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ENGINEERING HARMONY UNDER MULTI-CONSTRAINT OBJECTIVES: THE PERSPECTIVE OF META-ANALYSIS

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Abstract. Harmony is the process of coordinated development between the elements, subsystems and the environment in each Engineering stage of the engineering implementation. Quality, duration, cost and risk are the key factors to achieve engineering harmony. Clarifying the influencing factors of engineering harmony and its mechanism can improve the possibility of success. The meta-analysis method is used to carry out a restudy of existing researches of engineering harmony. First, quality, duration, cost and risk are selected as the variables of achieving engineering harmony. Second, the paper collects 29 existing researches including many countries and regions around the world on the relationship between the variables and engineering harmony. Third, each value is calculated and corrected according to literature coding. Forth, publication deviation and total effect test are checked. Finally, the research conclusions and engineering management implications are given based on the results of meta-analysis. The results show that quality objective, duration objective, cost objective and risk management objective all have positive impact on achieving engineering harmony. The engineering type has no regulatory effect on positive impact of the duration objective and cost objective, but has regulatory effect on positive impact of the quality objective and risk management objective on the engineering harmony.

Keywords: engineering harmony, scheduling, quality, lifestyle costing, risk management, meta-analysis.

Introduction

Engineering harmony is the process of conflict resolution between various elements, systems and the environment (Garwood & Poole, 2018). Clarifying the influencing factors of engineering harmony and its mechanism can effectively improve the possibility of success. To some extent, many international scholars have clarified the key elements of engineering harmony (Assaf & Al-Hejji, 2006; Marzouk & El-Rasas, 2014; Mohammed & Isah, 2012). Since the engineering management objectives are mostly evaluated comprehensively from the perspective of quality, duration, cost, risk, etc., the existing researches generally believe that there is a direct relationship between the objectives, such as quality, duration, cost, risk, and the realization of engineering harmony (Chen, Jin, Xia, Wu, & Skitmore, 2016; Liu, Xie, Xia, & Bridge, 2017; Molenaar & Dai, 2014). The existing literature has carried out a lot of research on the relationship between quality, duration, cost, risk and the realization of engineering harmony, but there are still great controversies about the specific mechanism of the impact. From the perspective of participants in engineering, each stakeholder has different standards for achieving project harmony (M. M. Musa, Amirudin, Sofield, & M. A. Musa, 2015). The final customer of the project believes that the achievement of goals such as quality, duration, cost and risk is an important standard to measure engineering harmony (Pinto & Slevin, 2013). The project managers believe that the process of achieving the quality goal, duration goal, cost goal and risk management goal is more conducive to achieving the engineering harmony (Wilson, 2015). Toor and Ogunlana (2009) also believe that the engineering should meet the expectations of all stakeholders in terms of quality, duration, cost and risk, and minimize disputes and conflicts to achieve the engineering harmony. From the macro and micro perspective of engineering management, the macro engineering harmony only involves the results of the operation stage (Lim & Mohamed, 1999). On the micro level, it includes the quality, duration, cost and risk of each construction stage to promote the success of the project (Zhang, Liu, Tan, Jiang, & Zhu, 2018). This means that during the implementation of the project, it is not only necessary to focus on the success of the project over a long time, but also to

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pay attention to the engineering harmony of the various implementation stages in the short term.

Quality, duration, cost and risk are the key factors to achieve engineering harmony. They are not independent of each other. Through theoretical and empirical studies, domestic and foreign scholars have extensively discussed the tradeoffs of quality, duration, cost and risk in the process of achieving engineering harmony. Due to the complexity of the influencing factors, there is no single best measurement method at present. Early researches mainly explained the relationship between quality, duration, cost, risk and engineering harmony from the perspective of project success. For example, Sambasivan and Soon (2007) determined the key factors of cost, duration and quality in project sustainable development by quantifying factors contributing to the success of 17% construction projects in Malaysia. In terms of theoretical research, Azaron, Katagiri, and Sakawa (2007) developed an analysis model of time-cost-risk tradeoff to promote engineering harmony by using optimal control theory in Markov Network. These studies provide valuable data and theoretical basis for exploring the realization of engineering harmony through coordination of quality, duration, cost and risk, but the research conclusion is worth discussing. The specific reasons include: firstly, the standards selected in the relevant empirical survey are not consistent, including the uncertainty of measurement caused by subjectivity of the definition of quality, risk and other factors (Idiake, Oke, & Shittu, 2015). Secondly, the research conclusions based on different perspectives such as project managers, project characteristics, project teams, and different research methods have a paradox, and there is a lack of research on the impact on engineering harmony from the perspective of multi-factor combination (Sanchez & Terlizzi, 2017). Thirdly, the existing researches have many characteristics such as engineering type difference and regional difference. Therefore, it is necessary to make a comprehensive study on the specific mechanism of quality, duration, cost, and risk affecting engineering harmony, so as to minimize various deviations and ensure the scientificity, objectivity and authenticity of the conclusion.

This paper attempts to focus on the existing research on the relationship between quality, duration, cost, risk and engineering harmony, which has differentiated conclusions and even paradoxes, and carries out a systematic study on engineering harmony under multi-objective constraints by using the method of meta-analysis.

1. The basic assumptions

As the most important and competitive factor in engineering management (Deshpande, Siddhalingeshwar, & Ekabote, 2016), quality objective plays a crucial role in the economic benefits of projects and enterprises (Alger, 2013). Engineering construction is an extremely complex process, involving a wide range of factors (S. Qureshi, S. M. Qureshi, Ullah, Memon, & Siddiqui, 2017), and there are many influencing factors that lead to quality objective, including material selection, mechanical category, topography and geology, hydrological conditions, meteorological changes, construction technology, operation method, management measures, etc. (Preethi & Monisha, 2017). The purpose of engineering quality management is to guarantee the engineering quality level, to meet the requirements of the owner or the set standards and norms, to ensure the smooth implementation of contracts and plans in the engineering management process, and to guarantee the harmonious coexistence of the project and people, nature, environment, etc. (Foy, 2013). The value of the project can be measured by the quality level associated with the project (Liberatore & Pollack-Johnson, 2013). The poor engineering quality will affect the construction period and cost. Therefore, it is necessary to control the engineering quality with the help of quality management, so as to achieve the harmonious development among the engineering, personnel management, engineering construction, and natural environment (Fu & Zhang, 2016). To sum up, this paper proposes the following hypothesis:

H1: the quality objective has positive impact on achieving engineering harmony.

