A FAIR CARBON SHARING MECHANISM FOR CONSTRUCTION PROJECTS: AN FDI CASE STUDY IN VIETNAM

Nguyen Anh Duc
Ha Noi University of Civil Engineering

ARTICLE INFO

Received: 21/6/2024
Revised: 10/7/2024
Published: 27/11/2024

KEYWORDS

Carbon credits
Construction
Sharing model
Optimization
Vietnam

ABSTRACT

This paper presents a novel approach to optimizing carbon emissions in construction projects through a project-based assessment framework. Set against Vietnam's commitment to achieving net-zero emissions by 2050, the study highlights the increasing importance of sustainable practices in the construction industry. By focusing on the critical decisions made by the owner, designer, and contractor, the approach provides a detailed understanding of how these choices impact the project's carbon footprint, cost, and schedule. Using a genetic algorithm in a case study of a foreign direct investment (FDI) project in Vietnam, the study generated solutions for a multi-objective optimization problem. Extensive discussions with stakeholders and a representative from the Ministry of Resources and Environment confirmed the approach's clarity, fairness, and potential for broader application. This study offers a foundational framework for project-based carbon assessment and optimization, providing actionable insights for stakeholders and contributing to the achievement of sustainable development goals. However, further refinement and validation are needed to enhance its applicability in real-world settings, paving the way for integration into future regulatory frameworks. This work underscores the necessity for dynamic and adaptable models to manage carbon emissions effectively in the construction sector.

MỘT CƠ CHẾ CHIA SẺ CARBON CÔNG BẰNG TRONG CÁC DỰ ÁN XÂY DỰNG: NGHIÊN CỨU KIỂM CHỨNG TRONG MỘT DỰ ÁN FDI TẠI VIỆT NAM

Nguyễn Anh Đức
Trường Đại học Xây dựng Hà Nội

THÔNG TIN BÀI BÁO

Ngày nhận bài: 21/6/2024
Ngày hoàn thiện: 10/7/2024
Ngày đăng: 27/11/2024

TỪ KHÓA

Tín chỉ carbon
Xây dựng
Mô hình chia sẻ
Tối ưu
Việt Nam

TÓM TẮT

Bài báo nêu một cách tiếp cận mới để tối ưu hóa lượng khí thải carbon trong các dự án xây dựng, một hướng đi phù hợp với cam kết của Việt Nam đạt mức phát thải ròng bằng không vào năm 2050. Tập trung vào các quyết định quan trọng và phụ thuộc lẫn nhau của chủ đầu tư, tư vấn thiết kế và nhà thầu, phương pháp đề xuất của nghiên cứu cung cấp một hiểu biết tổng thể về cách các quyết định này tác động đến tổng lượng khí thải carbon, chi phí và tiến độ của dự án. Nghiên cứu này áp dụng thuật toán di truyền trong một dự án đầu tư trực tiếp nước ngoài (FDI) tại Việt Nam để giải quyết bài toán tối ưu đa mục tiêu. Kết quả được kiểm chứng thông qua thảo luận với các bên liên quan và đại diện của Bộ Tài nguyên và Môi trường, đã xác nhận tính công bằng và tiềm năng áp dụng rộng rãi của phương pháp đề xuất, và cung cấp một khuôn khổ nền tảng để đánh giá và tối ưu hóa lượng carbon của dự án dựa trên các ràng buộc khác. Khi được phát triển mở rộng tính linh hoạt và thích ứng, phương pháp đề xuất có thể được nâng cao khả năng ứng dụng thực tế, mở đường cho việc tích hợp vào các khung pháp lý trong tương lai.

DOI: https://doi.org/10.34238/tnu-jst.10647

Email: ducna@huce.edu.vn

1. Introduction

1.1. Global climate agreements and the path forward

The global response to climate change has been structured through significant international agreements, overseen by the United Nations Framework Convention on Climate Change (UNFCCC), established at the Rio Earth Summit in 1992 [1]. Key agreements under this framework include:

- The European Union Emissions Trading System (EU ETS), a cap-and-trade mechanism initiated in 2005, sets a limit on greenhouse gas emissions by installations, allowing companies to trade emission allowances [2], [3]. This system has effectively reduced emissions in the EU [4].
- The Kyoto Protocol, adopted in 1997, was the first international agreement committing parties to reduce greenhouse gas emissions [5].
- The Paris Agreement of 2015 aimed to limit global temperature rise this century to below 2 degrees Celsius, with efforts to limit the increase to 1.5 degrees Celsius [6].

