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PROPOSED MANAGEMENT SYSTEM OF MARINE WORKS BASED ON BIM APPROACH (TECHNOLOGY)

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ABSTRACT

Management of marine construction projects have long been criticized for being inefficient especially in developing countries. At primary stages of this research a survey analysis was conducted to identify the main factors causing deficiencies depending on client perspective. The analysis showed that, change orders, inadequate planning, insufficient site investigation data, security precautions, poor supply and lack of awareness of health and safety precautions are main factors causing inefficiency. This paper aims to apply BIM on marine project management to examine BIM capabilities in solving marine management constrains. Integrated system was developed for this objective which consists of a framework and software to facilitate information flow and close information gaps during planning and construction phases. The proposed system aims to enhance management of time, cost, quality, sustainability and safety by providing augmented reality system to enable users to manage these dimensions together. In addition, the expected enhancement for each dimension was calculated to facilitate judging the proposed system capability for improving previous dimensions. Validating the proposed management system was carried out using a real case study. The results were within expected limits which reflect proposed system capability for achieving paper target.

KEYWORDS: Building information modeling, marine projects, schedule, cost estimation and integration.

1. INTRODUCTION

Marine projects are considered one of the biggest resources to the national income. It is considered the backbone for providing reliable and economical way for goods transportation from country to another. Construction and operation of marine projects have been poorly developed in the last decades [1]. Using traditional delivery system represents a fundamental constrain to sustain economic growth.

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Building Information Modeling (BIM) is an emerging technology which target improving data accessibility to all stakeholders. It also offers various features like; 3-D modeling, clash detection, schedule and cost estimation…. etc. Application of BIM on marine projects could pave the way for collaboration, integration and satisfaction between project participants.

1.1 Background of Research

Marine projects could be defined as a specialized construction technology branch which contains civil construction, repair and maintenance projects of structures like jetties, berths, dry dock, wharves, slipway, marinas, ship lift, marine railways, shipways, navigational aids, sea link bridges, offshore yard, shore protection works and other specialist foundation works in or near sea [2].

Marine projects still recorded claims, dispute, waste, risks, health and safety and quality problems, as well as delay and cost overrun as a result of many threats for the current management system applied. In essence, all stockholders are adversely being affected by these management threats. The current management system is mainly depending on 2-D delivery system in term of information flow, feasibility study, contract types, bidding procedure, contract award, method of payment, subcontractors' management, drawings and specifications.

BIM offers various features like; 3-D modeling, clash detection, schedule and cost estimation…. etc. Previous research showed that current BIM related researches concentrated on clash detection, data management and visualization, scheduling, and quantity takeoff. BIM development has evolved from three dimensions (3-D) to multi-dimension (N-D). The first step was by combining the fourth dimension (4-D) of time to demonstrate schedule and the fifth dimension (5-D) of cost to demonstrate cost estimation and cash flows. The term "N-D" modeling contains various technical features such as; quality, safety, environmental protection…etc. [3]

One of BIM challenges is what is called "information islands". This expression arises from using different software by each stakeholder, transformation of large amount of data and reentering of these data to fit that software. Consequently, this creates gaps, loss and duplication of data at almost all project stages. BIM experts suggested interoperability as solution to close information gaps. BIM development included additional areas such as; using higher level of detail (LOD), decomposition of elements and interoperability…. etc.

1.2 Objectives of the Study

This paper aims to develop integrated information system supported with visualized software to help project parties to close information gaps in current 2-D delivery system using BIM approach in marine projects.

1.3 Paper Organization

Figure 1 shows the whole research organization. In addition, the area included in the dotted rectangular shows the scope of this paper.