The degree of novelty, complexity and technical uncertainty of different types of engineering is different, and the methods and difficulty of realizing engineering quality objective are also different (Frank, Sadeh, & Ashkenasi, 2011). Different types of engineering have different requirements for quality management. With the increase of the quantity and scale of project organization, the requirements of quality objective for different types of projects have been improved, and higher requirements have been put forward for relevant project quality managers (Monghasemi, Nikoo, Fasaee, & Adamowski, 2015). Improving work flexibility and organizational support can have a positive impact on the satisfaction of engineers from the perspective of work and family, which is conducive to the improvement of project quality and the promotion of engineering internal harmony (Wu, Duan, Zuo, Yang, & Wen, 2016). Engineering projects are in a dynamic and open environment, and the constantly changing system environment requires the quality objective to be dynamically changed according to different stages of different project types. According to the different characteristics of quality management of different engineering types, coordination and priorities should be determined, quality target requirements should be defined, and the matching degree between quality target and project types should be improved, so as to promote the internal management harmony of engineering. To sum up, this paper proposes the following hypothesis:

H2: the engineering type may influence the positive impact of the quality objective on engineering harmony.

Generally speaking, the construction cycle of the engineering is relatively long, and there are many factors affected. Various unexpected events will occur in the actual construction process, so there is often error between the actual completion time and the initial target period of the engineering (Jaśkowski & Biruk, 2011). Delayed delivery of engineering is considered to be one of the most common problems. The failure of construction period management will affect the project's expected revenue and increase the financial cost. In the context of fierce competition in the engineering field, failure to complete the project in time may damage the credibility of the designer and the contractor, and the expected target may also be affected by construction delay. It can be seen that the realization of the construction period target is of great significance for promoting engineering harmony (Fernandez-Viagas & Framinan, 2015). Time buffer can alleviate the changes caused by the complexity of engineering and the uncertainty of external environment (Russell, Liu, Howell, & Hsiang, 2015). In order to effectively carry out construction schedule control, it is necessary to obtain the relevant status information regularly and timely (Feng, Wei, & Zhang, 2015). Therefore, the duration target should not only ensure the implementation according to the project plan, but also dynamically adjust it according to the changes of internal and external environment, so as to realize the internal management and external environment harmony. To sum up, this paper proposes the following hypothesis:

H3: the duration objective has positive impact on achieving engineering harmony.

The duration target runs through all stages of the project life cycle, so it is necessary to make the time schedule according to the characteristics of different types of engineering (Jin, 2015). The destructive impact of random factors can be avoided to ensure that the actual construction process of the project meets the expected planning (Jaśkowski, 2015). The construction schedule is affected by the objective and subjective environment in many ways, and the impact size of different types engineering is different, and the random events are also different in the construction process. There are differences on resource limitations in different types of engineering. Under the resource constraints, project scheduling problem is related to project management level (Lin & Hsiau, 2010), and the project duration shall be minimized on the basis of satisfying the priority relationship and resource constraints. Based on the operating conditions of different types of engineering, the construction period management is evaluated by multiple attributes, and the risk evaluation of construction duration can effectively optimize the duration objective and realize the internal management harmony (Fernandez-Viagas & Framinan, 2014). To sum up, this paper proposes the following hypothesis:

H4: the engineering type may influence the positive impact of the duration objective on engineering harmony.

The cost target control of engineering involves the multi-angle control of labor cost and material cost, dominant cost and recessive cost, which is a professional field with strong technical skills (Smith, 2016) and an important factor of engineering harmony (Mclean, Mcgovern, & Davie, 2015; Schuh et al., 2018). Since the problem of continuous simulation of cost estimation has not been effectively solved, and the cost uncertainty of construction, transportation and other projects is very obvious (Chou, 2011), many cases of cost overruns emerge one after another, causing a lot of time waste, project disputes and disharmony. This greatly requires more effective cost targets. Relatively speaking, the cost target has greatly narrowed the gap between capital and technology, and corresponding systematic cost uncertainty analysis (SCUA) can reduce the random uncertainty of cost target and reduce the total operating cost. In addition, the cost objective will promote the engineering management to actively identify, analyze and manage the cost risks faced, to optimize the delivery quality and schedule deadline within the appropriate cost range, and to promote the project harmony finally (Toutounchian, Abbaspour, Dana, & Abedi, 2018). To sum up, this paper proposes the following hypothesis:

H5: the cost objective has positive impact on achieving engineering harmony.

Specific approaches to achieving cost objective are often difficult to cope with different types of engineering, as cost objective of different types engineering are often closely related to the professionals involved in project management and management mode (Smith, 2016). The project type mainly adjusts the impact of the cost target on the engineering harmony through three aspects. First, different project types determine different leadership styles of project managers. Research shows that different leadership styles are more likely to succeed in different types of cost management (Müller & Turner, 2007). Second, different engineering types mean differentiated cost target control methods, which will push the cost target to achieve a lower cost status (Mota & de Castro, 2017). Since the cost issues of engineering must be resolved dynamically within the agreed scope. The validity of cost target control can also be adjusted from the perspective of project scale, duration, extension, and project manager power by engineering types (Sanchez & Terlizzi, 2017). Finally, the different information management system is applicable to different project types. Digital technologies and tools provide tremendous opportunities for cost management. Different types of information systems can be differentiated to reflect the quality, speed, accuracy, value and complexity of the realization of cost objective, and will change the relationship between cost objective and engineering harmony (Smith, 2016). To sum up, this paper proposes the following hypothesis:

H6: the engineering type may influence the positive impact of the cost objective on engineering harmony.

Risk management objective is based on activities such as communication, consultation, analysis, assessment, handling, monitoring and review of risks (Galvin, 2017;

Isaac & Edrei, 2016). Many projects show the characteristics of large scale, rapid construction speed, long period and complex operation, which make the project implementation of great risk and may cause serious social impact and economic loss. This requires the establishment of perfect engineering safety risk management laws, high-level risk management principles. Human factors are the main factors that lead to the occurrence of risk, but also the key factors of the occurrence of engineering collusion and speculation. In risk assessment, dissonance of engineering can be easily caused by organizational influence, unsafe supervision, unsafe behavior and emergency influence (Xie & Guo, 2017). At the same time, the manipulation of bidding is the main performance of engineering collusion (Reeves-Latour & Morselli, 2016). High-level risk management can better achieve the coordination of risk management objective and customer objective, and control the risk of illegal bidding (Olechowski, Oehmen, Seering, & Ben-Daya, 2016). Therefore, a good combination of risk composition, multidisciplinary nature, risk measurement and the development and use of risk management methods involved in risk management objective can promote engineering harmony by reducing the risk of engineering (Li, Yu, Jin, & Liu, 2018). To sum up, this paper proposes the following hypothesis:

H7: the risk management objective has positive impact on achieving engineering harmony.

Risk management is systematic and complex. Due to differences in engineering types, it is also structural and dynamic, which runs through the life cycle of engineering management (Domingues, Baptista, & Tato, 2017). Risk management should be as effective as possible and as realistic as possible because of the uncertainty reflected by the differences of engineering types. Therefore, investors with different preferences are attracted by different types of projects and decide to adopt risk preference, risk neutral or pure risk avoidance strategies according to the degree of risk return (Iqbal, Choudhry, Holschemacher, Ali, & Tamošaitienė, 2015). Some scholars have studied the impact of engineering types on risk management. Through the survey of 200 project managers, this study found that the difference of engineering types significantly affected the difficulty level of risk management (Pimchangthong & Boonjing, 2017). In many countries, engineering types also play a similar role. The project objective, product quality, delivery time and customer cost of the project management are relatively stable, and the risk avoidance, risk bearing or risk transfer strategy can be adopted according to the project type with high probability (Grennberg, 1993). Therefore, the impact of project type on engineering harmony focuses on control in multiple organizations, which plays an indirect regulatory role (Liu, Borman, & Gao, 2014). To sum up, this paper proposes the following hypothesis:

H8: the engineering type may influence the positive impact of the risk management objective on engineering harmony.

