

# Critical Success Factors for Green Building Promotion: A Systematic Review and Meta-analysis

Linyan Chen <sup>a,b,\*</sup>, Albert P. C. Chan <sup>b</sup>, Emmanuel K. Owusu <sup>b</sup>, Amos Darko <sup>b</sup>, Xin  
Gao <sup>a</sup>

<sup>a</sup> School of Economics and Management, Tongji University, Shanghai, 200092, China

<sup>b</sup> Department of Building and Real Estate, The Hong Kong Polytechnic University, 11 Yuk Choi  
Rd, Hung Hom, Kowloon, Hong Kong SAR, China

## ABSTRACT

As a significant attempt to save energy and minimize greenhouse gas emissions to the environment, green building has aroused public attention worldwide. The slow development of green buildings has become a primary concern in practice for many countries. Despite the identification of an array of critical success factors that influence green building promotion in previous studies, no consensus has been reached so far on the factors and their respective significance. Following the Preferred Reporting Items for Systematic Reviews and Meta-analysis guideline, this study, therefore, intends to fill this gap by conducting a systematic literature review on the critical success factors for green building promotion and further prioritizing the factors quantitatively through meta-analysis. Forty critical success factors in green building promotion were identified from twenty relevant studies selected from Web of Science and Scopus. After these factors were examined in terms of their significances using meta-analysis, publication bias,

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\* Corresponding author:

E-mail address: [linyan.chen@connect.polyu.hk](mailto:linyan.chen@connect.polyu.hk) (L. Chen).

20 subgroup analysis, and sensitivity analysis were conducted for further analysis. The results indicate  
21 that the roles of stakeholders and government are vital in green building promotion. The  
22 commitment and cooperation from stakeholders are essential in the green building practice, as well  
23 as adequate incentives and mandatory requirements from the statutory level. Besides, the difference  
24 in the building type subgroup is more significant than the differences in other subgroups. This study  
25 not only contributes to the existing green building knowledge body but also provides references to  
26 policy makers and practitioners in formulating policies and good practices to promote green  
27 buildings.

28 **KEYWORDS:** Green Building; Critical Success Factors; Meta-analysis; Systematic review;  
29 Sustainability

30

### **List of abbreviations**

CSF	Critical Success Factor
CMA 3.3	Comprehensive Meta Analysis 3.3
GB	Green Building
GBP	Green Building Promotion
G20	Group of Twenty
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analysis
SD	Standard Deviation
WoS	Web of Science

## 31 **1. INTRODUCTION**

32 Along with the increasing carbon emissions and the public concerns about global warming,  
33 technical innovations have been made in many industries. As one of the main contributors to carbon  
34 emissions, the construction industry has sought various innovative approaches to saving energy,  
35 reducing carbon emissions, and relieving the side effects of construction on the environment.  
36 Among them, green building (GB) is a critical innovation. GB, which has received public attention  
37 worldwide, is the building that takes responsibility for the environment and utilizes natural resources  
38 efficiently through its life cycle [1]. Previous research showed that GBs could reduce 50%, 48%,  
39 and 5% carbon emission less than conventional buildings in water consumption, solid waste  
40 management, and transportation, respectively [2]. Due to various merits of GBs, many countries  
41 have put green building promotion (GBP) on the agenda to substitute conventional buildings [3].  
42 Strategies, policies and regulations for promoting GBs have been proposed, and outstanding

43 achievements have been made in some countries [4]. For example, although the first GB was built  
44 in 2008 based on the Chinese GB standard, over 13000 certified GBs with over 1.4 million square  
45 meters were built in China by the end of 2018 [5]. However, barriers still exist in GBP around the  
46 world, such as failures of GB delivery and green renovation for existing buildings, as well as low  
47 quality of GBs [6–9]. To achieve better GB practice, a large number of studies have identified the  
48 critical success factors (CSFs) of GBP from different perspectives, but no consensus has been  
49 reached among these studies [10–12]. For example, Venkataraman and Cheng's research showed  
50 that effective collaboration, early involvement, and the commitment of all participants are the three  
51 most significant factors in GBs [13], while Mavi and Standing concluded that top management and  
52 sponsor support, stakeholder expectations, and end-users imposed restrictions are the most  
53 important factors [14]. Besides, Liang et al. have identified five CSFs for improving green retrofits  
54 in China: clear criteria and standards, clear government programs, clear vision, existing building  
55 evaluation and policies, and subsidies or tax reduction [15]. Although these conclusions were drawn  
56 under different contexts, the reasons for research divergences needed more exploration, which  
57 would contribute to the GB knowledge body and provide a holistic overview on this field.

58 Furthermore, several review papers discussed the drivers and barriers in GBP, which were also  
59 related to CSFs [16–18]. For instance, 64 drivers were identified from the selected studies and sorted  
60 into five categories, which provided valuable reference to the CSF identification [17]. Besides, some  
61 review papers disclosed the GB research trend and referred to CSFs in the discussion section [19,20].  
62 For instance, project management and project delivery attributes were considered as the potential  
63 factors to facilitate GB implementation [19]. Although the systematic literature review was  
64 undertaken in some studies, a conclusion could be drawn that previous review papers mainly

65 summarized the factors through qualitative approaches. A few review papers applied the  
66 quantitative approach, but they only summarized and investigated the frequency of critical factors.  
67 However, limitations existed in these methods, as the frequency of factors in previous studies cannot  
68 reveal the importance of CSFs exactly. Meta-analysis could overcome the shortage and precisely  
69 examine the CSF significance in GB implementation.

70 To fill this gap, this study followed the Preferred Reporting Items for Systematic Reviews and  
71 Meta-Analysis (PRISMA) guideline to systematically examine related literature on GBs. This study,  
72 therefore, intends to address some of the unanswered queries identified as gaps in the literature,  
73 such as the roles of CSFs in GBP and their respective levels of significance in GBP. Thus, to address  
74 these queries, the relevant studies were searched and selected by the inclusion and exclusion criteria.  
75 The data was collected from the studies and synthesized through meta-analysis, which is an effective  
76 quantitative approach to examine CSFs and provide their ranks. Besides, this study further compared  
77 the mean effect for different subgroups by subgroup analysis and examined the robustness of the  
78 results through sensitivity analysis. Moreover, the publication bias was checked, and the adjusted  
79 means were provided when the bias existed. This study is innovative in two aspects. First, the  
80 findings of this study shed new light on the GB realm, especially on the knowledge about  
81 determinative factors of GB success. Second, this systematic review combines meta-analysis, which  
82 ranks CSFs quantitatively based on previous studies.

83 The rest of this article is structured as follows. The methodology in conducting this research is  
84 outlined in Section 2, including the literature selection process and the meta-analysis procedures.  
85 Section 3 summarizes the identified CSFs, describes meta-analysis results, and presents the critical

86 findings from subgroup analysis and sensitivity analysis. Section 4 further discusses the top CSFs  
87 and the critical roles in GBP, followed by the conclusions in Section 5.

## 88 **2. METHODOLOGY**

89 This review followed the PRISMA guidelines, an evidence-based approach developed by  
90 Liberati in 2009 [21]. The PRISMA framework contains two parts, the systematic review, and the  
91 meta-analysis. Systematic review is a best-known type of literature review that provides a holistic  
92 picture of a research topic through a systematic literature selection, appraisal, and synthesis [22].  
93 Meta-analysis is a quantitative technique to synthesize the results of individual empirical studies  
94 and provide a more precise effect size of the results [23]. Systematic reviews provide comprehensive  
95 and repeatable literature selection procedures to collect and analyze secondary data, but many  
96 present the results only with narrative commentary, lacking quantitative analysis. By contrast,  
97 according to statistical principles, the meta-analysis needs to ensure that the included studies are  
98 complete because meta-analysis regards studies as samples, and the analysis is based on the data  
99 extracted from previous studies [24]. Therefore, the systematic review is combined with meta-  
100 analysis in this study to enlarge the strengths of both methods.

### 101 *2.1 Search strategies*

102 Web of Science (WoS) and Scopus are two world-leading academic databases with high  
103 reputations [25]. Research shows that more and more academic articles prefer to search literature in  
104 WoS and Scopus because they are highly recognized by researchers worldwide in tracking the  
105 newest knowledge in various research fields [26,27]. Besides, the lists of indexed content in WoS  
106 and Scopus are clear, which is another merit [28]. Although Google Scholar has rich content, the

107 information in Google Scholar is less clear than WoS and Scopus [28]. Therefore, this study chose  
108 to search relevant studies in WoS and Scopus. Two search strategies were proposed, aiming at  
109 collecting the literature comprehensively. The first strategy was to search studies with keywords.  
110 The representative keywords included "green building" and "critical success factor." "Sustainable  
111 building" was considered as an alternative keyword to "green building," which was a common  
112 search approach in previous research [19]. The searching strings were combined with Boolean  
113 operators in this strategy: (critical success factor) AND (green building OR sustainable building). It  
114 is not sufficient to search all the relevant studies only relying on the keyword search in the database  
115 [29]. For example, some studies identified GBP drivers, which were related to the CSFs in GBP.  
116 The second searching strategy, snowballing search, was conducted after the keyword search to avoid  
117 omitting the relevant studies. Based on the results of the first-round search, a combination searching  
118 method, including backward snowballing and forward snowballing, was adopted. The reference lists  
119 of these studies were scanned to pick out other relevant studies, which could be seen as backward  
120 snowballing. Meanwhile, the articles that cited these studies were examined with the same target,  
121 considered as the forward snowballing.