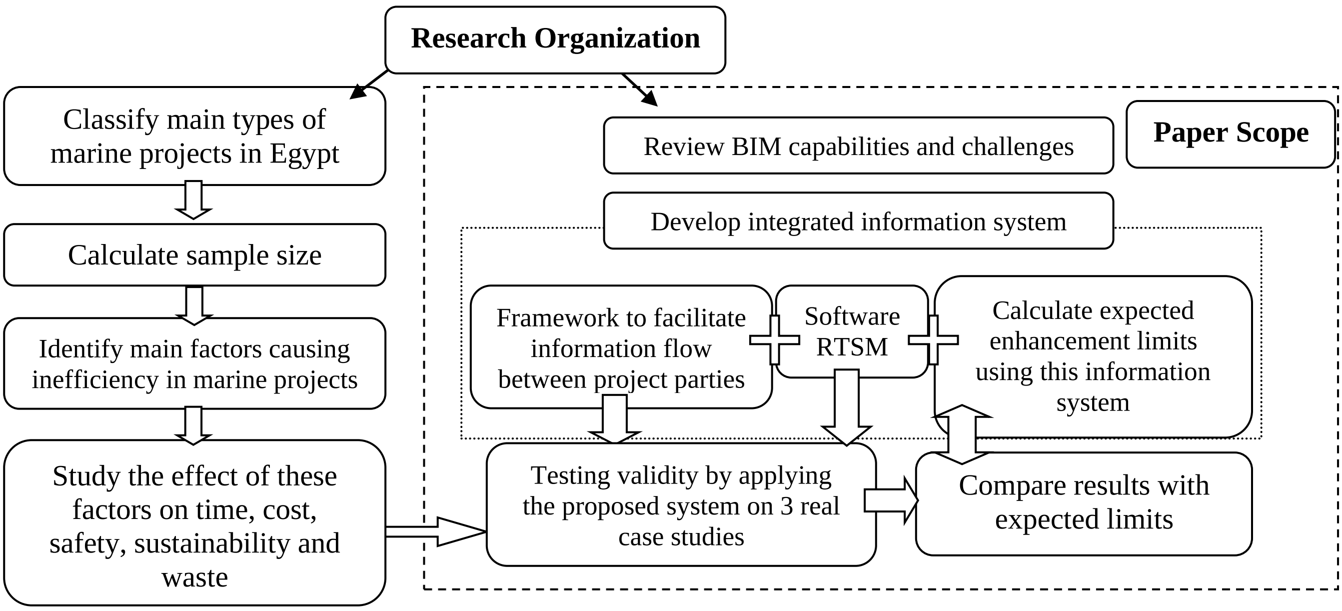

Fig. 1. Paper organization.

2. LITERATURE REVIEW

2.1 BIM Definition

Building information modeling (BIM) is an intelligent 3-D model-based process that gives in architecture engineer and construction professional the insight and tools to more efficient plan design construct and manage the building and infrastructure. BIM is a complex multiphase process that gathers input from team members to model the components and tools that will be used during the construction process to create a unique perspective of the building process [4].

The United States National Building Information Model Standard (NBIMS) initially characterized BIMs as digital representations of physical and functional aspects of a facility. But, in the most recent version released in July 2015, the NBIMS' definition of BIM includes three separate but linked functions, namely business process, digital representation, and organization and control [5].

2.2 BIM Challenges

Building Information Modeling is practiced internally within only a single organization of the project and not shared with the rest of the organizations. This is referred to as "lonely" BIM. For example, an architectural firm may decide to design a Building Information Model, and use it for visualization and energy analysis. Architect's firm may even have an internal collaboration. However, the architect may decide to provide the drawings in two dimensions and restrict the Building Information Model access. This would hinder the participation of the construction manager (CM) unless the CM creates a new model [6].

This section introduces latest recommendations suggested for future development. Although current BIM tools have achieved significant development transferring data in construction industry, developing these issues could enhance sharing information and provide better data workflow. These issues and recommendations could be summarized but not limited to the following items;

- Develop a site linked BIM model as none of current applications could deal with the corresponding modeling of the site in which the building is located as the building is no longer treated in isolation of its surround site [7].
- Decomposition and aggregation are strongly recommended for future development. Because objects shown as a single entity may need to be broken into parts to show construction procedure or how they will be constructed [8].
- Developing higher levels of detail (LOD) in BIM model, linking time and cost parameters concurrently to BIM components in the building model to deliver a

scheduled financial analysis, and allocation of resources on 4-D BIM model to analyze and plan the resource usage based on the most updated design, and even simulate the resource allocation [9].

