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Success Breakdown Structure: Application to Petrochemical Projects Success Assessment

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ABSTRACT: Project success is not fulfilled unless it lives up to stakeholders' expectations. The fact that project success barely can be envisaged and construed, along with want of agreed upon success dimensions and criteria, augment the convolutedness of studying the concept. This paper focuses on assessing the success of petrochemical projects which not only engender employment and wealth but also underlie significant added-value to economies. This momentum unequivocally necessitates investigating petrochemical projects success. Therefore, through reviewing the seminal literature and consulting with experts, four success dimensions, four main stakeholders, and eighteen success criteria for petrochemical projects were discovered. Using these findings and results of a subsequent questionnaire survey, two petrochemical projects Success Breakdown Structures (SBSs) have been advanced. SBS1 breaks down the structure of success for petrochemical projects and clarifies that the success of these projects has four dimensions each of which is perceived differently by the stakeholders. In other words, by this SBS, it is possible to measure the "project's efficiency", "business success", "preparing for future" and "impact on end-user" for each project. Having the success criteria rated, SBS2 or stakeholders-based SBS was developed. SBS2 not only contains the traditional success elements of cost, time, and quality but also reveals significant connections between stakeholders' attitudes and petrochemical projects success. To validate the SBSs, the Delphi method was used. Based on SBS2 a mathematical model was structured to quantify the success of the petrochemical projects. A case study was conducted to test the serviceability of the model. The case study showcased that the stakeholders' expectations directly affect the success of a petrochemical project. For instance, if contractors and consultants are unhappy with their profit margin or if the credit they gain is unsatisfactory, the success rate of the project declines. Similarly, from the viewpoints of end-users of petrochemical products supplying sufficient quantities of high-quality products is the most important contributor to the project success to which the project client has to pay attention

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INTRODUCTION

Since the advent of the construction management and engineering science, the researchers in the field have developed a number of breakdown structures to better manage the flow of tasks/activities in a construction project. The most well-known structures include work breakdown structure (WBS), cost breakdown structure (CBS), and resource breakdown structure (RBS). However, the literature review shows that construction management and engineering body of knowledge lacks a commonly accepted procedure to break the structure of project success down. Deemed the principal purpose of projects by owners, managers, and practitioners [1, 2] success is unpropitiously affected by technical, environmental, social, and economic hindrances [3]. In addition, the absence of a contrivance to define [2], orchestrate, and quantify the success of projects is a critical gap [4]. For long, project success had been associated with tangible parameters tradeoff [5, 6] allowing conventional triple measures of project success subsuming cost, time, and quality known as the iron triangle to dominate tacit knowledge of success management [7]. All the same, state-of-the-art conceptions have recently superseded this line of reasoning. In other words, it has presently been proved that these measures are vital but inadequate for project success [8]. To elucidate on, on top of the iron triangle, project success demands the realization of stakeholders' expectations [9] as well as success dimensions [10] and criteria [11]. Among all construction projects, petrochemical ones are of paramount importance, as they are expensive to construct and maintain, and usually could be affected adversely by feed costs and technological advancements. By virtue of economic and social contribution of the petrochemical industry to societies [12, 13], this study has been narrowed down to the success of petrochemical projects. Although former scholars have investigated the issue in other industries [14], to the best of the authors' knowledge, no previous research has examined intertwined

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dependencies of stakeholders, success dimensions, and success criteria in petrochemical projects. Moreover, limited studies have been done so far to frame a formal process to investigate success measurement in petrochemical projects. The existing literature has mainly focused on identifying factors contributing to the success of petrochemical projects [2, 15] rather than developing a unique approach to assess it, a gap which is targeted to be plugged in the present paper. This goal gives due prominence to the significance of breaking down project success and applying it to success measurement in the petrochemical industry. Developing such a structure is challenging since project success is tied to the continued support of the stakeholders, i.e. how dedicated they are to their pre-determined obligations. On the other hand, success is a subjective concept. It means that a set of criteria and dimension are to be identified in advance to avoid potential discrepancies in evaluating project success. Consequently, the authors aimed at developing two SBSs and formulizing success of petrochemical projects by dint of scrutinizing stakeholders, success dimensions, and success criteria coincidently. This article is an extended version of a technical paper that has been authored by Shariatfar et al. 2019 [16]. There are two important aspects which distinguish the present work with the mentioned research: 1) The present paper considers all stakeholders whereas the former study investigated the success from client's perspective only, 2) The present paper provides a model to measure/quantify the success.

Literature review

Herein pivotal studies within the field of project success management are summarized in inverse chronological order. The authors were determined to review as many papers as they could to identify a common area for success factors and criteria in the available relevant researches. The aim was to extract the relevant success criteria and factors because the reviewed papers were not necessarily focused on a single common topic. As indicated, they were covering multiple aspects of success management. Therefore, it is not an easy task to synthesize the papers. The only common point among all papers was that they were discussing either project success criteria or success factors. However, the papers were not selected randomly since they are grouped into three sections of "project success in a general context", "success management in petrochemical projects", and "project success quantification". These sections discuss project success in a general context, success management in petrochemical projects, and project success quantification respectively.

Project success in a general context

A broad spectrum of researchers has contemplated the notion of project success to identify contributing factors and criteria. In what follows, a couple of recent studies have been addressed all of which suggest at least one project success criterion and/or factor.

Considering two groups of customers and contractors, Kuwaiti et al., 2018 determined success factors in Abu Dhabi healthcare construction projects. They applied AHP to prioritize the explored success criteria and sub-criteria and concluded that "financial capability" and "management" are the most leading success factors [17]. Tripathi and Jha, 2018 tested how the six success factors they identified impact upon the success of construction organizations and evaluated the effect of the former on the latter in terms of five performance factors. Through a questionnaire survey of 106 industry experts from 90 Indian construction organizations and applying structural equation modelling, they explored that top management competence is the most overarching factor followed by experience and performance. Moreover, they averred that professionals could concentrate on fewer factors in lieu of analyzing numerous ones [1]. Volden, 2018 set forth that even though developed nations have carried out multitudinous infrastructure projects, scanty knowledge avails to researchers because they are seldom appraised ex-post. Propounding a six-criterion meta-evaluation framework, the author tested 20 Norwegian projects from building, defence, information and communications technology, railway, and road sectors in three success levels of operational, tactical, and strategic. The research led to the conclusion that the majority of the projects were successful especially in terms of operational, probably owing to external quality assurance from 2000 onwards [18]. Liu et al., 2017 identified 19 critical success factors through literature review and interviews and classified them into five groupings. Based on a subsequent questionnaire survey, they rated the rankings and the groupings hoping that this prioritization will assist managers in adopting strategies in future for the development of eco-city projects [19]. Krajangsri and Pongpeng, 2017 pronounced that though construction projects success can be a function of sustainable infrastructure assessment, this dependence has not been monitored thus far. Doing a questionnaire survey, they gathered the required data and used it to structure a model. They concluded that the six-fold construction project success criteria are client satisfaction, time, cost, quality, safety, and environment. Furthermore, a regression weight of 0.83 manifestly affirmed that sustainable infrastructure assessments commensurately affect the success of construction projects [20]. Luo et al., 2017 delved into the possible relationship between project success and complexity in complicated construction projects in China. Literature review, expert interviews, and a questionnaire survey of 245 projects formed the basis of their research. Structural equation modelling corroborated the significant linkage between project success and complexity and underscored that information and goal complexities contribute most adversely to the projects' success [21]. There are also tons of other useful papers that the interested readers can refer to [4, 14, 22-27].

