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Examining Strategies to Manage Climate Risks of PPP Infrastructure Projects

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Abstract

Tackling climate change in the public-private partnership (PPP) infrastructure sector means radically transforming projects to be resilient against climate risks and free from excessive carbon emissions. PPP infrastructures such as transport, power plants, hospitals, schools and residential buildings experience more than 30% of global climate change risks. Therefore, this study aims at examining the climate risk management strategies in PPP infrastructure projects. The first step in conducting this research was to identify the strategies through a comprehensive literature review. The second step was data collection from 147 PPP stakeholders with a questionnaire. The third step was analysing the interrelationships between the strategies using a partial least square- structural equation model approach. The findings include green procurement, defined climate-resilient contract award criteria, identification of climate-conscious projects, feasible and contract management strategies. The results provide understanding of actionable measures to countermeasure climate risks, and it encourages PPP stakeholders to promote climate-friendly strategies. The results also serve as foundational information to investigate into climate change risk management strategies in PPP research.

Keywords: climate risks; carbon emission; climate change; decarbonisation; infrastructures; public-private partnership

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1. Introduction

In the past few decades, public-private partnerships (PPPs) have attained enviable spot in project delivery in every nation [1]. Atamanov, et al. [2] mentioned that 40-60% of public infrastructures in many countries have been delivered by PPP arrangements between public institutions and private financiers. Projects such as the hospital of University of Sunshine Coast (Australia), Enugu-Port Harcourt Road (Nigeria), Saglemi affordable public houses (Ghana) and Shenzhen light rail (China) are prime examples PPP infrastructures [3]. These infrastructures generate a significant amount of carbon emissions with negative implications on climate change. Akomea-Frimpong, et al. [4] revealed that 20-33% of carbon emissions are associated PPP infrastructures. Batra [5] broke down the constituents of the carbon emissions of PPP projects as embodied (23%) and operational (77%). The source of embodied emissions includes the use of oil, bitumen, natural gas and other fossil fuel materials to construct the projects [6]. The operational carbon emissions are generated from cooling, lighting, maintenance and heating of the infrastructures [7]. Che, et al. [8] and Ali, et al. [9] also argued that the negative effects of carbon emissions is extreme climate risks against PPP infrastructures.

The intensity of climate change on PPP infrastructures has been widely reported in literature and the mass media. For instance, in the early 2025 in Southern California (United States), about 16,000 homes and valuable public properties were burnt down from wildfires [10]. The consequences of this incident is the culmination of insurance crisis where parties to partnership contracts supporting mortgages and operations of the infrastructures (properties) experienced huge financial losses [11]. In the Guangdong Province of China, a section of the freeway (road network) was swept away from heavy downpour of rain including twenty (20) cars and forty-eight (48) people [12]. Three

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countries (Germany, Belgium and Netherlands) within Europe have recorded over hundred (100) people killed, and many critical infrastructures destroyed within the last two years from torrential rain which are linked to climate change [13]. Between 1995 and 2025, Brazil has reported more than nine thousand cases of infrastructure damage from climatic risks [14]. Sub-Sharan African countries continue to experience long delays in completion of infrastructures as result of unfavorable weather with existing infrastructure not built to withstand climate change [15].

To manage these climate risks, there is an ongoing effort in the global PPP infrastructure sector to decarbonise and incorporate sustainable climate actions in alignment with the Paris Climate Accord and Sustainable Development Goals, SDGs [9,16]. However, there is limited empirical information about this important issue on PPP infrastructures. Moreover, a thorough search and review of documents from databases such as Scopus, Web of Science and Google Scholar demonstrate insufficient investigations into climate risk strategies suitable for PPP infrastructure delivery model. For example, Giesekam, et al. [17] and Sweet [18] listed climate change measures for construction projects but the studies failed to delve into their appropriateness for specific project delivery models such as PPP infrastructures. Furthermore, reviewed project reports demonstrate lack of practice frameworks and policies aimed at ensuring PPP projects meet climate targets [19,20]. Liu, et al. [21] also mentioned that very few studies on this topic have focused on the construction, demolition and waste management stages of PPP projects not the entire lifecycle. Therefore, this article's purpose is the examinations of strategies on climate risk management of PPP infrastructure projects. The implementation of the findings from this study is expected to support the understanding and development of strategies to achieve long-term net-zero and climate goals in PPP infrastructures. The next sections include literature review, conceptual framework, method of study, discussion of the findings and conclusion.

