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RESEARCH ARTICLE

Building Information Modeling (BIM) in Enhancing the Applying of Knowledge Areas in the Architecture, Engineering and Construction (AEC) Industry

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Abstract:

Background:

The Architecture, Engineering, and Construction (AEC) industry is one of the sectors that contribute the most to the Palestinian economy. However, it now suffers from many problems, one of which is not adopting new innovations, such as Building Information Modeling (BIM). BIM recently achieved far reaching consideration in the AEC industry.

Aim:

This research aimed to understand the contribution of BIM to the enhancement and application of Knowledge Areas (KAs) in the AEC industry in Palestine.

Methods:

A quantitative survey was utilized in the pilot study. Thirty copies of the questionnaire were dispersed to respondents from the target group. The completed questionnaires were analyzed to test for statistical validity and reliability. After the pilot study, the questionnaire was validated and dispersed to the entire sample, comprising respondents from the target group who were selected by convenience sampling. Eighty copies of the questionnaire were dispersed, and 71 copies of the questionnaire were obtained from the respondents with a response rate of 88.8%.

Results:

To draw meaningful results, the gathered information was analyzed by utilizing quantitative data analysis techniques, including the RII, Pearson correlation analysis, and Factor analysis.

Conclusion:

The results illustrated the extent of enhancing the application of KAs in the AEC industry using BIM technology from the highest to lowest as follows: Cost Management (CM), Time Management (TM), Resource Management (REM), Procurement Management (PROM), Scope Management (SCM), Stakeholder Management (STM), Integration Management (IM), Quality Management (QM), Communication Management (COM), Risk Management (RM), and Safety Management (SM). As an example, BIM is effectively applied to each KA, and high efficiency is achieved when BIM is applied to TM by 4D modeling; to CM by 5D modeling; to REM by collaboration; to PROM by quantity takeoff; to SCM by element-base; to STM and IM by using integrated project delivery; to QM by using clash detection; to COM by centralized, structured data management, and information flow; to RM by constructability; and to SM by automated safety code checking.

Keywords: BIM, Time management, Resource management, Procurement management, Scope management, Stakeholder management, Integration management, Quality management, Communication management, Risk management, Safety management.

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1. INTRODUCTION

In Palestine, the construction industry is considered one of the main sectors that contribute enormously to the Palestinian economy [1].

The construction sector has played a crucial role in extending job opportunities for the Palestinian labor force. Moreover, its expansion has generated many jobs for skilled, semi-skilled, and unskilled workers. Since the establishment of the Palestinian National Authority in 1994, the construction projects implemented by public and private sectors have supported the development of numerous related industries.

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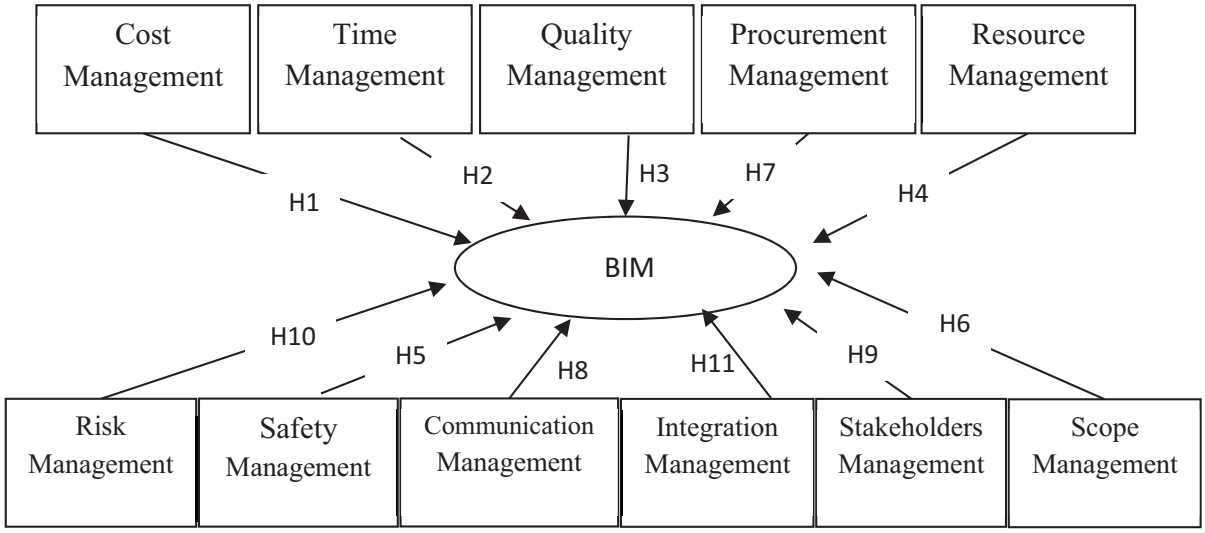

Fig. (1). Hypotheses model.

Its 33% share of the total local production is significant and influences economic, social, educational, and other professional sectors [2].

The data from the Palestinian Central Bureau of Statistics showed that the average contribution of the construction industry to the Palestinian gross domestic production ranged from 5.6% to 6.8% from 2017 to 2018 [3], and 11.6% of the total workforce in 2007 [4]. On the economic activity level, the value-added construction activities were 16.7% during 2020 compared with that in 2019 [5]. However, the construction projects in the Gaza Strip suffer from many complex issues because of the fragmented nature of the construction industry and the lack of knowledge sharing, as well as communication, among different professionals and stakeholders. In addition, the increasing cost of construction projects remains the greatest problem the construction industry is currently facing in the Gaza Strip [6]. Thus, the construction firms' adoption of knowledge areas would be pivotal in the overall development and success of the industry [7].

Project managers can design construction projects virtually by parametric modeling to escape probable pitfalls. This kind of modeling was greatly adopted by manufacturing companies to design, engineer, and manufacture products. In 1990s, the construction industry set up the foundation of object-oriented building product modeling. An increasing trend of adopting Building Information Modeling (BIM) among construction firms is currently observed worldwide. Construction companies now appreciate the benefits of this technology. The concept of BIM can bridge the gap of labor efficiency. To note some prominent examples in which BIM has been utilized, we can refer to Walt Disney Concert Hall and Shanghai Tower, and of course, some other less prominent and more personal projects. Although BIM has a great rate of usage in developed countries, companies are not inclined to use it in a developing country like Iran [8]. This study aimed to understand the contribution of BIM technology to the enhancement of the application of the Knowledge Areas (KAs) in the AEC industry based on this high effectiveness and efficiency when applied to each KA by testing these hypotheses (Fig. **1**).

