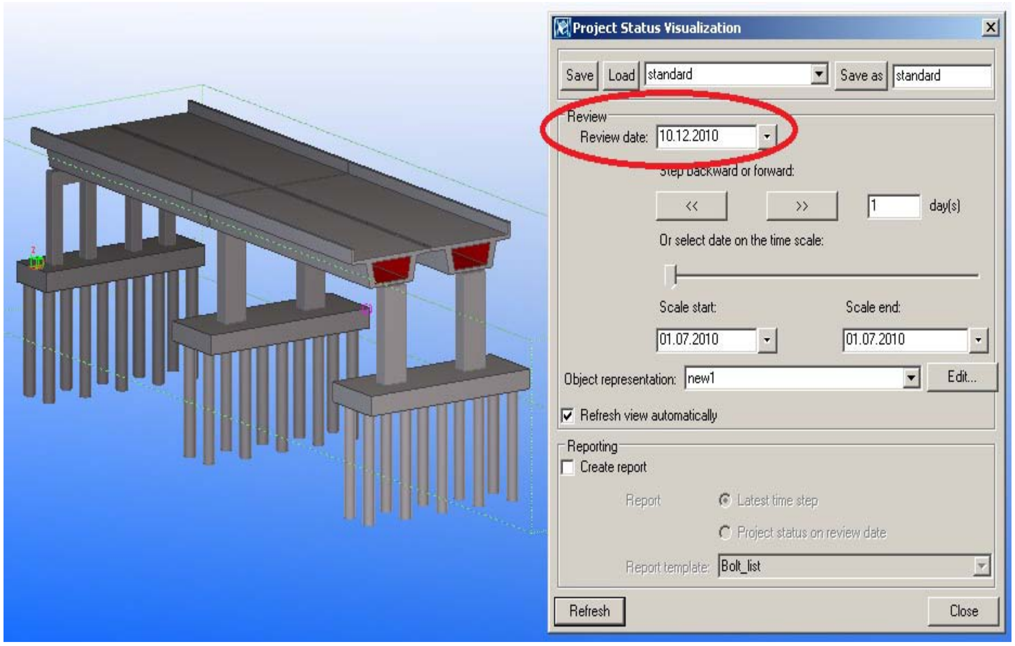

Figure 6: Project visualization at Specific Date

7. SUMMARY

This paper described the Integrated Project Delivery strategy (IPD) which depends on early involvement of all project parties to increase collaboration and increase the project performance. Also, it presented the Building Information Modeling (BIM) which is a digital representation of physical and functional characteristics of a facility, and it helps in sharing information between all project parties in an easy and an efficient way. The paper then describes the Integrated Design and Delivery Solutions (IDDS) which is provided by the adoption of Integrated Project Delivery (IPD) with Building Information Modeling (BIM) using people with enhanced skills and specific cultures. The IDDS helps in solving the problems arise from the traditional engineering and delivery methods in bridges projects. The paper described the method of implementing BIM on bridges' projects by forming Bridge Information Modeling project execution plan which requires four steps which are: identifying goals and uses; developing overview and detailed process maps; identifying information exchange requirements; and developing the infrastructure needed to support the implementation. A case study of implementing Bridge Information Modeling was illustrated to demonstrate the different uses of BIM including cost estimation and 4D modeling.

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