Dear Editors and Reviewers:

We would like to thank iCCPMCE2024 for giving us an opportunity to revise our manuscript.

We appreciate very much the editor and reviewers' insightful comments and suggestions. These comments are very helpful for us to revise the paper. We have carried out revisions on the manuscript in accordance with the comments.

The revisions and responses were addressed point by point below.

Thank you for considering our manuscript.

Kind regards,

Authors

Response to Reviewer #1:

General comments

The abstract reads well and falls within the conference themes. Please submit the full paper by 31 May via the Easy Chair submission.

Response:

Thank you for your valuable comments and suggestions.

Response to Reviewer #2:

General comments

The technological alliances within the construction industry have always been a significant and intriguing topic. This study focuses on technological alliances in the construction industry, utilizing a Bayesian Belief Network model to construct a comprehensive evaluation framework from a knowledge perspective, incorporating environmental, economic, social, and relational dimensions. This study aligns well with the theme of the ICCPMCE 2024 conference. However, I have some suggestions for your consideration.

Comment 1:

Justification for Knowledge Perspective: Why did you choose to focus on technological alliances in construction firms from a knowledge perspective? What specific aspects of the construction industry influenced this choice? Construction is typically not considered a knowledge-intensive industry. Articles on technological alliances, especially those based on a knowledge perspective, often originate from the biopharmaceutical, renewable energy, and autonomous driving industries.

Response:

Thank you for your important advice. The decision to focus on technological alliances in the construction industry from a knowledge perspective stems from the evolving nature of the industry. While traditionally not seen as knowledge-intensive, the construction sector is undergoing significant transformation, driven by advancements in digital technologies, sustainable practices, and complex project management. These developments are increasingly making knowledge a critical asset. Technological alliances in this context are no longer just about physical resources or operational collaboration; they are deeply intertwined with knowledge exchange, innovation, and the integration of specialized expertise. We chose the knowledge perspective to capture these subtle yet impactful dynamics, which are crucial for fostering innovation and maintaining competitive advantage in the construction industry. Furthermore, the complexities of modern construction projects, such as the integration of Building Information Modeling (BIM), smart construction technologies, modular construction and sustainability practices, necessitate a focus on knowledge flows and collaborative learning within alliances.

We have incorporated an explanation of the importance of knowledge to the construction industry in the introduction section of the manuscript. “For the construction industry, which is undergoing a significant transformation, knowledge is increasingly emerging as a critical asset. Technologies such as Building Information Modeling (BIM), smart building technologies, modular construction, and green building practices all necessitate a focus on the flow of knowledge within alliances.”

Comment 2:

Comparison with Other Industries: What are the key differences between technological alliances in the construction industry and those in industries such as biopharmaceuticals, renewable energy, and autonomous driving? Highlighting these distinctions can provide a clearer rationale for the choice of perspective and model used in your study.

Response:

Thank you for your valuable advice. We recognize that industries like biopharmaceuticals, renewable energy, and autonomous driving are often highlighted for their knowledge-intensive alliances. However, the construction industry presents unique challenges and opportunities that differentiate it from these sectors. Unlike biopharmaceuticals or autonomous driving, where technological innovation is often driven by a few leading firms, the construction industry involves a diverse range of stakeholders, including contractors, architects, engineers, and suppliers, each contributing different types of knowledge. Moreover, the nature of technological alliances in construction is heavily project-based, meaning that knowledge exchange is often temporary but must be highly effective and context-specific. This contrasts with the more ongoing and product-focused collaborations seen in other industries.

Therefore, accessing and analyzing the perspectives of different stakeholders across various projects within the construction industry is crucial. This approach not only preserves the uniqueness of knowledge at the project level but also allows for a deeper understanding of how knowledge aggregation and management in the construction sector differ from those in other industries. By focusing on these distinctive aspects, our study aims to provide a nuanced understanding of how knowledge is managed and leveraged in construction alliances, offering valuable insights that might not be fully addressed by studies in other sectors. This understanding is essential for advancing both theoretical frameworks and practical applications in the realm of construction industry alliances.