Based on that, its found that, for example, BIM will enhance Time Management (TM) by 4D modeling; Cost Management (CM) by model-based quantity take-off, cost planning, accurate and realistic cost estimation and flexibility, and faster computation of cost; Resource Management (REM) by collaboration; Procurement Management (PROM) by quantity take-off; Scope Management (SCM) by element-base; Stakeholder Management (STM) and Integration Management (IM) by integrated project delivery; Quality Management (QM) by clash detection; Communication Management (COM) by centralized, structured data management, and information flow; Risk Management (RM) by model-based analysis of possible hazards and particular risk scenarios and spatial visualization; and Safety Management (SM) by automated safety code checking.

2. LITERATURE REVIEW

A project is a temporary endeavor undertaken to create a unique product, service, or result [9]. As the project manager, it needs to rely on project management knowledge and general management skills. Here, the thinking of the items, such as the ability to plan, execute, and control the project properly and bring a successful conclusion along with the ability to guide the project team to achieve project objectives and balance project constraints [10].

BIM is a process that generates and manages digital representations of buildings that present both physical and functional characteristics. Companies that plan, design, construct, operate, and maintain diverse infrastructures use BIM to make reliable decisions about the building from construction to demolition; BIM software allows engineers to create a building on the computer before constructing it on the field [11].

The maturity levels are meant to be the degrees of BIM capacity in adoption and delivery [12].

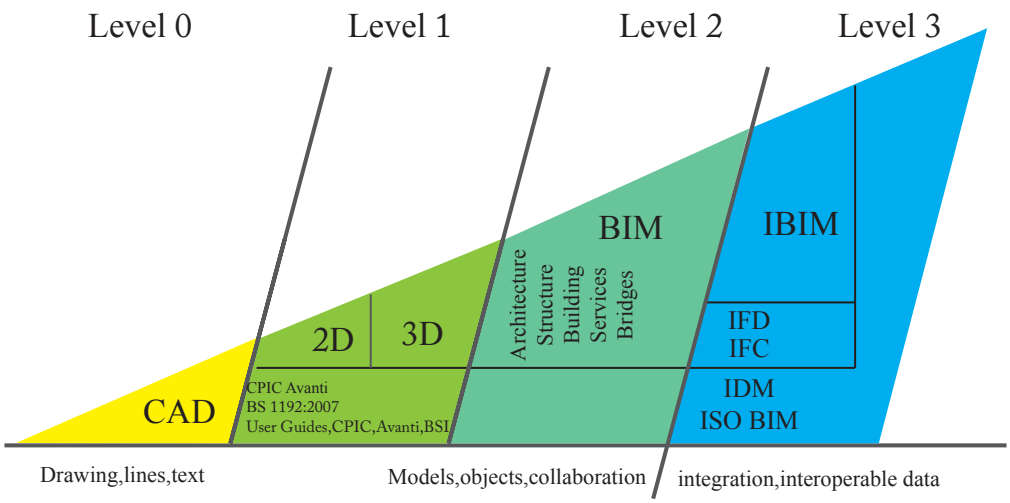

Fig. (2). Maturity Levels.

Although most companies that use BIM are in level 2, while some companies are in level 3 [13]. The maturity levels of BIM are shown (Fig. **2**) below [14]:

The project team can deal and interact with a unified model when a composite model is built from an amalgam of various disciplines' models. By having this capability and through the different phases of a construction project, BIM can coordinate the design, analysis, and construction activities of a project, thereby enhancing the integrity of projects [15].

BIM models generally are composed of objects and not geometries, such as line and surface. Thus, the whole model can be divided into a specific number of smaller objects. This breakdown allows the achievement of a defined and clear scope of projects. The distinction between the elements will result in a better management design, estimation, and construction [16].

BIM has recently attained widespread attention in the architectural, engineering, and construction industries. The design and construction schedules can be synchronized by linking the building model to the project schedule. BIM allows users to simulate the construction processes and display a virtual view of the building and the site. A BIM user can also generate accurate and reliable cost estimates *via* automatic quantity take-offs from the building model and can gain faster cost feedback on design changes [17].

BIM represents a new paradigm within AEC that encourages the integration of the roles of all stakeholders on a project. This integration can potentially bring about greater efficiency and harmony among players, who all too often in the past saw themselves as adversaries [18]; it can also enhance communication and collaboration among key stakeholders to increase productivity and to improve the overall quality of the final product (the building) [19]. According to Arayici *et al.* [20], the collaboration among stakeholder can increase organizational capacities, which enhance the performance of the project management during the design and construction processes. However, each stakeholder of AEC sector has individual workflow and demands; thus, BIM value propositions differ. Usually, such propositions change based on the specialization of a stakeholder or a phase of the building process (design, building supply, construction, and others).

The utilization of BIM for procurement purposes demands a very detailed model that includes all essential information to dispatch the tendering procedure, which is a noteworthy challenge [21, 22].

For CM, which is referred to as BIM 5D, using BIM brings many opportunities and challenges associated with the need for local workflows modification in accordance with information modeling needs. It represents a modern tool for solving both technical and economic issues related to CPs. The up-to-date involvement of modern technologies and methods to find the most cost-effective way to determine construction costs is also underpinned by the ever-growing pressure of the society on the accuracy and transparency of published building prices in public CPs. In Czech Republic, information modeling is developing in almost all construction sectors and phases [23].

Likewise, the potential of BIM to support the transformation of design and construction processes is evident in the construction industry. Although BIM is considered helpful in improving design quality by eliminating conflicts and reducing rework, few studies have investigated the use of BIM throughout the project for construction quality control and efficient information utilization. The potential of BIM implementation in quality management lies in its ability to present multi-dimensional data, including design data and time sequence, due to the consistency of design data with quality data and construction process with quality control process [24].

The management of resources and waste in construction and demolition projects needs more effective, efficient, and economical solutions. The need for projects to include BIM in waste and REM is critical, particularly in enormous-scale construction [25].

Lately, the attention and issues concerning risks have increased inside the AEC industry with the gradual increase in the risk of hazards due to the expansion of structural unpredictability, growing project size, and new and complicated construction methods. Expertise and mathematics-based RM

methodology have a practical effect on enhancing the systematic RM of a project. To resolve these growing issues, BIM is anticipated to play the noteworthy role of integrating RM with the design, construction, and maintenance of a project [26].