2. Literature Review

2.1. PPP Infrastructures

Public-private partnership (PPP) is a collaborative project delivery model between governmental institutions and private entities aimed at building and managing infrastructure projects in long-term contracts [22]. Tang, et al. [23] argued that PPPs are advantageous than other project delivery models because it solicits financial and technical supports from private investors for public projects. Zou, et al. [24] mentioned the downside of PPPs as potential contractual disagreements and exploitations from private partners against the interests of the society The following are the key examples of the application of PPPs across the globe. In Asia and Oceania region, Beijing Transport Subways (China), Silk (Ahimsa) Spinning Mill (India), ITE college buildings (Singapore) and Newcastle community health facilities (Australia) were built by the PPP model (Devkar et al., 2020). European PPP projects include Klettwitz Renewable Wind Farm (Germany), Stade de France (France), Royal London Hospital and HS2 High speed-rail project (United Kingdom). The United States and Canada have California hydrogen vehicle fuel cell partnerships and Ontario's 407 Highways [25]. Lastly, Gautrain Rails (South Africa) and Rio Olympic Stadium (Brazil) are all examples of PPP projects [26].

2.2. Climate Risks

Since the industrial revolution with massive expansion of manufacturing industries, the atmospheric temperature has risen beyond a threshold of 1.5°C [27]. Maslin, et al. [28] showed 2024 as the warmest year with temperature of more than 0.08± 0.01 per centigrade (approximately 1.55°C). Fawzy, et al. [29] attributes this occurrence to the rising volumes of greenhouse gases released into the atmosphere from modern technological, anthropogenic and industrial activities. For instance, Shivanna [30] explained that the actions of manufacturers in heavily industrialised nations such as United States, United Kingdom, China, India, Canada and the European Union (EU) countries produce the largest amount of carbon emission. The outcomes of the industrial activities relating to crude oil, wood and cements are instrumental in building PPP infrastructure activities [7]. These embodied carbon materials for PPP projects generate carbon emissions which cause negative changes in the weather conditions with harmful effects on construction workers and users of the projects.

2.3. Strategies on Managing Climate Risks

Strategies to minimise climate disasters in PPP infrastructures is explained in the context of implementing both human and non-human actions to either reduce or completely avoid exposure of the projects to the extreme weather conditions [4]. There are three layers of the strategy. First, emission reduction measures at the infrastructure project level. This includes the adoption and implementation of emission reduction policies and practices [31]. Amin [32] suggested sustainable supply of construction materials, and provision of zero carbon competency skills and knowledge to manage the embodied carbon emissions of the projects. Sanada and Zappa [33] argued for the replacement of non-renewable energies and continuous improvement to mitigate operational emissions. The second and third layers of decarbonisation actions involves strong collaborations among PPP practitioners and the state to improve standards and legislations such as the 2023 Climate Change (Net Zero Future) law of the New South Wales (Australia) [34].

3. Hypothesis Development

Figure 1 illustrates five categories of strategies to address climate risks in PPP infrastructures within the lifecycle stages of PPP projects of PPIAF [35]. The constructs (latent variables) and measurement items (indicators) are Ahmadi, et al. [36] put forward that the starting point in addressing climate risks in PPP infrastructures is the identification of projects which are threaten by climate change. It includes the assessment of climate resilience level of existing infrastructures. Out of the assessment of the nature of the projects, Tipu, et al. [37] that the various climate risks could be identified with the carbon emitting measures. For new infrastructure projects, Nguyen, et al. [38] proposed the identification and selection of green and climate adapting projects. At this stage, climate targets should be set together with the scope of potential risks. Alqahtani, et al. [39] argued for the involvement project leadership who have experienced in selecting and executing projects to promote emission reduction measures.

