

Article

Quantifying Embodied Carbon Impacts of Construction Disputes in Offshore Platform Building: A Tiered LCA Model

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Abstract

Construction disputes represent a significant yet overlooked source of embodied carbon in offshore platform projects. Existing LCA frameworks grounded in ISO 14040/14044 define system boundaries around planned resource consumption, but rarely account for incidental disruptions such as work stoppages and rework triggered by conflicts. This study introduces a novel tiered LCA model that quantifies dispute-induced embodied CO₂e surges during the construction phase by tracking three carbon sources: raw materials, machinery, and labor. Disputes are classified as mild (<1 week), moderate (1–12 weeks), and severe (>3 months) based on empirical literature, with escalating impacts from labor idleness to material degradation and comprehensive reconstruction. Applied to a South China Sea semi-submersible rig case study (35,000 t steel, ~395,000 t CO₂e baseline using provisional parameters comparable to the *Haiyang Shiyou 981*), results show that mild disputes add ~12 t CO₂e from idle labor, moderate ones ~1230 t CO₂e from partial rework (1% extra steel), and severe ones ~11,220 t CO₂e from full reconstruction (10% extra steel). The step-function escalation—driven by marine corrosion thresholds crossing from labor-only to material-intensive penalties—demonstrates that dispute carbon is a latent environmental cost. By bridging conflict management and LCA, the model validates the feasibility of embedding dispute-carbon tracking into BIM-LCA platforms to visualize and proactively mitigate delay-related emissions.

Keywords: offshore platform; BIM-LCA; embodied carbon; construction dispute



Academic Editor: Jun Cong Ge

Received: 6 July 2026

Revised: 29 July 2026

Accepted: 31 July 2026

Published: 3 August 2026

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1. Introduction

Economic development over the past few decades has significantly accelerated global urbanization, leading to massive construction activities that consume substantial energy and generate high carbon emissions [1,2]. The construction industry accounts for approximately one-third of global carbon emissions [3], prompting researchers to develop life cycle assessment (LCA)-based frameworks for evaluating emissions across building life cycles. Specifically, Pakdel et al. [4] compared embodied energy in traditional and contemporary Iranian construction systems but omitted labor carbon in their inventory. Zhang et al. [5] adopted a process-based LCA for China's building sector yet treated all delays as uniform schedule overruns without distinguishing dispute-induced idleness; Liang et al. [6] assessed a high-rise mass-timber building in the U.S. Pacific Northwest, but their boundary stopped at material gate-to-gate, excluding on-site machinery standby. Digital tools

have also emerged to monitor and manage these emissions more effectively. For instance, Sobhkhiz et al. [7] and Li et al. [8] advanced BIM-LCA integration for automated carbon tracking; however, their platforms assume continuous workflow and do not flag emission surges from unplanned stoppages. Panteli et al. [9] reviewed smart-building applications of BIM without addressing conflict scenarios. Furthermore, extensive research has focused on carbon emissions during the building construction phase, which includes sub-stages such as component production, material transportation, and on-site construction [10,11]. Key emission sources in this phase—raw materials, construction machinery, and labor—primarily contribute embodied carbon (i.e., the greenhouse-gas emissions associated with materials, equipment, and labor within modules A1–A5, expressed in CO₂ equivalent [12,13]), assessed via methods like carbon emission factors and energy analysis [14–16]. However, existing studies often define system boundaries narrowly, focusing on planned consumption of materials, energy, and labor [6,17,18], while overlooking incidental factors such as disputes that can cause delays and additional resource use. These gaps reveal a consistent pattern: existing LCA frameworks define system boundaries around planned consumption, leaving incidental factors such as disputes unquantified.

While the above studies have advanced carbon accounting for conventional land-based buildings, offshore platform construction presents distinct challenges that amplify the carbon consequences of project disruptions. Marine structures are exposed to high salinity, extreme humidity, and corrosive spray—environmental stressors that accelerate material degradation during idle periods. Consequently, delays caused by construction disputes in offshore settings can trigger qualitatively different carbon emissions compared to climate delays or force majeure events, because disputes often involve protracted litigation without protective protocols, whereas natural disasters typically invoke emergency preservation measures. This distinction justifies a separate modeling framework for “dispute carbon” rather than treating it as a subset of general delay emissions.

Disputes are common in construction projects [12,19], and can vary widely in severity and duration. While minor disputes may result in short delays attributable to labor emissions [20], more prolonged conflicts can lead to structural degradation, requiring material replacements, machinery reuse, and extensive rework (Designing Buildings Ltd., 2025, https://www.designingbuildings.co.uk/wiki/Degradation_of_construction_materials (accessed on 5 May 2026)).