The reviewed papers highlight the fact that project success has been studied from multiple aspects. In other words, the authors could not find any researches which had focused intensely on a unique or similar issue, although they have introduced a number of contributing factors and criteria. It is why one of the problems within this context is the fragmented nature of the studies, meaning that more academic endeavors are needed to identify and plug the existing gaps.

Success management in petrochemical projects

This section of the article sets out to review a few papers specifically on success management in petrochemical projects and to give a brief synopsis. The papers have been categorized into three groups as follows.

The first group of papers was related to the effect of stakeholders on the success of petrochemical projects. To gain feedback from top managing stakeholders, Tsiga et al, 2017 identified 58 key success factors for petroleum industry projects which were categorized into 11 groups by reviewing the literature and testing them in the industry based on their individual relative importance index. An online questionnaire survey of project managers who had at least 15 years of working experience underlay the research. The findings unveiled the fact that risk management and requirement management significantly contribute to project success [2]. Nordin et al., 2014 contended that communication climate provokes success and effectiveness of an organization. Studying a high-risk work environment of an oil and gas company, where the employees had to work with heavy equipment and volatile chemicals, they investigated how the communication conflict strategies contribute to the overall organizational success and communication climate. A questionnaire survey of 125 employees brought this fact to light that conflicts management is connected with the roles personnel take on in their organization [28].

The second group of researchers was interested in investigating different dimensions of success definition. Hassani et al., 2017 examined the technical aspects of success management in petrochemical projects and declared that survival of petroleum and petrochemical projects relies on advanced down-to-earth technologies and innovation due to intense competition in the industry, geopolitics, economic uncertainties, and fluctuating oil price. After going over the importance of technology and innovation, they switched to identifying their quantifiable and non-quantifiable influences on the industry [12]. Studying the concept of project success from the sustainable development perspective, Al-Sharrah et al., 2010 used indicators covering three aspects of sustainability namely safety, economic, and environmental for decision-making, optimization, and planning for success and performance in the petrochemical industry. They utilized mixed-integer programming to model the development of typical petrochemical projects. A subsequent Monte Carlo simulation confirmed the model is capable of adapting to alterations in demand and prices [29].

The third group of studies was within the field of problem solving and management. Ren, 2009 investigated barriers to and drivers for process innovation in the chemical industry through a case study of the petrochemical industry and asserted that the low rate of success in petrochemical projects rises innovation costs. The author believed that running of a full-scale, commercial-size petrochemical plant in conjunction with successful plant construction is a testimony to tried-and-proven innovative processes [30]. Lang, 1990 addressed difficulties and problems encountered in the oil industry, proposed solutions to them, and elaborated lessons which were to be learned to beget success in future oil projects. The first problem he specified was that phases of engineering, procurement, and construction were let separately by oil companies. EPC contract combined with lump sum job was proposed as a panacea for it. The second problem was resourcing difficulties including variations in crude oil price, reduction in the number of employees in production and construction industries, as well as the number of school leavers wishing to pursue engineering as a career [31].

A valuable lesson learned from reviewing the literature was that the petrochemical industry lacks a sound background in introducing success factors and criteria and analyzing the success of the projects from the perspective of involved stakeholders based on those factors and criteria. To overcome this challenge, based on the papers reviewed in the last two sections, a longlist of essential success factors and criteria was prepared. The longlist afterward was observed by petrochemical industry experts for revision and finalization purpose.

Project success quantification

The following is a concise summary of some papers on project success quantification. The selection of the papers was not random, but rather, it was in a manner based on which a mathematical model could have been established. Osei-Kyei and Chan, 2017 developed a project success index, *PSI*, to quantify the abstract concept of success in projects adopting a public-private partnership delivery method in developing countries [32]. This pragmatic index comprises three cardinal success criteria grouping indexes including cost & technical specifications, GI_1, local development and disputes reduction, GI_2, and profit, GI_3. Capitalizing on a fuzzy synthetic evaluation method Eq. (1) was attained:

$$PSI = 0.352 \times GI_1 + 0.301 \times GI_2 + 0.347 \times GI_3 \quad (1)$$

To substitute the grouping indexes with real numbers, one of the two methodological approaches proposed in the article could be taken. Axiomatically the corresponding measurement scale is to be applied to interpret the resultant *PSI*. In another research, Gingnell et al., 2014 stressed that many IT projects either fail annually due to financial or schedule problems or function poorer than the expected or planned. Data elicited from a survey of 51 experts were used to a form a Bayesian decision-support model which determined the effect of management decisions on IT projects beforehand and provided decision rendering support for enhancing the performance of the projects [33]. Finally, Hughes et al., 2004 argued that the identification of determinants of construction project success is the key to successful project execution. Selecting six success criteria of the operating environment, quality, cost, safety, schedule, and performance they devised a Construction Project Success Survey (CPSS) to score project success. The survey statements were assessed by the respondents using a Likert scale which ranged from -3 to +3, to determine their level of agreement followed by rating importance of each statement by assigning one of the integers of 1, 2, or 3. Ultimately, a simple and innovated algebraic

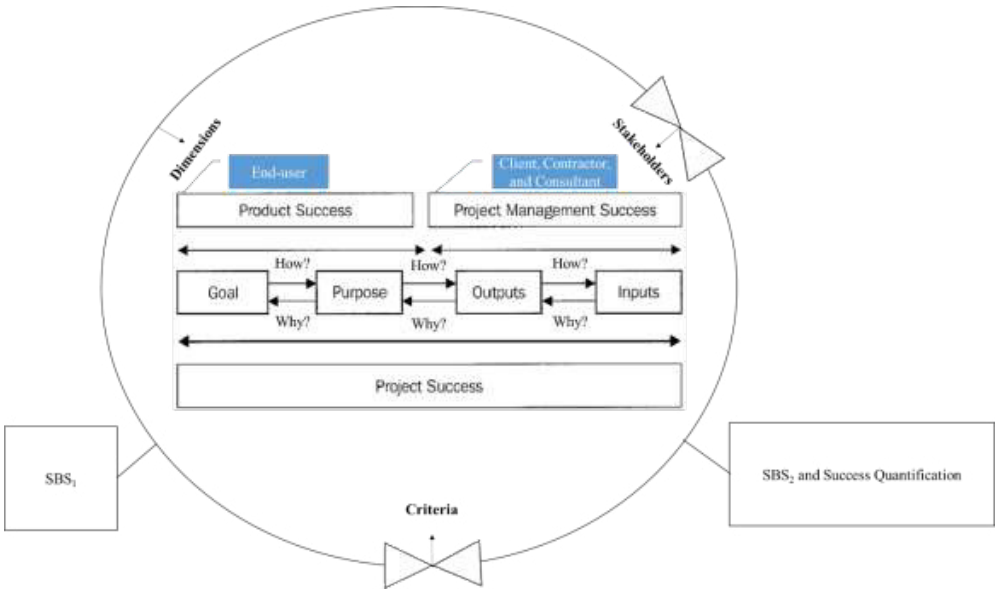

Fig 1. The latent connections between the studied subjects and the anticipated results of the research