## 122 *2.2 Inclusion and exclusion criteria*

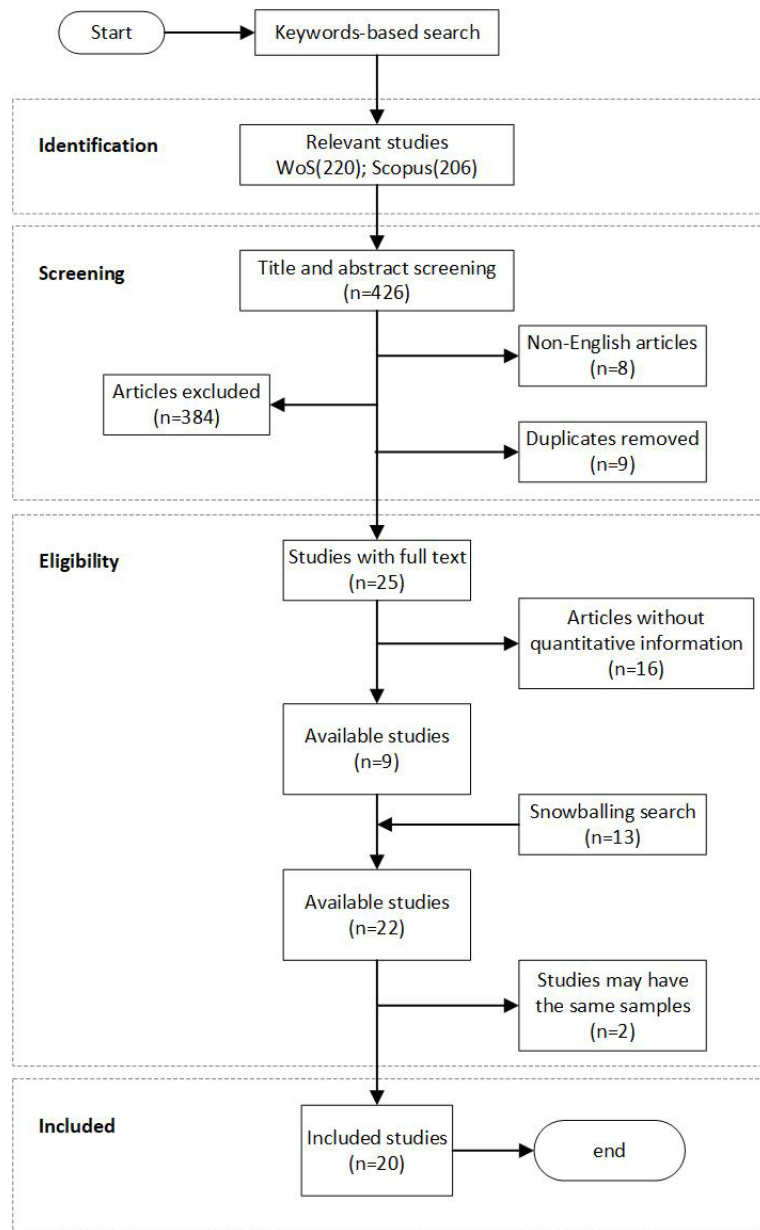
123 The inclusion and exclusion criteria were set as the benchmark of literature selection. The  
124 inclusion criteria included the following key points: (1) studies have tight correlations with the GBP  
125 factors; (2) studies conduct quantitative analysis on these factors; (3) studies report the mean,  
126 standard deviation (SD) of each factor clearly and give exact sample size. The exclusion criteria  
127 also contained three key points: (1) the language of the study was not English; (2) the study was  
128 duplicated with others; (3) the full text of this study was not available. To avoid omitting relevant

129 studies, there were no restrictions in the literature selection, such as article types, counties, and  
130 publication years.

### 131 *2.3 Literature selection*

132 The literature selection was completed in May 2021. According to the new PRISMA statement  
133 [30], the procedures of literature selection are shown in Figure 1. After the keywords-based search,  
134 426 studies were selected from WoS and Scopus. First, the non-English articles (n=8) and duplicates  
135 (n=9) were excluded. Second, the title and abstract were scanned. If relevant information on the  
136 GBP factors appeared in the title and the abstract, the full text of this study would be downloaded  
137 and examined. Twenty-five studies got through the scan of the title and abstract, and they were  
138 examined with full text. However, among these studies, sixteen studies lacked essential quantitative  
139 information, which led to exclusion from the literature database. Therefore, only nine studies met  
140 all the criteria and were left under the first searching strategy. Afterward, thirteen studies that were  
141 identified through the snowballing search strategy were included in the literature database. Thus,  
142 only twenty-two studies remained, including nine studies from keyword-based search and thirteen  
143 studies from snowballing search.





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145 **Figure 1.** PRISMA flow diagram for literature selection (Adapted based on the PRISMA

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2020 flow diagram [30]).

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After examination, a conclusion could be drawn that all the included studies conducted

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quantitative research on the GBP factors through questionnaires with the five-point Likert scale,

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indicating that the data from different studies could be compared directly. However, there were three

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similar studies conducted by the same research team. Although they focused on different topics, the

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sample size was the same in each study, revealing that the same sample may be utilized more than

152 once. In the meta-analysis, the samples from empirical studies should be used only once. The meta-  
153 analysis results will be affected if duplicate samples exist. After careful consideration, two of them  
154 were excluded to avoid the possible side effects.

155 In the end, there were twenty studies involved in the following meta-analysis, including sixteen  
156 journal articles and four conference articles. The publication year of these studies ranged between  
157 2011 and 2021. The majority of the included studies conducted research in a specific country, such  
158 as Australia, Singapore, and China, while three studies had an extended research scope as they  
159 collected data from the whole world.

#### 160 *2.4 Procedures of meta-analysis*

161 Meta-analysis is a quantitative research methodology that provides comprehensive synthesis  
162 by integrating several independent empirical studies which are comparable under the same criteria  
163 [31]. This is why meta-analysis was called "analysis of analyses" by Hunter and Schmidt [32]. At  
164 first, the meta-analysis was applied to summarize results from clinical trials in medical research [33].  
165 Then its research scope has been extended in various research areas for its quantitative advantages  
166 in conducting literature review [34–36]. Meta-analysis is often combined with a systematic review,  
167 which could guarantee the completeness of the literature selection [37–39]. Some researchers  
168 believe that the estimate in meta-analysis gets closer to the true effect size because meta-analysis is  
169 based on the statistics from previous studies, which also indicates that it is derived from larger  
170 datasets [40,41]. Two stages were performed in the meta-analysis [31]. The first stage is to choose  
171 the effect size and extract data from previous studies. The second stage is to analyze the data with  
172 suitable statistical models.

173 *2.4.1 Data collection and coding*

174 The mean of CSF, which represented the average opinions from the respondents in previous  
175 studies, was determined as the effect size in this study. The data extracted from previous studies  
176 contained the mean and SD values of each factor and the sample size. To make the data comparable,  
177 the raw data needed to be processed before conducting the meta-analysis. All the factors that  
178 influence GBP were selected from previous studies, and they were coded based on the independent  
179 samples within the same benchmark. Besides, each sample was involved in coding only once. If the  
180 study contained multiple independent samples, the coding process could be repeated. Only those  
181 factors that appeared in two or more studies could be selected in the final list of CSFs. Furthermore,  
182 the basic information of each study was collected for the following subgroup analysis, such as  
183 publication type, publication year, country, and building type.

184 *2.4.2 Statistical model*

185 The fixed-effect model and the random-effects model are two statistical models in meta-  
186 analysis [42]. They are constructed based on different assumptions. The fixed-effect model assumes  
187 that there is only one true effect size among all the studies. The observed differences in the effect  
188 size of each study are caused by random errors. By contrast, the random-effects model allows  
189 different true effect sizes exist between studies. The observed differences in the effect size of each  
190 study are caused by random errors and the different effect sizes of each study. In most cases, the  
191 assumption of only one true effect size in different studies is not convincing because there are  
192 various uncertain variables in each study, e.g., participants' age, education level, and income,  
193 leading to different effect sizes. The random-effects model has a wider application scope than the

194 fixed-effect model because it has higher compatibility by considering different research  
195 backgrounds.

196 First, the preliminary study was conducted to choose the appropriate model. After scanning the  
197 full text of included studies, a conclusion could be drawn that the external research environment  
198 varied in each study. These studies were conducted in different countries and published in different  
199 years. Statistical results of the preliminary study showed that high heterogeneity existed in most of  
200 CSFs. Considering the high heterogeneity and the variation in previous studies, this study applied  
201 the random-effects model in this research.

202 Before estimating the mean effect size, each study was weighted by the inverse of its variance.  
203 The weight of the study in the random-effects model was lower than it in the fixed-effect model  
204 because the variance in the random-effects model considered both the within-studies variance and  
205 the between-studies variance. The study weight in the random-effects model was estimated by  
206 Equation (1).

$$W_i^* = \frac{1}{V_{Y_i} + T^2} \quad (1)$$

207 Where  $W_i^*$  represents the weight assigned to study  $i$ ;  $V_{Y_i}$  represents the within-study variance  
208 for study  $i$ ;  $T$  represents the between-studies variance.

209 The mean effect size and the variance in the random-effects model were estimated using  
210 Equation (2) and Equation (3). The calculation processes above were completed by Comprehensive  
211 Meta Analysis 3.3 (CMA 3.3), a useful software for meta-analysis. All the CSFs identified from  
212 previous studies needed to get through the process independently, so it was repeated multiple times  
213 for each factor.

$$M^* = \frac{\sum_{i=1}^k W_i^* Y_i}{\sum_{i=1}^k W_i^*} \quad (2)$$

214 Where  $M^*$  represents the weighted mean;  $Y_i$  represents the observed effect for study  $i$ .

$$V_m^* = \frac{1}{\sum_{i=1}^k W_i^*} \quad (3)$$

215 Where  $V_m^*$  represents the variance of the summary effect.

### 216 2.4.3 Heterogeneity

217 The heterogeneity in effect sizes demonstrates the variation of the true effect sizes [42]. Under  
218 the assumption that there is only one true effect size among all the studies, heterogeneity does not  
219 exist. However, in most cases, although some studies conduct research on the same topic, the  
220 external research environment is different. It leads to different true effect sizes and the existence of  
221 heterogeneity [24]. If the true effect sizes vary among the studies, the difference of the observed  
222 effect sizes would contain two parts: 1) real heterogeneity; 2) within-study error.  $Q$  and  $I^2$  are  
223 commonly utilized to identify and quantify the heterogeneity.  $Q$  is the ratio of the observed variation  
224 to the within-study error, and  $I^2$  is the ratio of excess dispersion to total dispersion [42]. The  
225 judgment criteria of heterogeneity are in the following [43].