Offshore platform construction is complex, often conducted in environments characterized by extreme temperatures, high humidity, high salinity, and high corrosion [21]. Tian et al. [22] pointed out that the harsh environment of the South China Sea, with its high temperature, high salinity and high humidity and strong radiation, has caused severe corrosion damage to structural materials and marine engineering equipment in the region. Wang et al. [23] pointed out that corrosion of steel in the marine environment has become a key hidden danger to its safe use. These studies support the assumption that extended work stoppages in the South China Sea cross a corrosion threshold beyond which protective coatings degrade and structural rework becomes necessary. If a platform is idle for extended periods due to disputes without temporary preservation protocols (e.g., protective coverings, cathodic protection maintenance), the constructed parts are highly vulnerable to corrosion and other quality degradation, forcing the consumption of additional raw materials and generating further carbon emissions. This study adopts a worst-case scenario assumption—consistent with the precautionary principle in LCA—wherein no protective measures are implemented during stoppages, thereby maximizing the estimated embodied carbon penalty. Therefore, minimizing disputes during offshore platform construction has a significant positive impact on reducing carbon emissions throughout the entire construction process.

To address this issue, this study systematically analyzes disputes of varying severity through a literature review and case analysis, and develops a rigorous assessment model to quantify their embodied carbon impacts during the construction phase of off-shore platforms. Within the system boundary of this study, “embodied carbon” refers to the greenhouse-gas emissions associated with raw material extraction and processing (A1–A3), transportation to site (A4), and on-site construction (A5), as defined in EN 15978 and the GHG Protocol Scope 3 framework [10]. We explicitly exclude downstream operational emissions (B6) and end-of-life processes (C1–C4) [24]. Collateral emissions from dispute-resolution activities—such as legal travel, third-party audits, or emergency logistical mobilizations—are also excluded because they occur outside the physical construction site boundary and lack standardized emission factors; their inclusion would introduce unquantifiable uncertainty without materially altering the comparative magnitude of direct construction-phase increments. The carbon accounting methodology aligns with the GHG Protocol Corporate Standard and ISO 14040/14044 [25], ensuring that Scope 1 (on-site diesel combustion), Scope 2 (purchased electricity), and relevant Scope 3 (material manufacturing and transport) emissions are consistently classified and reported. Based on empirical data, the model categorizes disputes into mild, moderate, and severe levels and estimates emissions using validated carbon factors. Based on empirical data, the model categorizes disputes into mild, moderate, and severe levels and estimates emissions using validated carbon factors. The temporal thresholds for dispute severity are empirically grounded in construction-management literature: Cakmak & Cakmak [26] found that 67% of mild conflicts were resolved within one week through negotiation; Abdul-Nabi & El-Adaway [27] reported that modular-construction disputes requiring contractual adjustments averaged 4–12 weeks; and Zanelidin [28] documented that severe disputes in UAE construction projects escalated to litigation after 3 months of unresolved suspension.

The remainder of this manuscript is organized as follows. Section 2 details the tiered assessment methodology, including dispute classification, system boundaries, and emission-factor equations. Section 3 applies the model to a South China Sea semi-submersible rig case study under three dispute scenarios. Section 4 discusses the emission escalation, limitations, and integration pathways with BIM-LCA platforms. Section 5 concludes with main findings, limitations, and future research directions.

2. Methodology

2.1. Research Scope

Generally speaking, “carbon emissions” include six major greenhouse gases: CO₂, CH₄, N₂O, HFCs, PFCs, and SF₆ [13,29]. This study uses “carbon dioxide equivalent” (CO₂e) as a reference for carbon emissions. The system boundary is limited to raw materials, construction machinery, and labor—the primary embodied carbon sources affected by disputes [12]. Only disputes impacting these sources are considered, excluding upstream production or downstream operations. Emissions are calculated using the carbon emission factor method, with factors derived from validated sources [12,13,30] to ensure accuracy and reproducibility.

All LCA calculations were formulated algorithmically in Microsoft Excel to ensure full transparency and reproducibility of the dispute-carbon model. While commercial software such as SimaPro desktop edition 10.5 or OpenLCA 2.6 is commonly used for product-level LCA, the deterministic spreadsheet approach was chosen here because (i) the model requires custom conditional logic tied to dispute severity tiers that are not pre-configured in standard LCA packages, and (ii) all emission factors and activity data are publicly documented, allowing for third-party verification without proprietary database subscriptions.

2.2. Evaluation Model

Construction disputes stem from stakeholder misalignments, triggered by factors such as contracts, designs, contractor actions, owner demands, or human errors [31]. To assess their embodied carbon impacts, this study proposes a tiered model categorizing disputes by severity: mild, moderate, and severe. Classifications are informed by a systematic literature review of 25 studies [26], and real-world cases (Appendix A), using quantitative criteria like delay duration and resolution complexity. Thresholds are empirically derived: mild (<1 week, negotiation-based), moderate (1–12 weeks, involving adjustments like team changes), and severe (> 3 months, often litigious with structural degradation).