scoring system that combined the numerical assessments and ratings quantified project success [34]. Since no paper has addressed the concept of success quantification within the context of petrochemical projects to the extent of the authors' knowledge, synthesizing the methodologies of the studied researches, the authors have proposed a mathematical approach to model the success of petrochemical projects followed by a case study. For more details on the steps of the modelling, please refer to steps 7 and 8 of the methodology.

METHODOLOGY

This section is composed of a concise summary of the research methodology followed by detailing each step taken.

Methodology overview

The important steps taken to carry out the ongoing research are as follows:

- First, significant stakeholders involved in, success dimensions of, and success criteria of petrochemical projects were identified through reviewing the literature and consulting with experts. The rationale behind this step is that success is a complicated concept to study as it is affected by people, project, and policies. Therefore, a comprehensive investigation had to be done to identify who affects project success and how they evaluate project success.
- Second, intertwined relationships between the identified stakeholders, dimensions, and criteria were recognized to develop the first SBS, Dimensions-Based SBS or SBS_1. In other words, the findings of the previous step were structured to clarify what are the core elements of success.
- Third, a questionnaire survey (please see the appendix) was conducted to quantify the effect of each stakeholder satisfaction on petrochemical project success and to score the criteria from each stakeholder viewpoint. Facilitating the process of prioritizing the items from the viewpoint of each stakeholder, this survey formed the basis of developing the second SBS, Stakeholders-Based SBS or SBS_2, as well as modelling petrochemical project success measurement. For more details on SBS_2 and success measurement, please refer to steps 5 and 7 of the methodology.
- Fourth, the inputs from the respondents were analyzed to summarize their characteristics and responses, and to assess the reliability of the survey. Checking the reliability of the survey is a vital step, as without a reliable survey the results will be biased and statistically unacceptable.
- Fifth, based on the analyses and by filtering out the criteria scoring less than the minimum acceptable amount, SBS_2 was developed. The developed SBS underlies the mathematical model to measure the success of petrochemical projects.
- Sixth, to confirm the applicability of SBS_1 and SBS_2, Delphi method was adopted to test and validate them. Delphi method provides an excellent chance to receive inputs and feedbacks from field experts to the possible extent.
- Seventh, a mathematical model was structured to measure the success of petrochemical projects. This step is vital as the success of a petrochemical project has to be quantified to assess it unbiasedly. Without having a numerical scale of measuring success, the assessment will be vague and non-telling. This model is compatible with the logical framework suggested by Baccarini, 1999 which serves as a foundation for defining project success [35]. Using this logical framework, four levels of project objectives can be considered: goal, purpose, outputs, and inputs. It is proposed that project success consists of two components: product success and project management success. The former deals with goal and purpose while the latter is associated with outputs and inputs. The only studied stakeholder that is related to product success is end-user as the consumer of the petrochemical products while the remaining stakeholders are related to project management success. Fig. 1 shows the hidden relationships between the studied items and the expected outcomes of this

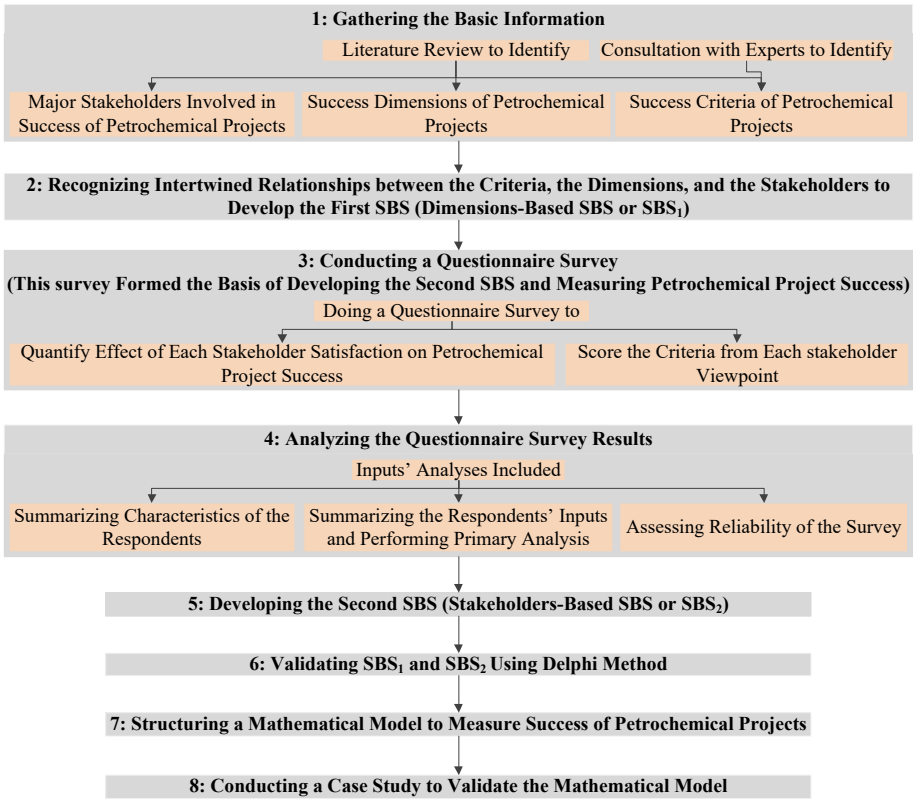

Fig 2. Summary of the research methodology

research:

- Eighth, the applicability of the mathematical model was confirmed through a subsequent case study. The significance of this step was that once the case study completed, the potential capability of the model in measuring the success of petrochemical projects was formally proven.

Fig. 2 outlines the entire procedure.

Steps overview

This section provides details of the taken steps in order.