Vietnam, like many developing countries, faces challenges in aligning with these global climate commitments [7], [8]. Integrating into the global carbon market landscape, driven by agreements like the Paris Agreement, compels Vietnam to adapt its policies and industries to comply with international standards [9]. This alignment is crucial for environmental sustainability, economic, and diplomatic relations [10].

1.2. Vietnam's commitment to climate action

Vietnam's climate commitments began with its participation in the Kyoto Protocol and continued with the Paris Agreement [11]. At COP26 in 2021, Vietnam pledged to achieve net zero emissions by 2050, marking a crucial step in its climate action efforts [12]. Despite limited resources and significant developmental challenges, Vietnam has demonstrated a commitment to global environmental standards.

The construction industry in Vietnam is a significant contributor to greenhouse gas emissions [13]. Rapid growth, driven by urbanization and infrastructure development, has led to increased energy consumption and carbon emissions [14]. As Vietnam continues to develop, mitigating the environmental impact of construction activities is paramount [15].

1.3. The role of foreign direct investment (FDI) in Vietnam's development

Foreign direct investment (FDI) plays a critical role in Vietnam's economic development [16]. Investors from developed regions, such as the EU, bring capital, advanced technologies, and sustainable practices. However, these investors are often bound by stringent carbon compliance regulations of their home countries, like the EU ETS, even when operating in countries with less stringent regulations like Vietnam [9]. This situation creates a unique challenge and opportunity for Vietnam to integrate more robust carbon management practices into its development framework [10].

1.4. The necessity of a comprehensive carbon accounting approach

The construction industry must adopt a comprehensive approach to carbon accounting to manage emissions effectively [14], [17]. This involves calculating the net total emissions of construction projects and attributing these emissions to the respective stakeholders based on their decisions [17]. Understanding individual contributions to total emissions enables stakeholders to make informed and responsible choices.

The proposed model uses project data and calculations from widely-used carbon calculators, like the Verified Carbon Standard (VCS) [18]. It incorporates game theory to analyze the interrelationships among stakeholders' choices, ensuring each decision is made with an awareness of its broader impact. The model is optimized using multi-objective optimization techniques to find the best balance between emissions, cost, and schedule.

1.5. Case study and validation

To demonstrate practical application, a case study on an FDI project in Vietnam, specifically a food production factory involving an EU investor, an EU design firm, and a Vietnamese contractor, was conducted. The results showed that stakeholders understood and agreed on the model's fairness, pledging to follow it as market, legal, and environmental conditions develop. To validate the model, a roundtable discussion with international experts in carbon markets, officials from the Vietnamese Ministry of Natural Resources and Environment, and project stakeholders was organized. Their feedback affirmed the model's robustness and applicability, providing a strong foundation for broader adoption in Vietnam and beyond.

2. Methodology

The methodology of this study involves several key steps designed to identify and optimize the carbon emissions of construction projects through a comprehensive and collaborative approach. Figure 1 depicts the entire methodology of the paper.

The first step is to identify major decisions made by stakeholders during construction by convening a panel of experts, including project managers, construction engineers, environmental consultants, and sustainability experts. The project's schedule is analyzed to break down construction phases, focusing on key decisions like material selection, technology adoption, construction methods, and energy usage. Workshops and interviews with stakeholders provide insights into decision points.

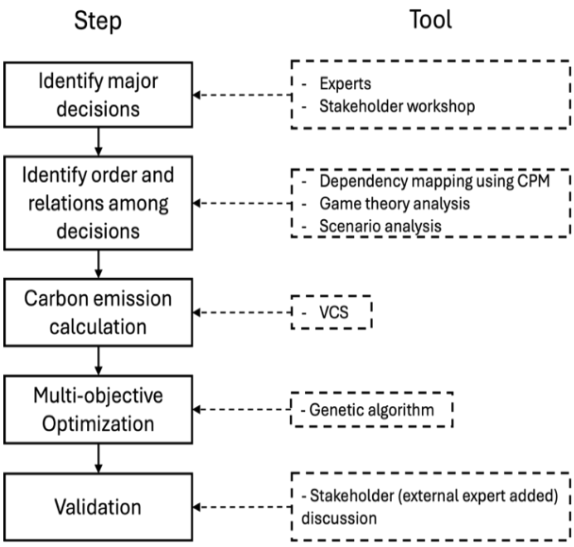

Figure 1. *The study's methodology*

Next, the interrelationships among these decisions are mapped using the Critical Path Method (CPM) [19] and game theory techniques:

- Dependency Mapping: Develop a dependency map to visualize decision relationships. CPM identifies the critical path, highlighting crucial tasks and decisions that impact the project's completion time.