- As it is hard to force people within the industry into using BIM on site and it would be a good idea to start in small scale with enthusiasts' eager to try new things then take development further in small steps through an iterative process and evaluate the results. So, this paper adopted marine projects as it is mainly consisting of around 20 activities which considered simple comparing with high rise building or brides [10].
- Integrating Augmented Reality (AR) into assembly is expected to reinforce assembly which manages how two or more objects are joined through a certain assembly sequences and operations [11].
- Game engine was suggested as a promising tool for creating different tools in task-based which would undoubtedly enhance the safety performance and also different areas in the near future [12].
- In order to have a comprehensive data model, it was suggested to integrate information such as structural design, topographic specifications of the project site, geology of the soil layers, quality, cost, risk analysis, scheduling, equipment, labor, safety, simulation, stakeholders, contractors, and subcontractors.
- Future research work proposed involves implementing and testing the systems in a real construction environment,
- Atomization of the data intake for construction progress and developing devices that are safe and wearable onsite. It is also very important to investigate a method to help the construction industry accept and adopt AR technology by realizing the benefits it includes [13].

3. INTEGRATED INFORMATION SYSTEM

3.1 Proposed Framework

This paper aims to develop integrated information system to overcome barriers which hinder development of interoperability in marine projects. This system is mainly consisting of framework and software to validate the framework. The framework of this system goes through many steps which are: project modeling, simulating operation, phase, entering soil properties, structural design, construction logistics, developing multi-dimensions plans and monitoring and controlling.

3.1.1 Project modeling

The first step in the framework is to create a three-dimensional model as a tool for discussion with the owner to ensure that the design requirements of the structure are satisfied. In this work, a 3-D model to help the owner to be more involved in the conceptual design processes is introduced.

3.1.2 Simulating operation phase

The second step which is intended to assure that the owner will receive the building as envisioned is simulation. Simulation assist in reaching and making the right decisions by testing the consequences of what will happen if a project is implemented. The main features of simulation are screening different alternatives and quantifying cost versus performance.

3.1.3 Structural design

The step of structural design aims to incorporate load, soil properties, design strength of required materials into the framework to get lengths and section modulus of sheet pile, tie and back wall. In addition to length and section modulus the framework will create 3D-models to be exported automatically to construction logistics stage.

3.1.4 Construction logistics

Construction logistics means how an element will be constructed in site. Most of current BIM software doesn’t give decomposition of elements the required consideration. The framework will provide the environment in which the user could construct the project by the same procedure in real life to predict the shortcomings and inefficiencies.

3.1.5 Developing multi-dimensions' plans

This framework intended adding additional dimension like time as discussed before and the dimension of cost to obtain cash flows. Adding other dimensions like waste, health and safety and sustainability and quality could be integrated in this framework, will support decision maker with analyzed and visualized data which certainly will close information gaps.

3.1.6 Monitoring and controlling

Neither of the current systems provides detailed constraints analysis at task level or assignment of responsibility and real-time task status updates to enable accurate production planning. However, such level of production planning is not yet available in any of the commercially available systems.

3.2 Proposed Software

The proposed software is the second step of this section. It aims to test validity of previous framework. It is a complicated process to gather all previous BIM features to be programmed in one manner. This research will use unity game engine to achieve its objectives. Unity has different features like rendering, scripting, asset tracking and physics. Above features could strongly support creating construction scenarios. The software structure consists of eight locations which takes part in any marine work which are; resource, storage, landfill, stone pit, supplier, patching plant, transportation area and finally offshore and onshore construction site. Figure 2 shows information flow network of the proposed information system