Step one: Gathering the necessary information

Achieving the set goals of the research, developing the SBSs and modelling petrochemical projects success, necessitated identifying major stakeholders involved in, success dimensions of, and success criteria of the projects. To this end, first, the seminal literature was reviewed to come up with a shortlist of stakeholders, dimensions, and criteria. Then, a couple of seasoned experts were consulted with one by one to make sure that no stakeholder, dimension, or criterion is missed out in the shortlist. Therefore, the authors met expert # 1 asking him to evaluate the shortlist by modifying it or adding/removing some items. Then expert # 2, expert # 3, and expert # 4 were met one by one while the authors asked them to do the same. After the list was evaluated/modified by these experts, expert # 5 was met who confirmed the comprehensiveness of the shortlist by not modifying/adding/removing any of the items. Then, expert # 6 was met who also approved the comprehensives of the shortlist. At this level of the experts' survey, the authors assumed that the finalized list of the items has been obtained. Table 1 summarizes the properties of the experts as well as their inputs. As a corollary, four major stakeholders, four success dimensions, and eighteen success criteria were identified as shown in Table 2

Step two: Recognizing the relationships between the identified items

In the wake of identifying the stakeholders, the dimensions, and the criteria, the intertwined relationships between them were recognized by the authors leading to the dimensions-based SBS or SBS_1 as illustrated in Table 3. To develop this table, the items listed in Table 2 were categorized by the same group of experts based on two important properties of project success: success dimensions and stakeholder criteria. The former clarifies which dimension the investigated item is related to, while the latter indicates the item under study concerns which stakeholder. A number of items appeared in more than one cell, highlighting the fact that there are internal relationships between success dimension, success criteria, and stakeholders' expectations of a successful petrochemical project. To orient the readers, it is worth pointing out that SBS is introduced as a critical project deliverable organizing the project success into controllable packages [16, 37].

Table 3 breaks down the structure of success for petrochemical projects and reiterates that success of these projects has four dimensions each of which is perceived

Table 1. The properties of the experts and their inputs

#	Sex	Age	Years of Work Experience	Field of Study	Degree	Organization	Role in the Company	Input: number of the items:		
								Modified	Added	Removed
1	Male	67	42	Business and Economics	Ph.D.	Marjan Petrochemical Complex	Chief executive officer	1	0	1
2	Male	46	25	Civil Engineering	Ph.D.	Jam Petrochemical Complex	Structural engineer	0	0	1
3	Male	65	45	Civil Engineering	Ph.D.	Zagros Petrochemical Complex	Project manager	1	0	0
4	Male	57	29	Industrial Engineering	Ph.D.	Mehr Petrochemical Complex	Project manager	1	0	0
5	Male	60	32	Petrochemical Engineering	Ph.D.	Morvarid Petrochemical Complex	Contractor	0	0	0
6	Male	58	30	Master of Business Administration	M.Sc.	Marjan Petrochemical Complex	Sales representative	0	0	0

Table 2. The identified stakeholders, dimensions, and criteria

Type	Ref.	Description	Source
Major stakeholders	1	Client	[4]
	2	Contractor	[22]
	3	Consultant	[4]
	4	End-user	[4, 10]
Success dimensions	1	Project efficiency	[6, 36]
	2	Business success	[10, 36]
	3	Preparing for future	[36]
	4	Impact on end-user	[36]
Success criteria	1	Finishing project within time	[7]
	2	Finishing project within budget	[7]
	3	Being of expected quality	[7]
	4	Meeting nominal performance in construction	Experts' input
	5	Meeting safety standards	[34]
	6	Meeting construction's technical specifications and standards	Experts' input
	7	Earning the expected profit	[28]
	8	Solving the end-user's problems (right product at the right time, or ability to produce exactly what the end-user needs)	[36]
	9	Living up to end-user expectation/Satisfying end-user	[9]
	10	Improving construction performance	[7]
	11	Learning lessons for future projects	Experts' input
	12	Gaining credit and having new opportunities in the future	Experts' input
	13	Developing new construction technology	[34]
	14	Using new construction technologies	[12]
	15	Fulfilling end-user needs	[7]
	16	Increasing project serviceability based on the product's demand in the market	Experts' input
	17	Flexibility in changing the product's type when the old product is not economically beneficial, i.e. when sudden inflation happens	Experts' input
	18	Adding new products based on the market's demand	Experts' input

Table 3. Petrochemical projects dimensions-based success breakdown structure, SBS_1

Success dimensions	Stakeholders' criteria			
	Client criteria	Contractor criteria	Consultant criteria	End-user criteria
Project efficiency	Finishing project within time	Learning lessons for future projects	Learning lessons for future projects	-
	Finishing project within budget	Improving construction performance		-
	Being of expected quality	Finishing project within time*	Improving construction performance	-
	Meeting safety standards	Finishing project within budget*		-
Business success	Earning the expected profit	Meeting nominal performance in construction	Meeting nominal performance in construction	-
	Gaining credit and having new opportunities in the future	Earning the expected profit	Earning the expected profit	-
		Gaining credit and having new opportunities in the future	Gaining credit and having new opportunities in the future	-
Preparing for future	Developing new construction technology	Developing new construction technology	Developing new construction technology	-
	Gaining credit and having new opportunities in the future	Gaining credit and having new opportunities in the future	Gaining credit and having new opportunities in the future	-
		Using new construction technologies	Using new construction technologies	-
Impact on end-user	-	-	-	Meeting nominal performance in construction
	-	-	-	Meeting construction's technical specifications and standards
	-	-	-	Solving the end-user's problems
	-	-	-	Living up to end-user expectation/Satisfying end-user
	-	-	-	Fulfilling end-user needs
	-	-	-	Increasing project serviceability based on the product's demand in the market
	-	-	-	Flexibility in changing the product's type when the old product is not economically beneficial, i.e. when sudden inflation happens
	-	-	-	Adding new products based on the market's demand

* These items have been added after the Delphi validation process. Please refer to this section: "the first round of the survey".

differently by the stakeholders because each stakeholder lays down specific criteria to evaluate the project in terms of a given dimension. For instance, as observable at the intersection of client criteria column and project efficiency row in the same table, a client will consider a petrochemical project efficient if it finishes within time and budget, is of expected quality, and meets safety standards. This pattern is similarly extendable for other dimensions, stakeholders, and criteria. Therefore, for the sake of project success, the criteria of every dimension from the viewpoint of each stakeholder must be met.

Step three: Conducting a questionnaire survey

A questionnaire survey, see the appendix, was carried out to quantify the effect of each stakeholder satisfaction on petrochemical project success and to score the criteria from each stakeholder viewpoint. The last question was open-ended, allowing the respondents to provide more comments. This survey also formed the basis of developing the second SBS, stakeholders-based SBS or SBS_2, as well as modelling petrochemical project success measurement.

Step four: Analyzing the questionnaire survey results

Characteristics of the respondents

Before the main survey, a pilot test was performed to assess coherency, comprehensibility, and suitability of the questionnaire. Fortunately, the respondents of the pilot survey

Table 4. Characteristics of the respondents.