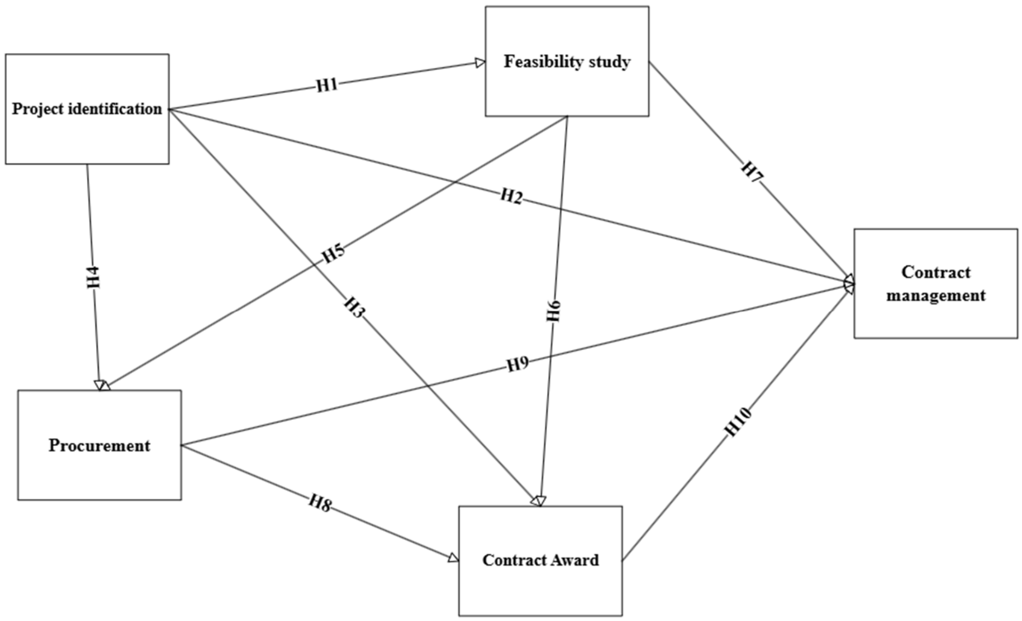

Figure 1. Conceptual model.

At this stage of the project, it is hypothesized that:

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H1. *project identification strategies influence feasibility study strategies*

H2. *project identification strategies influence contract management strategies*

H3. *project identification strategies influence awarding of contract strategies*

H4. *project identification strategies influence procurement strategies*

In the next stage of feasibility assessment, the goal is to ascertain the practicality and impacts of the proposed project identification strategies to manage climate change [16,31]. There are range of feasibility suitable to realise the effects of climate risks in PPP projects. These include thermal resilience analysis [40], carbon emission analysis [41], water analysis [42], biodiversity analysis [43], people (stakeholder) analysis [44]. Therefore, it is hypothesized that:

H5. *feasibility study strategies influence procurement strategies*

H6. *feasibility study strategies influence contract award strategies*

H7. *feasibility study strategies influence contract management strategies*

Sustainable procurements on PPP infrastructures are actionable drive to meet climate targets. Tipu, Mughal, Kundi, Nair and Thurasamy [37] analysed and explained the key climate-friendly materials from suppliers which promote green practices in the PPP projects. The study found positive relationships between green supply chain practices and climate adaptation of projects. Further, Tuffour, et al. [45] recounted the role of green procuring strategies in increasing the resilience of projects by 20%. Thus, it is hypothesized that:

H8. *procurement strategies influence contract award strategies*

H9. *procurement strategies influence contract management strategies*

Finally, Tian, et al. [46] Owusu (2024) highlighted that the contributions of awarding flexible and climate-induced contracts to successful management of PPP projects. Constant review of climate risks, setting of sound governance, insisting on including sustainable contract requirements shape the climate adaptation and mitigation strategies. Zhang, et al. [47] added that the information for partners and stakeholders should be improved together with upskilling of workers on climate change. Therefore, it is hypothesized that:

H10. *Contact award strategies influence contract management strategies.*

4. Methodology

This study is based on a quantitative research design with the following sub-sections:

4.1. Questionnaire

The questionnaire was data collection instrument, and it had two parts. The first part was the demographic profile of the respondents. The profile includes the positions held at work, country, project type, educational status and experiences on PPP projects. The second section of the questionnaire was assigned to climate risk strategies as presented in Table 1. The measurement items from Table 1 were measured on a Likert-Scale (LS) from 1 to 5 (strongly disagree to strongly agree). The measurement items were validated by experts on PPP projects [73]. The experts included seven senior lecturers in tertiary institutions and eight industry professionals. These experts have been involved in several PPP projects for many years. The drafted questionnaire was shared with them

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who confirmed the clarity, appropriateness and suggested modification of some of the measurement items.

Table 1. Strategies (variables) on climate risks of PPP projects.