- Game Theory and Scenario Analysis: Model strategic interactions between stakeholders, identifying Nash Equilibria where choices stabilize and creating payoff matrices to quantify benefits and costs of decision combinations [20]. Simulate various decision-making scenarios to understand potential outcomes and dependencies [21], identifying the most critical decisions with significant downstream effects.

With the major decisions and their relationships mapped, the next step is to calculate the carbon emissions corresponding to each decision. This involves using established techniques such as the VCS, which provides robust methodologies for quantifying emissions from various activities. Professionals familiar with these techniques (e.g., LEED consultants) perform the calculations, ensuring accuracy and reliability in the emission estimates. The calculated emissions are then presented to stakeholders in a collaborative discussion to reach a consensus on the emission values, ensuring transparency in the process.

To find the optimal set of decisions that minimize emissions, cost, and schedule, the study employs a genetic algorithm (GA) due to its advantage in solving multi-optimization problems [22]. This involves defining the objectives as minimizing total emissions, cost, and schedule, and treating each objective as a separate dimension in the optimization problem. The GA evolves a population of solutions over successive generations through processes such as selection, crossover, and mutation. Each solution is evaluated based on the defined objectives, and the fitness function considers the total emissions, cost, and schedule associated with each set of decisions. In general, a GA has seven steps:

1. Initialization: Create an initial population of candidate solutions randomly.
2. Evaluation: Assess the fitness of each candidate solution based on the defined objective functions.
3. Selection: Select a subset of the current population based on their fitness to be parents for the next generation.
4. Crossover: Combine pairs of parents to produce offspring (new candidate solutions) by exchanging portions of their structures.
5. Mutation: Introduce random variations to the offspring to maintain genetic diversity.
6. Replacement: Form a new population by replacing some of the old candidate solutions with new offspring.
7. Termination: Repeat the evaluation, selection, crossover, mutation, and replacement steps until a stopping criterion is met (e.g., a maximum number of generations or a satisfactory fitness level).

These steps can be summarized in the following pseudo-code:

```
Initialize population P with random candidate solutions
Evaluate fitness of each candidate in P
While stopping criterion not met:
   Select parent candidates from P
   Apply crossover to parent candidates to create offspring
   Apply mutation to offspring
   Evaluate fitness of each offspring
   Select candidates for the next generation from current population and offspring
End While
Return the best candidate solution(s) found
```

The algorithm generates a Pareto front, representing the set of non-dominated solutions that offer the best trade-offs between competing objectives [22]. The optimized results are validated through stakeholder discussions to ensure understanding and agreement on implications. Stakeholder meetings review optimization results and discuss impacts on emissions, cost, and schedule. External experts, including representatives from the Ministry of Resources and Environment, provide insights and validate the approach, helping generalize the model and seek policy-making benefits. This process aims to build consensus on preferred decisions, ensuring practical and acceptable optimized solutions.

The primary purpose of this paper is to gauge the viability of the proposed approach and its potential policy-making benefits. While identifying major decisions and VCS calculation steps are essential, the focus is on optimization and stakeholder discussion. The VCS calculation results mainly illustrate how the model can be applied in practice. By emphasizing optimization and stakeholder engagement, the study showcases a practical and scalable approach to carbon accounting in construction projects.

3. Results

3.1. Case study: results and validation

3.1.1. Project overview

The project involves a renowned EU food production company, subject to stringent carbon compliance rules. The company aims to reduce carbon emissions to lower export taxes to the EU and enhance its green image, crucial for competing in green manufacturing and gaining favor with the Vietnamese government. The main building is a one-story factory on an 11-hectare plot in northern Vietnam's industrial zone, designed to achieve LEED Platinum certification. The 10-month construction schedule and high contract cost reflect the commitment to sustainability and quality. The designer is a prestigious EU firm with LEED consultants, ensuring top environmental standards. The general contractor is a leading Vietnamese firm, ranked among the top 10 in the FDI sector according to the 2022 top 500 company list [23], bringing essential local expertise. All stakeholders are eager to participate in this study, recognizing that compliance with carbon market regulations is inevitable for all players in Vietnam, and they aim to be proactive leaders in this transition.