Property	Sub-property	Number of the respondents	Percentage	Sum	
				Total	Percent
Organization type	Client	14	21	66	100
	Contractor	25	38		
	Consultant	13	20		
	End-user	14	21		
Role in the company	Top manager	14	21	66	100
	Middle manager	29	44		
	Specialist	23	35		
Work experience (Years)	5-10	9	14	66	100
	11-20	35	53		
	≥ 21	22	33		
Gender	Male	61	92	66	100
	Female	5	8		
Age	26 - 35	6	9	66	100
	36 - 45	32	48		
	46 - 55	23	35		
	≥ 56	5	8		
Field of study	Petrochemical Engineering	20	30	66	100
	Chemical Engineering	9	14		
	Civil Engineering	18	27		
	Business and Economics	19	29		
Degree	M.Sc.	38	58	66	100
	Ph.D.	28	42		

Table 5. Arithmetic mean of the effect of each stakeholder satisfaction on petrochemical project success

Petrochemical project stakeholder	The average degree of satisfaction effectiveness (Out of 100)
Client	87
Contractor	76
Consultant	68
End-user	80

unanimously confirmed the well-being of the questionnaire and suggested no revisions. Based on Eq. (2) and choosing an error margin of 10% and confidence interval of 90% that resulted in the value of 1.28 for the normal variable (z), the required sample size (n) was 61:

$$n = \left(\frac{z\,\sigma}{d}\right)^2 = \left(\frac{1.28\times 0.61}{0.1}\right)^2 = 61 \quad (2)$$

Therefore, to carry out the main survey, 16 petrochemical companies in Iran, one of the most important contributors to the petrochemical industry, were contacted. The selection of the organizations was not random. Rather, they had different roles in petrochemical projects they were involved in: client, contractor, consultant, or end-user. These roles are indeed the stakeholders being studied in this paper. Once the companies gave their consent, the questionnaire was sent to 130 managers with different levels (top manager, middle manager, and specialist) in those companies. Thirty-nine questionnaires were never returned, and among 91 received ones, 25 were partially filled and hence were not considered for further analysis. Finally, with a response rate of 51%, 66 questionnaires were accepted. Table 4 summarizes the characteristics of the respondents.

Summarizing the respondents' inputs and performing primary analysis

The arithmetic mean is a good mathematical statistic to analyze and interpret results of questionnaires especially those of a Likert-scale one [38] which are called ordinal data [39, 40]. Therefore, this tool is used to summarize and for primary analysis of the responses, as shown in Tables 5 and 6.

A discussion on these findings is provided at the end of

Table 6. Arithmetic mean of the score of the criteria from each stakeholder viewpoint

Ref.	Criterion	Average Score (Out of 5)			
		Client	Contractor	Consultant	End-user
1	Finishing project within time	4.64	3.33	2.92	2.86
2	Finishing project within budget	4.64	2.98	3.00	1.88
3	Being of expected quality	4.50	3.02	3.71	4.39
4	Meeting nominal performance in construction	4.09	2.91	3.12	4.15
5	Meeting safety standards	4.36	3.24	3.35	4.30
6	Meeting construction's technical specifications and standards	3.80	2.89	3.62	4.00
7	Earning the expected profit	4.53	4.27	4.00	3.89
8	Solving the end-user's problems	3.58	1.86	2.30	4.56
9	Living up to end-user expectation/Satisfying end-user	4.00	2.08	2.50	4.71
10	Improving construction performance	3.45	3.11	3.33	2.53
11	Learning lessons for future projects	3.15	3.44	3.59	2.06
12	Gaining credit and having new opportunities in the future	3.68	4.06	3.97	2.17
13	Developing new construction technology	3.23	2.55	2.98	2.47
14	Using new construction technologies	3.15	2.91	3.21	2.27
15	Fulfilling end-user needs	3.52	1.80	2.33	4.50
16	Increasing project serviceability based on the product's demand in the market	3.35	1.65	2.20	4.27
17	Flexibility in changing the product's type when the old product is not economically beneficial, i.e. when sudden inflation happens	3.06	1.67	1.98	3.82
18	Adding new products based on the market's demand	2.86	1.56	2.00	3.79

step 5 of the methodology.

Assessing the Reliability of the Survey

Cronbach's alpha was calculated to evaluate the reliability of the survey as well as the internal and overall consistency of the inputs from the respondents. Since $\alpha=0.93>0.70$, the favorable consistency of the survey, as well as the goodness of the scale, were approved [41].

Step five: Developing the second SBS, stakeholders-based SBS or SBS_2

In a 5 point Likert-scale questionnaire survey with score 5 reflecting very high importance, which is a typical design of Likert-scale questionnaires [39, 42], it is intelligible that the respondents are in favor of a criterion if the corresponding average score is greater than 3 [38]. Selecting the criteria from Table 6 with the average score higher than 3 and descending sort of them with respect to each stakeholder led to the following stakeholders-based SBS or SBS_2:

1 Petrochemical Projects Stakeholders-Based Success Breakdown Structure

1.1 Client Success Criteria

1.1.1 Finishing project within time
1.1.2 Finishing project within budget
1.1.3 Earning the expected profit
1.1.4 Being of expected quality
1.1.5 Meeting safety standards
1.1.6 Meeting nominal performance in construction
1.1.7 Living up to end-user expectation/Satisfying end-user
1.1.8 Meeting construction's technical specifications and standards
1.1.9 Gaining credit and having new opportunities in the future
1.1.10 Solving the end-user's problems
1.1.11 Fulfilling end-user needs
1.1.12 Improving construction performance
1.1.13 Increasing project serviceability based on the product's demand in the market
1.1.14 Developing new construction technology
1.1.15 Learning lessons for future projects
1.1.16 Using new construction technologies
1.1.17 Flexibility in changing the product's type when the old product is not economically beneficial, i.e. when sudden inflation happens

1.2 Contractor Success Criteria

1.2.1 Earning the expected profit
1.2.2 Gaining credit and having new opportunities in the future
1.2.3 Learning lessons for future projects
1.2.4 Finishing project within time
1.2.5 Meeting safety standards
1.2.6 Improving construction performance
1.2.7 Being of expected quality

1.3 Consultant Success Criteria

1.3.1 Earning the expected profit
1.3.2 Gaining credit and having new opportunities in the future
1.3.3 Being of expected quality
1.3.4 Meeting construction's technical specifications and standards
1.3.5 Learning lessons for future projects
1.3.6 Meeting safety standards
1.3.7 Improving construction performance
1.3.8 Using new construction technologies

1.3.9 Meeting nominal performance in construction

1.3.10 Finishing project within budget (* This item has been added after the Delphi validation process. Please refer to this section: "the first round of the survey".).