Mild dispute: Mild disputes are defined in this study as events that minimally disrupt the construction process, allowing for resumption after a brief adjustment period of a few days. Such a dispute is relatively common and readily resolvable, with negligible effects on the project's quality but resulting in minor delays. Consequently, mild dispute primarily influences labor-related carbon emissions, specifically the additional embodied carbon attributable to project delays. This study names it "labor-carbon on hold."

For mild disputes, the model assumes that major construction machinery (cranes, welding rigs, generators) is shut down rather than idling in standby mode. This assumption is operationally justified because offshore platform construction involves discrete campaign phases; a brief negotiation-based stoppage typically occurs at phase transitions when equipment is already secured. Auxiliary systems (lighting, HVAC, galley) continue operating and are captured within the labor-carbon-on-hold estimate, which accounts for worker survival energy demand. Meanwhile, the model treats multiple consecutive minor stoppages as additive independent events, provided their total duration within any 30-day window does not exceed the moderate-dispute threshold (1 week). Concurrent disputes affecting different work fronts are calculated separately and summed, under the assumption that carbon sources (labor, machinery, materials) are not shared between fronts. If overlapping disputes share resources, the higher-severity tier governs to avoid double counting.

Moderate dispute: Moderate dispute is characterized by a more significant impact on the construction process, necessitating weeks to months for resolution and resumption of work. These disputes frequently entail extensive adjustments and negotiations, potentially leading to the replacement of labor teams and consequent impacts on incomplete work [27]. For example, if a construction team has completed part of a project but withdraws from the project due to an unresolved dispute, the previously completed work may deteriorate due to the downtime and need to be re-constructed after a replacement team is found. Thus, the assessment of moderate dispute must account for the supplementary embodied carbon associated with both raw materials and labor. The embodied carbon of labor also takes into account the embodied carbon generated by reconstruction on the basis of carbon on hold, so this study is named "labor—carbon on construction".

Severe dispute: Severe disputes are those that profoundly disrupt the construction process, often requiring months or even years to resolve and resume work. Such a dispute typically involves protracted litigation [20,27]. Extended project suspensions invariably lead to deterioration of completed building elements, necessitating substantial repair and reconstruction efforts upon resumption. For instance, certain projects in China have experienced suspensions exceeding one year before work could recommence. Accordingly, the evaluation of severe dispute must comprehensively incorporate the additional embodied carbon stemming from raw materials, construction machinery, and labor. It is worth noting that due to the long suspension of the project, this study believes that the original construction team is unlikely to continue to stick to it, and a new team needs to be reorganized after resuming work. Therefore, labor-carbon on hold does not need to be considered in this case.

The model does not account for emissions generated from transporting alternative construction teams to the site in the event of serious disputes, because personnel rotation can be achieved directly via regularly replenished supply ships that operate according to standard logistics cycles. Furthermore, quantifying such emissions requires proprietary personnel scheduling data, which is not publicly available to the case study platform.

Appendix A gives three real-life examples of disputes in news or cases. Table 1 introduces the dispute classifications in this study and their corresponding characteristics.

Table 1. Three types of disputes and their characteristics.

Features	Dispute Types	Dispute		
		Mild	Moderate	Severe
Delay		<1 week	1 to 12 weeks	>3 months
Embodied carbon sources		Labor—carbon on hold	Labor—carbon on construction	Labor—carbon on construction
Typical cases		Any factors	Raw material Engineering team replacement	Raw material Machinery Broken capital chain

2.3. Estimation Method

The carbon emission factor method is applied, with equations specified for each source. For raw materials:

$$CE_{\text{mat}} = \sum_{i=1}^n (Q_i \times EF_i) \quad (1)$$

where CE_{mat} = material emissions (kgCO₂e), Q_i = quantity of material i (units), EF_i = emission factor (kgCO₂e/unit) from Table 2.

Table 2. The carbon emission factors of building materials [13,30].

Serial Number	Building Material	Unit	Carbon Emission Factor (kg CO ₂ /Unit)	Serial Number	Building Material	Unit	Carbon Emission Factor (kg CO ₂ /Unit)
1	Aluminum	t	1020.00	6	Broken bridge aluminum alloy window (30% recycled aluminum)	m ²	194.00
2*	High-strength steel	t	2200.00	7	Cement 32.5	m ³	820.00
3	Medium and small profile	t	959.90	8	C20 concrete	m ³	250.00
4	Steel bar and steel wire	t	2670.00	9	C25 concrete	m ³	267.70
5	Gravel	t	3.00	10	Waterproof roll	m ²	2.00

*: Data are from Taiwan [32].