3.1.2. Decisions and carbon emission calculation

After the first three steps in the methodology, data were obtained from the stakeholders. The data included project schedules, cost estimates, carbon emissions, decision points, constraints, stakeholder input, and regulatory requirements. Here is a summary of the key decision points with their corresponding decision makers, dependencies, schedules, costs, and CO_2 emissions (Table 1).

Table 1. *Decision points with related factors (input for the optimization)*

Decision Category	Decision Maker	Option	Duration of related tasks (days)	Cost ($k)	CO_2 Emissions (tons)	Dependency
Material Selection	Owner	1a	30	100	300	None
		1b	40	150	200	None
		1c	50	200	100	None
Technology Adoption	Owner	2a	20	80	600	Material Selection
		2b	30	120	400	Material Selection
		2c	40	160	200	Material Selection
Construction Method	Contractor	3a	50	140	800	Technology Adoption
		3b	60	180	600	Technology Adoption
		3c	70	220	400	Technology Adoption
Energy Source	Designer	4a	10	50	600	None
		4b	20	70	400	None
		4c	30	90	200	None
Waste Management	Contractor	5a	20	30	400	None
		5b	30	60	250	None
		5c	40	90	100	None
Equipment Efficiency	Designer	6a	20	40	300	None
		6b	30	70	200	None
		6c	40	100	100	None

Table 1 outlines the simplified key decisions made by each stakeholder (owner, designer, contractor), their dependencies, and their impacts on the schedule, cost, and carbon emissions. Dependencies indicate how certain decisions influence subsequent decisions, which is critical for simulating various scenarios and optimizing the project for the best balance between emissions, cost, and schedule.

3.1.3. Optimization results

The optimization focused on balancing total emissions, cost, and schedule; these three dependent variables' distribution are shown in Figure 2. The distributions show that the range of the total emissions is between 2000-4000 (tCO2e), the total cost range is 620-1200 (units of cost), the schedule range is between 270 – 400 (days).

The stacked bar plot depicting the distribution of emissions by stakeholder provides a clear visualization of how emissions are divided among the owner, designer, and contractor (Figure 3).

From the plot, it is evident that the contractor's decisions contribute the most to overall emissions in many scenarios, often ranging between 800 to 1700 tons of CO_2. The owner's contributions typically range from 500 to 1400 tons, while the designer's contributions range from 600 to 1200 tons. This distribution, viewed more clearly in Figure 4, underscores the critical role each stakeholder plays in the project's total carbon footprint and highlights areas where targeted emission reduction strategies could be implemented.