1.4 End-user Success Criteria

1.4.1 Living up to end-user expectation/Satisfying end-user

1.4.2 Solving the end-user's problems

1.4.3 Fulfilling end-user needs

1.4.4 Being of expected quality

1.4.5 Meeting safety standards

1.4.6 Increasing project serviceability based on the product's demand in the market

1.4.7 Meeting nominal performance in construction

1.4.8 Meeting construction's technical specifications and standards

1.4.9 Earning the expected profit

1.4.10 Flexibility in changing the product's type when the old product is not economically beneficial, i.e. when sudden inflation happens

1.4.11 Adding new products based on the market's demand

A petrochemical project is successful if all the criteria mentioned above in SBS_2 from viewpoints of the corresponding stakeholders are satisfied. As SBS_2 highlights, the elements of the traditional iron triangle (time, cost, and quality) appear as items 1.1.1, 1.1.2, and 1.1.4 and as lower-rank criteria for other stakeholders. This fact implies a number of important points: 1) these factors are still important in developing SBS_2 and managing project success i.e. SBS_2 incorporate the basic elements of project success, 2) these traditional elements are of the highest importance only to the clients, meaning that none of these criteria were on top of the list of criteria for other studied stakeholders i.e. consultants, contractors, and end-users, 3) from the viewpoints of contractors and consultants earning the expected profit was the number one priority which makes sense as they work to be paid; therefore they will not be dedicated to their assigned tasks if they do not have secured profit margins, 4) contractors and consultants also share "gaining credit and having new opportunities in the future" as the second important success criterion. Again, this criterion stems from the human-being inherent tendency to consolidate his position in the job market, 5) the rest of the success criteria from contractors and consultants viewpoints are directly related to the project, indicating that these stakeholders will not necessarily consider a project successful if their primary criteria of profit and credit are not fulfilled, 6) a similar explanation can be provided for end-users, as the most important criterion to judge the success of a project from an end-user viewpoint is how far his/her expectations are lived up to regardless of the time or money spent on the project. It is also the case for the rest of the end-user success criteria i.e. project-specific success criteria including "finishing project within time, finishing project within budget, improving construction performance, using new construction technologies, and developing new construction technology" do not show up in the list and therefore are not important to the end-users.

Additionally, client success criteria include 17 out of 18 identified criteria. The sole excluded criterion is "adding new products based on the market's demand" which implies clients do not plan for short-term changes in their petrochemical projects as they prefer stable and deterministic conditions to probabilistic and unknown ones which may occur if they plan for long periods. In other words, they plan to have a successful project which will produce the same product(s) for a long time without any radical changes in the processes. Moreover, covering 17 out of 18 criteria by the project clients highlights the fact that it is the responsibility of the client to take care of nearly all success dimensions and criteria since other stakeholders' viewpoints to project success are not as comprehensive as that of the client (contractor, consultant, and end-user viewpoints consider only 7, 10, and 11 criteria out of 17 criteria indicating that they neglect several criteria).

In summary, SBS_2 not only contains the traditional concept of the iron triangle but also reveals more critical aspects of other stakeholders' attitudes to the petrochemical projects success.

Step six: Validating SBS_1 and SBS_2 using Delphi method

To obtain realistic and refereed results, the authors used the Delphi method by involving as many experts as possible. A brief explanation of the method is presented in the following section to introduce and highlight the applicability of the method for this research. Furthermore, Hallowell and Gambatese guide developed in 2010 [43], which is applied to the research, is described in section "helpful guides to the Delphi method". Finally, the section "the adopted validation process" elaborates the validation process based on the introduced guide.

What is the Delphi method?

The Delphi method is a questionnaire-based survey founded on collating opinions of wide range/panel of experts who are requested to answer the questionnaire in several consecutive rounds. A facilitator provides an anonymous summary of their comments and the reasons for their judgments after each round [43]. Within the next round, the panelists are fostered to revise their earlier answers in light of comments and explanations of other panel members [44]. It is supposed that during this process the range of the answers will decrease and the respondents' suppositions will converge. The process terminates once a pre-determined stop criterion, e.g. stability of results, a certain number of rounds, or achievement of consensus is met [43]. Rand Corporation first developed the method in their Project Delphi for U.S. Air Force [45]. Since then, it has been widely used for validation purposes in construction management and engineering [45, 46] and other fields of study [44].

Helpful guides to the Delphi method

Unfortunately, in construction management and engineering subfield different researchers have adopted or

Table 7. Flexible point system for qualification of expert panelists

Achievement or experience	Points (Each)
Professional registration	3
Year of professional experience	1
Conference presentation	0.5
Member of a committee	1
Chair of a committee	3
Peer-reviewed journal article	2
A faculty member at an accredited university	3
Writer/editor of a book	4
A writer of a book chapter	2
Advanced degrees:	-
B.Sc.	4
M.Sc.	2
Ph.D.	4

proposed dissimilar and vague structures to conduct a Delphi study, the problem which has been overcome to the possible extent when Hallowell and Gambatese, 2010 developed a comprehensive guideline for the method. Essential parts of this guideline that the authors used are directly rewritten in the following without major paraphrasing [43]:

- Number of rounds: 3
- Number of panelists: 8-12

The panelist must satisfy at least four of the following criteria:

- A primary or secondary writer of at least three peer-reviewed journal articles
- Invited to present at a conference
- Member or chair of a nationally recognized committee
- At least 5 years of professional experience in the construction industry
- A faculty member at an accredited institution of higher learning
- Writer or editor of a book or book chapter on the topic of construction management
- Advanced degree in the field of civil engineering, construction engineering and management, or other related fields (minimum of a B.Sc.)
- Professional registration such as Professional Engineer, Licensed Architect, Certified Safety Professional, Associated Risk Manager.

Also, it is suggested that panelists score at least one point in four different achievement or experience categories of Table 7 and a minimum of 11 total points to qualify for participation.

The adopted validation process

This section elaborates the validation process based on the guide introduced in the previous part.

Selecting qualified panelists

Following the explained guideline in the previous section, 12 experts were invited to participate in the validation process of SBS_1 and SBS_2 through Delphi method. All the panelists were qualified enough thanks to the following:

- They all satisfied four qualification criteria: they were invited to present at a conference at least once, had at least five years of professional experience in the construction industry, held M.Sc. degree, and were professional engineers.
- The scored more than 11 points.

Table 8 illustrates the characteristics of the panelists as well as their score.