The BIM safety project has led to new insights and solid outcomes, which serve as guides for corporations and analysis communities to succeed in the subsequent level. The construction sector with its requisite qualities and challenges, may provide a remarkable benchmarking chance to alternative business sectors [27].

Fig. (**3**) summarizes the relation between Knowledge areas and BIM and how they are integrated.

3. METHODOLOGY

This section portrayed the exhaustive embraced methodology of the study to analyze the impact of BIM technology on the knowledge area. It incorporated the main research framework for the research, sample size, and population as shown in Fig. (**4**). The questionnaire design was detailed, including the initial draft that was altered and refined through a pilot study. Quantitative data analysis techniques, which incorporate Pearson correlation analysis and reliability test, were intended to be applied by the tools of SPSS. For the objectives of testing the research validity, reliability, and sufficiency of methods utilized in the analysis, distinctive statistical tests were utilized and clarified in detail. All the statistical tests affirmed the reliability and validity of the questionnaire.

Fig. (**5**) shows the main steps of developing the survey followed by a detailed discussion for each step in the subsequent sections.

4. RESULTS AND DISCUSSION

This section consists of results and discussion of BIM to Apply Knowledge Areas were grouped into 11 knowledge areas. These areas were subjected to the views of respondents. The descriptive statistics, *i.e.* Means, Standard Deviations (SD), t-value (two tailed), probabilities (P-value), Relative Importance Indices (RII), and finally the ranks were established.

4.1. Cost Management

4.1.1. Hypothesis #.1: H1: There is a positive relation among the CM area and BIM in the AEC industry in Palestine

Table **1** shows that "Model based quantity take-off" is ranked in the first position by the respondents among the other factors in this group with a relative importance index (RII) of 86.20%, Test-value = 14.39, P-value = 0.000 < LOS α= 0.05. Also, the test sign is positive; thus, the mean factor is significantly greater than the hypothesized value. Based on the result that this factor takes the first rank from the viewpoint of respondents, the "Model based quantity take-off" is important in CM and can be performed with more effectiveness and efficiency with the use of BIM in the construction industry, as clearly illustrated in previous studies [28, 29, 16, 17], thereby confirming that BIM will be an effective tool for achieving better quantity take-offs based on the model.

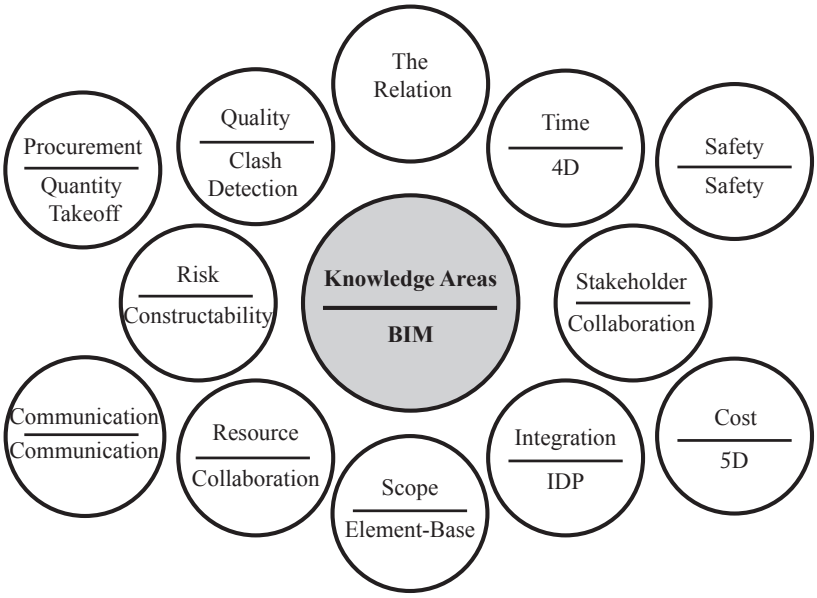

Fig. (3). Knowledge areas *VS* BIM.