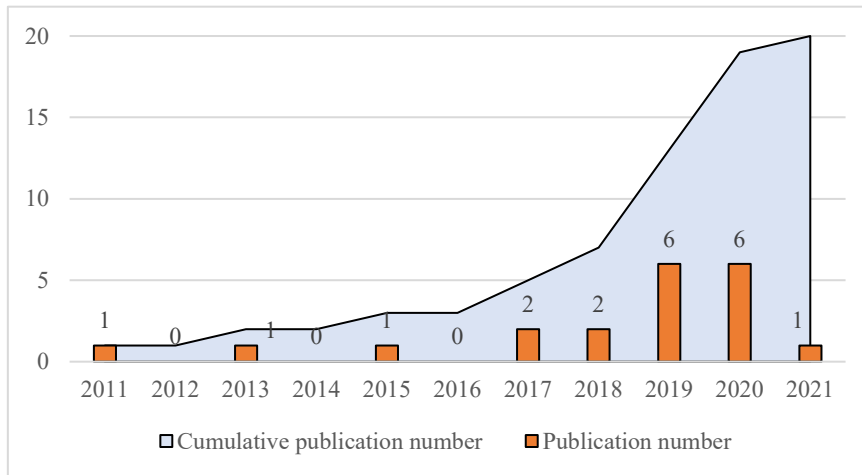
- 226 ● If  $I^2 < 25\%$ , low heterogeneity exists.
- 227 ● If  $25\% \leq I^2 \leq 75\%$ , moderate heterogeneity exists.
- 228 ● If  $75\% < I^2$ , high heterogeneity exists.

229 To reduce the heterogeneity as much as possible, several approaches were applied in this study.  
230 The first one was to adopt the random-effects model, under a prerequisite that the differences  
231 between studies truly exist. Besides, the subgroup analysis was conducted to discuss the differences  
232 between subgroups. Moreover, sensitivity analysis was conducted to discuss the influence of  
233 individual studies on the results.

234 2.4.4 Subgroup analysis

235 Focusing on the variation, subgroup analysis divides studies into several subgroups according  
236 to different characteristics and discusses the impact on the results [42]. It is a good approach to  
237 interpret the heterogeneity if a significant difference could be observed between subgroups. In this  
238 research, four subgroups were proposed to classify the studies:

- 239 ● Publication type. There were two publication types in the literature database: journal  
240 articles and conference papers. Publication procedures are stricter in journals than in  
241 conferences. Journal articles normally need to get through several-round revisions before  
242 the final publication, especially in the top journals. Although some conferences require  
243 peer review when reviewing papers, the process is not as strict as journals in this research  
244 field. Compared with journal articles, conference papers are more concise, and they tend  
245 to focus on the research frontier and publish timely.
- 246 ● Publication year. All the studies in the database were published from 2011 to 2021. The  
247 publication trend is shown in Figure 2. From 2011 to 2016, there was either one study or  
248 no study in each year. The situation has slightly improved in 2017 and 2018. After 2019,  
249 the publication number was highly increased. Therefore, according to the publication  
250 trend, three subgroups were divided based on the publication year: (1) 2011-2016; (2)  
251 2017-2018; (3) 2019-2021.



**Figure 2.** Publication trend.

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- Country's economy. Three studies in the database collected data from the whole world, while the others focused on different countries. Research showed that the regional economy highly impacts GB development [9]. Group of Twenty (G20), which is composed of 19 countries and the European Union, highly impacts the global economy.

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Therefore, the studies were divided into three groups: the G20 group, the non-G20 group, and the whole world. There was an exception in these studies, which conducted research in three countries [44]. Two of them were G20 members. This study was deleted in the subgroup analysis.

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- Building type. There were three building types in the literature database: general building, hospital building, and housing. Among the studies, general building and housing were the mainstream, and only one study referred to the hospital building. Therefore, the study of the hospital building was deleted in the subgroup analysis because of the low sample size.

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Two categories in this subgroup were proposed: general building and housing.

267 *2.4.5 Sensitivity analysis*

268 The sensitivity analysis aims to investigate the robustness of results and discuss the impact of  
269 other elements on the results [42]. There are different approaches to conducting sensitivity analysis.  
270 The first approach concentrates on data influence. For instance, if the inclusion and exclusion  
271 criteria for literature selection are changed, the data utilized in meta-analysis is different, which  
272 would lead to different results. The second approach aims to change statistical methods in the meta-  
273 analysis, such as choosing different effect sizes or changing the statistical model. As discussed in  
274 Section 2.4.2, there are solid reasons to choose the appropriate effect size and random-effects model,  
275 so this study adopted the first approach to discuss the impact of a specific study on the results.  
276 Sensitivity analysis was conducted in this study by the module of one study removed in CMA 3.3.

277 *2.4.6 Publication bias*

278 Research shows that studies that report high effect sizes are more likely to be published, so  
279 they are easier to be included in the meta-analysis. On the contrary, studies with unsatisfied results  
280 may encounter problems in publication, so they cannot be searched. This phenomenon, namely  
281 publication bias, affects the result accuracy [42]. Publication bias could be displayed through a  
282 funnel plot, which illustrates the relationship between the effect size and the study size. If there is  
283 no publication bias, the funnel plot is symmetrical. Some approaches could determine the  
284 publication bias quantitatively, such as Rosenthal's Fail-safe N, Orwin's Fail-safe N, and Duval and  
285 Tweedie's Trim and Fill. The last one, Duval and Tweedie's Trim and Fill, was applied in this study  
286 because it could provide an adjusted effect size when publication bias exists.



287 **3. RESULTS**

288 *3.1 CSF identification*

289 After the literature selection procedures were completed, twenty studies that met the criteria  
290 were included in the literature database, shown in Table 1. These studies were classified into  
291 different subgroups for further analysis: publication type, publication year, country, and building  
292 type. With respect to the building type, 14 studies concentrated on the general building, which was  
293 the mainstream, while five studies focused on housing. Besides, only one study explored CSFs of  
294 hospital buildings.

295 **Table 1.**

296 Basic information of selected literature.

Study ID	Sample size	Publication type	Publication year	Country	Building type	Reference
1 Li et al., 2011 (J) (SGP) (G)	37	Journal	2011	Singapore	General building	[45]
2 Venkataraman and Cheng 2018 (J) (W) (G)	67	Journal	2018	Global	General building	[13]
3 Adabre and Chan 2019 (J) (W) (H)	51	Journal	2019	Global	Housing	[46]
4 Oluleye et al., 2020 (J) (NG) (H)	74	Journal	2020	Nigeria	Housing	[47]

5	Sang and Yao 2019 (J) (CHN) (H)	76	Journal	2019	China	Housing	[48]
6	Tang et al., 2020 (C) (HK) (G)	106	Conference	2020	Hong Kong	General building	[49]
7	Olawumi and Chan 2020 (J) (W) (G)	220	Journal	2020	Global	General building	[50]
8	Wong et al., 2021 (C) (MY) (G)	36	Conference	2021	Malaysia	General building	[51]
9	Awaili et al., 2020 (J) (LY) (G)	20	Journal	2020	Libya	General building	[52]
10	Nguyen et al., 2017 (J) (VN) (G)	215	Journal	2017	Vietnam	General building	[53]
11	Azeem et al., 2017 (J) (PK) (G)	103	Journal	2017	Pakistan	General building	[54]
12	Deng et al., 2018 (J) (CHN) (G)	87	Journal	2018	China	General building	[55]
13	Li et al., 2019 (J) (NZ) (H)	26	Journal	2019	New Zealand	Housing	[56]
14	Ahn et al., 2013 (J) (USA) (G)	100	Journal	2013	United States	General building	[57]
15	Yang and Yang 2015 (J) (AUS) (H)	50	Journal	2015	Australia	Housing	[58]

16	Sahamir et al., 2019 (C) (MY) (HO)	82	Conference	2019	Malaysia	Hospital building	[59]
17	Agyekum et al., 2020 (J) (GH) (G)	520	Journal	2020	Ghana	General building	[60]
18	Wu et al., 2019 (J) (CHN) (G)	78	Journal	2019	China	General building	[61]
19	Dalirazar and Sabzi 2020 (J) (SUN) (G)	54	Journal	2020	Sweden, United States and New Zealand	General building	[44]
20	Nguyen et al., 2019 (C) (VN) (G)	166	Conference	2019	Vietnam	General building	[62]

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297 Following a thorough review of the selected studies, forty CSFs were identified. All the  
298 identified factors, shown in Table 2, were classified into 11 categories: finance, stakeholders, human  
299 resource, management, technology, education and knowledge, government, research and innovation,  
300 economy and industry, market and culture, covering all the aspects. Among these categories, further  
301 explanations for a clear boundary of the stakeholders were provided. Although several studies  
302 incorporated internal stakeholders (e.g., architects, contractors, consultants, and end-users) and  
303 external stakeholders (e.g., governments, researchers, and the public) within green-related  
304 stakeholders [63,64], the majority of studies concentrated on internal stakeholders [65,66], which  
305 revealed that internal stakeholders, such as designers and contractors, played significant roles in GB

306 construction [67]. Therefore, the category of stakeholders in this study only included the green-  
 307 related internal stakeholders and considered the government as an external stakeholder, which was  
 308 separated into another category. The frequency of CSFs that appeared in the included studies was  
 309 also presented in Table 2. The top 4 factors were CSF2 "*Low cost of green buildings*" (12 times),  
 310 CSF22 "*Training*" (10 times), CSF5 "*Cooperation between stakeholders*" (8 times), and CSF30  
 311 "*Comprehensive code and standard*" (8 times).