We have revised the manuscript to explain the uniqueness of knowledge at the project level in building sector. “Additionally, unlike the knowledge-intensive alliances in industries like biopharmaceuticals, renewable energy, and autonomous driving, knowledge innovation in the construction industry’s technological alliances often occurs through the exchange among stakeholders at the project level. This makes the efficient capture and management of knowledge from various stakeholders especially important.”

Response to Reviewer #3:

General comments

The paper highlights the importance of technology alliances in the construction sector to tackle environmental issues and market competition. It views technology alliances as knowledge management activities crucial for sustainable growth. The study aims to create a comprehensive evaluation framework for CETA sustainability from a knowledge perspective, addressing the gap in existing research. The research employs expert interviews and questionnaires to gather data, focusing on middle and senior managers in the construction industry. A Bayesian Belief Network (BBN) is used to model and evaluate the sustainability, providing a probabilistic approach to handle uncertainties and complex causal relationships. The BBN model shows that environmental sustainability, primarily driven by green innovation, significantly impacts overall sustainability. The model reveals the positive effects of green innovation, cost feasibility, health and safety practices, and a shared vision on CETA sustainability. Conversely, a pessimistic scenario with failures in key areas drastically reduces sustainability.

Comment 1:

However, since the model heavily relies on expert interviews and questionnaires to gather data and build the Bayesian Belief Network. Therefore, this approach may introduce subjectivity and bias, as the accuracy of the model depends on the experts' knowledge and perspectives.

Response:

Thank you for your constructive feedback. We acknowledge that relying on expert interviews and questionnaires to build the Bayesian Belief Network (BBN) introduces the potential for subjectivity and bias. To mitigate this, we carefully selected a diverse group of experts from different sectors within the construction industry, ensuring a broad representation of knowledge and perspectives. Furthermore, we employed a rigorous validation process, including cross-validation techniques and sensitivity analysis, to test the robustness of the model against varying expert inputs. While some level of subjectivity is inherent in qualitative data collection, we believe that these measures help to minimize bias and enhance the model's accuracy. However, the conference paper template was only allowed to have 6 pages, so it was deleted. (Template FullPaper_iCCPMCE2024: "Full paper must be in the range of 4 to 6 pages long including tables, figures and list of references.").

Comment 2:

Moreover, The BBN can be complex and may require significant expertise to develop and interpret. Practitioners without a background in probabilistic graphical models might find it challenging to apply the model effectively. In addition, this study uses a relatively small sample size of 279 valid questionnaires, which may not be sufficient to capture the full diversity of opinions and experiences in the construction industry. A larger sample size could provide more robust and generalise results.

Response:

Thank you for your valuable comments. We agree that the BBN approach can be complex and may require specialized expertise to develop and interpret. To make the model more accessible, we have included detailed methodological explanations and step-by-step guidance on its application. Additionally, we recognize the limitation of our sample size of 279 valid questionnaires. Although this sample size provided valuable insights, we concur that a larger sample could offer more generalizable results. Future research could benefit from expanding the sample size to capture a wider range of opinions and experiences across the construction industry, which would further strengthen the findings.

Comment 3:

The grammar and syntax could be improved. Some sentences are long and complex, which can make them difficult to follow. Breaking them into shorter, more concise sentences can improve readability. Also, ensure correct use of punctuation marks to enhance clarity.

Response:

Thank you for your valuable comments. We appreciate your comments on the grammar and syntax. We will revise the manuscript to break down long and complex sentences into shorter, more concise ones, improving overall readability. We will also carefully review punctuation usage to ensure clarity and coherence throughout the text.

Leveraging a Bayesian Belief Network to model and evaluate the sustainability of construction enterprise technology alliances: Insights from a knowledge perspective

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Abstract

In an era of knowledge economy, most construction enterprises are adopting technology alliances to address increasingly serious environmental issues and severe market rivalry. Despite the rapid development of such alliances, there is a high failure rate, how to evaluate the sustainability of construction enterprises technology alliances (CETA) is relatively lacking. However, distinct from other alliances, technology alliances are dedicated to knowledge diffusion and innovation, it's more insightful from a knowledge perspective to analysis sustainability. Thus, based on knowledge viewpoint, this study builds a Bayesian Belief Network (BBN) model for assessing the sustainability of CETA, aiming to construct a scientific evaluation framework encompassed four dimensions, focusing on environmental, economic, social, and relational. The results indicate that: (1) Integrating of various theories, the constructed evaluation framework provide a comprehensive measure of the overall sustainability for CETA; (2) Knowledge spreads through construction activities, socio-economic events and alliance network building; (3) The environmental sustainability is most significant for CETA, and green innovation plays an effective transmission effect, driven by green motivation, to promote the growth of green benefits. Moreover, the shared vision and asset specificity are the most important in relational sustainability. Additionally, cost feasibility and health and safety play a crucial role in economic sustainability and social sustainability, respectively.