2. Methodology

Meta-analysis is an important data statistical technique in empirical research (Hedges & Olkin, 1985). The correlation between variables is verified by using meta-analysis software for analysis after coding the data of all independent samples in literatures related to the research topic (King, Dalton, Daily, & Covin, 2004). Due to the differences in research objectives and methods selected by different literature when constructing and validating models, the conclusions drawn from the sample data in a certain literature cannot accurately reflect the relationship between variables (Hunter & Schmidt, 2004; Cooper, Hedges, & Valentine, 2009). Therefore, after sorting out samples from all literatures related to the research topic, the meta-analysis method and software can be used to convert all data into uniform weights and indicators, so as to avoid differences in selection of different literature samples and research objectives, and to verify the connection between variables more accurately. The meta-analysis is defined by the National (U.S.) Library of Medicine as "a quantitative method for combining results of independent studies (usually drawn from published literature) and synthesizing summaries and conclusions that can be used to assess therapeutic effectiveness, plan new studies, education, etc., with application mainly in the areas of research and medicine" (Gioacchino, 2005). For us, it is therefore equate "clinical studies" in medicine to "study problems domains" in management discipline (Card, 2012; Razo, Ramos, & Occello, 2010).

In practical application, not only in the field of medicine, but also in the field of management, meta-analysis is widely used, because meta-analysis has considerable utility in clarifying management strategies and practical performance (Davis, Mengersen, Bennett, & Mazerolle, 2014; Glass, McGaw, & Smith, 1981; Mann, 1994; Petty, McGee, & Cavender, 1984). Such as, specific application includes performance management (Bowen, Rostami, & Steel, 2010; Springer, Stanne, & Donovan, 1999), strategic management (Crook, Ketchen, Combs, & Todd, 2008), innovation management (Büschgens, Bausch, & Balkin, 2013; Weiss, Hoegl, & Gibbert, 2017), organizational behaviour management (Atinc, Darrat, Fuller, & Parker, 2010; Stajkovic & Luthans, 2003), financial management (Dalton, Daily, Certo, & Roengpitya, 2003), project management (Littau, Jyothi Jujagiri, & Adlbrecht, 2010), construction management (Horman & Kenley, 2005), etc. Moreover, there are two trends in the study of meta-analysis in management field: the rapid growth of literature number and the rapid expansion of the application field (Jiang, 2012). The meta-analysis method is applicable to the research of engineering management problems. For example, the control index for construction time waste needs to be structured and replicable, which can be effectively done by meta-analysis (Horman & Kenley, 2005). The meta-analysis method has been verified to be applicable to study the whole engineering decision-making process from planning to construction, involving in building informatization, transportation engineering, architecture and construction technology, etc. (Abdal Noor, 2018; Zhao, 2017).

Scholars at home and abroad have extensively discussed the trade-offs of quality, duration, cost and risk in the process of realizing engineering harmony through theoretical and empirical research (Amusan, Afolabi, Ojelabi, Omuh, & Okagbue, 2018; Idiake et al., 2015), but the specific mechanism of influence is still controversial. The controversies include the standards for achieving engineering harmony (Musa et al., 2015). The clients of the terminal believe that engineering harmony originates from the achievement of goals such as quality, duration, cost and risk (Pinto & Slevin, 2013); managers believe that it is the process of achieving the four goals (Wilson, 2015), and stakeholders believe that all four goals need to meet their expectations (Toor & Ogunlana, 2009). A problem has its constituent properties, each of which must be identified by text or abstract analysis and then linked to at least one of the domains to which it belongs. Meta-analysis using probabilistic representation to describe problems based on Bayesian programming is an accurate choice (Razo et al., 2010). By analyzing the set of grouped results, the most accurate results are found to be suitable for a given problem (Hunter & Schmidt, 2004). Therefore, the controversy about the specific influence mechanisms makes this study suitable to use the meta-analysis method to deal with.

3. Literature collection and analysis

3.1. Literature collection

This study mainly collects the empirical literatures on the relationship among quality, duration, cost, risk, and engineering harmony. By combining key words related to engineering harmony (such as project success, project performance, project satisfaction, etc.) and major factors of the dimension of "physical fitness" (such as quality, duration, cost and risk), the database such as EBSCOhost, Elsevier Science Direct, Springerlink, etc. were consulted. In addition, in order to reduce publication deviation, unpublished studies were searched through network search software such as SSRN database, Baidu academy and Baidu Wenku, and a total of 29 studies were conducted.

In the process of screening relevant literature, this study mainly adopts the following standards. First, focus on construction or engineering, including housing, transportation, energy and infrastructure-related projects, not corporate projects. Second, independent samples must be used in relevant studies. In literature coding, if the same data set is used more than once but contains different variables, the corresponding data is calculated respectively. An average is used to represent it when a variable contains multiple dimensions. Under this standard, there were 29 preliminary studies, i.e., 31 independent samples, as shown in Table 1.

3.2. Literature coding

3.2.1. Variable selection

Whether the engineering is harmonious or not is difficult to be measured by a certain standard. Al-Bahar and Crandall (1990) suggest judging whether the engineering is harmonious through the comprehensive performance of the engineering. Some scholars believe that stakeholders' satisfaction with the engineering is an important indicator of engineering harmony (Hwang & Ng, 2016). In addition, most scholars believe that the successful completion of the engineering in the aspects of people, things, objects and environment can be reflected as engineering harmony. On the whole, the results of previous studies have been summarized in the existing literature, and it is believed that the basic standards of engineering harmony in the physical fitness dimension can be measured by factors such as quality, duration, cost and risk (Lim & Mohamed, 1999). That is, whether the project is harmonious or not, comes from the comprehensive impact of quality, duration, cost and risk.

3.2.2. Meta-analysis process

According to the results of literature coding, namely the correlation coefficient in the Pearson correlation matrix between variables, the effect value is calculated. If there are multiple correlation coefficients between variables in a certain study, the average value is calculated. The estimated value of measurement error is adjusted to obtain the corrected effect value.

Second, publication deviation is checked. Publication deviation refers to the selectivity deviation caused by the journal publishing preference of significantly different results. And papers that have unverified research hypotheses or have insignificant results will not be published. The check of publication deviation is generally expressed with fail-safe Number (fs N), which is the minimum to make existing conclusions less significant. The higher the value, the less likely the deviation is. When fs N exceeds the Rosenthal standard (i.e. 5* number of studies +10), there is no significant publication deviation. In the process of research, if potential regulatory variables need to be identified, homogeneity test shall be conducted, that is, Q test shall be adopted to confirm whether the difference coefficient is significant. The emphasis of the meta-analysis method is the accuracy of sampling, and the weight is given by the "sample size" in the original independent sample. The utility value data in table 1 can be automatically unified and standardized converted by "Comprehensive Meta Analysis" software, and there is no need to carry out weight design again.