312 **Table 2.**

313 Critical success factors (CSFs) for green building promotion (GBP).

Category	Factor ID	Critical success factor	Frequency	Reference
C1 Finance	CSF1	Adequate financial budget	7	[45], [13], [48], [51], [54], [60], [61]
	CSF2	Low cost of green buildings	12	[44], [46], [49], [51], [52], [53], [54], [55], [57], [58], [60], [61]
	CSF3	Effective auditing programs	5	[44], [45], [13], [53], [57],
	CSF4	Tax and fiscal incentives	5	[44], [46], [47], [53], [58]
C2 Stakeholders	CSF5	Cooperation between stakeholders	8	[45], [13], [46], [47], [48], [50], [55], [58]
	CSF6	Communication between stakeholders	7	[44], [45], [13], [52], [53], [54], [58]
	CSF7	Early involvement of project participants	5	[45], [13], [47], [48], [50]

	CSF8	Commitment of all project participants	2	[45], [13]
C3 Human resource	CSF9	Skilled participants	6	[44], [45], [13], [50], [54], [55]
	CSF10	Experience in GBs	3	[44], [48], [50]
C4 Management	CSF11	Detailed plan	2	[45], [48]
	CSF12	Innovative management approaches	5	[44], [45], [13], [48], [54]
	CSF13	Support from senior management	3	[45], [13], [48]
	CSF14	Effective feedback and troubleshooting	3	[45], [13], [48]
	CSF15	High motivation	3	[45], [48], [55]
	CSF16	Integrated design	4	[46], [47], [57], [58]
C5 Technology	CSF17	Advanced machinery and equipment	4	[45], [13], [48], [54]
	CSF18	Available sustainable materials	5	[44], [47], [53], [54], [59]
	CSF19	Innovative technological approaches	7	[44], [45], [53], [54], [58], [60], [61]
	CSF20	Software application	2	[45], [50]

	CSF21	Available databases	3	[50], [51], [60]
C6 Education and knowledge	CSF22	Training	10	[44], [48], [50], [51], [52], [53], [54], [57], [58], [61]
	CSF23	Knowledge	6	[44], [50], [52], [54], [55], [60]
	CSF24	Demonstration projects	3	[44], [53], [61]
C7 Government	CSF25	Adequate incentives	7	[44], [46], [47], [54], [55], [57], [60]
	CSF26	Effective government policies	7	[44], [46], [47], [48], [56], [58], [61]
	CSF27	Regulation support	5	[44], [51], [54], [56], [57]
	CSF28	Mandatory requirements	3	[46], [47], [55]
	CSF29	Legislation	4	[44], [50], [53], [54]
	CSF30	Comprehensive code and standard	8	[44], [48], [53], [54], [55], [57], [58], [62]
C8 Research and innovation	CSF31	Research	3	[50], [51], [58]
	CSF32	Innovation	2	[54], [57]
C9 Economy and industry	CSF33	Industrialization	3	[53], [55], [61]
	CSF34	Supply chain	2	[51], [55]
C10 Market	CSF35	Obvious Economic benefit	4	[54], [57], [61], [62]
	CSF36	Short payback period	4	[44], [51], [53], [54]
	CSF37	Market demand	7	[44], [51], [53], [54], [56], [61], [62]

C11 Culture	CSF38	Reputation	3	[44], [58], [61]
	CSF39	Effective leadership	3	[50], [56], [62]
	CSF40	Public awareness	6	[47], [53], [54], [56], [58], [61]

314 *3.2 Numerical example*

315 Because the calculation process was the same for each factor, this study just used the  
316 calculation of CSF2 "*low cost of green building*" as an example. The low cost of GBs is a critical  
317 factor in GBP, which highly motivates stakeholders to adopt GBs rather than conventional buildings.  
318 This factor appeared in twelve studies, which was the highest frequency. The statistical data of CSF2,  
319 obtained from included studies, are shown in Table 3, including study ID, mean, SD, and sample  
320 size. The information of CSF2 in Table 3 was enough for meta-analysis. The results contained a  
321 heterogeneity report, the statistical result of meta-analysis, subgroup analysis, sensitivity analysis,  
322 and the publication bias. For the final presentation of results in the following sections, only the most  
323 important parts were reported.

324 **Table 3.**

325 Statistical data of CSF2 for the Meta-analysis.

Study ID	Mean	SD	Sample size
Adabre and Chan 2019 (J) (W) (H)	4.083	0.739	51
Tang et al., 2020 (C) (HK) (G)	4.180	0.906	106
Wong et al., 2021 (C) (MY) (G)	3.750	1.160	36
Awaili et al., 2020 (J) (LY) (G)	3.400	1.040	20
Nguyen et al., 2017 (J) (VN) (G)	3.950	0.970	215

Azeem et al., 2017 (J) (PK) (G)	3.250	1.178	103
Deng et al., 2018 (J) (CHN) (G)	3.920	1.010	87
Ahn et al., 2013 (J) (USA) (G)	2.620	1.406	100
Yang and Yang 2015 (J) (AUS) (H)	4.120	0.860	50
Agyekum et al., 2020 (J) (GH) (G)	4.330	0.739	520
Wu et al., 2019 (J) (CHN) (G)	3.962	1.211	78
Dalirazar and Sabzi 2020 (J) (SUN) (G)	3.704	1.057	54

326 Heterogeneity report showed that P-value was 0.000, and the  $I^2$  was 95.501%. According to  
327 the criteria that have been mentioned in Section 2.4.3, high heterogeneity existed in the CSF2. A  
328 random-effects model was adopted to reduce the high heterogeneity.

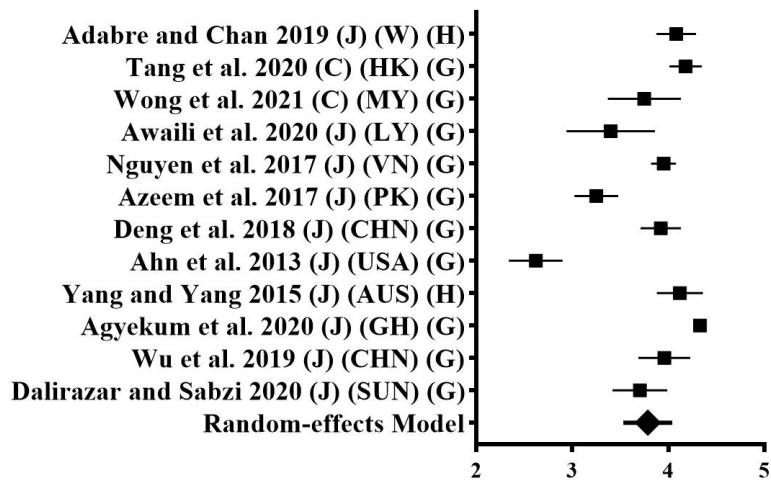
329 The meta-analysis result of CSF2 and its forest plot are shown in Table 4 and Figure 3.  
330 According to Table 4, the synthetical mean value of CSF2 was 3.786. The effect size of a study was  
331 depicted as a point estimate that was bounded by its confidence interval (95% in this study). Figure  
332 3 contributes to the result interpretation with a visual approach. The square in the figure represents  
333 the mean value of this study, and the confidence intervals could track the precision. A narrower  
334 interval reflects better precision. The last one was a diamond, which shows the synthetical mean. In  
335 the forest plot, the mean values of most studies are not far away from the synthetical mean, except  
336 the study of Ahn [57], which had a lower estimate compared with the synthetical mean. Although  
337 this study has identified financial elements, such as the first cost premium of the project and long  
338 payback periods, as the primary barriers in sustainable design and construction, there was a  
339 perception in this study that the effect of implementing GB practice through reducing the initial  
340 project cost was limited [57].



341 **Table 4.**

342 Meta-analysis result of CSF2.

Study ID	Statistics for each study		
	Mean	Standard error	Lower and upper limit
Adabre and Chan 2019 (J) (W) (H)	4.083	0.103	[3.880, 4.286]
Tang et al., 2020 (C) (HK) (G)	4.180	0.088	[4.008, 4.352]
Wong et al., 2021 (C) (MY) (G)	3.750	0.193	[3.371, 4.129]
Awaili et al., 2020 (J) (LY) (G)	3.400	0.233	[2.944, 3.856]
Nguyen et al., 2017 (J) (VN) (G)	3.950	0.066	[3.820, 4.080]
Azeem et al., 2017 (J) (PK) (G)	3.250	0.116	[3.023, 3.477]
Deng et al., 2018 (J) (CHN) (G)	3.920	0.108	[3.708, 4.132]
Ahn et al., 2013 (J) (USA) (G)	2.620	0.141	[2.344, 2.896]
Yang and Yang 2015 (J) (AUS) (H)	4.120	0.122	[3.882, 4.358]
Agyekum et al., 2020 (J) (GH) (G)	4.330	0.032	[4.266, 4.394]
Wu et al., 2019 (J) (CHN) (G)	3.962	0.137	[3.693, 4.230]
Dalirazar and Sabzi 2020 (J) (SUN) (G)	3.704	0.144	[3.422, 3.986]
Random-effects Model	3.786	0.129	[3.533, 4.039]



343

344

**Figure 3.** Forest plot of CSF2

345

The subgroup analysis results are shown in Table 5. Observed from Table 5, a conclusion could

346

be drawn that different subgroups had different distribution patterns. Among these subgroups, the

347

impact of publication year was the most significant. It showed that the importance of CSF2 was

348

increasing year by year, indicating GB cost has received more and more attention in recent years.

349

As for the country's economy, little difference existed between the G20 subgroup and the others,

350

but the estimated mean was higher in the whole world. The reason may come from the insufficient

351

global samples because there is only one study investigating this factor worldwide. Concerning the

352

publication type, studies in the conference emphasized more meanings on the GB cost than the

353

studies in journals. Furthermore, in the building type, CSF2 was more important for housing projects

354

than the general buildings.

355

**Table 5.**

356

Subgroup analysis of CSF2.