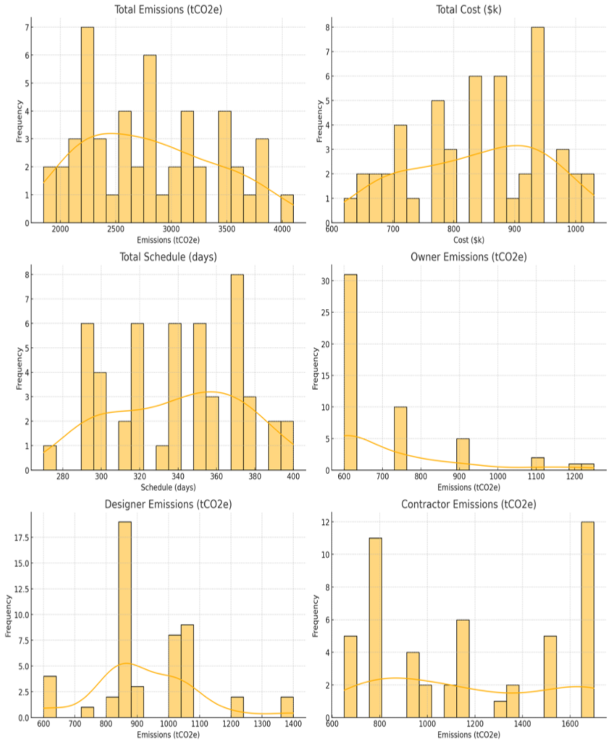

Figure 2. *Distribution of the dependent variables*

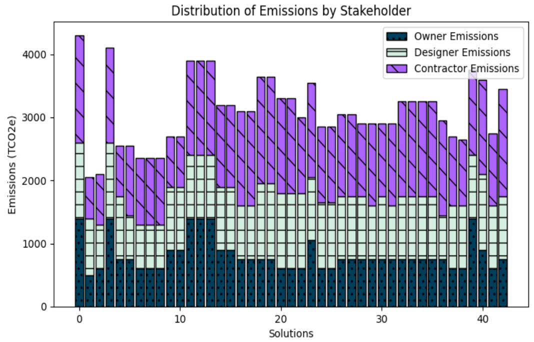

Figure 3. *Emission distribution among stakeholders*

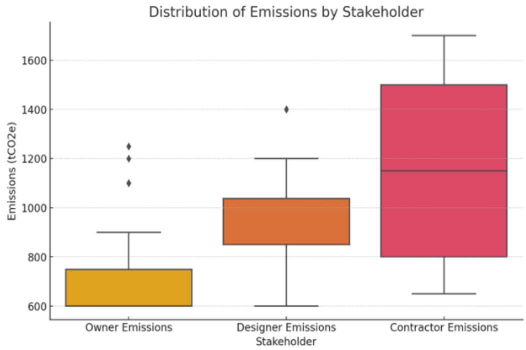

Figure 4. *The box-and-whisker distribution of emission plot*

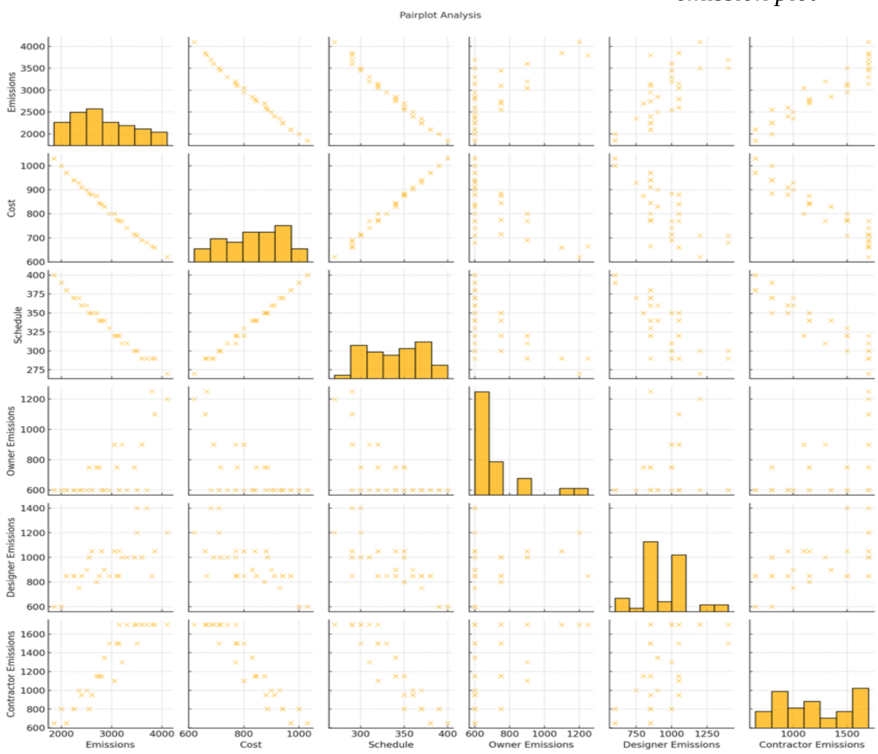

Figure 5. *Pairplot analysis between pairs of variables*

The pairplot analysis in Figure 5 provides a comprehensive view of the relationships between emissions, cost, schedule, and the contributions of each stakeholder. The scatter plots and histograms within the pairplot matrix help identify correlations and patterns. For instance, higher costs are often associated with lower emissions, indicating a trade-off between financial investment and environmental impact.

The pairplot also shows how different stakeholders' decisions correlate with overall project outcomes, emphasizing the need for coordinated decision-making to achieve optimal results. For example, a high-efficiency equipment choice by the designer (reducing emissions to 100 tons) could correlate with higher initial costs but offer long-term benefits.

The Pareto front plot, shown in Figure 6, of emissions versus cost with schedule as the color gradient illustrates the trade-offs between these three critical factors. Each point on the Pareto front represents a non-dominated solution, meaning that no other solution is better in all three objectives simultaneously.

The plot shows that some solutions offer low emissions (e.g., around 1500 tons) at high costs (e.g., $650k) and longer schedules (e.g., 250 days), while others achieve a balance between moderate emissions (e.g., 2000 tons), cost (e.g., $500k), and schedule (e.g., 200 days). This visualization helps stakeholders identify the most efficient solutions that meet their priorities and constraints, emphasizing the importance of multi-objective optimization in decision-making.