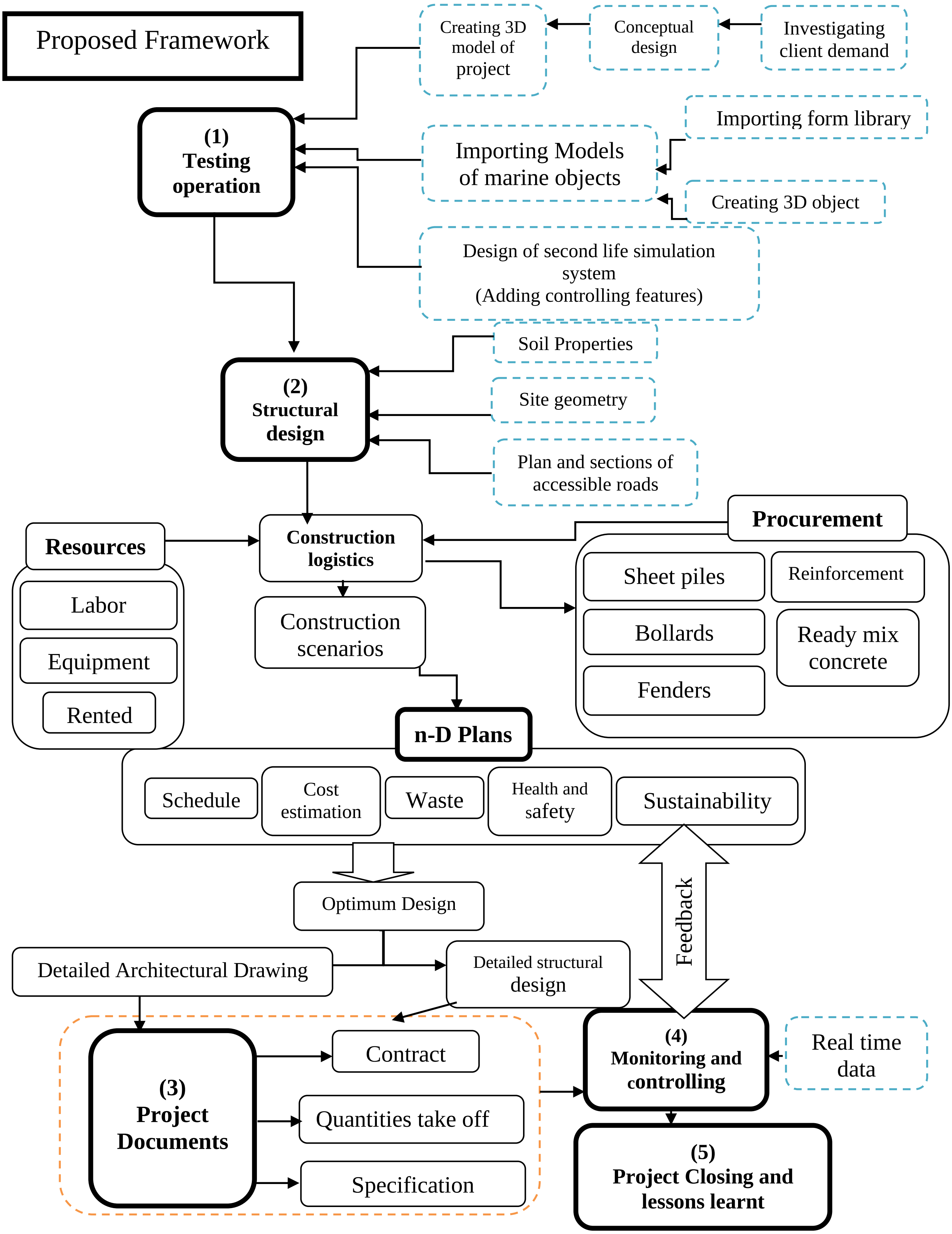

Fig. 2. Proposed framework.

3.3 Expected Improvement by Integrated Information System

This section aims to determine the expected improvements by using proposed framework and software (RTSM). The first step is to evaluate the current situation of marine projects by investigating repetitive constrains caused by 2-D delivery system and classify these constrains according to weight. Then, detect which of these constrains could be solved by using BIM system.

The second step is to define an indicator for n-D parameters; time, cost, quality, safety and sustainability. The main goal of setting indicators for each parameter is to establish a measurement tool to judge the framework capabilities for enhancing current deficiencies of 2-D delivery system.

Choosing qualified contractor for marine construction enhanced quality. This paper aimed to develop different direction of project management. Quality was one of those directions. The indicators for measuring quality are the number and value of penalties in project delivery. None of the investigated projects showed any penalties regarding poor quality which results from using specialized contractors. So, quality has got out from RTSM scope.

The third step is to apply the software on various case studies and compare the results with the expected limits of improvement.

3.3.1 Evaluation of current constrains of marine projects

At primary stage of this research a statistical analysis was conducted to identify the main factors causing inefficiency in marine projects. Then, the impact of each on time, cost, waste, sustainability and safety is determined. In addition, the responsible stakeholder for each cause is also detected. Finally, Table 1 classifies the eight factors in to two groups. The first group is expected to be out of BIM scope and the second group could be enhanced using BIM approach.