For machinery:

$$CE_{\text{mach}} = \sum_{j=1}^m (E_j \times EF_j) \quad (2)$$

where CE_{mach} = machinery emissions, E_j = energy use of machine j (e.g., fuel kg), EF_j = fuel factor (kgCO₂e/kg) from Table 3.

Table 3. Carbon emissions from fuel [13,30].

Fuel	Gas (kg)			Diesel (kg)		
	Greenhouse Gas	Production and Transport	Subtotal (kgCO ₂ /kg)	Production and Transport	Construction	Subtotal (kgCO ₂ /kg)
CO ₂		4.81×10^{-1}	2.907	3.75×10^{-1}	3.097	
Methane		2.20×10^{-2}	4.31×10^{-5}	2.05×10^{-2}	4.27×10^{-5}	3.49
Nitrogen dioxide		8.68×10^{-6}	8.61×10^{-6}	7.40×10^{-6}	8.53×10^{-6}	

For labor, an intensity-graded method is used [12]:

$$CE_{\text{lab}} = \sum_{k=1}^p (N_k \times D \times LF_k) \quad (3)$$

where N_k = workers at level k , D = days, LF_k = daily factor ($\text{kgCO}_2\text{e/person-day}$): light (I: 6.61), medium (II: 8.05), heavy (III: 9.31), based on metabolic and per capita data [12].

Total dispute emissions:

$$CE_{\text{dis}} = CE_{\text{mat}} + CE_{\text{mach}} + CE_{\text{lab}} \quad (4)$$

2.4. Uncertainty and Sensitivity Considerations

The proposed model is deterministic; all outputs are point estimates derived from fixed input parameters. Future users are encouraged to address statistical variability through Monte Carlo simulation, treating key assumptions (steel replacement ratios, diesel increments, corrosion rates, labor intensity distributions) as triangular or uniform probability distributions. A preliminary one-at-a-time sensitivity analysis (detailed in Section 4) indicates that the severe-dispute total is most sensitive to the steel replacement ratio ($\pm 10\%$ change in steel input produces $\pm 9.8\%$ change in total dispute carbon), followed by diesel consumption ($\pm 1\%$ change produces $\pm 0.3\%$ change), and least sensitive to labor allocation ($\pm 10\%$ change produces $< \pm 0.1\%$ change).

3. Case Study

Based on three dispute scenarios, this study uses a proposed offshore platform in the South China Sea as an analysis case, designs specific embodied carbon impacts, and calculates the corresponding additional embodied carbon increments.

3.1. Case Introduction

In this research, we examine a deepwater semi-submersible drilling rig, scheduled for imminent deployment in the South China Sea, as our illustrative case. As construction is ongoing, the parameters outlined below are provisional and subject to revision; they serve here merely as a baseline for computational analysis. The rig spans 120 m in length, 95 m in width, and 145 m in height, offering roughly 8000 square meters of deck space. It supports operations to depths of up to 3500 m and drilling depths of up to 13,000 m. Weighing about 35,000 tons with a full-load displacement of approximately 65,000 tons, it features a DP3+ dynamic positioning system and 10 thrusters rated at 4500 kilowatts each, capable of withstanding a 17-level typhoon. Constructed from approximately 35,000 tons of high-strength marine steel, the platform incorporates a dual-derrick arrangement and an advanced intelligent drilling control system, with accommodations for up to 180 crew members. It is destined for the exploration and development of ultra-deepwater oil and gas fields in the South China Sea. Overall, its technical specifications and operational profile align closely with those of the “Haiyang Shiyu 981,” which began service in 2012. Figure 1 shows an actual image of this reference platform.



Figure 1. “Haiyang Shiyu 981”.

Estimating carbon emissions during the construction phase of this project is not the primary focus of this study. Therefore, a more detailed assessment framework and parameters (including energy consumption, worker shifts, and clean energy use) are provided in Appendix B. Section 4 directly selects the required data to estimate the embodied carbon emissions associated with the disputes.

3.2. Mild Dispute

According to data in Appendix B, the offshore platform is scheduled to be constructed over a two-year construction period (730 days), requiring a total of 180 workers. This study assumes that mild disputes each year result in a 10-day work stoppage, during which workers' carbon emissions are calculated as light labor. It should be noted that the 10 days refers to the cumulative effect of multiple mild disputes occurring within a year, resulting in 10 days of stoppage, not the consumption of 10 days by a single dispute. The additional carbon emissions during the construction phase are:

$$180 \times 6.61 \times 10 \times 2 = 23,796 \text{ kgCO}_2\text{e} \text{ (23.80 t CO}_2\text{e)} \quad (5)$$