Keywords: Construction enterprise technology alliances (CETA), Sustainability, Bayesian Belief Network (BBN), Knowledge

1 INTRODUCTION

Construction enterprises are forming technology alliances is critical to addressing problems and ensuring long-term growth in the construction sector (Zainul Abidin, 2010). On the one hand, technology alliances are strategic partnerships between organizations that collaborate on technological cooperation and innovation. Since technology is considered a special form of knowledge, the creation of such alliances is viewed as a knowledge management activity. This activity transcends traditional market boundaries, enabling organizations to quickly respond to changes in both international and domestic markets, while meeting owners' needs for resources, technology, and the implementation of corporate green and sustainable strategies. (Yang et al., 2021). On the other hand, transforming, reorganizing and ultimately marketing the internal and external knowledge representing knowledge flow among various enterprises during technology alliances to achieve sustainability of different dimensions, such as environmental, economic and social (Mu et al., 2010). For the construction industry, which is undergoing a significant transformation, knowledge is increasingly emerging as a critical asset. Technologies such as Building Information Modeling (BIM), smart building technologies, modular construction, and green building practices all necessitate a focus on the flow of knowledge within alliances. Therefore, from the perspective of knowledge, constructing a scientific evaluation framework for assessing the sustainability of CETA is crucial for the sustainable growth of China's building sector and further promote worldwide carbon-neutral activity.

Previous research on sustainability focused on supply chain sustainability management and corporate sustainability strategies. Additionally, the dimensions they select for the evaluation of sustainable development primarily includes economic, environmental, and social dimensions. For instance, Govindan et al. (2013) assess sustainability performance of a supplier based on the "triple bottom line" of social, environmental, and economic benefits. However, in contrast to individual firm and supply chains, alliance partnerships can help improve overall organizational operational activities and value chain coordination and are critical in the study of corporate strategic alliances. Insights from a knowledge viewpoint, technology alliances means a relationship ensuring novelty and heterogeneity in the exposure of firms to knowledge and helping firms to expand their knowledge base and increase the opportunities for combining knowledge elements for technological innovation and sustainable development (Bornmann et al., 2018). Additionally, unlike the knowledge-intensive alliances in industries like biopharmaceuticals, renewable energy, and autonomous driving, knowledge innovation in the construction industry's technological alliances often occurs through the exchange among stakeholders at the project level. This makes the efficient capture and management of knowledge from various stakeholders especially important. Bayesian belief network (BBN) is a powerful tool for knowledge representation and reasoning under uncertainty, which can exclude numerous impossible network structures based on a priori expert knowledge, greatly improving the efficiency of structure learning algorithms (Yang and Xu, 2016). Given that the sustainability evaluation of CETA engages numerous indicators and complex causal relationships from expert knowledge base, it is more appropriate to use BBN method for sustainability measurement in this paper. Although existing studies have provided fragmented support for the study of sustainability evaluation, there is still a lack of appropriate and comprehensive dimensions to build a framework for assessing the sustainability of CETA using BBN approach.