4. Results of the study

4.1. Homogeneity test

The homogeneity test is used to determine whether there is homogeneity or heterogeneity among different research

Table 1. Basic data of original research

Original research	Sample number	Countries and Areas	Engineering types	Bachelor and above	Work experience	Quality	Duration	Cost	Risk
García, Valles, Sánchez, Noriega, and Dominguez (2017)	256	Mexico	Road			0.428	0.398	0.497	0.438
Semab, Khan, and Shah (2017)	264	Pakistan	Roads/Govt Buildings/Houses		60%		–0.644		
Yang, Chen, and Huang (2013)	213	Taiwan	Construction industry	53.06%	33.80%	0.56	0.92	0.87	
Chandra (2015)	180	Surabaya	Construction industry		15%	0.873	0.804	0.876	0.137
Chandra, Indarto, Wiguna, and Kaming (2012)	204	East Java	Construction industry			0.71	0.63	0.58	
Badewi (2016)	300	around the world	House				0.81	0.85	
Musa et al. (2015)	276	Nigeria	Houses	80.80%	64.10%	0.62	0.70	0.61	
Nguyen and Hadikusumo (2017)	586	Thailand	Energy			0.53	0.83	0.56	
Hasan (2017)	376	China	House					0.35	0.62
Sun, Shen, and Fan (2012)	136	China	PPP			0.97	–0.53	–0.55	0.67
Hu and Zhang (2016)	142	China	Road			1	–0.58	–0.45	0.94
Sambasivan, Deepak, Salim, and Ponniah (2017)	308	Tanzania	Construction		46%			0.59	
Sambasivan et al. (2017)	308	Tanzania	Construction		46%				0.497
Jin, Shen, and Wang (2018)	57	North America	Industrial construction			–0.272			
Liu et al. (2017)	150	China	Construction		11.34%				0.256
Ikediashi and Ogwueleka (2016)	240	Nigeria	Construction		80%	0.526	0.307	0.441	
Amusan et al. (2018)	70	Nigeria	Construction		42.80%	0.576	0.796	0.656	
Doloi, Iyer, and Sawhney (2011)	97	Australia	Construction		59.30%	0.46			
Golchin Rad and Kim (2018)	152	Iran	Construction			0.73	0.83		
Daihu (2015)	443	China	Construction	90%	9.70%	0.16	0.15		
Liu (2016)	63	China							–0.5
Zhang et al. (2018)	121	China							–0.31
Teller and Kock (2013)	176	Germany	Energy and infrastructure						–0.15
Suprapto, Bakker, Mooi, and Hertogh (2016)	119	Netherlands	Engineering and construction			0.465			
Sarigiannidis and Chatzoglou (2014)	112	Greece				–0.293			
D. Y. Kim, H. Kim, Han, and Park (2009)	126		Construction			0.417		0.457	
Haq, Liang, Gu, and Ma (2016)	354	Pakistan				0.173			0.089
Nam, Duc, and Duy (2016)	212	Vietnam	Railway						–0.028
Nitithamyong, Skibniewski, and Clark (2007)	82	United States	Build/Construction			0.629	0.792	0.773	0.625

tissues, and to determine whether the correlation coefficient is analyzed by using the fixed effect model or random effect model. In this study, the homogeneity test results of effect values for quality, duration, cost and risk affecting engineering harmony are shown in Table 2. The Q values are 720.531, 1655.500, 746.045 and 581.086, respectively, and all p values are less than 0.001, indicating that the effect values are heterogeneous. I-squared is 97.641, 99.154, 98.123 and 97.935, respectively, both greater than 75%, indicating that the effect value have high heterogeneity. From the above analysis results, it can be concluded that the random effect model should be adopted in this study. In addition, the Tau-squared value in Table 2 also shows that the total variation has inter-group error.

4.2. Publication deviation test

In order to avoid publication deviation in selected literatures and to affect the evaluation of effect values, this study adopted multiple methods such as safety loss coefficients, rank correlation test, regression intercept, clipping method (see Table 3) and funnel plot (see Figures 1–4) to measure publication deviation. The data in Table 3 shows that the safety loss coefficients are 5546, 4487, 4977 and 1051 respectively, both greater than 5K+10 (the K values of quality, duration, cost and risk in this study are 19, 15, 15 and 11 respectively). In addition, from the perspective of Tau value of the rank correlation test and regression intercept, p value is all greater than 0.1, which is not significant, indicating that there is no publication deviation in the effect value of quality, duration, cost and risk affecting engineering harmony. Figures 1–4 funnel plot shows that most of the relevant studies are located at the top of funnel plot, and are distributed relatively uniformly in the peripheral region of the intermediate value, which also indicates that there is less possibility of publication deviation of effect values.

4.3. Total effect test

As shown in Table 4, there are 17, 14, 14 and 11 effect values for the relationship between quality, duration, cost and risk and engineering harmony, respectively. The total sample sizes are 3845, 3544, 3495 and 2556, and the correlation coefficients are 0.540 ($p < 0.05$), 0.528 ($p < 0.05$), 0.548 ($p < 0.05$), and 0.332 ($p < 0.05$), respectively, which are significant. According to Lipsey and Wilson (2001), when the absolute value of correlation coefficient is greater than 0.1, it is moderately correlated, and when