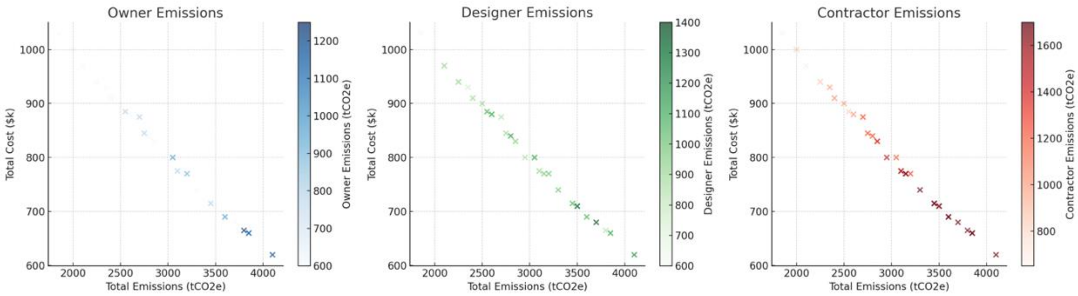

Figure 6. *The Pareto front*

The 3D Pareto front plot in Figure 7 provides a more detailed view of the trade-offs between emissions, cost, and schedule. By rotating the plot and examining it from different angles, stakeholders can better understand the complex interactions between these objectives.

The 3D visualization reveals clusters of solutions that offer similar trade-offs, helping stakeholders explore different decision scenarios and select the most suitable one based on their preferences and constraints. For example, one cluster might offer solutions with emissions around 1600 tons, costs around $550k, and schedules around 210 days, which could be optimal for balancing all three objectives.

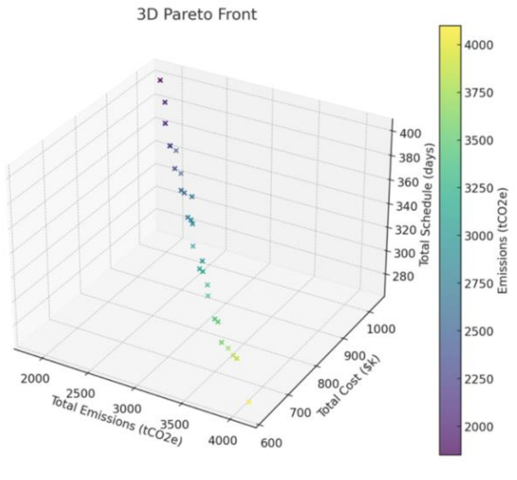

Figure 7. *The 3D Pareto front plot*

The results from these visualizations provide several key insights:

- Role of Contractors: The contractor's decisions have a significant impact on emissions, highlighting the need for targeted emission reduction strategies in construction methods and waste management.

- Stakeholder Contributions: Emissions are unevenly distributed among stakeholders, suggesting that each party needs to focus on their specific areas of influence to achieve overall emission reductions.
- Trade-offs: There are inherent trade-offs between emissions, cost, and schedule. Multi-objective optimization helps identify the best solutions that balance these factors according to stakeholder priorities.
- Decision Coordination: The pairplot analysis and 3D Pareto front emphasize the importance of coordinated decision-making among stakeholders to optimize project outcomes.
- Policy Implications: These findings support the need for policies that incentivize low-emission technologies and practices, and provide clear guidelines for emissions accounting and reduction in the construction industry.

3.1.4. Validation

The validation process aimed to ensure that the proposed approach is clear, understandable, and fair among stakeholders. It was crucial to verify that all stakeholders were comfortable with the results and methodology. Additionally, the validation aimed to assess whether this method could be applied on a larger scale in the future, especially when legal and policy requirements make such practices common. A series of discussions and interviews were conducted with the key stakeholders: the owner, the designer, the contractor and a representative from the Ministry of Resources and Environment. The validation process confirmed that the stakeholders found the approach clear, understandable, and fair. All stakeholders and external government agency recognized the significance of their decisions on the project's emissions and expressed confidence in the methodology's applicability for future projects, especially under forthcoming legal and policy frameworks.

3.2. Discussion

This study presents significant implications for policy-making and practical applications in the construction industry. One key insight is the potential for using high-scored project owners as benchmarks for future investments. Owners achieving better environmental performance through optimized decision-making may gain advantages such as preferential treatment in funding, subsidies, or expedited regulatory approvals, driving broader adoption of sustainable practices across the industry. Traditionally, companies' carbon allowances are assessed based on overall business activities, known as a business-based approach. This study introduces a project-based assessment, where carbon emissions are calculated and optimized for individual projects. Juxtaposing these approaches could provide a comprehensive framework for carbon management, similar to the T-account concept in accounting. This dual assessment method could serve as a robust carbon audit tool, ensuring project-based emissions align with overall business targets.