Latent variables	Code	Indicator/measurement variables	References
Project identification strategies	PIS		
	PIS1	Set achievable climate risk targets	Akhtar, et al. [48]
	PIS2	Develop timelines on the actions to reduce carbon emissions	Almarri and Boussabaine [49]
	PIS3	Get leadership support to the decarbonisation roadmap	Ampratwum, et al. [50]
	PIS4	Define the performance assessment targets	Demirel, et al. [51]
	PIS5	Specify the scope of climate risks	Akomea-Frimpong, et al. [52]
Feasibility assessment strategies	FSS		
	FSS1	Carbon emission footprint assessment	Kim, et al. [53]
	FSS2	Retrofitting and redesign of infrastructures	Xiahou, et al. [54]
	FSS3	Compute the potential costs on each climate action	Mello and Ter-Minassian [55]
	FSS4	Assess the appropriate clean energy tools	Abden, et al. [56]
	FSS5	Determine the applicability of climate risk models	Perera, et al. [57]
	FSS6	Justify the benefits of measures against climate risks	Dafermos, et al. [58]
Procurement strategies	PRS		
	PRS1	Climate-friendly supply chains	Moradi Shahdadi, et al. [59]
	PRS2	Carbon neutral bidding measures	Hai, et al. [60]
	PRS3	Green procurement policies	Lupton, et al. [61]

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	PRS4	Strong partnership with suppliers	Akomea-Frimpong, Agyekum, Amoakwa, Babon-Ayeng and Pariafsai [4]
	PRS5	Circular procurement initiatives	Wang, Liu and Zhou [6]
	PRS6	Real-time procurement tracking systems	Hoeft, et al. [62]
Contract award strategies	CAS		
	CAS 1	Climate-conscious contracts	Nguyen, Hallo and Gunawan [38]
	CAS 2	Commitment to implement climate risk management practices	Casady, et al. [63]
	CAS 3	Contract clauses ensure meeting decarbonisation targets	Sundararajan and Suriyagoda [64]
	CAS 4	Incorporate sustainability requirements	Akomea-Frimpong, et al. [65]
	CAS 5	Select the lowest climate risk contract	Jiang, et al. [66]
Contract management strategies	CMS		
	CMS 1	Implement climate resilience and adaptation measures	Khahro, et al. [67]
	CMS 2	Utilise renewable energies for infrastructures	Akomea-Frimpong, et al. [68]
	CMS 3	Upskill teams towards net-zero project management	Li and Wang [69]
	CM4	Emission reduction monitoring systems	Jayasena, et al. [70]
	CM5	Review of contract risks	Feng, et al. [71]
	CM6	Establish climate-based governance structures	Arijeloye, et al. [72]

4.2. Respondents and Survey

Once the questionnaire was improved with the feedback from the experts, potential participants (respondents) were sampled through a mixture of purposive and snowball sampling techniques. First, participants were targeted purposely by PPP stakeholders. The search for the participants took place on LinkedIn where the profiles of potential respondents were searched and screened. Direct messages were sent to the targeted participants. In reply, 42 potential participants showed interest in the research. These 42 participants were asked to invite other stakeholders who qualified to be part of this research in a snowballing sampling approach. The total potential participants from these two exercises were 216. The questionnaire was shared with 216 participants via email. One hundred and

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forty-seven (147) responses were returned representing 68% rate of response. Comparing this response rate to 44% of Akomea-Frimpong, et al. [74] and 14% of Osei-Kyei, et al. [75], it is sufficiently representative for this study.

4.3. Analysing the Data

The statistical technique employed to analyse the collected data was the partial least squares structural equation modelling (PLS-SEM). The PLS-SEM was chosen over the covariance based (CB) SEM for three reasons. First, the PLS-SEM is suitable for a data set which is not normally distributed [76]. Second, the PLS-SEM is appropriate for a smaller sampled dataset [77]. Third, it is designed for easier interaction of multiple latent variables like the variables in Table 1 [78]. The software utilised for the PLS-SEM analysis is SmartPLS 4.

5. Results and Discussions

5.1. Profile of Respondents

Table 2 illustrates most of the respondents are project managers who are involved in building and managing the PPP infrastructures with architects, operators and financial consultants. The respondents hold first degrees who are knowledgeable in addition to 6-10 years working experiences on the subject. Most of the respondents are in India, Ghana and Nigeria and have worked on many PPP housing projects.

Table 2. Background information of respondents.