Category	Mean [lower limit, upper limit]	Reference
1. Publication type	3.832 [3.590, 4.074]	

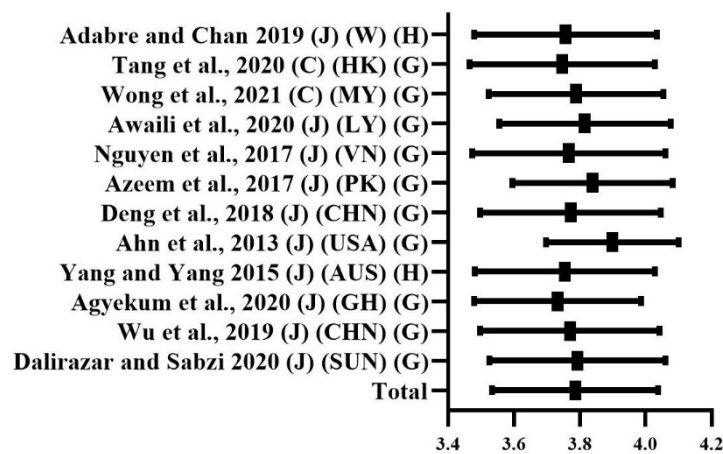
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1.1 Journal	3.746 [3.448, 4.044]	[46], [52], [53], [54], [55], [57], [58], [60], [61], [44]
1.2 Conference	3.999 [3.584, 4.415]	[49], [51]
2. Publication year	3.900 [3.708, 4.091]	
2.1 2011-2016	3.372 [1.902, 4.842]	[57], [58]
2.2 2017-2018	3.713 [3.303, 4.123]	[53], [54], [55]
2.3 2019-2021	3.964 [3.746, 4.183]	[46], [49], [51], [52], [60], [61], [44]
3. Country's economy	3.756 [3.462, 4.050]	
3.1 G20	3.756 [3.333, 4.179]	[49], [55], [57], [58], [61], [44]
3.2 Others	3.757 [3.348, 4.165]	[51], [52], [53], [54], [60]
3.3 Whole world	4.083 [3.880, 4.286]	[46]
4. Building type	4.020 [3.883, 4.158]	
4.1 General building	3.719 [3.416, 4.022]	[49], [51], [52], [53], [54], [55], [57], [60], [61], [44]
4.2 Housing	4.099 [3.944, 4.253]	[46], [58]

---

357 The forest plot of sensitivity analysis is shown in Figure 4. If the study in the Y-axis was  
358 removed, the synthetical mean value, lower limit, and upper limit were shown in the right line (the  
359 middle point, left point, and the right point of the line, respectively). If one of the five studies was  
360 excluded from the meta-analysis, the synthetical mean would be higher. The IDs of the five studies  
361 are as follows: Wong et al., 2021 (C) (MY) (G), Awaili et al., 2020 (J) (LY) (G), Azeem et al., 2017

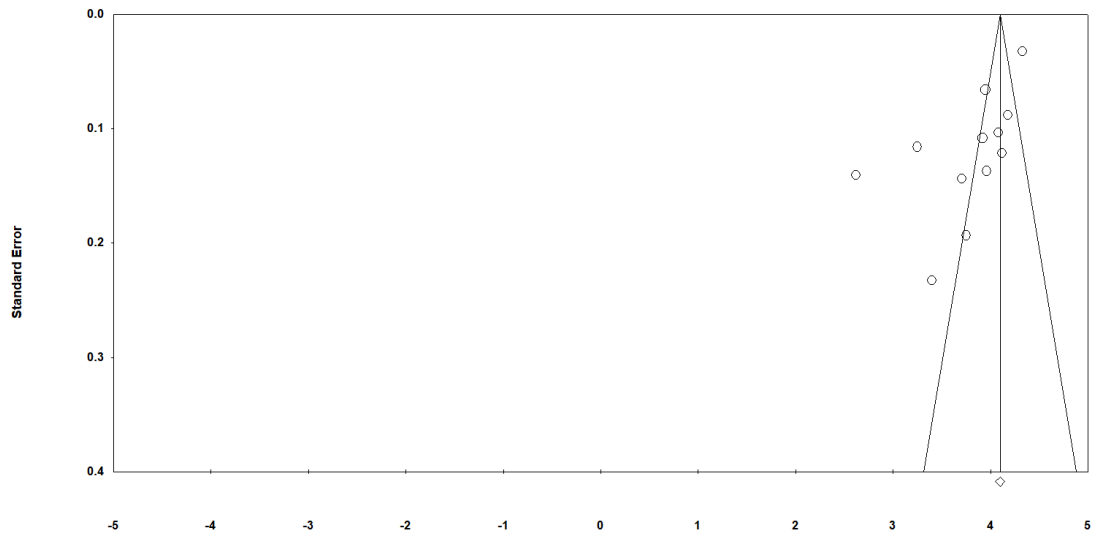
362 (J) (PK) (G), Ahn et al., 2013 (J) (USA) (G), Dalirazar and Sabzi 2020 (J) (SUN) (G). It seemed  
 363 that the studies could not affect the result significantly except the study of Ahn et al. [57]. When  
 364 this study was removed, the mean value increased from 3.786 to 3.899, indicating a significant  
 365 change in the sensitivity analysis. As mentioned in the illustration of the forest plot, the estimate in  
 366 this study was lower than in other studies, leading to a significant change when it was excluded in  
 367 the sensitivity analysis.



368

369 **Figure 4.** Sensitivity analysis of CSF2

370 The funnel plot of standard error by mean for CSF2 is shown in Figure 5. As seen in the figure,  
 371 there were more studies on the left side of the synthetical mean line than the right side, so the plot  
 372 was not symmetrical, indicating that the publication bias existed in CSF2. However, after  
 373 conducting Tweedie's Trim and Fill, the adjusted mean value remained the same, which proved that  
 374 the publication bias was too slight to affect the result.



375

376

**Figure 5.** Funnel plot of standard error by mean for CSF2.

377

*3.3 Meta-analysis results*

378

According to the calculation process in Section 3.2, meta-analysis results were calculated and

379

summarized in Figure 6, including the synthetical mean of each factor and the adjusted mean of

380

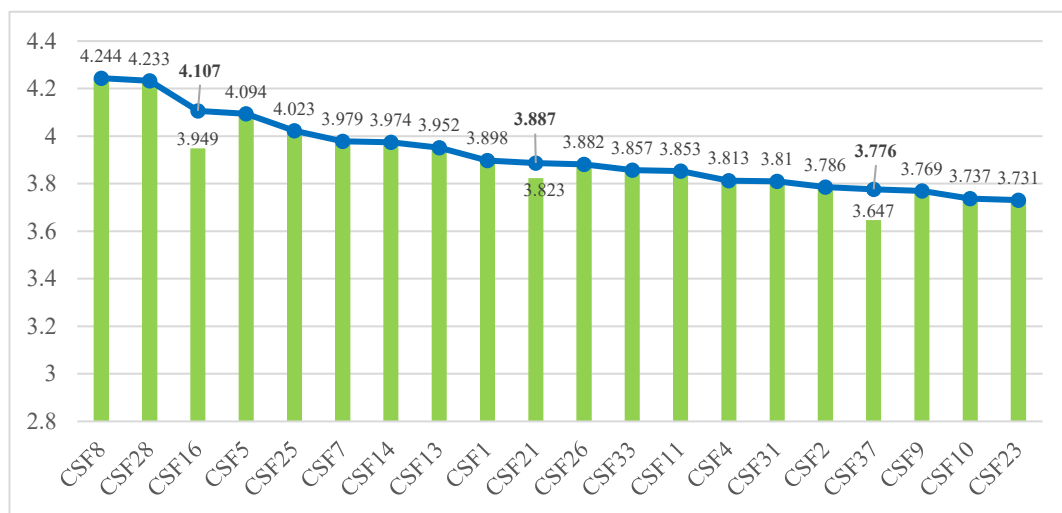
some CSFs in which publication bias exists. As Figure 6 shows, the mean values of nine CSFs

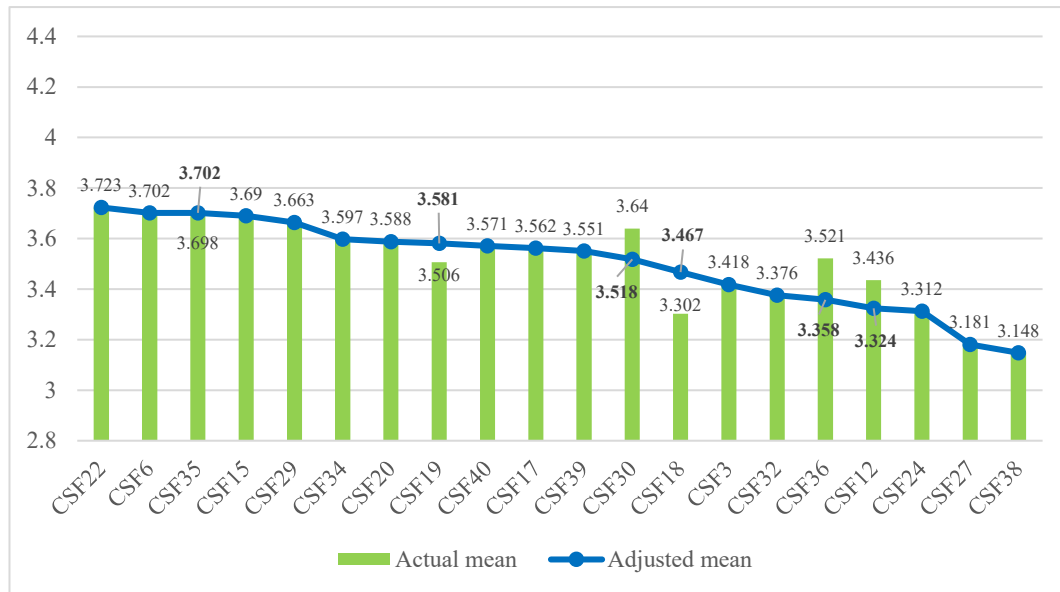
381

changed, which means publication bias existed, including CSF12, CSF16, CSF18, CSF19, CSF21,

382

CSF30, CSF35, CSF36, CSF37.