3.3. Moderate Dispute

Under the medium competition scenario, this study assumes that all underwater construction and some above-water constructions are completed. However, exposure to high ocean humidity and salinity degrades high-strength steel components, requiring reconstruction. This study assumes an additional 1% of high-strength steel consumption, which results in an additional 1.1% increase in diesel consumption. The 1% steel consumption figure (and the 10% below) is for reference only. The core of this study is a research and development assessment framework, not a precise calculation of the carbon emissions from a dispute for a specific project. If subsequent projects require calculations, the actual values resulting from the dispute can be used to evaluate the emissions within our provided framework. For moderate disputes, as steel consumption increases, so will diesel consumption. Furthermore, the additional diesel used to sustain workers' daily needs during the extended construction period must be considered. Therefore, this study assumes an additional steel consumption of $a\%$, corresponding to an additional diesel consumption of $1.1a\%$ (construction fuel consumption $a\%$ + additional living fuel consumption $10\% \times a\%$). Thus, 1% additional steel consumption leads to 1.1% additional diesel consumption. In addition, based on the above estimated data, an additional 1% of the workload was added, which in turn increased the working time by 1%, rounding 7.3 days to 8 days.

Consequently, the medium competition scenario results in additional embodied carbon in raw materials, increased energy consumption by machinery, longer worker waiting times, and extended construction times. Tables 2 and 3 list the carbon emission factors for various raw materials in the project, and Table 4 estimates the additional embodied carbon under the medium competition scenario.

Table 4. Estimation table in the moderate dispute.

Carbon Source	Carbon Emission Factor (kgCO ₂ /Unit)	Consumption	Carbon Emission (tCO ₂)
High-strength steel	2200.00	350 t	770.00
Machine	3.49	98,287.2 kg	343.02
Labor—carbon on hold	6.61	180 workers, 90 days	107.08
	6.61	Level I: 126 workers, 8 days	6.67
Labor—carbon on construction	8.05	Level II: 36 workers, 8 days	2.32
	9.31	Level III: 18 workers, 8 days	1.34
		Total:	1230.43

3.4. Severe Dispute

In the severe dispute scenario, this study assumes that construction on the project's above-water portion is suspended for two years due to the owner's funding shortage. During this period, the original construction team will leave the project to pursue other projects. Upon resumption, the newly assembled construction team will have the same number of members as the original. However, due to prolonged exposure to wind and rain, most of the above-water portion will be severely damaged and require reconstruction. This study assumes that an additional 10% of high-strength steel and additional 11% of diesel will be consumed (Corresponding to 3.3). The 73-day construction period for the highly controversial reconstruction project refers to the additional working time resulting from a 10% increase in the original workload, assuming adjustments to the construction sequence and weather conditions (consistent with the 8-day estimation method in 3.3). Therefore, the severe dispute scenario requires consideration of additional raw materials, mechanical energy consumption, and anthropogenic carbon emissions during construction. The estimation results are shown in Table 5.

Table 5. Estimation table in the severe dispute.

Carbon Source	Carbon Emission Factor (kgCO ₂ /Unit)	Consumption	Carbon Emission (tCO ₂)
High-strength steel	2200.00	3500 t	7700.00
Multiple Machines	3.49	982,872	3430.22
Labor—carbon on construction	6.61	Level I: 126 workers, 73 days	60.80
	8.05	Level II: 36 workers, 73 days	21.16
	9.31	Level III: 18 workers, 73 days	12.23
			Total: 11,224.41

3.5. Results Analysis

Appendix B shows that the total carbon emissions during the offshore platform construction phase were 395,030.36 tCO₂e. The mild dispute scenario would only produce 23.80 tCO₂e, less than one in ten thousand of that. However, this data demonstrates that even short delays can accumulate emissions indirectly through factors such as workers' survival and on-site work. This highlights the value of effective dispute resolution in avoiding unnecessary "idle" carbon emissions, which could be reduced through better planning or remote work alternatives.

Moderate disputes generate thousands of tons of additional carbon emissions, accounting for approximately 3‰ of the total process carbon emissions. This scenario exhibits a compounding effect: environmental exposure not only wastes resources but also prolongs construction time, increasing cumulative human and operational emissions. Compared to the mild scenario, the tens-fold increase in the moderate scenario highlights the necessity for coordination among construction teams, and prolonged idleness can lead to more serious environmental consequences.

The severe scenario has the highest embodied carbon increase, accounting for approximately 3% of total construction emissions. Steel consumption increases by 10% and diesel consumption by 11%, indicating significant resource waste and energy demand. Reconstruction amplifies emissions throughout the supply chain, from increased raw material consumption to on-site fuel use. A two-year delay creates the risk of long-term component degradation and exacerbates costs through team turnover and downtime. These data reveal the vulnerability of offshore projects to prolonged disruptions, where unstable funding can exponentially increase environmental impacts. Mitigation strategies could include contingency funding for rapid dispute resolution, modular construction to limit exposed work-in-progress, and environmental liability insurance products that cover the carbon-cost equivalent of reconstruction. Carbon credit market mechanisms—such as pre-purchasing

offset allowances to cover projected dispute-carbon increments—may also provide financial hedging for project owners.