Category	Profile and number of respondents
Job position	Risk consultant (24), Project manager (45), Public regulator (18), Architect (31), Operator (29)
Education	Diploma (25), First degree (74), master's degree (38), Doctoral degree (10)
Experience	0 to 5 years (12), 6 to 10 years (94), more than 10 years (41)
Project type	Roads (33), Hospitals (24), Energy & electricity (37), Housing (53)
Country	Australia (7), India (34), Ghana (27), Nigeria (18), US (8), UK (6), Kenya (23), Canada (5), South Africa (9), China (10)

5.2. Analysis Using the PLS-SEM

5.2.1. The Measurement Model

The analysis of the measurement model aimed to determine the extent of relationships between the latent variables and the measurement items. The key indicators of this model include internal reliability (Cronbach Alpha, CA), composite reliability, CR) convergent validity (average variance explained, AVE) shown in Table 3. The discriminant validity is assessed by cross loadings, Fornell-Larcker criterion and heterotrait-monotrait (HTMT). Table 3 demonstrates that all the five key constructs (PIS, FSS, PRS, CAS and CMS) produced significant internal consistency above thresholds of CA (0.700), CR (0.700) and the convergent validity of AVE (0.500) [79]. In addition, the cross-loadings, the Fornell-Larcker criterion and HTMT as presented in Table 4 and 5 indicate the constricts are distinct from one another at the threshold of 0.85 or less [80]. These outcomes in Table 3 confirm the robustness of the validity and reliability of the measurement items of the study. Furthermore, keeping or dropping of some of the measurement items were assessed in accordance with established thresholds in literature. Generally, a stringent threshold of factor loading of 0.7 or more is acceptable to keep a measurement item for the PLS-SEM analysis [81,82]. Cheung, et al. [83], Wieland, et al. [84] and Hair, Risher, Sarstedt and Ringle [76] have recommended 0.4 factor loading coefficient or greater if the average variance explained (AVE) of the construct is greater than 0.5. Therefore, all the

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measurement items are kept except CAS 4 which was deleted because it recorded a factor loading of -0.147.

Table 3. The outcomes of the measurement model.

Constructs	Indicators	Factor loadings	CA	CR	AVE	VIF
PIS			0.851	0.857	0.635	
	PIS1	0.717				1.467
	PIS2	0.811				1.185
	PIS3	0.946				1.304
	PIS4	0.814				1.411
	PIS5	0.667				1.327
FSS			0.778	0.802	0.507	
	FSS1	0.681				1.890
	FSS2	0.641				1.375
	FSS3	0.646				1.436
	FSS4	0.626				1.499
	FSS5	0.786				1.772
	FSS6	0.721				1.790
PRS			0.805	0.816	0.518	
	PRS1	0.620				1.490
	PRS2	0.756				2.161
	PRS3	0.754				1.897
	PRS4	0.681				2.208
	PRS5	0.796				2.057
	PRS6	0.654				1.630
CAS			0.859	0.860	0.702	
	CAS1	0.835				2.014
	CAS2	0.826				1.937
	CAS3	0.865				2.256
	CAS5	0.825				1.971
CMS			0.845	0.852	0.576	
	CMS1	0.814				2.565
	CMS2	0.848				1.944
	CMS3	0.744				1.782
	CMS4	0.846				2.401
	CMS5	0.739				1.645
	CMS6	0.509				1.193