To fill this gap, this study selects the conventional sustainable dimensions and incorporates the relational sustainability dimension into the study of CETA, aiming to aiming to construct a scientific evaluation framework encompassed four dimensions, focusing on environmental, economic, social, and relational. Meanwhile, sustainable development of technology alliances and innovation and diffusion of knowledge are interdependent and intertwined. Firstly, for environmental sustainability, green innovation has emerged as a powerful instrument for overcoming resource and advancing environmental sustainable development (Medeiros et al., 2014). The green innovation knowledge flow produces an evolution of products, services, processes, and management frameworks that can be used to address environmental issues (Rennings, 2000), reducing the production and transportation of toxic gases like CO2, CO, SOx, and NOx as well as the consumption of non-renewable energy sources like crude oil and coal (Ben Arfi et al., 2018). Secondly, economic sustainability is defined as the use of sustainable production and consumption techniques to promote economic development, profit, and successful governance while reducing negative consequences on the community's environmental and social components (El Amrani et al., 2021). Enterprises can better adapt to fast-changing markets and obtain competitive advantages only if they continue to introduce new products in a timely manner through knowledge diffusion and innovation (Sheth et al., 2010). Thirdly, social sustainability strikes a balance between society's and individuals' demands and nature's capabilities and economic well-being (Choi and Ng, 2011), and these elements intertwine to form a vast social network in which knowledge is integrated and diffused. Firms gain an innovative advantage by embedding themselves in networks that are rich in knowledge assets. Lastly, relational sustainability was defined as healthy and enduring alliance relationships that enable the flow, transfer, absorption, and re-creation of high-quality knowledge across organizations and contribute to alliance value and risk reduction, thereby improving alliance success and performance.

Against above analysis, insights from a knowledge perspective, this study aims to o construct a scientific evaluation framework encompassed four dimensions, focusing on environmental, economic, social, and relational. And this study attempts to answer the following questions:

1. In what way does knowledge contribute to the sustainable development of CETA?
2. How does the environmental and relational sustainability influencing mechanism of CETA operate based on knowledge perspective?

A study framework for assessing the sustainability of CETA based on knowledge viewpoint was identified illustrated in Fig. 1. synthesizing several theories, combining traditional sustainability systems and the strategic alliance evolution life cycle. A comprehensive literature research and expert interviews identified the sub-criteria, and knowledge. Furthermore, BBN structure were established through knowledge base and parameters learning. The results were deeply analyzed and discussed.