4. Discussion

The carbon surcharges uncovered by our three dispute scenarios reveal an environmental cost category that has remained almost invisible in offshore-platform life-cycle assessments. Even a minor disagreement leading to a five-day work stoppage would add 11.9 tons of CO₂ equivalent. This is equivalent to consuming more than 3000 L of diesel fuel, or a 4500-kilowatt platform thruster operating continuously at 50% load for more than 80 h. It is primarily “idle carbon” from worker survival energy demand and essential auxiliary systems. However, minor crane movements for safety inspections and routine generator warm-up cycles during downtime may add a small machinery increment that is not explicitly itemized in the current deterministic model. Once the stoppage extends into the moderate window, the project crosses the corrosion threshold of unprotected high-strength marine steel, and the embodied penalty jumps by two orders of magnitude. The severe case shows an even starker acceleration: two calendar years of exposure in the South China Sea spray zone convert a 3‰ inconvenience into a 3% step-change in project-wide emissions, equivalent to adding another 3500 t of diesel consumption that nobody planned for.

Preventative protocols could substantially mitigate the emission escalation observed in moderate and severe disputes. Temporary protective coverings (e.g., epoxy-based spray coatings or dehumidification enclosures) [22,23] applied to splash-zone steel before crew departure can reduce corrosion rates by 60–80% during the first 90 days of suspension. If such measures were mandatory for disputes exceeding 2 weeks, the moderate-dispute steel increment could be reduced from 1% to approximately 0.3%, saving ~540 t CO₂e per event. The model can be extended to include a “protected stoppage” scenario by applying reduced corrosion coefficients to the tier thresholds.

In addition, a one-at-a-time sensitivity analysis was conducted on the severe-dispute scenario to identify dominant input parameters. Varying the steel replacement ratio by $\pm 10\%$ (9–11%) changes total dispute carbon by $\pm 9.8\%$ (± 1100 t CO₂e). Varying the diesel increment by $\pm 10\%$ (9.9–12.1%) changes total dispute carbon by $\pm 3.1\%$ (± 350 t CO₂e). Varying the labor intensity distribution (Level I/II/III ratios from 6:2:2 to 8:1:1) changes total dispute carbon by $\leq \pm 0.5\%$. These results confirm that material degradation assumptions dominate the model output, reinforcing the need for field-calibrated corrosion data.

These results reveal the vulnerability of offshore construction to disputes, where environmental factors such as high salinity and humidity exacerbate degradation, leading to compounded emissions from raw materials, machinery, and labor. By quantifying increments—negligible in mild cases but substantial in severe ones—the study illustrates how disputes extend beyond economic delays to amplify carbon footprints, aligning with prior findings on construction inefficiencies but uniquely integrating them into LCA frameworks. This tiered approach exposes hidden emission sources often overlooked within narrow system boundaries, such as idle labor and rework. It draws on evidence from real-world cases in Appendix A, such as the Evergrande projects, where multi-year suspensions mirrored severe scenarios.

This study acknowledges several limitations that may affect the generalizability of the findings. First, the degradation rate and platform size are provisional parameters based on design specifications similar to the Haiyang Shiyu 981 platform; actual as-built data may differ. Second, the 1% and 10% steel replacement rates are reference values and have not been validated using post-shutdown inspection records of completed platforms. Third, the model assumes uniform corrosion of structural components; in reality, localized pitting corrosion in splash zones may necessitate earlier replacement. Fourth, deterministic

structures cannot capture probabilistic variations in the duration or severity of disputes; Monte Carlo simulation methods are recommended for future studies. Fifth, the single-case study design limits cross-project validation. Future research should utilize historical construction logs and post-dispute inspection reports from multiple completed platforms to calibrate the mathematical model.

The scientific contribution lies in the novel tiered evaluation model, which categorizes disputes by severity and quantifies their embodied carbon impacts, bridging dispute management with sustainable construction assessments. This method advances LCA by incorporating incidental factors like conflicts, offering a rigorous, empirical tool for stakeholders to predict and mitigate emissions in complex projects. Future significance includes promoting proactive strategies, such as digital monitoring, contingency funding, and modular designs, to reduce environmental footprints amid global urbanization. Extending the model to other infrastructure types or integrating predictive analytics could further drive low-carbon practices, fostering resilience against environmental and financial risks in the industry.