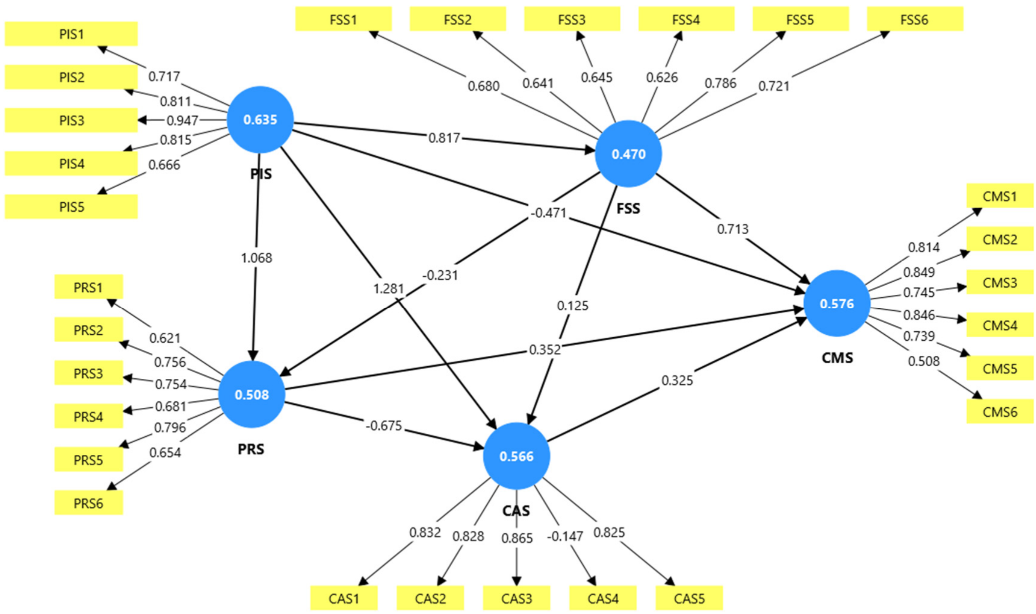

Figure 2. Analysis of the measurement model.

Table 4. Discriminant validity assessment with cross loadings.

	CAS	CMS	FSS	PIS	PRS
CAS1	0.435	0.552	0.620	0.634	0.393
CAS2	0.526	0.464	0.540	0.672	0.414
CAS3	0.665	0.619	0.644	0.684	0.477
CAS5	0.325	0.586	0.674	0.629	0.479
CMS1	0.480	0.214	0.611	0.468	0.428
CMS2	0.429	0.648	0.557	0.435	0.447
CMS3	0.463	0.544	0.530	0.415	0.377
CMS4	0.501	0.246	0.630	0.536	0.439
CMS5	0.106	0.439	0.670	0.600	0.386
CMS6	0.389	0.509	0.580	0.614	0.511
FSS1	0.416	0.301	0.681	0.478	0.323
FSS2	0.444	0.328	0.641	0.658	0.535
FSS3	0.350	0.427	0.646	0.501	0.362
FSS4	0.413	0.567	0.626	0.488	0.486
FSS5	0.173	0.476	0.286	0.661	0.544
FSS6	0.568	0.403	0.321	0.532	0.319
PIS1	0.585	0.477	0.178	0.317	0.512
PIS2	0.444	0.450	0.509	0.411	0.455
PIS3	0.746	0.604	0.638	0.146	0.111
PIS4	0.851	0.592	0.589	0.214	0.526
PIS5	0.445	0.556	0.632	0.667	0.494
PRS1	0.263	0.255	0.342	0.625	0.620
PRS2	0.444	0.428	0.441	0.303	0.556
PRS3	0.399	0.438	0.485	0.694	0.254
PRS4	0.463	0.457	0.499	0.544	0.581

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PRS5	0.445	0.491	0.552	0.661	0.296
PRS6	0.162	0.321	0.405	0.503	0.654

Table 5. Determining the discriminant validity with Fornell-Larcker criterion and HTMT.

Fornell-Larcker					
	CAS	CMS	FSS	PIS	PRS
CAS	0.838				
CMS	0.664	0.759			
FSS	0.74	0.793	0.686		
PIS	0.781	0.678	0.817	0.797	
PRS	0.526	0.568	0.641	0.879	0.713
Heterotrait-monotrait (HTMT)					
	CAS	CMS	FSS	PIS	PRS
CAS					
CMS	0.772				
FSS	0.765	0.619			
PIS	0.808	0.803	0.792		
PRS	0.613	0.687	0.783	0.762	

5.2.2. The Structural Model Assessment

With the assistance of the bootstrapping function within the SmartPLS 4, the structural model was analyzed with the focus on the interrelationships the five key latent variables in this study [85]. To ascertain the robustness of the model (Figure 1), the r-squared was used to determine the predictive power and goodness of fitness of the model. The results in Figure 3 indicate goodness of the model with more 0.5 coefficient, which is based on the variations in the relationships between the latent variables [86,87]. Furthermore, Table 6 presents the outcomes of the examination of the hypothesized relationships (H1-H10) specified in Section 3. Statistically, project identification strategies have significant positive effects in working with feasibility study strategies to address climate risks at a coefficient of 0.817 (HI). Project identification strategies (PIS) also influence procurement and contract award actionable measures on climate risks at 1.238 (H3) and 1.070 (H4) respectively. However, the relationship between PIS and contract management strategies was found to be insignificant (H2).

Table 6. Hypothesis testing.