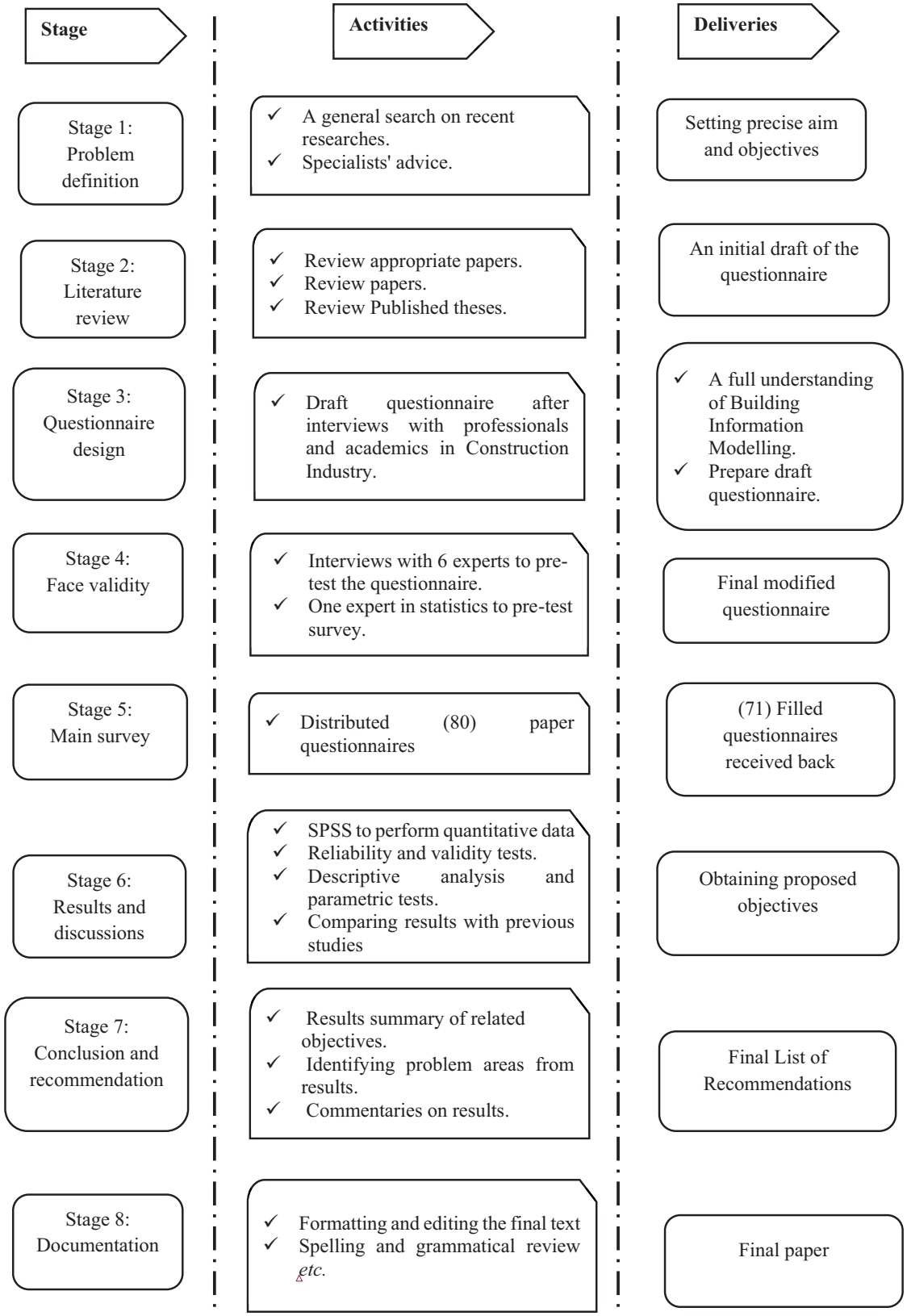

Fig. (4). Framework of the research methodology.

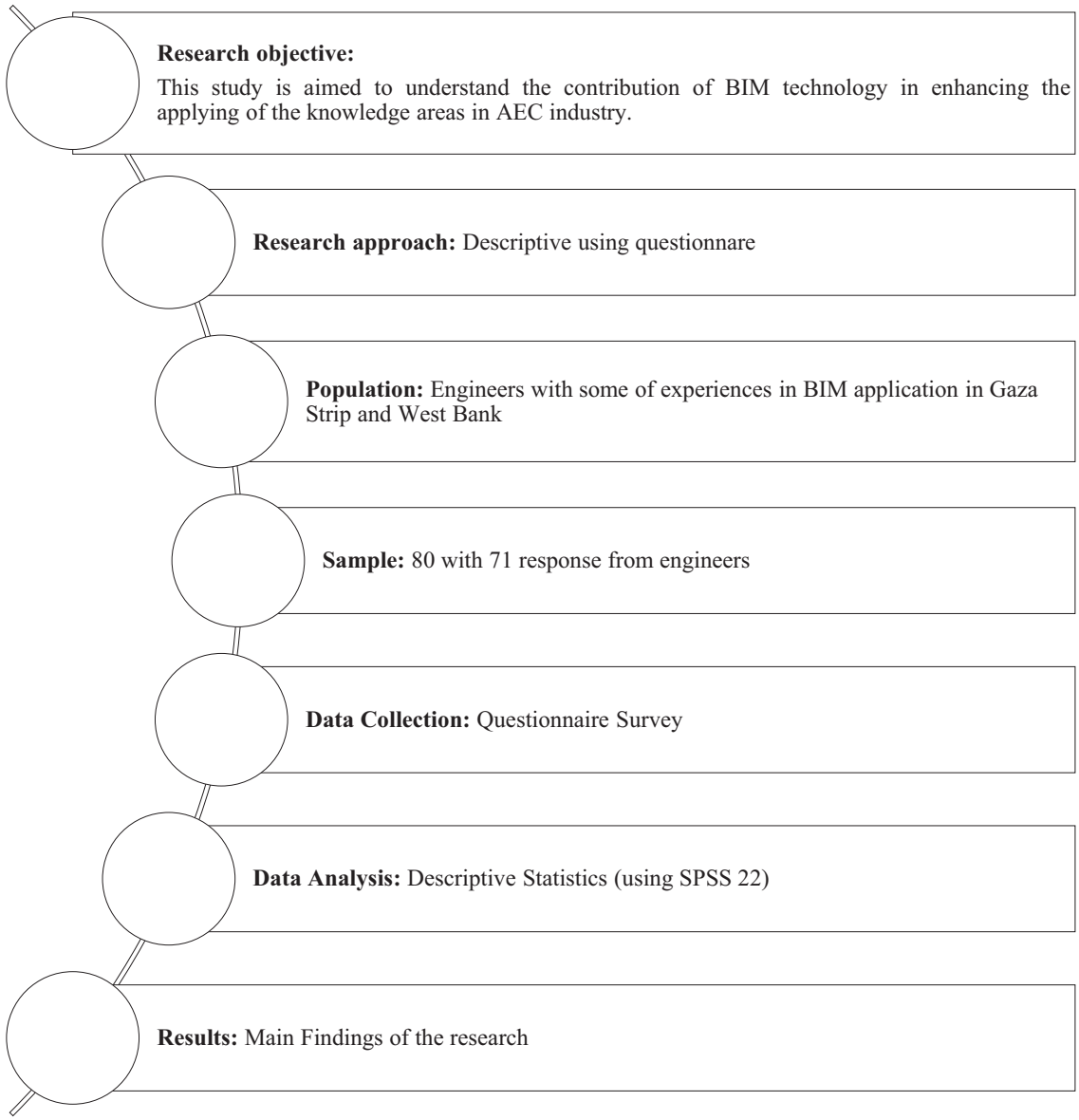

Fig. (5). Main steps of developing the survey.

Table 1. RII and test values for (Cost Management).

#.	Item	Mean	Std. Dev	RII (%)	T-value	P-value Sig.	Rank
1.	Model based quantity take-off	4.31	0.77	86.20	14.39	0.000	1
2.	Cost planning	4.21	0.81	84.23	12.61	0.000	2
3.	Accuracy and Realistic of cost estimation	4.17	0.91	83.38	10.82	0.000	3
4.	Flexibility and Faster of cost	4.08	0.91	81.69	10.08	0.000	7
5.	Collaboration and Consistencies	4.11	0.84	82.25	11.20	0.000	4
6.	Early cost decisions	4.08	0.87	81.69	10.45	0.000	6
7.	Higher productivity	4.00	0.89	80.00	9.42	0.000	9
8.	Real monitoring for cost	4.10	0.78	81.97	11.91	0.000	5
9.	Better cost control	4.07	0.76	81.41	11.84	0.000	8
All items		4.13	0.64	82.54	14.75	0.000	-

"Higher productivity" was ranked in the last position by the respondents under this group with RII of 80.00%, Test-value = 9.42, and P-value = 0.000 < LOS α= 0.05. Also, the test sign is positive. Thus, the mean factor is significantly greater than the hypothesized value. Based on the results, this factor takes the last rank from the viewpoint of respondents despite that "higher productivity" achieved high RII value. Based on the nature of understanding of respondents of this factor and on their experiences and knowledge in BIM in the construction industry, the majority of respondents proved that BIM increased the productivity. In a previous study [30], findings clearly showed that BIM achieved higher productivity.