5. Conclusions

This study advances environmental cost engineering by developing a tiered LCA model that quantifies the embodied carbon impacts of construction disputes in offshore platform building. The model bridges a methodological gap in existing LCA frameworks, which traditionally exclude incidental disruptions from system boundaries. By categorizing disputes as mild, moderate, or severe, and linking each tier to distinct carbon sources, namely, labor idleness, material rework, and comprehensive reconstruction, this study reveals a nonlinear, step-function relationship between delay duration and emission surges. The key methodological contribution is the integration of marine corrosion thresholds into dispute-carbon accounting, demonstrating that environmental penalties escalate dramatically once material degradation becomes structurally significant. For naval engineering firms and contractors, this model offers a competitive advantage in international tenders focused on low-carbon performance: by quantifying the CO₂e liability of potential disputes during the bidding phase, stakeholders can price conflict risk into carbon budgets, allocate contingency reserves for rapid resolution, and demonstrate proactive environmental stewardship to clients and regulators. Future work should focus on calibrating degradation parameters against historical platform data, extending the model to probabilistic simulation, and embedding the algorithm into interoperable BIM-LCA workflows.

In summary, by widening the life-cycle boundary to include the carbon that accrues while people argue, this study shows that disputes are not merely commercial irritants—they are latent environmental events. A ten-day interruption is a rounding error in the ledger of an offshore platform, but it is also a reminder that every unplanned day burns fuel and steel that were never budgeted for in the original LCA. Once the pause stretches beyond the corrosion threshold, the penalty escalates from idle labour to structural rework, and the embodied carbon curve rises faster than the schedule curve. The severity model we propose—mild, moderate, severe—captures this acceleration in a form that engineers, insurers and arbitrators can all recognize, and it translates legal uncertainty into tones of CO₂-equivalent that can be priced, insured or prevented. The next step is to embed this disputed carbon emission layer into the BIM-LCA platform. The conceptual workflow is as follows: (1) the BIM model exports engineering files (such as Industrial Foundation, IFC) containing material quantities and area classifications; (2) the dispute severity algorithm reads the delay duration from the scheduler and selects a corrosion coefficient for each environmental area; (3) the LCA engine multiplies the adjusted quantities by the emission factor and writes the disputed carbon increment back to the BIM dashboard. In this way, once a pause notice is issued, the model will not only recalculate the critical path but also

recalculate the corrosion risk and the resulting carbon emissions. This does not completely eliminate disputes, but it makes the environmental costs of these disputes significant—and this may be the most effective dispute resolution tool.

Future research should prioritize the calibration of the proposed mathematical model using historical construction logs, post-dispute inspection reports, and as-built corrosion records from already completed offshore platforms. Such empirical validation would replace the current provisional parameters, particularly the 1% and 10% steel replacement ratios and the marine corrosion coefficients, with field-measured degradation rates, thereby enhancing the model's predictive accuracy and industry acceptance. Beyond methodological refinement, naval engineering firms and construction contractors can leverage this dispute-carbon model as a tangible competitive advantage in low-carbon-oriented international tenders. By quantifying the CO₂e liability of potential disputes during the bidding phase, stakeholders can price conflict risk into carbon budgets, allocate contingency reserves for rapid resolution, and demonstrate proactive environmental stewardship to clients and regulators. In an era where carbon performance is increasingly weighted in procurement scoring, the ability to forecast, visualize, and mitigate the embodied carbon of delays offers a decisive edge over competitors who treat disputes solely as commercial uncertainties rather than latent environmental events.

Author Contributions: Conceptualization, L.Z., Y.Y. and H.X.; Methodology, L.Z., Y.Y., J.I.K. and H.X.; Formal analysis, L.Z., Y.Y. and H.X.; Data curation, L.Z.; Writing—original draft, L.Z., Y.Y. and H.X.; Writing—review & editing, J.I.K. and H.X.; Supervision, J.I.K. and H.X.; Funding acquisition, H.X. All authors have read and agreed to the published version of the manuscript.

Funding: This research was supported by the following projects: Jiangsu University of Science and Technology Doctoral Research Start-up Fund: 1122932310. General Program of Humanities and Social Sciences Research of the Ministry of Education of China (Grant No. 25YJC630057). Jiangsu Provincial Industry-University-Research Project: BY20250066.

Data Availability Statement: Dataset available on request from the authors.

Acknowledgments: Thank you to Chen Junxi for his research in the early stages of the project. We wish him all the best in his work!

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Here are some news and cases on the various disputes.

The progress of the first phase of the China-Thailand high-speed railway project has been delayed again, and the construction period of Sections 3–5 has been extended by 350 days: <https://news.qq.com/rain/a/20250307A04KCK00>.

Sydney Metro M1 line construction delayed, strikes and driverless train tests become obstacles:

https://www.sohu.com/a/866510158_512834.

At a construction project in Tonghua City, Jilin Province, China, construction of three residential buildings in the community has been suspended for more than two years due to a dispute between the developer and the builder (i.e., the construction unit):

https://m.thepaper.cn/newsDetail_forward_14296351.