The study also underscores the importance of transparent and accountable decision-making among stakeholders. Clearly defining the carbon impacts of each decision equips stakeholders to make informed choices that balance environmental, financial, and scheduling considerations. This approach promotes a culture of responsibility and collaboration, crucial for achieving sustainable development goals.

Despite the promising findings, this study has limitations. First, the carbon calculation methods used were not independently validated. While expert consultants performed these calculations, there remains uncertainty about the accuracy and consistency of the emission estimates. Future research should involve rigorous validation processes to ensure the reliability of carbon data. Second, the optimization model for carbon sharing among stakeholders was static, not accounting for dynamic changes during the project's lifecycle, such as unexpected delays, material shortages, or regulatory changes. In real-world scenarios, stakeholders may need to adjust their decisions in response to emerging risks. Therefore, future models should incorporate dynamic optimization capabilities, allowing real-time adjustments and continuous improvement in response to changing conditions.

4. Conclusion

Vietnam's commitment to achieving net-zero emissions by 2050 and the growing importance of sustainable practices in the construction industry formed the backdrop for this study. Given the significance of FDI in Vietnam's development, particularly from regions like the EU with stringent carbon compliance rules, this study highlights the need for robust carbon accounting methodologies. This paper presented a comprehensive approach to optimizing carbon emissions in construction projects through a detailed project-based assessment. By focusing on the critical decisions made by the owner, designer, and contractor, the study provided insights into how these choices impact the overall carbon footprint, cost, and schedule of the project. The case study of a one-story factory project in northern Vietnam, involving a renowned EU food production company, illustrated the practical application of this approach. The data collected encompassed project schedules, cost estimates, carbon emissions, and stakeholder inputs, forming a robust foundation for the optimization model. The genetic algorithm successfully generated a Pareto front of non-dominated solutions, highlighting the trade-offs between emissions, cost, and schedule. Validation of the approach involved discussions with key stakeholders, including the owner, designer, and contractor. All stakeholders found the methodology clear, understandable, and fair. They expressed confidence in the applicability of this method for future projects, especially as legal and policy requirements evolve. Additionally, a representative from the Ministry of Resources and Environment provided positive feedback, recognizing the potential of this approach to inform future policies and enhance sustainable practices in the construction industry.

The study's implications are significant for policy-making and practical applications. High-scored project owners could gain advantages in future investments, and the dual assessment approach—business-based and project-based—offers a comprehensive framework for carbon management. However, the study also has limitations. The carbon calculation methods were not independently validated, and the optimization model was static, lacking dynamic capabilities to adapt to real-time changes during the project lifecycle. By fostering greater accountability and informed decision-making, this approach can significantly contribute to achieving sustainable development goals in the construction industry. Further refinement and validation are needed to enhance its accuracy and applicability in real-world settings, paving the way for its broader adoption and integration into future regulatory frameworks.

REFERENCES

[1] P. Sands, "The United Nations Framework Convention on Climate Change," *Review of European Community & International Environmental Law*, vol. 1, no. 3, 1992, doi: 10.1111/j.1467-9388.1992.tb00046.x.

[2] S. Kollenberg and L. Taschini, "The European Union Emissions Trading System and the Market Stability Reserve: Optimal Dynamic Supply Adjustment," *SSRN Electronic Journal*, 2015, doi: 10.2139/ssrn.2610213.

[3] C. Brink, H. R. J. Vollebergh, and E. van der Werf, "Carbon pricing in the EU: Evaluation of different EU ETS reform options," *Energy Policy*, vol. 97, 2016, doi: 10.1016/j.enpol.2016.07.023.

[4] A. D. Ellerman, C. Marcantonini, and A. Zaklan, "The european union emissions trading system: Ten years and counting," *Rev Environ Econ Policy*, vol. 10, no. 1, 2016, doi: 10.1093/reep/rev014.

[5] N. Maamoun, "The Kyoto protocol: Empirical evidence of a hidden success," *J. Environ. Econ. Manage*, vol. 95, 2019, doi: 10.1016/j.jeem.2019.04.001.