Table 1. Evaluation of current constrains of marine projects [14].

		Group (1)*1			Group (2) *2				
Problem No.		1	2	3	4	5	6	7	8
Problem Type		Insufficient site investigation data	Bad climate	Security Reasons	Change orders	Uneconomic design	Poor supply	Low consideration given for health and safety	Inadequate planning
Main stakeholder causing problem	Client role	-	-	-	√	√	√	-	√
	Contractor	√	-	-	-	-	√	-	-
	Consultant	-	-	-	-	-	-	√	-
	other	-	√	√	-	-	-	-	-
Time (Delay)	Percent	17.74	0.8	36.0	7.99	12.23	1.80	1	3.72
Cost (overrun)	Percent	9.32	-	-	3.24	5.85	-	-	-
Quality (rework Value)	Percent	-	-	-	-	-	-	-	-
Safety	injury (Number)	-	-	-	-	-	1	-	-
	death (Number)	-	-	-	-	-	1	-	-
Sustainability	Cost of unsustainable materials/ service time	18.25							

*1 Group (1): consists of three factors which are not affected by BIM development.

*2 Group (2): consists of five factors which are affected by BIM development.

3.3.1 Definition of indicators

3.3.1.1 Percent indicator

For any set of data, the mean and standard deviation can be calculated. Standard deviation is a measure of spread, that is, how spread out a set of data is. A low standard deviation shows that the data is closely clustered around the mean (or average), while a high standard deviation indicates that the data is dispersed over a wider range of values. The 68-95-99.7 rule shows that about 68% of the data fall within one standard deviation of the mean. About 95% of data fall within two standard deviations of the mean. And about 99.7% of data fall within 3 standard deviations of the mean.

Mean and standard deviation are used for detecting the expected limits for three parameters; time, cost and waste. The higher limit equals the mean plus standard deviation and the lower limit equals the mean minus standard deviation.

a- Time: Table 2 shows the distribution of factors affecting time.

Table 2. Distribution of factors affecting time.

	Change orders	Uneconomic design	Poor supply	Low consideration given for health and safety	Inadequate planning
Time	7.99%	12.23%	1.80%	1%	3.72%
Distribution	30%	46%	6%	4%	14%

The mean value of weight of factors affecting time is 5.35 %. Standard deviation is a measure that is used to quantify the amount of variation or dispersion of a set of data values. The standard deviation for time effect percent (Group 2) is 4.70%. The expected higher and lower limit are presented in the Table 3.

Table 3. Expected upper and lower limits for time.

	1 σ	2 σ	3 σ
Expected Upper Limit	10.05	14.75	19.45
Expected Lower Limit	.65	-4.05	-8.75

b- Cost: Table 4 shows the distribution of factors affecting cost

Table 4. Distribution of factors affecting cost.

	Uneconomic design	Change orders
Cost	2.55	3.24
Distribution	44.00	56.00

The mean value of weight of factors affecting cost is 2.90 %. The standard deviation for cost effect percent (Group 2) is .49%. The expected higher and lower limit are presented in the Table 5.

Table 5. Expected upper and lower limits for cost.

	1 σ	2 σ	3 σ
Expected Upper Limit	3.39	3.88	4.37
Expected Lower Limit	2.41	1.92	1.43

c- Waste: Table 6 shows the distribution of factors affecting waste.

Table 6. Distribution of factors affecting waste.

Factor	Change orders	Uneconomic design
Waste	2.57%	3.30%
Distribution	44%	56%

The mean value of weight of factors affecting cost is 2.935 %. The standard deviation for waste effect percent (Group 2) is .52%. The expected higher and lower limits are presented in the Table 7.

Table 7. Expected upper and lower limits for waste.

	1 σ	2 σ	3 σ
Expected Upper Limit	3.455	3.975	4.495
Expected Lower Limit	2.415	1.895	1.375

3.3.1.2 Ratio indicator

This indicator is designed for measuring and controlling sustainability. The mean service time for marine project is about 50 years. Using sustainable materials will raise the initial costs and reduce maintenance costs. The main element in marine industry is steel but it adversely affected by corrosion. Bollards, reinforced steel bars, sheet piles and rail are examples of steel elements.