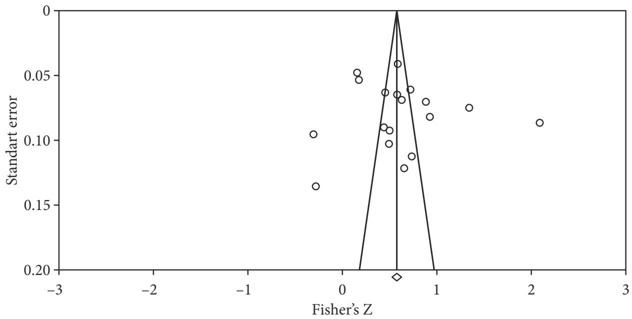

Figure 1. Funnel plot of quality-engineering harmony effect value

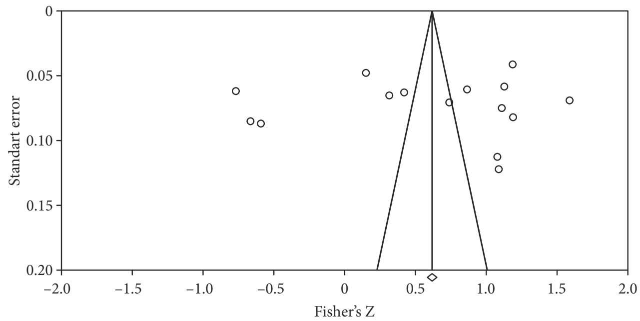

Figure 2. Funnel plot of duration-engineering harmony effect value

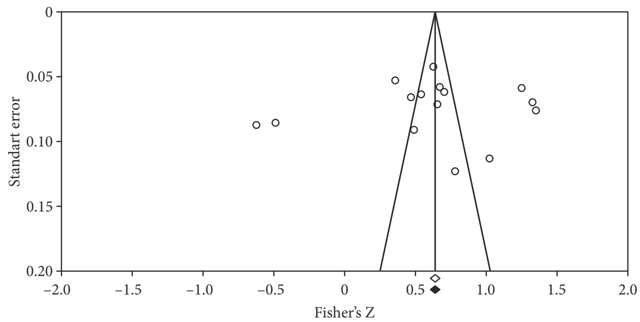

Figure 3. Funnel plot of cost-engineering harmony effect value

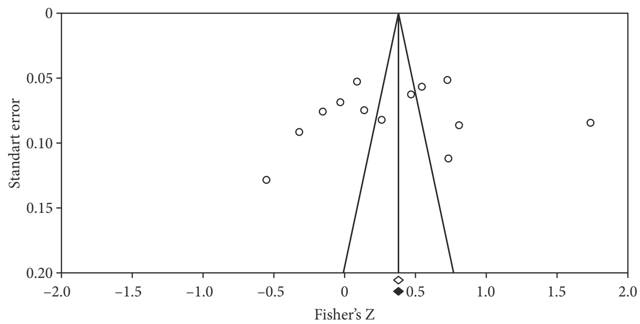

Figure 4. Funnel plot of risk-engineering harmony effect value

Table 2. The homogeneity test results of effect values (Q statistics)

Random effect model	Number of samples	Heterogeneity				Tau-squared			
		Q-value	Df(Q)	P-value	I-squared	Tau-squared	SE	Variance	Tau
Quality	19	720.531	17	0.000	97.641	0.210	0.087	0.008	0.458
Duration	15	1655.500	14	0.000	99.154	0.514	0.221	0.049	0.717
Cost	15	746.045	14	0.000	98.123	0.232	0.100	0.010	0.482
Risk	13	581.086	12	0.000	97.935	0.250	0.115	0.013	0.500

Table 3. The test value of publication deviation

Safety loss coefficients (Nfs)	Rank correlation test (Tau)	Regression intercept	Trim and fill		
			Observations	Adjusted value	Variation value
5546	0.059 (p = 0.762)	3.094 (p = 0.275)	0.521	0.521	0
4487	–0.124 (p = 0.276)	–4.407 (p = 0.347)	0.548	0.648	0
4977	–0.029 (p = 0.461)	–3.059 (p = 0.342)	0.568	0.568	0
1051	–0.179 (p = 0.214)	–3.214 (p = 0.350)	0.361	0.361	0

Table 4. Random model analysis of the relationship between quality, duration, cost, risk and engineering harmony

Independent variable	Number of studies	Sample capacity	Effect value and 95% confidence interval			Two-tailed test	
			Point estimation	Lower limit	Upper limit	Z-value	P-value
Quality	17	3845	0.540	0.371	0.675	5.506	0.000
Duration	14	3544	0.528	0.221	0.740	3.174	0.002
Cost	14	3495	0.548	0.352	0.697	4.879	0.000
Risk	11	2556	0.332	0.070	0.552	2.456	0.014

Table 5. Regulatory effect of engineering type on engineering harmony affected by quality, duration, cost and risk

Independent variable	K	Sample capacity	Average effect value	95% Confidence interval	Q-value	P-value
Quality	17	3845	0.117	–0.241~0.447	7.534	0.023
Duration	14	3544	0.650	0.083~0.899	0.254	0.881
Cost	14	3495	0.717	0.202~0.921	1.744	0.418
Risk	11	2556	–0.066	–0.426~0.312	12.321	0.002

it is greater than 0.4, it is highly correlated. It can be seen that the relationship between quality, duration, cost, risk and engineering harmony is above moderate correlation. The 95% confidence intervals are [0.371, 0.675], [0.221, 0.740], [0.352, 0.697], [0.070, 0.552]. Thus, hypotheses 1, 3, 5 and 7 all pass.

4.4. Regulatory effect of engineering type

The engineering included in the meta-analysis are divided into single type and compound type. The data in Table 5 shows that there is no significant difference in the impact of duration and cost on engineering harmony under the two types (Q-value = 0.254, $p > 0.1$; Q-value = 1.744, $p > 0.1$), while there is significant difference in the impact of quality and risk on engineering harmony (Q-value = 7.534, $p < 0.1$; Q-value = 12.321, $p < 0.1$). It is shown that the engineering type has no regulatory effect on the impact of the duration and cost on engineering harmony, and has regulatory effect on the quality and risk. So hypothesis 4 and hypothesis 6 fail, and hypothesis 2 and hypothesis 8 pass.

Research conclusions and management implications

(1) *Quality objective, engineering type and engineering harmony*

The hypothesis 1 and hypothesis 2 are verified in this study, that is to say, the quality objective has positive impact on the realization of engineering harmony. By actively carrying out quality management, engineering harmony can be effectively promoted. This conclusion is consistent with the views of scholars such as Kiew, Ismail, and Yusof (2016) and Sullivan (2011). Engineering construction is a people-oriented production activity. The technical level, organizational capacity, ideological level, psychological behavior, consciousness level and judgment ability of engineering organizers will affect the project quality directly, and internal harmony can be achieved through personnel restriction by engineering quality management (Kiew et al., 2016). Whether the engineering materials are up to standard, whether the engineering technology is advanced, and whether the engineering operation is correct will affect the realization of the engineering quality directly. Carrying out the engineering quality management can improve the structural safety and the personal safety of users, and also directly affect the economic return of investors. Engineering quality management can effectively improve the progress, quality and economic benefits of the engineering, improve customer satisfaction, and enhance the harmonious relationship between the proprietor, contractor and builder (Sullivan, 2011). Hypothesis 2: The engineering type effect of positive impact of quality objective on engineering harmony has been verified, which is consistent with the views of scholars such as Lines, Sullivan, Smithwick, and Mischung (2015). As the engineering type involves multiple fields such as highway, railway and housing construction, different types of engineering have different degrees of novelty, complexity and technical uncertainty, as well as different methods and difficulties of project quality management (Lines et al., 2015). In the process of engineering management, it is particularly important to take quality as the objective to control the engineering stage, which needs to be treated separately according to different engineering types. As a result, the regulation effect of engineering type is established on quality objective on engineering harmony.