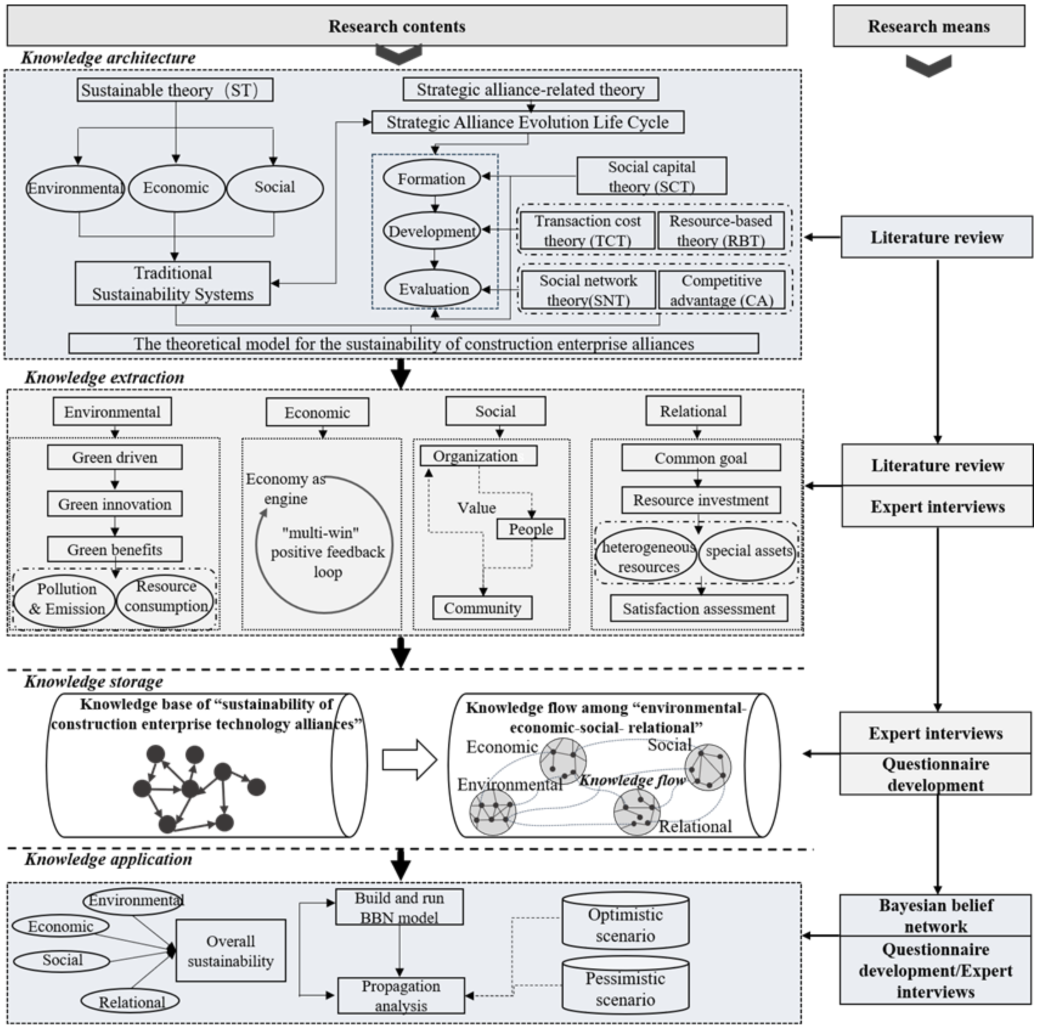

Fig.1. Study framework

2 METHODS

Expert Interviews and Questionnaire development have been often applicated by construction scholars owing to their scientific and practicality and feature (Xu et al., 2023). Expert interviews are primarily utilized for indicator identification, questionnaire feedback and indicator relationship measurement. Eight construction specialists with rich experience of sustainable development, green innovation, green buildings and low-carbon products were interviewed with two rounds. The questionnaire was divided into two parts. collecting the basic information with education, position, working years and so on is the first part, ensuring that they could accurately judge and answer these issues. The second part focused on assessing sustainability of CETA. For sake of clarity, we clearly explained the meaning and characteristics of all influencing factors in the questionnaires and evaluated the survey questions on a 5-point Likert-type scale, ranging from 1 (strongly disagree) to 5 (strongly agree). Furthermore, for the purpose of the subsequent study, we categorized the variables into two equally spaced states: [1, 3.4] for false and [3.4, 5] for true (Yang and Xu, 2016). A total of 360 questionnaires were distributed, and the research subjects were primarily middle and senior managers of construction enterprises who have experience in alliances or are in the process of forming alliances. With 279 valid questionnaires evaluated using the questionnaire screening item, resulting in a 77.5% valid return rate.

This paper used BBN analysis to model and evaluate the sustainability of CETA and presents a probabilistic graphical model to explain modeling uncertainty. Undeniably speaking, it can handle complete, noisy, partial, or missing information that is discrete or continuous or the beliefs of decision-makers and experts. Meanwhile, BBN is easier to derive probabilities for each variable due to the reduced burden of parameter acquisition from expert knowledge base, and the results of the model are self-explanatory. Furthermore, the scenario analysis approach is a tool for telling future tales and exploring uncertainty. It offers decision-maker potential future scenarios (Stewart et al., 2013). The joint probability distribution for a BBN is given by the following formula:

$$P(X) = \prod_{i=1}^{n} P(X_i|Pa(X_i)) \quad (1)$$

where X = X1, X2, …. Xn represents the set of random variables or features in the network and Pa(Xi) represents the parent(s) of Xi.

3 RESULTS

A Boolean variable consists of dichotomous responses and is expressed in the form of two states, True and False, to demonstrate the positive and negative outcomes. Fig. 2 shows the overall structure of the sustainable network of the CETA, and the values in this figure have all indicators without parent nodes as prior probabilities and the rest as posterior probabilities. It is worth our attention that the CETA of true = 65.5% is in the case that the distributions of true for the four dimensions of environment, economy, society, and relationship are 68.2%, 70.9%, 74.4%, and 61.8%, respectively.