Hypotheses	Path coefficient	T- Stat	P values	Decision
H1 (PIS -> FSS)	0.817	22.657	0.000	Supported
H2 (PIS -> CMS)	-0.426	1.725	0.085	Reject
H3 (PIS -> CAS)	1.238	6.157	0.000	Supported
H4 (PIS -> PRS)	1.070	16.121	0.000	Supported
H5 (FSS -> PRS)	-0.233	2.870	0.004	Supported
H6 (FSS -> CAS)	0.150	1.385	0.166	Reject
H7 (FSS -> CMS)	0.708	7.014	0.000	Supported
H8 (PRS -> CAS)	-0.659	4.611	0.000	Supported
H9 (PRS -> CMS)	0.331	1.844	0.065	Reject
H10 (CAS -> CMS)	0.299	1.892	0.059	Reject

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In the case of feasibility study strategies, the results demonstrate significant negative relationship between feasibility study and procurement strategies at (-0.233), H5 and positive impacts on contract management strategies at 0.708 (H7). But the results show insignificant effect of feasibility study on contract awards (H6). Procurement strategies were identified to have insignificant effects on contract management (H9) but pose negative effects on contract awards at -0.659 (H8). Lastly, Table 6 shows there is no unsubstantial impact of contract award on contract management (H10).

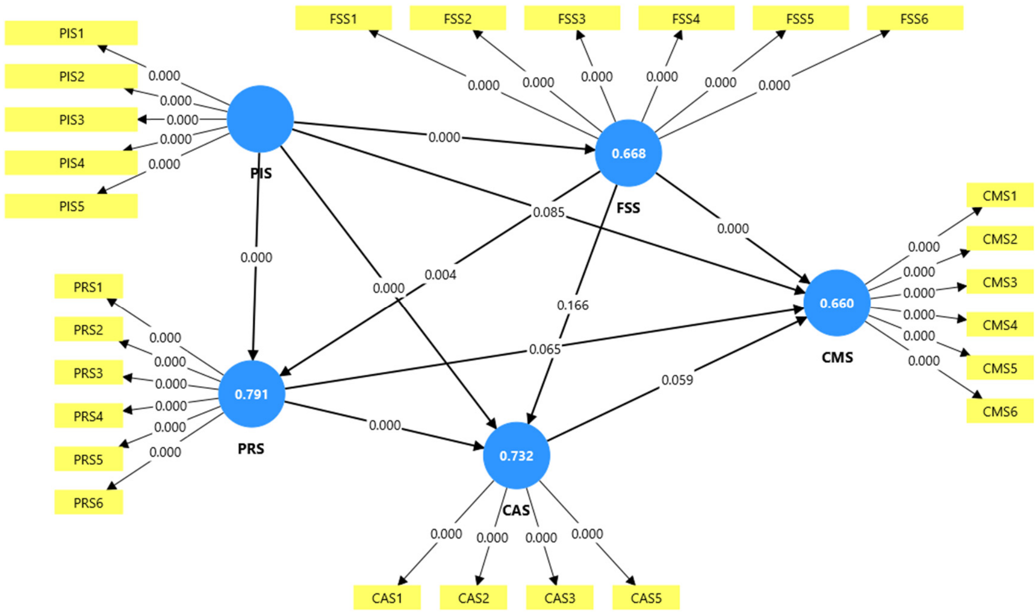

Figure 3. Final structural model.

6. Discussions

In accordance with the research objectives and hypotheses set in Section 1 and Section 3 of the study, the first hypothesis, H1 (Table 6) confirms that identifying appropriate climate resilient projects forms the foundation of better PPP project feasibility studies. This means, strategies to identify climate-friendly PPP infrastructure are essential in assessing the viability of PPP projects against climate crisis. Casady, Cepparulo and Giuriato [63] mentioned that these strategies prioritize the scope of the threats taking into count the extent and magnitude of potential climate risks at project proposal meetings. Lupton, Jiménez, Bayraktar and Tsagdis [61] expanded this with the empirical evidence of the identifying climate adaptation and resilience issues at the identification stage of the projects. With respect to H2, the results in Table 6 indicate rejection of the relationship between project identification and contract management. This means identifying the right climate-conscious projects may not have any influence on ensuring the management of the contracts respond adequately to climate change. This is opposed by Akomea-Frimpong, Agyekum, Amoakwa, Babon-Ayeng and Pariafsai [4] research findings that argue that project identification influence climate actions related to contract management of PPP projects. Moreover, climate action documents from OECD countries such as Australia, Canada and New Zealand government for instance recognizes the strong link between project identification, climate and contract management strategies of PPP infrastructures [38]. This outcome on H2 provides a viable avenue for exploration of further studies to ascertain the mishaps between the two climate risk measures. In the case of H3 and H4, project identification strategies were found to significantly influence contract award and procurement protocols. Increasingly, public projects which are executed within the PPP arrangements have seen climate requirements as a key prerequisite in awarding contracts [32]. Governments are taking note of bidding and procurements contractors who can accept and manage climate risks. Contractors who fail to incorporate and comply with climate-friendly procurement practices are likely to lose contracts