The research shows that, in the construction practice and academic research of engineering projects, the quality target is affected by the common influence of personnel, material and environmental factors, which has indirect influence on the engineering harmony. Therefore, in the process of engineering management, it is necessary to strengthen the management resource input. To achieve engineering harmony, construction personnel training and education should be strengthened to improve personnel quality management level, quality assurance system should be established to standardize material quality management, and environmental change features and limitations should be mastered to break through environmental quality management (Mao & Xu, 2011). By improving the engineering organization and management system, setting up project quality supervision standards, and efficiently implementing quality control methods and measures, the project quality management level can be improved. Furthermore, it can promote the harmonious development between project personnel management, project construction and natural environment effectively (Rao, Viswanadhan, & Raghunandana, 2015).

(2) *Duration objective*, *engineering type and engineering harmony*

Hypothesis 3 is verified, while hypothesis 4 is not verified in this study. That is to say, the duration objective has a positive impact on the realization of engineering harmony. This result verifies the research of Fernandez-Viagas & Framinan (2015), Russell et al. (2015) and other scholars. The project involves multiple interests, including the owner, constructer and supervisor, which not only requires construction quality assurance of the project construction, but also requires timely completion and guarantee of construction period. In fact, in the process of engineering construction, due to the influence of various factors such as construction plan, technical plan and personnel allocation, the actual duration cannot be completely consistent with the planned duration, and there is a certain error (Aliverdi, Naeni, & Salehipour, 2013). In the long run, the construction delay caused by the improper management of the construction period will affect the reputation and image of the constructer and the owner, as well as create conflict among stakeholders. Thus it can be seen that the high efficiency and high quality duration objective can achieve engineering harmony effectively. Hypothesis 4: The engineering type effect of positive impact of duration objective on engineering harmony has not been verified, which is contrary to the views of scholars such as Wang, Yu, and Chan (2012). There are differences in the environment, technical standards, personnel arrangement and construction plans of different types of engineering projects, so there are differences in the planned construction period (Khamooshi & Cioffi, 2013; Thoedtida, 2014). Although different types of projects have different risks, different quality and standards, schedule management is necessary and indispensable for stakeholders. To some extent, the difference of engineering type will affect the standard of construction period management. However, there is no significant difference in the process, purpose and process control of construction period management. Therefore, engineering type is not the factor that affects the engineering harmony and regulates construction period management.

For both theoretical and practical aspects, the schedule management of engineering is an important link of engineering management, which affects the achievement of engineering harmony indirectly. Although there are differences in the engineering types, the realization process of duration target is consistent, and the standards of duration management are much the same. Real-time tracking and feedback of project progress information is required, and an emergency response team should be established to give timely feedback and quickly form a response plan in case of emergency. Therefore, the construction period management not only needs to be prepared in advance to ensure that the period is guaranteed under the premise of buffer zone setting, but also needs to adapt to the dynamic changes of the environment to achieve the harmony of the internal management and the external environment.

(3) *Cost objective*, *engineering type and engineering harmony*

Hypothesis 5 is verified, while hypothesis 6 is not verified in this study, that is, the cost objective has positive impact on the realization of engineering harmony. In previous studies Ameh, Soyingbe, and Odusami (2010) and other scholars believed that engineering can improve engineering performance by pursuing the optimization of cost. The cost objective is a comprehensive index to reflect the engineering harmony. Especially in the market economy, construction enterprise is regarded as independent competitor, its operation and management objective is to coordinate various internal economic relations with the lowest cost continuously, so as to achieve the engineering harmony. The cost objective management is a strategic cost control, on the premise of ensuring the engineering quality, through satisfaction design of quantitative cost management method and its interaction and coupling, which can reduce energy consumption, improve labor productivity, coordinate the economic interests of stakeholders, promote the continuous improvement of project management, and achieve the minimum cost and maximum engineering harmony finally. Hypothesis 6: The engineering type effect of positive impact of cost objective on engineering harmony has not been verified, which is contrary to the research of scholars such as Safapour, Kermanshachi, Habibi, and Shane (2018). Although different types of engineering have different degrees of complexity, since cost management is a comprehensive dynamic management process, there are both material production activities and non-material production activities related to the engineering itself. Moreover, due to the great uncertainty of the internal conditions and objective environment, the realization of the cost objective depends on the feasibility of the investment planning and the effectiveness of the target control largely. The impact of the engineering type is limited, so the engineering type is not an element of impact of cost objective on engineering harmony.

The conclusion has some implications for the realization of engineering harmony management. Engineering projects are characterized by multiple key links and complex interference factors. Controlling project cost and realizing management harmony are always the goals of engineering management. Combining the cost objective with the engineering management, we will build a modern cost management system based on engineering harmony, promote the cost management to be transparent and the department responsibility to be specific, and allow more enterprise employees to be stakeholders of the cost objective, so as to mobilize their enthusiasm and creativity.

(4) *Risk management objective*, *engineering type and engineering harmony*

The hypothesis 7 and hypothesis 8 are verified in this study, that is, risk management objective has a positive impact on the realization of engineering harmony, and the engineering type has a regulatory effect on the engineering harmony to the positive effect of risk management objective. The conclusion is in line with the views of scholars such as M. Arashpour, Abbasi, M. Arashpour, Hosseini, and Yang (2017), Hwang and Ng (2016), Xia, Zou, Griffin, Wang, and Zhong (2018). The contradiction between risk management objective and stakeholders' demands is particularly prominent in the construction project, and the failure of the project is also common (Mok, Shen, & Yang, 2015). To some extent, good control of risk management objective can meet the demands of stakeholders directly or indirectly, thus engineering harmony can be achieved (Xia et al., 2018). In addition, the differences of engineering types have a great influence on the degree of implementing risk management and a certain degree of adjustment to the realization of engineering harmony (Pimchangthong & Boonjing, 2017). Engineering projects can be classified into general projects and major projects according to their importance. Compared with general projects, major projects involve more capital, complex processes and high safety requirements, so both capital risk and construction risk are obvious, and the probability of project collusion is also higher. The focus of each project is different, and the required risk management objective is also different. Moreover, the differences of engineering types also indirectly affect the risk management mode, including risk transfer, risk avoidance, risk taking, risk sharing and other strategies.

Both in academic research and in practical operation, risk management and stakeholder management are often attached with negative views (Wang, Xia, Zhang, Wu, & Liu, 2017), that is, risk discovery and stakeholder conflict are not conducive to promoting project construction. This study reveals the relationship between risk management, engineering types and engineering harmony. It is believed that if engineering harmony is to be achieved, construction enterprises should pay attention to risk management, and different engineering types should be considered in the process of risk management. Targeted risk control should be conducted according to engineering types. The purpose of risk management is to increase the possibility and impact of positive events and reduce negative events in the engineering (Arashpour et al., 2017). The realization of engineering harmony not only requires a reasonable and efficient risk management model, but also needs to analyze the relationship network of stakeholders deeply. According to the differences in the interest demands of stakeholders such as the government, shareholders and creditors, a differentiated and targeted risk warning, risk sharing, risk transfer and risk control strategy is formulated.

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Author contributions

Qiankun Wang conceived the study and supervised the whole research process. Weiwei Zuo was responsible for data analysis and interpretation as well as wrote the manuscript. Qianyao Li was responsible for data collection and proofreading of the manuscript.