Regarding the whole group of "Cost Management" with RII of 82.54%, Test-value =14.75, and P-value = 0.000 < LOS α= 0.05, the sign of the test is positive. Thus, the mean of this group is significantly greater than the hypothesized value. Based on the result that this group takes the second rank from the viewpoint of respondents, the important achievement for BIM in this area is the diminishing of the waste and rework in all project phases from the initiating phase to the closing phase in AEC industry. As a result, the hypothesis stated is accepted, thereby confirming that BIM will enhance the capabilities of project managers to apply CM in the AEC industry. This finding is consistent with the outcomes of previous studies [23, 28 - 39, 16, 17].

4.2. Risk Management

4.2.1. Hypothesis #.2: H1: There is a positive relation among the RM area and BIM in the AEC industry in Palestine

Table **2** illustrates the results of "Reduce financial risk and risk related schedule." Based on the table, this factor takes the first rank from the viewpoint of respondents, thereby clearly showing the importance of "Reduce financial risk and risk related schedule" in RM. The financial and time aspects are critical in any project, because any risk that can affect one of them can lead to the failure of the entire project. This means BIM is an effective tool for dealing with this issue and gives satisfactory results. These findings are consistent with the outcomes of previous studies [40, 41], thereby confirming that BIM will be an effective tool for reducing financial risk and risk-related schedule.

The factor "Reduce contingencies" takes the last rank from the viewpoint of respondents, even if it had a high RII of 74.37%. This result means that BIM assists in diminishing the alternative plans in the projects, thereby helping managers apply this model to this area with more efficiency and effectiveness because alternative plans appear when high risk and approximation are present. This finding is clearly illustrated in a previous study [30], confirming that BIM reduces contingencies based on managers' experiences and knowledge.

The whole group of "Risk management" takes the tenth rank from the viewpoint of respondents. The RII for this factor is high, but this does not mean that BIM does not help in alleviating the risk or managing it. This ranking was due to the fact that the experiences and knowledge of respondents in the RM area in Palestine are insufficient; thus, the RM area receives less attention and concern. However, previous studies [16, 18, 29, 30, 38, 40, 42 - 44] showed that BIM is a powerful tool to deal with RM in the construction industry. As a result, the hypothesis stated is accepted, thereby confirming that BIM will enhance the capabilities of project managers in applying RM to the AEC industry.

4.3. Time Management

4.3.1. Hypothesis #.3: H1: There is a positive relation between the TM area and BIM in the AEC industry in Palestine

Table **3** illustrates the results for the factor of "Maintain the construction schedule," which takes the first rank from the viewpoint of respondents. This ranking means that this factor has high momentum from respondents, thereby supporting the benefit of BIM to this area, as clearly illustrated in previous studies [18, 31, 37, 45]. Previous and current studies confirm how BIM will be an effective tool for maintaining the construction schedule.

"Reduce time and mitigates delays" takes the last rank from the viewpoint of respondents even if the factor "Reduce contingencies" has a high RII of 83.66% and even if this RII is near that of "Maintain the construction schedule." This finding clearly illustrates the important advantage of BIM to this area in the construction industry by diminishing the delays and enhancing the benefit from the time available in the project. This finding is consistent with the outcomes of another study [30], thereby proving that BIM reduces time and mitigates delays.

Table 2. RII and test values for (RM).

#.	Item	Mean	Std. Dev	RII (%)	T-value	P-value Sig.	Rank
1.	Risk assessment and mitigation	3.87	1.00	77.46	7.37	0.000	4
2.	Model – based analysis of possible hazards and Particular Risk scenarios	3.86	0.93	77.18	7.78	0.000	5
3.	Spatial visualization	3.85	1.02	76.90	6.96	0.000	6
4.	Reduce financial risk and risk related schedule	4.00	0.76	80.00	11.15	0.000	1
5.	Reduce contingencies	3.72	0.99	74.37	6.12	0.000	7
6.	Raise opportunity	3.97	0.83	79.44	9.90	0.000	2
7.	Decision making	3.94	0.84	78.87	9.43	0.000	3
All items		3.89	0.72	77.75	10.34	0.000	-

Table 3. RII and test values for (TM).

#.	Item	Mean	Std. Dev	RII (%)	T-value	P-value Sig.	Rank
1.	Reduce time and mitigates delays	4.18	0.85	83.66	11.72	0.000	3
2.	Maintain the construction schedule	4.25	0.82	85.07	12.83	0.000	1
3.	Timely monitoring the progress	4.19	0.92	83.71	10.77	0.000	2
All items		4.20	0.81	83.99	12.44	0.000	-

Table 4. RII and test values for (REM).

#.	Item	Mean	Std. Dev	RII (%)	T-value	P-value Sig.	Rank
1.	Reduce conflicts by Enhancing Interdisciplinary collaboration and coordination	4.01	0.89	80.28	9.64	0.000	3
2.	Reference for conflicts	3.90	0.91	78.03	8.32	0.000	4
3.	Efficient use of resource and tracking	4.03	0.81	80.56	10.69	0.000	2
4.	Collectively make decision	4.14	0.76	82.82	12.62	0.000	1
5.	Inventory management	3.79	0.79	75.77	8.40	0.000	5
All items		3.97	0.68	79.49	12.04	0.000	-

The whole group of "Time Management" takes the first rank from the viewpoint of respondents. This finding indicates how powerful BIM can be when used as a tool in TM and its benefits. Also, this result illustrates the awareness of the respondents of the importance of TM and the effects of using BIM on it. As a result, the hypothesis stated is accepted, which confirms that BIM will enhance the capabilities of project managers to apply TM to the AEC industry. This finding was also mentioned in other studies [18, 30, 31, 33, 37, 45 - 47].