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or be fined. This scenario has been identified in United Kingdom (UK) where more than 30 government contractors were fined for lack of due diligence to safety and environmentally conscious practices towards reducing carbon emissions [88].

Table 6 also demonstrates that two (H5 and H7) out of the three hypotheses on feasibility studies on climate risks of PPP projects were found to be empirically significant. Sustainable feasibility studies influence procurement and contract management-based climate actions [5,30]. Wang, et al. [89] recounted that environmentally conscious feasible studies on mechanisms and systems such as the studies on heat pumps and carbon performance levels of infrastructures are important in assessing the carbon emission status of projects. The feasibility analysis also considers the social support systems available within emission neutral projects to assist community development and foster preservation of indigenous cultures. Lastly, through feasibility analysis, the financial viability of PPP projects is ascertain triggering the selection of sustainable green finance models. Despite these outcomes, H6 discounts the relevance of feasibility studies in awarding climate-friendly contracts in the PPP sector. This finding is contrary to existing studies such as Martimort and Straub [90] and Feng, et al. [91] who mentioned that feasibility is an integral part of awarding climate-sensitive contracts in infrastructure developments. Procurement strategies were found to impact contract award but not contract management with H8 and H9 (See Table 6). Akomea-Frimpong, Jin and Osei-Kyei [68] explained that contractors prioritize procuring recycling materials and construction inputs which produce the least emissions and financial risks. Sustainable packaging initiatives together with partnerships promote sustainable practices. Project managers adopt cleaner technologies and tracking systems in the supply chain for PPP sustainable development. Giesekam, Tingley and Cotton [17] argued for procuring tensile project materials and green facades for PPP housing and buildings are important to stand against climate change. Lastly, H10 was not supported statistically, and it was rejected where no significant connection was found to exist between awarding contracts and contract management towards climate risk management in PPP infrastructure.

7. Conclusions, Implications and Limitations

The consequences of climate change negatively affect the sustainability of PPP infrastructure projects. In this research, various strategies to mitigate the risks have been presented considering the principal stages of the PPP project lifecycle. The study solicited primary data from key PPP stakeholders through online survey of questionnaires which were distributed to respondents in different parts of the world. The main data analysis tool to analyze the relationships between the strategies was PLS-SEM analysis. The results from the data collected indicated that most of the participants were gathered from various continents of the world showing the diversity of the participants. Also, majority of the PPP projects which featured prominently in the responses of the participants are housing and transportation infrastructures. From the measurement model analysis of the PLS-SEM, twenty-seven strategies were retained and CAS4 (incorporate sustainability requirements) was removed because it recorded a factor loading of -0.147. The structural model exhibits significant relationships and gaps between principal strategies of procurement, feasibility study, contract management, project identification and contract award towards climate risk management.

This article has two main potential implications. First, for practice, the findings provide understanding of key project identification measures on climate change management for PPP infrastructures. It encourages setting the appropriate targets, development of realistic timelines and defines the areas of climate risk management. Climate risk indicators for performance assessment should be set with the assistance of project leadership supervision and evaluation. The results provide insights for feasibility assessment taking into consideration retrofitting, cost, carbon footprint and justification of assessing the state of climate resilience and adaptation position of PPP projects. The findings also provide information on strategies to improve procurement, contract award and management. Secondly, the study is important for enriching few theoretical information and research on strategies on climate change risks of PPP projects. The outcomes are essential for further investigations and development of models to support future studies. Despite these contributions to research and practices, the study has the following limitations. The dataset for this analysis is limited to 147 PPP stakeholders. Even though it was proven to be significant for this research, further studies must expand the participants to cover a wider coverage of responses. Next, the strategies analyzed in this study are linked to all forms of PPP infrastructures. It is suggested that further studies should embark on project-specific analysis using case studies of ongoing and completed projects. Lastly, it would be great if future studies assess the geographical differences of the strategies and delve into practice and policy frameworks in every country or region about the strategies.

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