The first round of the survey

Once the qualified panelists were selected, the first round of the survey began. SBS_1 and SBS_2 were printed one-sided on A4 sheets. Then the two sheets were stapled and delivered to the panelists to review and comment on. As for SBS_1, 5 panelists accepted it as it was, 3 and 2 panelists suggested considering the criteria "Finishing project within time" and "Finishing project within budget" separately as one efficient project criterion from contractor viewpoint, and 2 panelists suggested considering both criteria simultaneously. No further comments were received on SBS_1. Regarding SBS_2, 10 panelists accepted it as it was, 1 panelist did not comment on it, and 1 panelist believed that the criteria scoring 3 should not be omitted. It is noteworthy that the primary SBS_2 was based

Table 8. Characteristics of the panelists as well as their score

Expert	Expert score				
	0.5 * Number of presentations at conferences	1 * Years of professional experience	Holding M.Sc. degree	Professional registration (Professional engineer)	Total score (≥ 11)
1	0.5 * 3 = 1.5	1 * 6 = 6	6	3	16.5
2	0.5 * 2 = 1	1 * 8 = 8	6	3	18
3	0.5 * 1 = 0.5	1 * 9 = 9	6	3	18.5
4	0.5 * 2 = 1	1 * 13 = 13	6	3	23
5	0.5 * 2 = 1	1 * 7 = 7	6	3	17
6	0.5 * 2 = 1	1 * 10 = 10	6	3	20
7	0.5 * 1 = 0.5	1 * 11 = 11	6	3	20.5
8	0.5 * 2 = 1	1 * 6 = 6	6	3	16
9	0.5 * 1 = 0.5	1 * 7 = 7	6	3	16.5
10	0.5 * 2 = 1	1 * 11 = 11	6	3	21
11	0.5 * 2 = 1	1 * 9 = 9	6	3	19
12	0.5 * 2 = 1	1 * 6 = 6	6	3	16

Table 9. Results of the case study

Stakeholder	D_i	Criterion (j)	S_{ij}	A_{ij}	W_{ij}
Client	87	1.1.1	91	4.64	0.119
		1.1.2	70	4.64	0.119
		1.1.3	75	4.53	0.111
		1.1.4	95	4.5	0.109
		1.1.5	90	4.36	0.099
		1.1.6	93	4.09	0.079
		1.1.7	90	4	0.073
		1.1.8	93	3.8	0.058
		1.1.9	98	3.68	0.05
		1.1.10	96	3.58	0.042
		1.1.11	89	3.52	0.038
		1.1.12	85	3.45	0.033
		1.1.13	95	3.35	0.025
		1.1.14	95	3.23	0.017
		1.1.15	98	3.15	0.011
		1.1.16	97	3.15	0.011
		1.1.17	90	3.06	0.004
		$\sum_{j=1}^{m} S_{ij} \times W_{ij} = 87.674$			
Contractor	76	1.2.1	75	4.27	0.366
		1.2.2	85	4.06	0.305
		1.2.3	88	3.44	0.127
		1.2.4	90	3.33	0.095
		1.2.5	90	3.24	0.069
		1.2.6	90	3.11	0.032
		1.2.7	90	3.02	0.006
		$\sum_{j=1}^{m} S_{ij} \times W_{ij} = 82.731$			
Consultant	68	1.3.1	72	4	0.204
		1.3.2	75	3.97	0.198
		1.3.3	85	3.71	0.145
		1.3.4	90	3.62	0.127
		1.3.5	90	3.59	0.12
		1.3.6	88	3.35	0.071
		1.3.7	85	3.33	0.067
		1.3.8	88	3.21	0.043
		1.3.9	71	3.12	0.024
		1.3.10	80	3	0
		$\sum_{j=1}^{m} S_{ij} \times W_{ij} = 81.524$			
End-user	80	1.4.1	75	4.71	0.128
		1.4.2	75	4.56	0.117
		1.4.3	75	4.5	0.112
		1.4.4	90	4.39	0.104
		1.4.5	93	4.3	0.097
		1.4.6	94	4.27	0.095
		1.4.7	92	4.15	0.086
		1.4.8	92	4	0.075
		1.4.9	94	3.89	0.067
		1.4.10	50	3.82	0.061
		1.4.11	90	3.79	0.059
		$\sum_{j=1}^{m} S_{ij} \times W_{ij} = 83.556$			

on criteria scoring more than 3.

As per the comments received, two new criteria of "Finishing project within time" and "Finishing project within budget" were added to SBS_1 at the intersection of contractor criteria column and project efficiency row in Table 3.

Moreover, since the only criterion scoring 3 in Table 6 was "Finishing project within budget" from consultant viewpoint, this criterion was added to SBS_2 as the last consultant success criterion, or item 1.3.10.

The second round of the survey

In the second round, the panelists were requested to review the revised SBS_1 and SBS_2. Fortunately, a consensus was reached and they unanimously approved the revised SBSs.

Step 7: A mathematical model to measure the success of petrochemical projects

Quantifying a specific project success provides decision-makers with an opportunity to evaluate the project and compare its success level with those of other projects for benchmarking goals [32]. With this purpose in mind, the authors have proposed Eq. (3) to calculate the petrochemical project success index, *PPSI*. This index is designed to range from 0 to 100 indicating the least and the most successfulne0ss respectively.

$$PPSI = \frac{\sum_{i=1}^{n}(D_i \times \sum_{j=1}^{m} S_{ij} \times W_{ij})}{\sum_{i=1}^{n} D_i} \quad (3)$$

Where:

- n is the number of stakeholders (4 in this paper),
- D_i is the degree of influence of stakeholder i satisfaction on project success (out of 100, obtainable from Table 5),
- m is the number of criteria in SBS_2 attributed to stakeholder i,
- S_{ij} is a score given by stakeholder i to determine how much the j^{th} success criterion attributed to the same stakeholder in SBS_2 has been met (out of 100),
- W_{ij} is the weight factor of the j^{th} success criterion attributed to stakeholder i in SBS_2 according to Eq. (4):

$$W_{ij} = \frac{A_{ij} - 3}{\sum_{j=1}^{m}(A_{ij} - 3)}, \sum_{j=1}^{m} W_{ij} = 1 \quad (4)$$

Where A_{ij} is the average score of the j^{th} success criterion attributed to stakeholder i in SBS_2 from the same stakeholder viewpoint (out of 5, obtainable from Table 6). It is noteworthy to mention that in Eq. (3), weighted score or $\sum_{j=1}^{m} S_{ij} \times W_{ij}$ shows how a project was successful from the perspective of stakeholder i.

Step 8: Conducting a case study to validate the mathematical model

One possible way to validate a model which describes a property of a civil project is applying the model to a real project or conducting a case study [47]. The wide use of this method in construction management highlights its applicability [48, 49]. To test the applicability of the developed mathematical model in step 7, it was applied to Marjan Petrochemical Complex which is a methanol production plant in Asallouyeh, Booshehr, Iran. The petrochemical project recently has been finished and operated. Different stakeholders were asked to rate the parameter S_{ij}. Other parameters were accessible from Tables 5 and 6 and Eq. (4). Results of the case study are shown in Table 9.

The data in Table 9 were inserted into one M.S. Excel spreadsheet where simple mathematical functions were coded to calculate *PPSI* according to Eq. (3). The index was found to be 84.146, meaning that from the surveyed stakeholders' points of view, the project was 84% successful. This output makes sense, as according to an informal interview with the project chief executive officer and the top manager the actual project was in an acceptable status in terms of the studied stakeholders' satisfaction, success criteria, and success dimensions. It is worth reminding that this index evaluates overall project goals achievement [7] which are identified in the SBSs. In the conducted case study, the lowest weighted score, 81.524 out of 100, corresponds to consultants. When the surveyed consultants were questioned why did they give a relatively low score to the project? they replied that they earned less profit in this project than what they expected. This reply conforms well to the developed SBS_2 where "earning the expected profit" ranks first in the consultants' list of criteria.