4.4. Resource Management

4.4.1. Hypothesis #.4: H1: There is a positive relation between the REM area and BIM in the AEC industry in Palestine

Table **4** illustrates the results for "Collectively make decision." This factor takes the first rank from the viewpoint of respondents. Decision-making is a critical issue for managers because it can lead to the failure of the project. BIM provides benefit to the factor of "Collectively make decision," which can help the managers decrease the risks related to this factor by making decisions based on different viewpoints from the team and by depending on a unified model. This finding is clearly illustrated in other studies [45, 48], confirming how BIM will be an effective tool for collectively making decisions.

"Inventory management" takes the last rank from the viewpoint of respondents even if the factor "Reduce contingencies" has a high RII (75.77%). Such a ranking is due to the limited knowledge and experience of the respondents of the benefit of BIM for this factor. However, this does not mean that BIM is not effective. A previous study [49] shows that respondents can change their perspective and will be able to see the benefit of BIM to this factor when they learn more about it.

The whole group of "Resource Management" takes the seventh rank from the viewpoint of respondents. BIM provides so many benefits to the REM area, which are clear in the 5D model. With this model, a manager can manage all kinds of resources, such as human and material resources. As a result, the hypothesis stated is accepted, thereby confirming that BIM will enhance the capabilities of project managers to apply REM to the AEC industry. This result is also mentioned in previous studies [18, 19, 30, 33, 37, 40, 45, 48 - 54].

4.5. Procurement Management

4.5.1. Hypothesis #.5: H1: There is a positive relation between the PROM area and BIM in the AEC industry in Palestine

Table **5** illustrates the results for "Good procurement plan, Limit the requisition list, and Diminishing of errors," which takes the first rank from the viewpoint of respondents. This means that this factor is the main benefit of BIM to the PROM area when applied. Moreover, this ranking confirms that BIM is good for many areas in the planning phase, including PROM. Previous studies [33, 45] clearly illustrate how BIM can provide a good procurement plan, limit the requisition list, and diminish errors in the PROM area in construction industry.

Table 5. RII and test values for (PROM).

#.	Item	Mean	Std. Dev	RII (%)	T-value	P-value Sig.	Rank
1.	Product description and modeling	3.87	0.91	77.46	8.09	0.000	3
2.	Contractual management for procurement	3.73	0.89	74.65	6.91	0.000	5
3.	Integrity and Reliability of procurement	3.86	0.95	77.18	7.66	0.000	4

(Table 5) contd.....

#.	Item	Mean	Std. Dev	RII (%)	T-value	P-value Sig.	Rank
4.	Good procurement plan and Limit the requisition list and Diminishing of errors	4.04	0.79	80.80	10.93	0.000	1
5.	Managing deliveries	4.03	0.81	80.56	10.69	0.000	2
All items		3.90	0.67	78.08	11.31	0.000	-

"Contractual management for procurement" takes the last rank from the viewpoint of respondents, but this does not mean that BIM is not effective on this factor, because this factor has a high RII value of 74.65%. Moreover, the benefit can be applied *via* BIM, because BIM is active in the REM and STM areas, leading to its effectiveness on the contractual management in the procurement process. A previous study [21] showed the same results. The last position of this factor in the ranking is due to the nature of respondents' understanding, but the majority of respondents prove that BIM improves "Contractual management for procurement" based on their experiences and knowledge.

The whole group of "Procurement Management" takes the ninth rank from the viewpoint of respondents. BIM brings many benefits for this area, such as product description and modeling, contractual management for procurement, integrity and reliability of procurement, good procurement plan, limiting the requisition list, diminishing of errors, and managing deliveries. All these benefits will enhance the capabilities of the manager to apply BIM to this area with more effectiveness and efficiency. As a result, the hypothesis stated is accepted, which confirms that BIM will enhance the capabilities of project managers to apply PROM to the AEC industry. Also, this finding is mentioned in previous studies [21, 33, 45].

4.6. Scope Management

4.6.1. Hypothesis #.6: H1: There is a positive relation between the SCM area and BIM in the AEC industry in Palestine

Table **6** illustrates the results of "Visual scoping of work," which takes the first rank from the viewpoint of respondents. This means the benefit that BIM brings to this area is so vital, because when there is visualization for the scope of work, no detail will be missed in the project. This happens when a model with high LOD and at least with 4D type is used. These benefits can be easily achieved by using BIM, as implied by findings of the current study and in a previous research work [31].

"Element based model" takes the last rank from the viewpoint of respondents despite this benefit. This finding means that each element in the model can be differentiated because each element has unique characteristics different from the others. Also, the model can provide a comprehensive vision for the project in total and helps the managers in SCM based on the fact that each element will be known in the project. This is clearly illustrated in a previous study [16]. The ranking result is due to the nature of understanding of respondents of this factor. However, the majority of respondents prove that BIM is a satisfactory element-based model based on their experiences and knowledge.

The group of "Scope Management" takes the fifth rank from the viewpoint of respondents. This means that BIM can bring many benefits to this area, such as element-based model and visual scoping of work, which will help managers control and monitor this area during the phases of the project. As a result, the hypothesis stated is accepted, which confirms that BIM will enhance the capabilities of project managers to apply SCM to the AEC industry. This result is consistent with the outcomes of previous studies [16, 31].

4.7. Stakeholders Management

4.7.1. Hypothesis #.7: H1: There is a positive relation between the STM area and BIM in the AEC industry in Palestine

Table **7** illustrates the results for "Informed decisions from stakeholder," which takes the first rank from the viewpoint of respondents. This benefit is so important, because based on the interaction among the stakeholders, they are able to make informed decisions due to the unified model. Also, this result is clearly illustrated in [55].

Table 6. RII and test values for (SCM).

#.	Item	Mean	Std. Dev	RII (%)	T-value	P-value Sig.	Rank
1.	Element based model	3.94	0.91	78.87	8.75	0.000	2
2.	Visual scoping of work	4.06	0.84	81.13	10.56	0.000	1
All items		4.00	0.81	80.00	10.45	0.000	-

Table 7. RII and test values for (STM).

#.	Item	Mean	Std. Dev	RII (%)	T-value	P-value Sig.	Rank
1.	Deal with stakeholders with different backgrounds	3.89	0.81	77.80	9.34	0.000	6
2.	Enhancing stakeholder involvement, communication and Fostering relationship	3.93	0.85	78.59	9.21	0.000	4

(Table 7) contd.....