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There is no competing financial, professional, or personal interest from other parties.

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APPENDIX

Results of meta-analysis

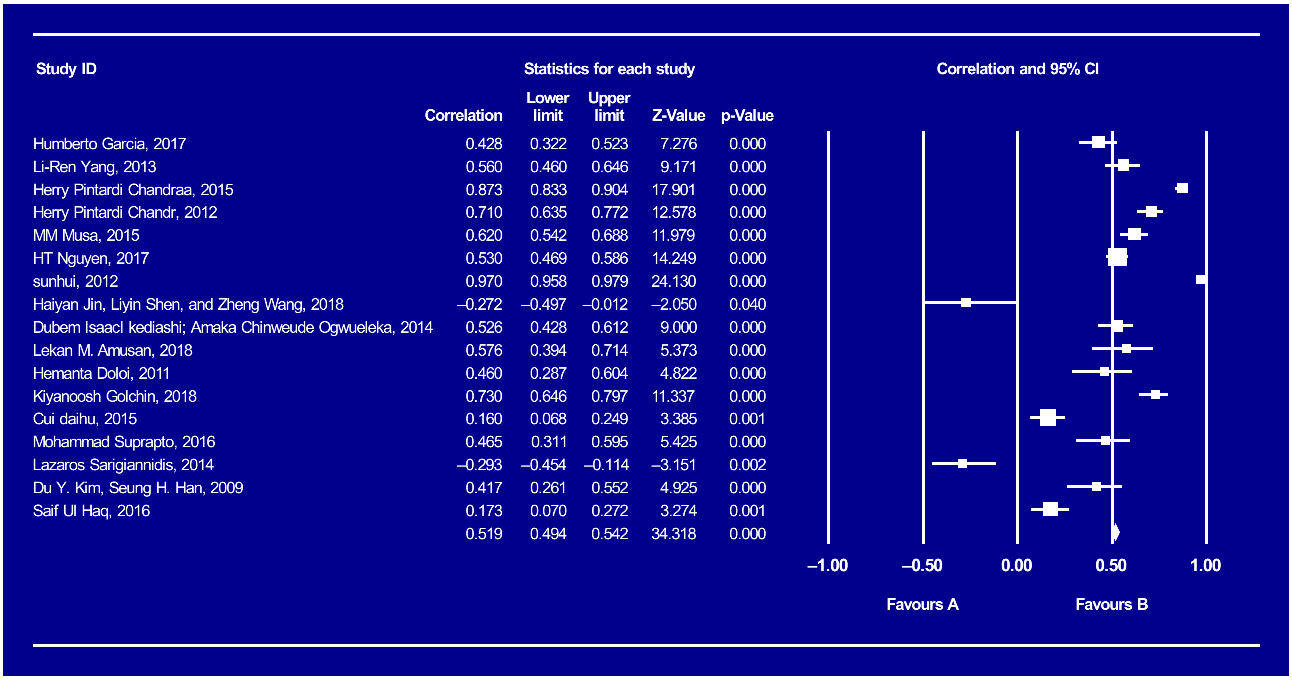


Figure A1. Results of meta-analysis (Quality)