383 **Figure 6.** The actual mean of each CSF and adjusted mean through publication bias analysis.

384 The significance of CSFs was ranked according to their adjusted mean values in Figure 6. As

385 shown in the figure, all the adjusted mean values of CSFs were higher than 3. It implies that all the

386 factors identified in this study have essential roles in GB practice, revealing that this study's critical

387 factor identification was scientific and reasonable. In the rank list of adjusted mean value, the top 5

388 CSFs were CSF8 "*Commitment of all project participants*" (4.244), CSF28 "*mandatory*

389 *requirement*" (4.23), CSF16 "*Integrated design*" (4.107), CSF5 "*Cooperation between*

390 *stakeholders*" (4.094), CSF25 "*Adequate incentives*" (4.023). Among the top five CSFs, two were

391 from the stakeholder category, and two were from the government category. The other one was from

392 the management category. The stakeholders and the government are two primary roles in GBP.

393 Some stakeholders, who undertake the main responsibility to construct GB projects, act as the

394 decision-makers. According to the results, the commitment and the cooperation among stakeholders

395 were vital in GBP, emphasizing the interactions between stakeholders. The possibility of GBP

396 success would be increased if all the stakeholders share the same targets in GB construction and

397 join hands to achieve it.

398 For the government, adequate incentives and mandatory requirements are indispensable. The  
399 financial incentives, including tax reduction and financial subsidy, are effective policies that benefit  
400 stakeholders and take effect immediately. Other incentives, such as simplifying the administrative  
401 processes, are also effective in GBP. The mandatory requirements are the regulations and laws that  
402 the stakeholders cannot violate. Different from the incentives, mandatory requirements guarantee  
403 the bottom line of GBP. For example, China has regulated that office buildings invested by  
404 governments should be constructed under the GB code and apply for GB certifications. When the  
405 government proposes mandatory requirements, it needs careful consideration that it should achieve  
406 the effect of promoting GBP without harming stakeholders' enthusiasm in the market.

407 With respect to the publication bias, the approach of Duval and Tweedie's Trim and Fill was  
408 adopted in the examination. It also provided the adjusted mean, which eliminated the side effects of  
409 publication bias as much as possible. Among the nine CSFs in which publication bias existed, the  
410 adjusted means of six CSFs (CSF16, CSF21, CSF2, CSF37, CSF19, CSF18) were higher than the  
411 actual means, indicating that the unpublished research had higher estimates on these CSFs. On the  
412 contrary, the adjusted means of other CSFs (CSF30, CSF36, CSF12) were lower than the actual  
413 means, indicating that the unpublished research had lower estimates.

#### 414 *3.4 Subgroup analysis*

415 The included studies were divided into four categories. The first category was the publication  
416 type (i.e., journal and conference publications). Most of the CSFs were not suitable for the subgroup  
417 analysis in publication type because most studies were published in academic journals. Among the  
418 suitable CSFs, there were apparent differences in the effect sizes between journal articles and  
419 conference papers except for CSF18, "*Available sustainable materials*." It seems studies achieved

420 an agreement on the importance of sustainable materials, but there were substantial divergences  
421 among other CSFs. The most significant difference existed in CSF36, "*Short payback period*," with  
422 an effect size of 2.530 in conference papers and 3.830 in journal articles.

423 As for the category of publication year, the changing trends of the effect size represented the  
424 cognitive changes at different periods, which means that the knowledge researchers perceived was  
425 constantly expanding along with the research progress. Four trends emerged by observing the data:  
426 (1) continuously increasing (7 CSFs); (2) continuously decreasing (11 CSFs); (3) increasing first,  
427 then decreasing (10 CSFs); (4) decreasing first, then increasing (2 CSFs). The most striking result  
428 was the sudden drop in the effect size of CSF13 "*Support from senior management*" and CSF27  
429 "*Regulation support*" in the last four years. The effect size of CSF13 dropped from 4.110 to 3.260,  
430 and the effect size of CSF27 dropped from 4.200 to 2.804. The first one emphasized senior support  
431 in the GB project, and the other one was the administrative support from the government. Moreover,  
432 the demands for advanced equipment and materials were increasing because of the climbing trends  
433 of CSF17 "*Advanced machinery and equipment*" and CSF18 "*Available sustainable materials*."

434 In the category of country's economy, included studies were divided into three subgroups: G20  
435 countries, other countries, and the whole world. G20 represents the countries that occupy critical  
436 positions in the global economy. Other countries refer to the non-G20 countries. Different from G20  
437 and non-G20 subgroups, three studies investigated CSFs in GBP from the whole world, which was  
438 the reason that the whole world was set as an independent subgroup in this study. As the assumption,  
439 if GB development had correlations with countries' economies, the effect size of the whole world  
440 should be within the range of the other subgroups. However, only five CSFs satisfied this  
441 assumption (CSF4, CSF6, CSF16, CSF25 and CSF29). In most cases, the effect sizes in the



442 subgroup of the whole world were larger than those in other subgroups. The reason may relate to  
443 the limited sample size of the whole world. The statistical results may not be precise only based on  
444 three studies, leading to higher estimations.

445 To determine the influence of different building types, the studies were classified into the  
446 general building and housing subgroups. Results showed that the difference between general  
447 building and housing was more evident than the difference in other categories. The most significant  
448 difference existed in CSF18 "*Available sustainable materials*," with 2.913 in general building and  
449 4.420 in housing, respectively. From the overall trends, the CSFs for general buildings paid more  
450 attention to the stakeholders' cooperation while the CSFs for housing concentrated on financial  
451 support and governmental incentives.

**Table 6.** Subgroup analysis results for each CSF.

Factor	Publication type			Publication year			Country's economy			Building type				
	Conference	Journal	Overall	2011-2016	2017-2018	2019-2021	Overall	G20	Others	Whole world	Overall	General building	Housing	Overall
CSF1	3.440	3.967	3.801	3.650	3.954	3.919	3.908	3.927	3.863	3.940	3.923	3.890	3.930	3.914
CSF2	3.999	3.746	3.832	3.372	3.713	3.964	3.900	3.756	3.757	4.083	3.978	3.719	4.099	4.020
CSF3	-	-	-	3.351	3.571	3.222	3.319	3.143	3.460	3.830	3.415	-	-	-
CSF4	-	-	-	4.060	3.970	3.663	3.988	3.294	4.344	3.729	3.788	3.252	4.178	4.032
CSF5	-	-	-	4.016	4.210	4.077	4.082	3.894	4.182	4.219	4.046	4.206	3.976	4.084
CSF6	-	-	-	3.707	3.744	3.499	3.712	3.493	3.762	3.740	3.710	3.723	3.550	3.697
CSF7	-	-	-	3.430	4.310	4.016	4.143	3.480	3.895	4.258	4.082	4.064	3.901	4.042
CSF9	-	-	-	3.890	3.861	3.564	3.874	3.205	3.829	4.254	3.971	-	-	-

---

CSF10	-	-	-	-	-	-	-	3.482	-	4.220	4.201	3.703	3.770	3.768
CSF12	-	-	-	3.350	3.772	3.116	3.673	3.116	3.616	3.690	3.663	3.387	3.610	3.571
CSF13	-	-	-	4.490	4.110	3.260	3.901	-	-	-	-	4.296	3.260	3.477
CSF14	-	-	-	-	-	-	-	-	-	-	-	3.870	4.170	4.134
CSF15	-	-	-	-	-	-	-	3.648	3.780	-	3.760	3.867	3.370	3.661
CSF16	-	-	-	3.861	-	4.034	3.955	3.861	4.150	3.872	4.040	3.720	4.045	3.930
CSF17	-	-	-	3.350	3.497	3.860	3.686	3.860	3.500	3.370	3.672	3.463	3.860	3.688
CSF18	3.378	3.282	3.372	-	3.043	3.481	3.060	2.630	3.467	-	2.730	2.913	4.420	4.138
CSF19	-	-	-	3.465	3.456	3.553	3.470	3.455	3.545	-	3.539	3.524	3.350	3.492
CSF21	3.610	3.887	3.774	-	-	-	-	-	3.752	4.010	3.874	-	-	-
CSF22	3.440	3.753	3.633	3.620	3.946	3.668	3.770	3.539	3.816	4.270	4.143	3.694	3.840	3.800
CSF23	-	-	-	-	3.799	3.694	3.761	3.327	3.822	4.070	3.978	-	-	-
CSF24	-	-	-	-	3.460	3.231	3.456	3.231	3.460	-	3.456	-	-	-

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CSF25	-	-	-	3.070	4.235	4.178	3.827	3.528	4.408	4.192	4.336	3.866	4.411	4.147
CSF26	-	-	-	4.020	-	3.853	3.981	3.786	3.642	4.575	4.446	3.533	4.036	3.922
CSF27	3.530	3.087	3.475	3.240	4.200	2.804	3.784	2.947	3.337	-	3.054	3.407	2.200	2.646
CSF28	-	-	-	-	3.850	4.432	3.977	-	-	-	-	3.850	4.432	3.977
CSF29	-	-	-	-	4.014	3.262	3.974	2.519	4.014	3.990	3.845	-	-	-
CSF30	3.920	3.596	3.824	3.950	3.663	3.384	3.753	3.578	3.727	-	3.691	3.586	3.796	3.633
CSF31	3.390	4.029	3.978	3.900	-	3.741	3.876	-	-	-	-	3.741	3.900	3.876
CSF33	-	-	-	-	3.798	3.987	3.964	4.047	3.500	-	3.726	-	-	-
CSF35	4.050	3.566	3.793	3.620	3.510	3.825	3.587	3.601	3.786	-	3.617	-	-	-
CSF36	2.530	3.830	3.597	-	3.853	3.148	3.831	3.759	3.438	-	3.703	-	-	-
CSF37	4.032	3.504	3.604	-	3.626	3.637	3.627	3.567	3.669	-	3.600	3.742	2.800	3.607
CSF38	-	-	-	3.370	-	3.035	3.359	-	-	-	-	3.035	3.370	3.359
CSF39	3.870	3.345	3.865	-	-	-	-	-	3.246	4.070	4.064	3.977	2.600	3.654