Different alternatives are suggested to steel like stainless steel. Stailess steel is recommended for bollards, new materials like fiber glass is recommended for light column, plastic sheet pile is a new technology but unfortunatly it could only be used for small berths. The common way to face corrosion is by sacrafaction and painting which could not full prevent corrosion, it only could reduce its effect.

The following section will show intial and maintenance costs for steel in different activities in marine projects. The proposed framework aims to offer checklist supporting incorportion of sustainability in marinee projects. The final result of the checklist will show the crossponding saving if sustainable materials are used. The recommended alternative is considered succesful if the total cost along project life cycle is less than traditional materials. The indictator is considered effective if the cost of the sustainable materials to traditional materials is less than 1 .

3.3.1.3 Number indicator

This indicator is designed for safety control measure. This indicator measures the proposed system success for developing health and safety by reducing the number of injuries and death during construction activities through commitment to advices in a checklist. Firstly, the current situation health and safety are represented as a number. Table 8 and 9 show how to covert hazard to a figure depending on severity and probability factors. By investigating seven marine projects two accidents occurred. One caused immediate death and the other caused injury. Tables 8 and 9 show the main criterion for risk assessment [15].

Table 8. Probability and severity for risks.

Probability	Severity
1 Very Unlikely	1 Negligible
2 Unlikely	2 Slight
3 Possible	3 Moderate
4 Likely	4 Major
5 Very Likely	5 Catastrophic

Table 9. Low, medium and high limits for risks.

	Start	End
Low Risk	1	6
Medium Risk	8	12
High Risk	15	25

4. CASE STUDY (Ferry Berth)

The main objective of this study is to compare the current 2D-delivery system with Integrated BIM system. BIM offer many features which could overcome current problems of 2D-system. To achieve this goal a case study will be presented to reveal causes of information gabs. The effect of each problem on various dimensions will be estimated. These problems will be studied to evaluate if BIM could enhance it or not.

4.1 Project Description

The project is a ferry for conveying passengers and vehicles over a relatively short lane. The ferry is prepared with two flaps on both sides to enable vehicles to enter and exit quickly and safely. The flap is a piece of metal attached or hinged with main body of ferry. The angle of opening or closing the flab could be controlled from ferry captain. Two marine structures are constructed on both lane sides to provide mooring and berthing for the ferry. Each structure is characterized by two main service levels. The first is horizontal and relatively high, in which bollard are allocated for mooring. It is also provided with fender to absorb ferry's energy when berthing. The second service level is inclined to enable the flab to lay safely over it. The angle of inclination of the second service level must be calculated accurately to decrease straining actions over the flab. The main challenge in this project is high variance in tidal range what makes calculating angle of inclined level more complicated.

4.2 Project Problems

This project aims to construct two berths for the ferry in a year. The initial estimated budget for this project is EGP 1.6 million. Due to many change orders, project cost and duration exceeded the primary estimated values. The main problem in this project is poor feasibility study which decreased project efficiency by 25% as illustrated in the following section of this case study. By reviewing project's daily report, Table 10 shows the main problems which were the main causes of project delay and losses.

Table 10. Problems of third case study.

No.	Problems	Effect on Multi-Dimensions				
		Time days	Cost EGP	Safety No. of accidents	Sustainability Cost/ lifetime	Waste EGP
1	Difficulty of obtaining required permits	48				
2	Client delay in stone supply	69				
3	The contractor was ordered to delay the work in the inclined level until the technical studies confirm the angle of inclination	64				
4	During construction the owner decided to test the ferry. The results showed bad determination of inclination angle which oblige the client to make a change order to modify the inclination angle in addition to demolishing existing inclined level.	15	20000			20000
5	After testing the ferry, the client orders another change to cover the exterior faces of the berth towards sea with steel plates.	18	35000			
6	The contractor couldn't enter construction site due to security precautions	11				
7	Bad climate conditions	15				
8	Using unsustainable materials for light columns				18.26	

4.3 Application of RTSM

4.3.1 Simulating operational phase

As discussed before, detecting the degree of inclination of the inclined surface is very important item to facilitate loading vehicles to ferry. Poor studies regarding critical cases of loading caused uncomfortable degree of inclination which caused reduction of ferry working hours from 24 a day to 18 hours a day. To get a better understanding about this problem, critical cases of loading should be firstly discussed. The first case of loading is when the ferry is empty, and the water level is very high. The second case is when the ferry is loaded, and the water is very low. As the owner is not the end user, as the end user in this case are thousands of car drivers. Many car types couldn't enter or exit the ferry in these critical cases due to uncomfortable degree of inclination as shown in Figs. 4 and 5.