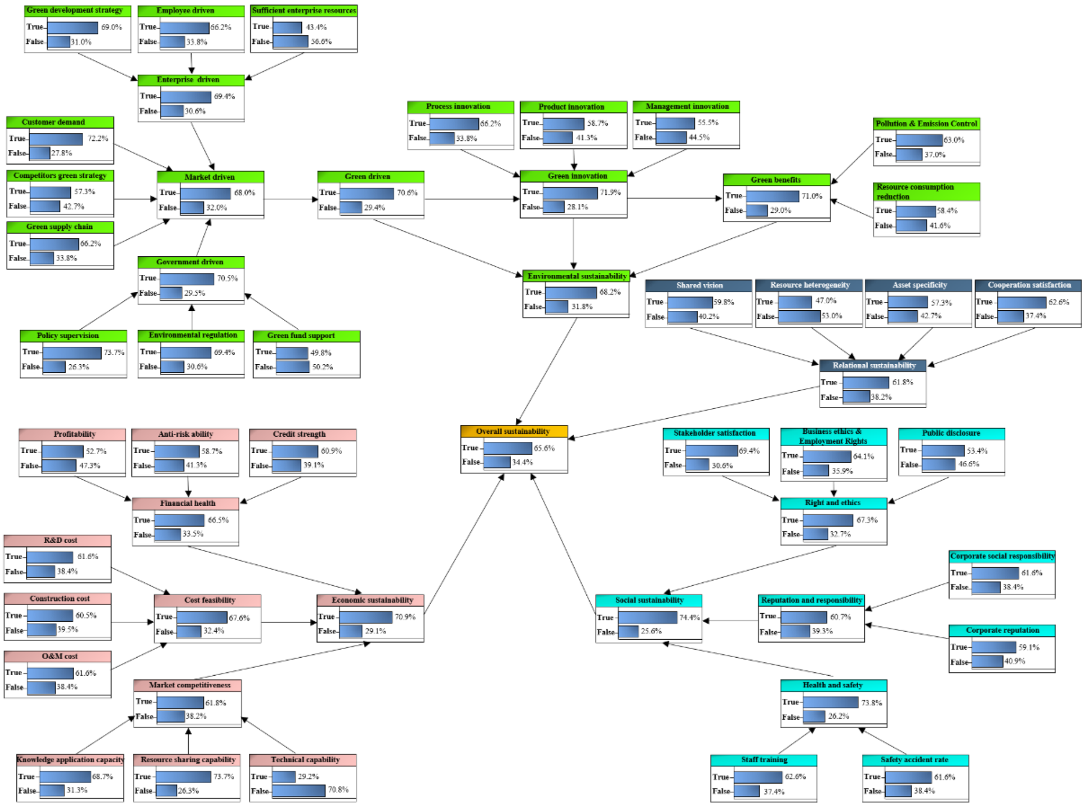

Fig. 2. BBN model for measuring sustainability of construction enterprise technology alliances

Forward propagation analysis of BBN refers to causal inference from cause to effect and reflects the expected support of grandparent nodes to descendants in the network. This study uses four dimensions: environmental, economic, social, and relational for forwarding propagation analysis. We designed two scenarios (1) optimistic and (2) pessimistic. In the case of the optimistic scenario, there are four assumptions: (i) green innovation adjusted to 100%, which means that the alliance's fully green-oriented drive and green benefits will be fully successful in minimizing negative environmental impacts from construction activities; (ii) cost feasibility set to 100%, which means securing its highest services in the most economical way to achieve higher economic sustainability; (iii) health and safety are set to 100%, which means that alliance organizations will maintain the best standards of health and safety practices; (iv) shared vision and asset specificity is set to 100%, the closest way to strive for a common goal to achieve higher relational sustainability. the overall sustainability increases from

65.6% to 86.3%, improving the standard sustainability level.

On the contrary, the pessimistic scenario simulates the failure of four observations: rights and ethics, green benefits, market competitiveness, and cooperation satisfaction. The results show that all these observations hurt the overall sustainability of the CETA, and subsequently, the overall sustainability decreases from 65.6% to 36.7%, ultimately reducing the standard sustainability level.

4 DISCUSSION AND CONCLUSIONS

For environmental sustainability, knowledge dissemination via construction activities. The operating mechanism aligned with TPB (Ajzen, 1991), which follows the research paradigm of "motivation-behavior-result". Starting with the motivation for alliances, three viewpoints of internal enterprise-driven, market-driven, and government-driven as drivers (Darko et al., 2018). Green innovation is considered of innovations in processes, products, and management that can lead organizations to achieve sustainable competitive advantage in ecologically efficient ways. Additionally, generating green environmental benefits, conservation of natural resources is the ultimate goal, as shown in Fig. 2.