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CSF40	-	-	-	3.590	4.141	3.174	3.502	3.511	3.588	-	3.516	3.923	3.201	3.451
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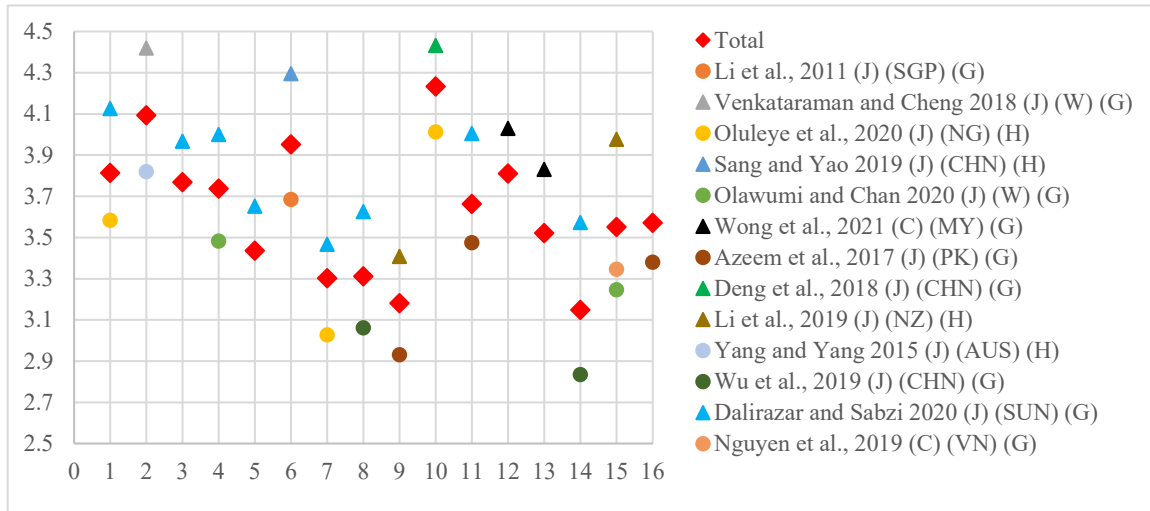
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Note: "-" means it was not suitable for subgroup analysis. Besides, five CSFs, which were also not suitable for the subgroup analysis, were deleted in this table, including CSF8, CSF11, CSF20, CSF32 and CSF34.

452 *3.5 Sensitivity analysis*

453 Aiming at investigating the robustness of results, sensitivity analysis was conducted by  
454 removing one study in the meta-analysis. The complete results of sensitivity analysis are presented  
455 in Table A1 of the appendix. Five CSFs, including CSF8, CSF11, CSF20, CSF32 and CSF34, were  
456 not suitable for sensitivity analysis because these factors were only supported by two studies, which  
457 was no meaning if one study was deleted. In sensitivity analysis, the synthetical mean would be  
458 changed after removing one study. Observing the change rate was critical to probe the robustness.  
459 In this study, the change rate of 5% was set as a benchmark. Those significant changes, which were  
460 beyond the range of 5%, were illustrated in Figure 7. 17 CSFs were included. The red diamonds in  
461 this figure represent the original means in the meta-analysis, while the points with other colors were  
462 the changed means, which shows the results after removing one study.

463 As shown in Figure 7, the study of Dalirazar and Sabzi [44] appeared eight times, which is the  
464 most frequent one in the figure. It indicates that this study may have different observations on CSFs  
465 in GBP. When this study was deleted, the synthetical mean increased. This study was unique in  
466 many aspects. The first aspect was the regions. Different from other studies focused on a specific  
467 country or the whole world, this study distributed questionnaires in three countries: Sweden, the  
468 United States, and New Zealand. The second was its research objective. This study investigated the  
469 barriers to sustainable building development, leading to more conservative estimates on CSFs.



470

471

**Figure 7.** Major mean changes through sensitivity analysis.

472 **4. DISCUSSION**

473 There were 40 CSFs in total, which were identified from 20 studies. The statistical results of  
 474 the meta-analysis were synthesized from 2168 respondents in these studies ranging from 2011 to  
 475 2021. The large sample size in meta-analysis guaranteed more accurate results than the independent  
 476 empirical study. Meanwhile, this study considered the heterogeneity problem and made efforts to  
 477 minimize it through the random-effects model as much as possible. Besides, subgroup analysis was  
 478 utilized to examine whether the variables affect the results, which was also an approach to  
 479 incorporate heterogeneity. In the end, the sensitivity analysis was conducted to investigate the  
 480 robustness of the models.

481 *4.1 Further discussion on top CSFs*

482 As shown in Section 3.1, the top four CSFs in the frequency list were CSF2 "Low cost of green  
 483 buildings" (12), CSF22 "Training" (10), CSF5 "Cooperation between stakeholders" (8), and CSF30  
 484 "Comprehensive code and standard" (8). As shown in Section 3.3, the top four CSFs in the  
 485 significance list were CSF8 "Commitment of all project participants" (4.244), CSF28 "Mandatory

486 requirement" (4.23), CSF16 "Integrated design" (4.107), CSF5 "Cooperation between  
 487 stakeholders" (4.094), CSF25 "Adequate incentives Training" (4.023). Those top CSFs mentioned  
 488 above are presented in Table 7. This study found that only CSF5 was in both top lists, implying that  
 489 CSF5 appeared in previous studies frequently and had high significance in GBP. Although the  
 490 factors such as CSF2 and CSF22 were mentioned many times in previous studies, their significance  
 491 in GBP was not very high. According to the finding, a conclusion could be drawn that if the literature  
 492 review was only conducted through qualitative approaches, critical information would be omitted,  
 493 leading to inaccurate conclusions, which had no benefits to the GBP practice. This finding supports  
 494 the study of Hussein and Zayed [68], which demonstrated that the meta-analysis plays a vital role  
 495 in capturing the quantitative messages conveyed by previous studies.

496 **Table 7.** CSF ranking list in frequency and significance.

Rank	Frequency		Significance	
	Factor	Frequency	Factor	Mean
1	CSF2 Low cost of green buildings	12	CSF8 Commitment of all project participants	4.244
2	CSF22 Training	10	CSF28 mandatory requirement	4.233
3	CSF5 Cooperation between stakeholders	8	CSF16 Integrated design	4.107
4	CSF30 Comprehensive code and standard	8	CSF5 Cooperation between stakeholders	4.094

497 CSF8, "Commitment of all project participants," was the first one ranking in the list of  
 498 significance. This CSF was proposed in a number of previous studies, and its importance was



499 verified through several empirical research. For instance, a case study in Hong Kong demonstrated  
500 that 10 of 11 developers believed that their companies' commitments to sustainability were  
501 significant to their respective GB projects [69]. Besides, the structural equation modeling results in  
502 another study revealed that owners' commitment contributed to the delivery performance of GB  
503 projects [70]. This CSF represents the internal motivation of stakeholders in GB construction, which  
504 is a determinant in GB success.

505 As Section 3.3 has mentioned, CSF28 "*Mandatory requirements*" (2nd) and CSF25 "*Adequate*  
506 *incentives*" (5th) complement each other and take effect synergistically. They are effective measures  
507 for governments to intervene in the GB market, guiding the market to healthy and prospective  
508 approaches. The mandatory requirements provide GBP baselines and guarantee that GBP targets set  
509 by the government were accomplished successfully. For example, the Chinese Ministry of Housing  
510 and Urban-Rural Development issued the *Action Plan for Green Building Promotion* in 2020,  
511 stipulating that the construction area proportion of newly built GBs should reach 70% by the end of  
512 2022 [71]. This mandatory requirement from the Chinese central government gave local  
513 governments a clear target. To achieve the target, detailed plans were made by local governments.  
514 With respect to the incentives, expedited permits and density bonuses are considered attractive  
515 measures in GBP [69]. Other financial incentives, such as concluding fee deferral, fee reduction,  
516 and fee waiver, also take effect quickly [72].

517 GBs are the buildings that concentrate on environmental sustainability in the whole life-cycle,  
518 from siting to design, construction, operation, maintenance, and renovation [73]. The CSF16  
519 "*Integrated design*" represents the whole life-cycle thoughts in GB design. It considers all the  
520 following phases of buildings in the design and integrates design with technical approaches to

521 optimize the buildings, so it needs the interdisciplinary collaboration of all participants in the project  
522 [74]. It proves the importance of CSF5 "*Cooperation between stakeholders*," which is seen as a  
523 prerequisite of GB success [50].

#### 524 *4.2 Critical role analysis in GBP*

525       What is worth noting in the statistical results is the critical roles of stakeholders and  
526 governments in GBP. It also corresponds with previous studies. The research from Li and his  
527 colleagues has shown that government organizations have the most significant impact on the GB  
528 project [73]. However, for the CSF average importance, the stakeholder category (4.00) is higher  
529 than the government category (3.75) in this study. Although the calculation method of average  
530 importance neglected the weight of CSFs, it still makes sense. The perception of GBP patterns was  
531 gradually increasing along with the extensive GB research and practice. Previous research showed  
532 that the collaborative network of GB innovation has changed from the single driver—leading by  
533 government, to multiple drivers—the joint force from government and stakeholders [75], which was  
534 consistent with the findings in this study. The external stakeholders, including the government, lead  
535 to high risk in the GB project [76], so it requires more coordination between external stakeholders  
536 and internal stakeholders [77]. There is a lack of an effective participatory mechanism to get all the  
537 stakeholders involved in the GB decisions. Formulating a universal and effective participation  
538 framework is beneficial to enhancing the transparency of GB project and reducing the controversy  
539 between stakeholders, which also alleviates the government pressure of tackling environmental  
540 complaints from the public [73].