#.	Item	Mean	Std. Dev	RII (%)	T-value	P-value Sig.	Rank
3.	Client satisfaction, trust and confidence	3.85	0.94	76.90	7.61	0.000	7
4.	Positive impact on marketing	3.90	0.91	78.03	8.32	0.000	5
5.	Mitigate conflicts	3.96	0.89	79.15	9.12	0.000	3
6.	Core managing	4.04	0.78	80.85	11.22	0.000	2
7.	Informed decisions from stakeholder	4.08	0.69	81.69	13.21	0.000	1
All items		3.95	0.67	79.03	11.95	0.000	-

"Client satisfaction, trust, and confidence" takes the last rank from the viewpoint of respondents, which does not mean this benefit is not reachable by using BIM. This ranking result happened because of the nature of respondents' understanding of this factor, but the majority of respondents accept that this benefit is vital to the STM area. For example, client satisfaction, trust, and confidence are achievable when the client has a comprehensive vision of the project, which occurs due to the full-detailed BIM. This finding is clearly illustrated in previous studies [31, 46, 49].

The whole group of "Stakeholders management" takes the eightieth rank from the viewpoint of respondents, confirming that BIM has many benefits to this area, as follows: dealing with stakeholders from different backgrounds; enhancing stakeholder involvement; communication and fostering relation-ships; client satisfaction, trust, and confidence; positive impact on marketing; mitigating conflicts; core management; and informed decisions from stakeholder. All of these benefits help project managers by improving their ability to manage this area. As a result, the hypothesis stated is accepted, confirming that BIM will enhance the capabilities of project managers to apply STM to the AEC industry. This finding is also mentioned in previous studies [16, 19, 29, 31, 34, 39, 45, 46, 49, 55].

4.8. Integration Management

4.8.1. Hypothesis #.8: H1: There is a positive relation between IM area and BIM in the AEC industry in Palestine

Table **8** illustrates the results for "Information availability" which takes the first rank from the viewpoint of respondents. This led to thought more about BIM as a good tool for enhancing information availability which will promote the capabilities of PM in the IM area. Also, as known who owns the information owns the field and this consistent with the outcomes of that is clearly illustrated in a previous research work [49].

"Integrated project delivery with increase collaboration and integration" takes the last rank from the viewpoint of respondents. Still, on the same side, its RII value high and equal to 80.28% which means it is not different as compared to the first factor. Also, Integrated Project Delivery (IDP) is such a wide broad term which means it will achieve all of the knowledge areas with full competence and more effectiveness at the same way, will give PMs full control on the outcomes of the project with less waste and rework. This finding is clearly illustrated in these previous studies [16, 19, 47].

The whole group of "Integration Management" takes the third rank from the viewpoint of respondents, confirming that BIM has many benefits to this area, as follows: integrated project delivery with increased collaboration; and integration of unified system; cost and schedule integration; visualization and immersion experience; the inclusion of all parties; information availability; better coordination between documents; and logic analysis. The findings is also mentioned in these previous studies [16, 17, 19, 33, 39, 44, 45, 47, 49, 52, 56]. As a result, the hypothesis stated is accepted, confirming that BIM will enhance the capabilities of project managers to apply STM in the AEC industry.

4.9. Safety Management

4.9.1. Hypothesis #.9: H1: There is a positive relation between SM area and BIM in the AEC industry in Palestine

Table **9** illustrates the results for "Safety communication" which takes the first rank from the viewpoint of respondents. This means that it will be a big achievement in the SM area as a whole and the COM area because based on that will have fewer mistakes, reworks, and waste in the project due to safety issues [57, 58] clearly illustrated in a previous research work [44]. Also, it confirms how BIM will be an effective tool for safety communication.

Table 8. RII and test values for (IM).

#.	Item	Mean	Std. Dev	RII (%)	T-value	P-value Sig.	Rank
1.	Integrated project delivery with increase collaboration and integration	4.01	0.78	80.28	10.90	0.000	7
2.	Unified system	4.06	0.81	81.13	11.01	0.000	6
3.	Cost and schedule integration	4.15	0.82	83.10	11.84	0.000	3
4.	Visualization and immersion experience	4.07	0.85	81.41	10.60	0.000	5
5.	Information availability	4.23	0.78	84.51	13.27	0.000	1
6.	Better coordination between documents	4.20	0.77	83.94	13.14	0.000	2
7.	Logic analysis	4.14	0.78	82.82	12.32	0.000	4
All items		4.12	0.67	82.45	14.20	0.000	-

Table 9. RII and test values for (SM).

#	Item	Mean	Std. Dev	RII (%)	T-value	P-value Sig.	Rank
1.	Automated safety code checking	3.85	0.90	76.90	7.87	0.000	3
2.	Design for safety	3.90	0.86	78.03	8.79	0.000	2
3.	Safety communication	3.92	0.81	78.31	9.57	0.000	1
All items		3.89	0.80	77.75	9.39	0.000	-

"Automated safety code checking" takes the last rank from the viewpoint of respondents which does not mean that BIM cannot derive the value of RII which is high and near to the first factor value. This means that the majority of the respondents agree that BIM is beneficial and based on this will bring a strong tool for PMs to be applied on SM area also. Subsequently, the safety code will be fully applied in the projects and decrease the risks by anticipating it with using scenarios which BIM models can brings it to check all of the safety issues. And that is consistent with these previous studies [35, 44, 59].

The whole group of "Safety Management" takes the eleventh rank from the viewpoint of respondents. On the same side, respondents were not sure about the abilities and readiness of BIM to provide full control for PMs in SM area. But also, it is still that the maturation level of BIM is currently sufficient to solve the safety issues. Also, more information from the institutions to enhance the application of BIM is required [27, 30, 35, 44, 45, 47, 59]. As a result, the hypothesis stated is accepted, confirming that BIM will enhance the capabilities of project managers to apply SM in the AEC industry.

4.10. Quality Management

4.10.1. Hypothesis #.10: H1: There is a positive relation between QM area and BIM in the AEC industry in Palestine

Table **10** illustrates the results for "Efficient information utilization" which takes the first rank from the viewpoint of respondents. This means that based on using BIM from the PMs, the maximum benefit from available information will be achieved. The finding is also consistent with previous research work [39] and confirms how BIM will be so effective tool for efficient information utilization.

"Defect management system and recording" takes the last rank from the viewpoint of respondents but it does not mean that BIM cannot derive the value of RII which is high and near to the first factor value at the same side. This means that BIM can be a powerful tool for PMs to be able to manage QM area with more effectiveness and efficiency by depending on the defect management system which by this the rework, waste and, omissions will be avoidable. The finding is clearly illustrated in previous studies [30, 33, 34].