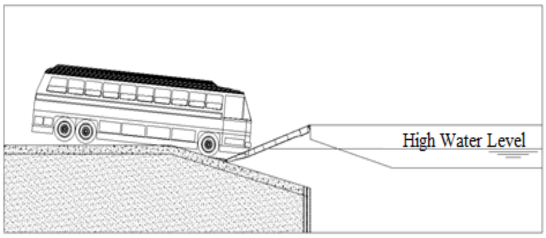

Fig. 4. First case of loading is when the ferry is empty and the water level is very high.

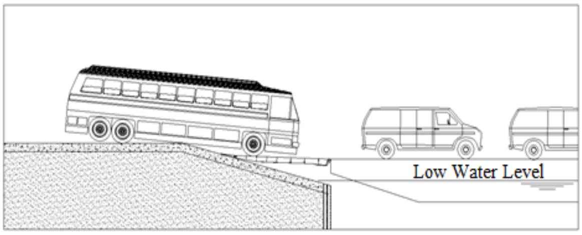

Fig. 5. Second case is when the ferry is loaded and the water is very low.

4.3.2 Construction Logistics

This section reviews the construction procedure of the project to show how could BIM solve the expected problem and offer alternative solutions. Running construction procedure during planning phase will dissipate shortcomings and conflict. It also will reduce claims and solve disputes.

The next step is to fill between front wall and back wall with stones. Filling with stones enhance the soil capability to resist the live load by transfering stress to nearst hard strata. In 2-D delivery system the contractor submit a list of all his equipment and previous experience to enable the owner to evaluate contractor's technical and financial capabilities. the contractor must clarify the required equipment for each activity in his plan.

In this case, the contractor used loader to perform filling with stones. As the ties are designed to resist axial load only, using loader for filling could perform residual bending stresses. This fact push the consultant to refuse the method statement for this activity. The contractor was compelled to use floating crane for performing this activity which consumed time and cost. BIM provides visulazed plan to be summited to the owner in early planning phase showing the construction procedure with all the required equipment for each activity. Reaching an agreement during planning phase decrease chances for disputes during construction phase.

One of RTSM features; it facilitates determining specific details like best position for pumps and truck mixer. It also provides the capability of testing maneuvering of this equipment. Figure 6 shows details of casting retaining wall surrounding the inclined level.

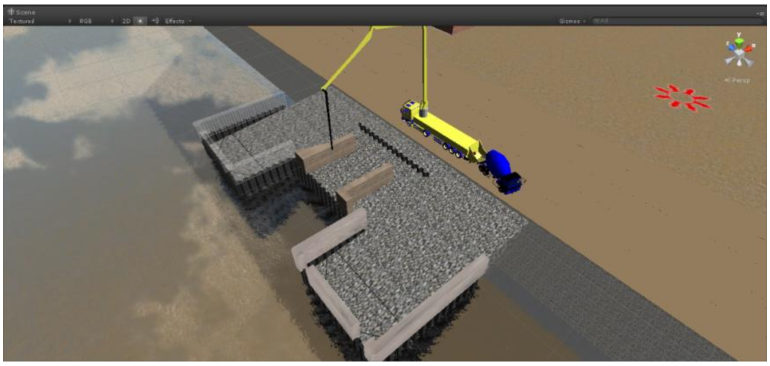

Fig. 6. Casting the retaining walls surrounding inclined level.

4.4 Summary of Case Study

This section summarizes various problems which affected project progress. It also will classify these problems into groups. Finally, the results of applying RTSM will be presented to show how BIM could solve project problems. Table 11 shows the problems categories.

Table 11. Efficiency of using proposed integrated information system on third case study.