The second lowest weighted score, 82.731 out of 100, corresponds to contractors. Similarly, they claimed that they have not earned the profit they expected. Once more this reply conforms well to the developed SBS_2 where "earning the expected profit" ranks first in the contractors' list of criteria. The surveyed contractors revealed that due to their low profit margin they had the minimum incentive to meet nominal performance in the construction phase. This matter of fact is observable in scores of consultants where "nominal meeting performance in construction" is the item receiving the lowest score in the case study (71 out of 100, item 1.3.9 in consultants list of criteria, Table 9).

The third lowest weighted score in the case study, 83.556 out of 100, corresponds to end-users. All the scores are at least 75 but that of item 1.4.10 or "flexibility in changing the product's type". The reason that the surveyed-respondents provided for this low score was that they expect the producers to prevent fluctuations in the price of their products by adjusting their quantity and quality. They thought that the project under study will not be good at managing the cost of its products in the market, as it produces less than needed and therefore more plants are to be constructed in the future. This finding makes sense as the "flexibility in changing the product's type" appeared at the end of client's list of criteria and the current client of the project does not aim at covering all the demand in the market.

Finally, the top weighted score, 87.674 out of 100, corresponds to clients. The most critical score given to items in the client list of criteria items was 70 out of 100 for item 1.1.2 or "finishing project within budget", as the project suffered from cost escalation. The second critical item which scored 75 out of 100 was item 1.1.3 or "earning the expected profit". As discussed earlier, two important stakeholders i.e. consultants and contractors were unhappy with their profit margin and this could be why this item got a low score.

Using a similar approach to that of the present paper, other scholars can follow the methodology of this research for their projects to obtain the *PPSI* and analyze the project's success level. The more the *PPSI*, the more the project goals have been achieved.

RESULTS

The most important contributions of this paper are SBS_1, SBS_2, and a model to quantify petrochemical projects success:

SBS_1 breaks down the structure of success for petrochemical projects and clarifies that the success of these projects has four dimensions each of which is perceived differently by the stakeholders. In other words, by this SBS, it is possible to measure the "project's efficiency", "business success", "preparing for future" and "impact on end-user" for each project. It happens because each stakeholder lays down specific criteria to evaluate the project in terms of a given dimension. Therefore, for the sake of project success, the criteria of every dimension from the viewpoint of each stakeholder must be met.

Having the success criteria rated, SBS_2 or stakeholders-based SBS was developed. SBS_2 not only contains the traditional success elements of cost, time, and quality but also reveals significant connections between stakeholders' attitudes and petrochemical projects success. To elucidate on, the triple traditional elements are of the highest importance only to the clients, meaning that none of these criteria were on top of the list of criteria for other studied stakeholders i.e. consultants, contractors, and end-users. In addition, from the viewpoints of contractors and consultants, "earning the expected profit" was the number one priority; therefore they will not be dedicated to their assigned tasks if they do not have secured profit margins. Contractors and consultants also share "gaining credit and having new opportunities in the future" as the second important success criterion. The rest of the success criteria from contractors and consultants viewpoints are directly related to the project, indicating that these stakeholders will not necessarily consider a project successful if their primary criteria of profit and credit are not fulfilled. A similar explanation can be provided for end-users, as the most important criterion to judge the success of a project from an end-user viewpoint is how far his/her expectations are lived up to regardless of the time or money spent on the project. It is also the case for the rest of the end-user success criteria i.e. project-specific success criteria including "finishing project within time, finishing project within budget, improving construction performance, using new construction technologies, and developing new construction technology" do not show up in the list and therefore are not important to the end-users. More importantly, client success criteria include 17 out of 18 identified criteria. The sole excluded criterion is "adding new products based on the market's demand" which implies clients do not plan for short-term changes in their petrochemical projects as they prefer stable and deterministic conditions to probabilistic and unknown ones which may occur if they plan for long periods of time. It also reiterates that it is the responsibility of the client to take care of nearly all success dimensions and criteria since other stakeholders' viewpoints to project success are not as comprehensive as that of the client (contractor, consultant, and end-user viewpoints consider only 7, 10, and 11 criteria

out of 17 criteria indicating that they neglect several criteria).

Based on SBS_2 a mathematical model was structured to quantify the success of the petrochemical projects. A case study was conducted to test the serviceability of the model. The case study showcased that the stakeholders' expectations directly affect the success of a petrochemical project. For instance, if contractors and consultants are unhappy with their profit margin or if the credit they gain is unsatisfactory, the success rate of the project declines. Similarly, from the viewpoints of end-users of petrochemical products supplying sufficient quantities of high-quality products is the most important contributor to the project success to which the project client has to pay attention. These findings are synonymous with those resulted in the analysis of SBS_2. On the other hand, the model worked well in predicting criteria in which the studied project had faced problems e.g. finishing the project within budget. It also estimated the success rate of the estimated project accurately as confirmed by the project chief executive officer and the top manager. Therefore, the developed mathematical model is proven to be valid enough in terms of quantifying the success of petrochemical projects.

DISCUSSION AND CONCLUSIONS

The reviewed literature highlights the fact that project success has been studied from multiple aspects. In other words, the authors could not find any researches which had focused deeply on a unique or similar issue, although different scholars have introduced a number of contributing factors and criteria. This is why one of the crucial problems within this context is the fragmented nature of the studies, meaning that more academic endeavors are needed to identify and plug the existing gaps. To this end, the main objective of this study was to evaluate, define and finally assess the success in a petrochemical project. Petrochemical projects were selected since they are very sensitive to volatile feed price and end product market fluctuations. They require a huge amount of money for construction and usually, the owners should be assured for project success under these circumstances. Therefore, the authors applied the new concept of SBS to come up with an applicable novel success measurement index. According to the reviewed literature, there were a few viewpoints and standards/scales to quantify the success of petrochemical projects. However, in this paper, using a holistic lifecycle approach for petrochemical projects, all relevant points of view have been considered to develop a comprehensive model. Another important contribution of the present paper is taking into account the impact of involved stakeholders, as a project cannot be successful unless the expectations of all stakeholders have been lived up to. The findings of this research indicated that four major stakeholders, four success dimensions, and eighteen success criteria have to be considered to study the success of petrochemical projects and establish corresponding SBSs.

The methodology of the research was based on the literature review, comprehensive discussions and interviews with experts, questionnaire surveys, statistical analysis, the Delphi method, and a case study. However, the research was limited by the number of investigated dimensions, criteria, and stakeholders, which can be improved by future researchers. They also may adopt the methodology of this paper to frame SBSs for other types of infrastructure projects i.e. highways, dams, airports etc.

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