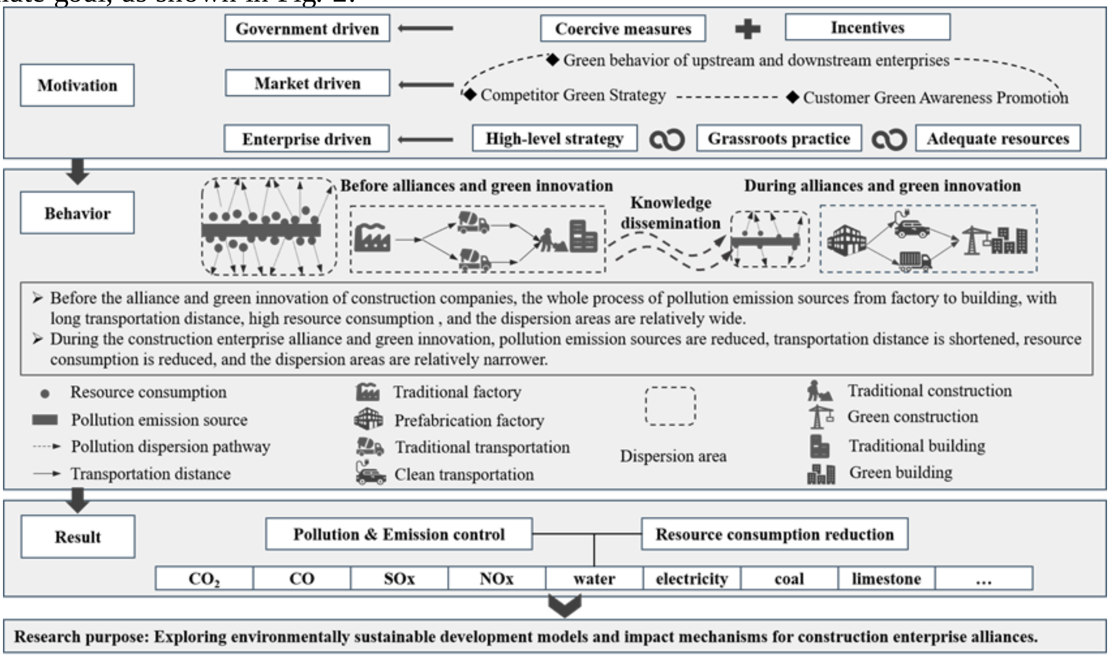

Fig. 2: Environment sustainable development model of construction enterprise technology alliances

For economic sustainability and social sustainability usually intertwined, knowledge spreads through rich socio-economic events (Munny et al., 2019). Economic sustainability can be recognized as the effort of societies and organizations to manage their own and the business network's impact on life on Earth and its ecosystems. Green economic development as an "engine of growth" that creates social sustainability in the pursuit of people's well-being, such as the economic benefits of alliance organizations in reducing various cost projects and the social aspects of employee safety and health. Moreover, knowledge exchange via alliance network building for relational sustainability. Shared vision reflects the "collective goals and aspirations of the organization's members" at the cognitive level. At the practical level, the partnership has invested in special assets such as equipment and infrastructure. Simultaneously, the variations of technical and relational resources, are the keyways that alliance resource heterogeneity is reflected. The more heterogeneous resources and the greater the variability of knowledge and information in the alliance, the more conducive it is for the enterprises to expand and create affluent value (Horbach et al., 2012). Alliance organizations learn from and trust each other after investing resources and committing to collaborate in the presence of uncertainty, resulting in alliance practices that are measured at the outcome assessment level through satisfaction with the collaboration to promote.

This work proposes a BBN model for evaluating the sustainability of CETA, improving strategic choices. Some conclusions are summarized below: (1) The sustainability of CETA are most affected by environmental sustainability. Green innovation is crucial, which plays a top-down role, driven by green factors that promote green benefits and lead organizations to achieve sustainable competitive advantages in an eco-effective way; (2) For economic and social sustainability, cost savings throughout the life cycle of a construction project and employee safety and training have the best incentive effectiveness; (3) Relational sustainability in alliances involves integrating various theories and three layers, and the shared vision and asset specificity are most significant.

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