Problem No.	BIM role	Effect on Multi-Dimensions				
		Time	Cost	Waste	Sustainability	Safety
1	×	5.26	-	-	-	-
2	×	9.45	-	-	-	-
3	√	8.77	-	-	-	-
4	√	2.05	0.40	0.40	-	-
5	√	2.47	0.50	-	-	-
6	×	1.51	-	-	-	-
7	×	2.05	-	-	-	-
8	√	-	-	-	18.26	-
Total losses using 2-D delivery system		31.56	0.90	0.40	18.26	-
Percent of losses solved by proposed framework		13.29	0.90	0.40	10.95	-
Efficiency using proposed framework		42.11	100	100	59.97	-

5. SYSTEM ANALYSIS

In this case study, eight problems affected project progress. Four problems could be solved by proposed system and four problems are out of BIM scope.

By answering health and safety questions in the checklist, the probability for injuries or death reduced to 4.5. The upper limit for low risks zone is 6. So, the software is expected to reduce hazard probability in this case study.

In this case several steel elements could be exchanged with other sustainable alternatives. Using alternative sustainable materials reduce sustainability ratios from 18.26 to 10.95 which is equal 0.60.

Table 12 summarizes the resulted improvement by using the proposed framework compared with the expected enhancement.

Table 12. Cumulative diagram for third case study.

Multi-Dimensions	Indicator	Results	Expected Limits
Time	Percent	13.29	19.45
Waste	Percent	0.40	4.49
Cost	Percent	0.90	4.37
Health and Safety	Number	4.5	6
Sustainability	Ratio	0.60	1

6. CONCLUSION

The first part of this research investigated seven marine projects to find out the most repetitive and influential factors causing inefficiency. The investigation showed that the main factors are; insufficient site investigation data, change orders, security precautions, bad climate conditions, uneconomic design, poor supply, low consideration given for health and safety and finally inadequate planning.

BIM was introduced as a cutting-edge solution for different marine industry problems. This paper developed an integrated management system to overcome barriers which hinder development of interoperability in marine projects. This system is mainly consisting of framework and software to validate the framework. To test validity of the proposed framework and RTSM software, an indicator for N-D parameters; time, cost, quality, safety and sustainability was designed. The main goal for setting indicators for each parameter is to establish a measurement tool to judge the framework capabilities for enhancing current deficiencies of 2-D delivery system and closing information gabs.

By applying the software to a real case study, it was found the RTSM software enhanced project parties' capabilities to gain BIM benefits by reducing losses of time and cost, offering sustainable materials as an alternative for traditional materials and finally, reducing the probability of expected risks.

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تطوير نظام ادارى للمشروعات البحرية بالاعتماد على تكنولوجيا نمذجة معلومات البناء

يهدف البحث إلى التعريف على اهم الاسباب المتسببه فى تدهور القطاع الادارى للمشروعات البحرية وتحديد اهم العوامل التى ادت الى التدهور الادارى لتلك المشروعات ونظراً لما حققه نظام ادراة نمذجة معاومات التشييد من انجازات فى قطاعات التشييد المختلفه فقد تناول البحث اهمية نظام ادارة نمذجة معلومات البناء و المزايا المتعدده التى يقدمها لاطراف المشروع المختلفه وما اوصت به الدراسات الاخيره المتعلقه بهذا النظام بالاستمرار فى دعم التكامل بين اطراف المشروع و ايجاد وسائل لغلق الفجوات الناشئة من نقل احجام بيانات عملاقه اثناء الانتقال بالتخطيط من مرحله لاخرى وقدم البحث تصميم اطار لنقل البيانات ودعمه ببرنامج لقياس مدى قابليه هذا الاطار للتطبيق ويهدف لمراقبه تدفق المعلومات من بداية المشروع حتى نهايته بدايه من مرحلة التصور الابتدائى الى المحاكاه والتصميم الانشائى ثم خطه تنفيذ الاعمال وانتهاء بعمل جدول زمنى وخطه للتدفقات النقديه ومقياس للاداء تجاه السلامه والصحه المهنيه والجوده والفاقد والاستدامه وتم تطبيق النظام على مشروعات حقيقيه وادى الى تحسينات متفاوته للمعايير السابقه.