## 541 5. CONCLUSIONS

542 Along with the arising attention on sustainability in many industries, the GB construction trend  
543 is imperative worldwide. Several factors are vital as they could determine whether the GBP practice  
544 achieves success. This research provided a systematic review on the CSFs in GBP and conducted  
545 quantitative research on the factors through the meta-analysis. Twenty relevant studies were selected  
546 by following the PRISMA framework. Overall, forty CSFs were identified from previous studies.  
547 Moreover, the synthetical means were calculated through the meta-analysis, and nine of them were  
548 revised by the approach of Duval and Tweedie's Trim and Fill because of the publication bias.  
549 Furthermore, subgroup analysis and sensitivity analysis were performed to investigate the  
550 subgroups and the robustness of the results. The results show that the top 5 CSFs are "*Commitment*  
551 *of all project participants*," "*Mandatory requirements*," "*Integrated design*," "*Cooperation between*  
552 *stakeholders*," "*Adequate incentives*," respectively, revealing the vital roles of stakeholders and  
553 government in GBP. With regards to subgroup analysis, the difference in the subgroups of building  
554 types is more significant than it in other subgroups. Moreover, the factors with higher importance  
555 are different from the factors with higher frequency, proving the significance of conducting the  
556 meta-analysis.

557 This study contributes to the existing GB knowledge by identifying the CSFs in GBP with an  
558 innovative approach, and the findings in this research have practical implications for government  
559 and practitioners. First, CSFs have been identified with the meta-analysis through a systematic  
560 review on independent empirical studies. Different from using questionnaire and interviews to  
561 identify CSFs, the review with meta-analysis synthesizes previous studies in a more comprehensive  
562 approach because the sample size of meta-analysis is larger. Second, the findings also provide

563 references for governments to adopt appropriate incentives and policies to promote GBs. Although  
564 the actions from the government are proved to be effective, the government should pay more  
565 attention to raising stakeholders' enthusiasm in GB construction.

566 Although this study bridged the gap in previous research, a few limitations still existed.  
567 Although this study identified CSFs and provided more objective and precise findings, these  
568 identified CSFs may have internal relationships, which are invisible and may affect GB practice.  
569 This issue was not considered in this study. Therefore, future research could switch the attention to  
570 investigating the relationships between these CSFs.

571

#### 572 **Credit author statement**

573 Linyan Chen: Conceptualization, Methodology, Software, Writing-original draft; Albert P. C.  
574 Chan: Writing - review & editing, Supervision; Emmanuel K. Owusu: Methodology, Writing -  
575 review & editing; Amos Darko: Conceptualization, Writing - review & editing; Xin Gao: Writing -  
576 review; Supervision

577

#### 578 **Declaration of competing interest**

579 The authors declare that they have no known competing financial interests or personal  
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581

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590

591 **Appendix A. Supplementary data**

592 Table A1. Primary mean and adjusted mean by removing one study in sensitivity analysis.

ID	Mean	ID	Mean	ID	Mean	ID	Mean	ID	Mean	ID	Mean
<b>CSF1</b>	<b>3.898</b>	[3]	4.042	[19]	3.652	[19]	3.557	[3]	3.756	[10]	4.047
[1]	3.937	[4]	4.160	<b>CSF13</b>	<b>3.952</b>	<b>CSF21</b>	<b>3.823</b>	[4]	3.773	[12]	3.735
[2]	3.889	[5]	3.860	[1]	3.685	[7]	3.752	[5]	3.852	[18]	3.798
[5]	3.890	[7]	4.170	[2]	3.874	[8]	3.887	[13]	4.036	<b>CSF35</b>	<b>3.698</b>
[8]	3.967	[12]	3.990	[5]	4.296	[17]	3.833	[15]	3.853	[11]	3.761
[11]	3.881	[15]	3.820	<b>CSF14</b>	<b>3.974</b>	<b>CSF22</b>	<b>3.723</b>	[18]	3.880	[14]	3.721
[17]	3.840	<b>CSF6</b>	<b>3.702</b>	[1]	4.126	[5]	3.708	[19]	4.009	[18]	3.734
[18]	3.892	[1]	3.679	[2]	3.914	[7]	3.657	<b>CSF27</b>	<b>3.181</b>	[20]	3.566
<b>CSF2</b>	<b>3.786</b>	[2]	3.691	[5]	3.870	[8]	3.753	[8]	3.087	<b>CSF36</b>	<b>3.521</b>
[3]	3.757	[9]	3.700	<b>CSF15</b>	<b>3.690</b>	[9]	3.712	[11]	2.930	[8]	3.830
[6]	3.747	[10]	3.694	[1]	3.648	[10]	3.714	[13]	3.407	[10]	3.429
[8]	3.789	[11]	3.677	[5]	3.867	[11]	3.676	[14]	3.157	[11]	3.358
[9]	3.815	[15]	3.723	[12]	3.568	[14]	3.754	[19]	3.321	[19]	3.438
[10]	3.767	[19]	3.736	<b>CSF16</b>	<b>3.949</b>	[15]	3.713	<b>CSF28</b>	<b>4.233</b>	<b>CSF37</b>	<b>3.647</b>
[11]	3.839	<b>CSF7</b>	<b>3.979</b>	[3]	3.969	[18]	3.749	[3]	4.250	[8]	3.567
[12]	3.772	[1]	4.089	[4]	3.858	[19]	3.797	[4]	4.012	[10]	3.638
[14]	3.899	[2]	3.889	[14]	4.045	<b>CSF23</b>	<b>3.731</b>	[12]	4.432	[11]	3.649
[15]	3.754	[4]	3.884	[15]	3.924	[7]	3.649	<b>CSF29</b>	<b>3.663</b>	[13]	3.742
[17]	3.733	[5]	4.158	<b>CSF17</b>	<b>3.562</b>	[9]	3.701	[7]	3.533	[18]	3.654

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[18]	3.770	[7]	3.900	[1]	3.622	[11]	3.688	[10]	3.588	[19]	3.658
[19]	3.793	<b>CSF9</b>	<b>3.769</b>	[2]	3.625	[12]	3.745	[11]	3.474	[20]	3.604
<b>CSF3</b>	<b>3.418</b>	[1]	3.744	[5]	3.463	[17]	3.725	[19]	4.005	<b>CSF38</b>	<b>3.148</b>
[1]	3.368	[2]	3.692	[11]	3.540	[19]	3.867	<b>CSF30</b>	<b>3.640</b>	[15]	3.035
[2]	3.318	[7]	3.651	<b>CSF18</b>	<b>3.302</b>	<b>CSF24</b>	<b>3.312</b>	[5]	3.653	[18]	2.835
[10]	3.442	[11]	3.763	[4]	3.027	[10]	3.231	[10]	3.621	[19]	3.573
[14]	3.500	[12]	3.796	[10]	3.341	[18]	3.062	[11]	3.659	<b>CSF39</b>	<b>3.551</b>
[19]	3.463	[19]	3.968	[11]	3.396	[19]	3.626	[12]	3.625	[7]	3.246
<b>CSF4</b>	<b>3.813</b>	<b>CSF10</b>	<b>3.737</b>	[16]	3.282	<b>CSF25</b>	<b>4.023</b>	[14]	3.608	[13]	3.977
[3]	3.832	[5]	3.703	[19]	3.467	[3]	3.994	[15]	3.582	[20]	3.345
[4]	3.584	[7]	3.482	<b>CSF19</b>	<b>3.506</b>	[4]	3.921	[19]	3.762	<b>CSF40</b>	<b>3.571</b>
[10]	3.766	[19]	4.000	[1]	3.499	[11]	3.967	[20]	3.596	[4]	3.637
[15]	3.748	<b>CSF12</b>	<b>3.436</b>	[10]	3.519	[12]	4.002	<b>CSF31</b>	<b>3.810</b>	[10]	3.529
[19]	4.127	[1]	3.454	[11]	3.505	[14]	4.216	[7]	3.656	[11]	3.380
<b>CSF5</b>	<b>4.094</b>	[2]	3.365	[15]	3.524	[17]	3.958	[8]	4.029	[13]	3.725
[1]	4.220	[5]	3.387	[17]	3.474	[19]	4.118	[15]	3.741	[15]	3.566
[2]	4.420	[11]	3.326	[18]	3.461	<b>CSF26</b>	<b>3.882</b>	<b>CSF33</b>	<b>3.857</b>	[18]	3.589

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593 Note: [1]= Li et al., 2011 (J) (SGP) (G); [2]=Venkataraman and Cheng 2018 (J) (W) (G); [3]=  
594 Adabre and Chan 2019 (J) (W) (H); [4]= Oluleye et al., 2020 (J) (NG) (H); [5]=Sang and Yao 2019  
595 (J) (CHN) (H); [6]=Tang et al., 2020 (C) (HK) (G); [7]= Olawumi and Chan 2020 (J) (W) (G); [8]=  
596 Wong et al., 2021 (C) (MY) (G); [9]= Awaili et al., 2020 (J) (LY) (G); [10]= Nguyen et al., 2017  
597 (J) (VN) (G); [11]= Azeem et al., 2017 (J) (PK) (G); [12]= Deng et al., 2018 (J) (CHN) (G); [13]=

598 Li et al., 2019 (J) (NZ) (H); [14]= Ahn et al., 2013 (J) (USA) (G); [15]= Yang and Yang 2015 (J)  
599 (AUS) (H); [16]= Sahamir et al., 2019 (C) (MY) (HO); [17]= Agyekum et al., 2020 (J) (GH) (G);  
600 [18]= Wu et al., 2019 (J) (CHN) (G); [19]= Dalirazar and Sabzi 2020 (J) (SUN) (G); [20]= Nguyen  
601 et al., 2019 (C) (VN) (G).

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