The whole group of "Quality Management" takes the sixth rank from the viewpoint of respondents. BIM can be a strong tool for QM area for PMs and it is confirmed based on the benefits provided from it for QM area mentioned in previous studies [18, 19, 24, 30, 33, 34, 39, 40, 43 - 48, 51, 53, 55, 60 - 62]. As a result, the hypothesis stated is accepted, confirming that BIM will enhance the capabilities of project managers to apply QM in the AEC industry.

4.11. Communication Management

4.11.1. Hypothesis #.11: H1: There is a positive relation between the COM area and BIM in the AEC industry in Palestine

Table **11** illustrates the results for "Planning several responsibilities" which takes the first rank from the viewpoint of respondents which means responsibilities will be distributed so well on the team from the PMs based on using the BIM. Also, this will decrease the conflicts which will happen if the responsibilities are not well managed at the same time hence ineffective COM will be achieved by the PMs as clearly illustrated in previous research work [39].

Table 10. RII and test values for (QM).

#.	Item	Mean	Std. Dev	RII (%)	T-value	P-value Sig.	Rank
1.	Defect management system and recording	3.86	0.80	77.18	9.07	0.000	10
2.	Decrease repeat errors and avoiding rework	4.06	0.84	81.13	10.56	0.000	3
3.	Enhancing quality by Quality status feedback	3.99	0.85	79.72	9.73	0.000	5
4.	Physical clash detection	3.93	0.88	78.59	8.87	0.000	8
5.	Detecting failure root-cause	3.97	0.86	79.44	9.51	0.000	6
6.	Lower waste and omissions	3.90	0.88	78.03	8.62	0.000	9
7.	Timely supervising quality	3.96	0.82	79.15	9.86	0.000	7
8.	Maintenance helping	4.00	0.85	80.00	9.97	0.000	4
9.	Comprehensive quality information repository	4.08	0.81	81.69	11.34	0.000	2
10.	Efficient information utilization	4.11	0.77	82.25	12.24	0.000	1
All items		3.99	0.66	79.72	12.53	0.000	-

Table 11. RII and test values for (COM).

#.	Item	Mean	Std. Dev	RII (%)	T-value	P-value Sig.	Rank
1.	Centralized, Structured data management and Information flow	4.06	0.81	81.13	11.01	0.000	5
2.	Descriptive information (Object and it is information)	4.10	0.81	81.97	11.38	0.000	2
3.	Planning several responsibilities	4.14	0.83	82.82	11.54	0.000	1
4.	Model based approach of working	4.09	0.86	81.80	10.71	0.000	3
5.	Unique language	4.00	0.85	80.00	9.97	0.000	7
6.	Clear and concise channel (Enhancing communication)	3.96	0.84	79.15	9.66	0.000	8
7.	Speed up understanding	4.03	0.84	80.56	10.26	0.000	6
8.	Decision making	4.08	0.82	81.69	11.09	0.000	4
All items		4.06	0.68	81.16	13.07	0.000	-

"Clear and concise channel (Enhancing communication)" takes the last rank from the viewpoint of respondents but it does not mean it is not a benefit of BIM because RII value is 79.15% which mean this value is so high if compared to the RII value of the first factor at the same time. BIM can be powerful to decrease the conflicts which resulted from the communication channels contradictions. Also, that happens when all team members work on the same model, which means there is a coincide on all details in the model. The finding also is consistent with these previous studies [30, 33, 34].

The whole group of "Communication Management" takes the fourth rank from the viewpoint of respondents, confirming that BIM has many benefits to this area, as follows: Centralized, Structured data management and Information flow; descriptive information (Object and it is information); planning several responsibilities; model based approach of working; unique language; clear and concise channel (Enhancing communication) ; speed up understanding and decision making. This finding is also consistent with these previous studies [18, 19, 24, 30, 33, 34, 39, 40, 43 - 48, 51, 53, 55, 60 - 66]. As a result, the stated hypothesis is accepted, confirming that BIM will enhance the capabilities of project managers to apply COM in the AEC industry.

CONCLUSION AND RECOMMENDATION

In achieving the aim of the study, the primary objective has been outlined and made through the findings from the analysis of collected questionnaires. This objective is related to the study questions, which are developed to increase knowledge and familiarity with the subject. The outcomes contribute to the elucidation of the contribution of BIM to the application of KAs in the AEC industry in Palestine in the most effective way. Study findings of the RII test indicate that BIM has different positive impacts on the application of KAs in the AEC industry in Palestine. BIM positively affects some KAs more than others from professional viewpoint. KAs based on the degree of positive BIM impact that obtained top ranking according to the respondents are as follows: (1) TM; (2) CM; (3) IM; (4) COM; (5) SCM; (6) QM; (7) REM; (8) STM; (9) PROM; (10) RM; and (11) SM.

Also, to achieve this objective, 11 hypotheses were tested by applying statistical analysis. They all have been accepted. The findings of the hypotheses are as follows:

- At first for H1, H2, H3, H4, H5, H6, H7, H8, H9, H10, and H11, based on the statistical results, a strong positive relationship was found between BIM technology in the AEC industry in Palestine and the following factors: Time Management (TM); Cost Management (CM); Integration Management (IM); Communication Management (COM); Scope Management (SCM); Quality Management (QM); Resource Management (REM); Stakeholders Management (STM); Procurement Management (PROM); Risk Management (RM); and Safety Management (SM). Thus, the increasing application of BIM by the project managers will increase the effectiveness of applying the KAs to the AEC industry in the Gaza strip.

Each KA is ranked based on the effectiveness of BIM's application in each one. For instance, BIM shows high effectiveness when applied to TM, which is performed based on the following factors: reduction of time and mitigating delays; maintaining the construction schedule; and timely monitoring of progress using BIM.

Based on the achieved objective of this study and the results, the recommendations are presented as follows:

Its recommended to increase the awareness about the BIM among the engineers in general and project managers, specifically in the construction industry to promote the application of KAs in any project.

Its recommended to start technical training in programs and to start using tools related to BIM to enhance the awareness of BIM for knowledge and experience.

Its recommended to build a framework for applying BIM in the construction industry to enhance project management.

Its recommended to use BIM as management tool rather than technical to enhance PMs capabilities in applying knowledge areas in construction industry.

Its recommended to start the adoption of BIM technology based on some of regulations and laws, which needed to create it by the government of Palestine to organize the applying of BIM technology.

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CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

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