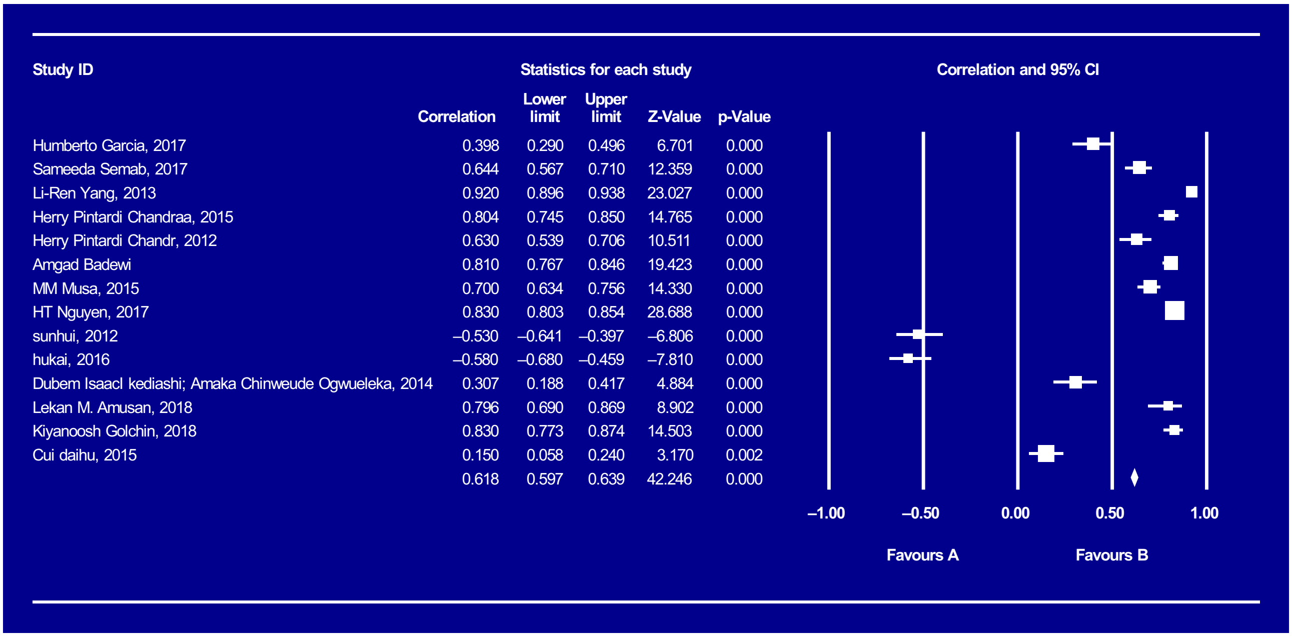
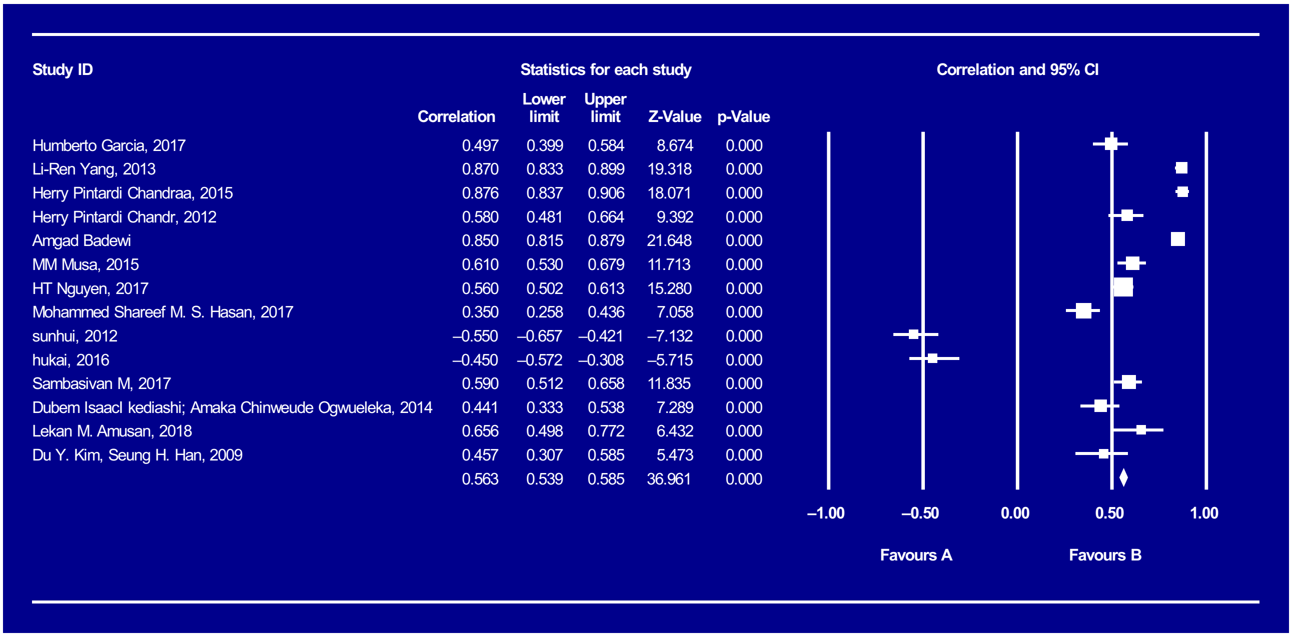
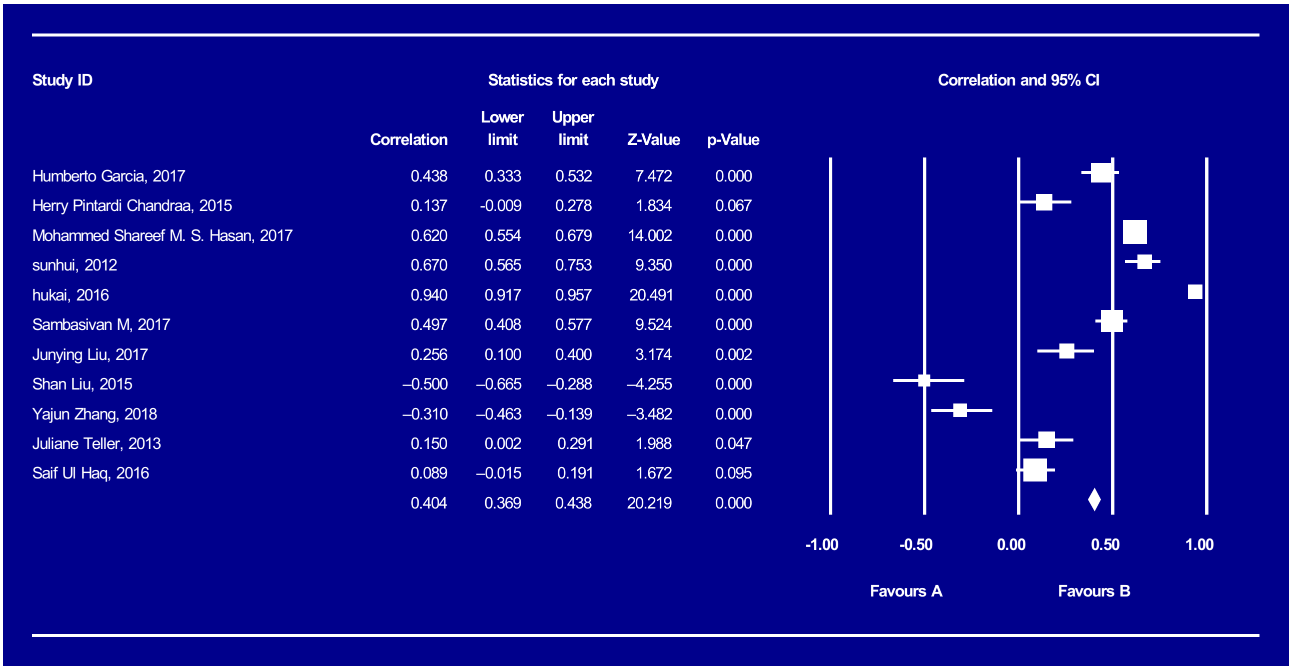


Figure A2. Results of meta-analysis (Duration)



Study ID	Correlation	Lower limit	Upper limit	Z-Value	p-Value
Humberto Garcia, 2017	0.497	0.399	0.584	8.674	0.000
Li-Ren Yang, 2013	0.870	0.833	0.899	19.318	0.000
Herry Pintardi Chandraa, 2015	0.876	0.837	0.906	18.071	0.000
Herry Pintardi Chandr, 2012	0.580	0.481	0.664	9.392	0.000
Amgad Badewi	0.850	0.815	0.879	21.648	0.000
MM Musa, 2015	0.610	0.530	0.679	11.713	0.000
HT Nguyen, 2017	0.560	0.502	0.613	15.280	0.000
Mohammed Shareef M. S. Hasan, 2017	0.350	0.258	0.436	7.058	0.000
sunhui, 2012	−0.550	−0.657	−0.421	−7.132	0.000
hukai, 2016	−0.450	−0.572	−0.308	−5.715	0.000
Sambasivan M, 2017	0.590	0.512	0.658	11.835	0.000
Dubem Isaacl kediashi; Amaka Chinweude Ogwueleka, 2014	0.441	0.333	0.538	7.289	0.000
Lekan M. Amusan, 2018	0.656	0.498	0.772	6.432	0.000
Du Y. Kim, Seung H. Han, 2009	0.457	0.307	0.585	5.473	0.000
	0.563	0.539	0.585	36.961	0.000

Figure A3. Results of meta-analysis (Cost)



Study ID	Correlation	Lower limit	Upper limit	Z-Value	p-Value
Humberto Garcia, 2017	0.438	0.333	0.532	7.472	0.000
Herry Pintardi Chandraa, 2015	0.137	-0.009	0.278	1.834	0.067
Mohammed Shareef M. S. Hasan, 2017	0.620	0.554	0.679	14.002	0.000
sunhui, 2012	0.670	0.565	0.753	9.350	0.000
hukai, 2016	0.940	0.917	0.957	20.491	0.000
Sambasivan M, 2017	0.497	0.408	0.577	9.524	0.000
Junying Liu, 2017	0.256	0.100	0.400	3.174	0.002
Shan Liu, 2015	–0.500	–0.665	–0.288	–4.255	0.000
Yajun Zhang, 2018	–0.310	–0.463	–0.139	–3.482	0.000
Juliane Teller, 2013	0.150	0.002	0.291	1.988	0.047
Saif Ul Haq, 2016	0.089	–0.015	0.191	1.672	0.095
	0.404	0.369	0.438	20.219	0.000

Figure A4. Results of meta-analysis (Risk)