[6] S. Mor, R. Aneja, S. Madan, and M. Ghimire, "Kyoto Protocol and Paris Agreement: Transition from Bindings to Pledges – A Review," *Millennial Asia*, 2023, doi: 10.1177/09763996221141546.

[7] P. S. Chinowsky, A. E. Schweikert, N. Strzepek, and K. Strzepek, "Road infrastructure and climate change in Vietnam," *Sustainability (Switzerland)*, vol. 7, no. 5, 2015, doi: 10.3390/su7055452.

[8] D. T. Pham, H. V. Pham, and T. Q. Dang, "Renewable Energy Consumption, Energy Efficiency, Trade, Economic Development and FDI on Climate Change in Vietnam," *International Journal of Energy Economics and Policy*, vol. 13, no. 6, 2023, doi: 10.32479/ijeep.14571.
[9] A. Zimmer, M. Jakob, and J. C. Steckel, "What motivates Vietnam to strive for a low-carbon economy? - On the drivers of climate policy in a developing country," *Energy for Sustainable Development*, vol. 24, 2015, doi: 10.1016/j.esd.2014.10.003.
[10] T. X. P. Nguyen, "Green Economic Development: International Lessons for Vietnam," *International Journal of Advanced Research in Economics and Finance*, vol. 5, no. 2, pp. 201–212, 2023, doi: 10.55057/ijaref.2023.5.2.19.
[11] T. Fatima, M. S. Meo, F. V. Bekun, and T. O. Ibrahim, "The impact of energy consumption to environmental sustainability: an extension of foreign direct investment induce pollution in Vietnam," *International Journal of Energy Sector Management*, vol. 15, no. 6, 2021, doi: 10.1108/IJESM-01-2021-0001.
[12] T. K. Tran, C. Y. Lin, Y. T. Tu, N. T. Duong, T. T. D. Pham, and K. Shoh-Jakhon, "Nexus between natural resource depletion and rent and COP26 commitments: Empirical evidence from Vietnam," *Resources Policy*, vol. 85, 2023, doi: 10.1016/j.resourpol.2023.104024.
[13] D. Cheng *et al.*, "Projecting future carbon emissions from cement production in developing countries," *Nat. Commun.*, vol. 14, no. 1, 2023, doi: 10.1038/s41467-023-43660-x.
[14] L. Huang, G. Krigsvoll, F. Johansen, Y. Liu, and X. Zhang, "Carbon emission of global construction sector," *Renewable and Sustainable Energy Reviews*, vol. 81, 2018, doi: 10.1016/j.rser.2017.06.001.
[15] UN Environment, "2018 Global Status Report: Towards a Zero-emission, Efficient and Resilient Buildings and Construction Sector," 2018.
[16] Q. A. Do, Q. H. Le, T. D. Nguyen, V. A. Vu, L. H. Tran, and C. T. T. Nguyen, "Spatial Impact of Foreign Direct Investment on Poverty Reduction in Vietnam," *Journal of Risk and Financial Management*, vol. 14, no. 7, 2021, doi: 10.3390/jrfm14070292.
[17] P. Zhang, J. Hu, K. Zhao, H. Chen, S. Zhao, and W. Li, "Dynamics and Decoupling Analysis of Carbon Emissions from Construction Industry in China," *Buildings*, vol. 12, no. 3, 2022, doi: 10.3390/buildings12030257.
[18] A. von Avenarius, T. S. Devaraja, and R. Kiesel, "An empirical comparison of carbon credit projects under the clean development mechanism and verified carbon standard," *Climate*, vol. 6, no. 2, 2018, doi: 10.3390/cli6020049.
[19] J. M. Antill and R. W. Woodhead, *Critical Path Methods in Construction Practice*, Wiley-Interscience Publications, 1990.
[20] F. Hou, Y. Zhai, and X. You, "An equilibrium in group decision and its association with the Nash equilibrium in game theory," *Comput Ind Eng*, vol. 139, 2020, doi: 10.1016/j.cie.2019.106138.
[21] H. Li *et al.*, "A review of scenario analysis methods in planning and operation of modern power systems: Methodologies, applications, and challenges," *Electric Power Systems Research*, vol. 205, 2022, doi: 10.1016/j.epsr.2021.107722.
[22] S. Katoch, S. S. Chauhan, and V. Kumar, "A review on genetic algorithm: past, present, and future," *Multimed Tools Appl.*, vol. 80, no. 5, 2021, doi: 10.1007/s11042-020-10139-6.
[23] Vietnam Report JSC, "Top 500 company list," Hanoi, Vietnam, 2022.