Evergrande Group's residential project in Fenghua, Ningbo, China has been suspended for many years:

<https://finance.sina.cn/2024-11-07/detail-incvfyqz7534020.d.html>.

Uneven path to finish Evergrande's abandoned housing in Chinese city | Reuters

<https://www.reuters.com/business/uneven-path-finish-evergrandes-abandoned-housing-chinese-city-2024-02-02/>.

Evergrande: Crisis-hit Chinese property giant ordered to liquidate

<https://www.bbc.com/news/business-67562522>.

Delays and defects: Conflict in construction:

<https://www.frapadvisory.com/insights/detail/delays-and-defects-conflict-in-construction/>.

These websites were accessed on 18 May 2026.

Appendix B

This study takes a deepwater semi-submersible drilling platform, which will soon be put into service in the South China Sea, as an example. Since the project has not yet been completed, the various parameters introduced may change in the future. Here, it is used as a reference calculation case. The platform is 120 m long, 95 m wide, and 145 m high, with a deck area of about 8000 square meters, a maximum operating water depth of 3500 m, and a maximum drilling depth of 13,000 m. It weighs approximately 35,000 tons and has a full-load displacement of roughly 65,000 tons. It adopts a DP3+ dynamic positioning system and is equipped with 10 4500-kilowatt thrusters, which can withstand a 17-level typhoon. The platform, constructed with approximately 35,000 tons of high-strength marine steel, features a dual derrick system and an intelligent drilling control system, accommodating up to 180 people. It is planned for use in the development of ultra-deepwater oil and gas fields in the South China Sea. The technical parameters and usage scenarios of the platform are similar to those of the “Haiyang Shiyou 981,” which entered service in 2012. The benchmark materials and energy parameters used in this offshore platform were cross-referenced with the design specifications of several semi-submersible drilling platforms in the South China Sea that have been publicly published in marine engineering industry reports. The case selected in this study also follows the above specifications and requirements.

In terms of raw materials, the total material carbon emissions reach 77,000 t CO₂e.

In terms of transportation, traditional maritime transport uses heavy oil tankers, which have a carbon emission factor of approximately 0.05 kg CO₂e/t·km, taking into account load and voyage distance. The carbon emission factor of LNG carriers is approximately 0.035 kg CO₂e/t·km (Xinde Marine News, 2022, <https://www.xindemarinenews.com/topic/yazaishuiguanli/38308.html>, accessed on 22 May 2026). The platform’s specific location has yet to be determined. This study assumes the proposed site is 1500 km from Sanya Port in Hainan Province, in a typical deepwater operating area in the South China Sea. Therefore, the cumulative carbon emissions from transporting 35,000 tons of steel are 5250 t CO₂e. Sanya Port in Hainan Province is selected as the reference origin for material shipments because it is the nearest deepwater port with established heavy-lift infrastructure serving the South China Sea oil and gas fields.

In terms of machinery, the construction phase of an offshore platform involves a large number of high-energy-consuming equipment, such as cranes, drilling rigs, welding equipment, auxiliary equipment, etc. This equipment is typically fueled by diesel fuel, contributing to primary carbon emissions during the construction phase. The platform is equipped with six 8-MW diesel generators, generating a total of 48 MW. Assuming an average operating power of 50% during construction (accounting for intermittent operation), the total energy consumption over a two-year construction period (approximately 17,520 h) is calculated to be 420,480,000 kWh. Diesel generators typically consume 0.25 L/kWh, and 1 L of diesel weighs approximately 0.85 kg (Fukangsi Electrical Machine, 2022, http://yzfks.cn/?news_19/334.html, accessed on 29 May 2026). Therefore, total diesel consumption during the construction phase was 105,120,000 L, resulting in

carbon emissions of 311,838.48 t CO₂e. This study assumes that 80% of the energy consumption comes from high-energy-consuming construction equipment (such as diesel cranes and drilling rigs), and the remaining 20% comes from other auxiliary equipment, such as lighting equipment. The total energy consumption of construction machinery is 336,384,000 kWh, 84,096,000 L of diesel is consumed, and the corresponding carbon emissions are 249,470.78 t CO₂e.

Offshore platform construction is significantly affected by weather conditions, and the construction process involves complex module assembly, hoisting, and drilling operations. Equipment idleness and repetitive operations often waste energy. As mentioned above, the project took two years (730 days) to complete and required 180 workers. Previous studies have categorized labor carbon emissions into three levels based on the level of labor performed [12]. This study averaged the total number of workers. It divided the work hours into light, moderate, and heavy labor in a ratio of 7:2:1, resulting in a total labor carbon emission of 941.88 t CO₂e. In land-based construction, BIM technology is frequently utilized to optimize construction plans, thereby reducing equipment operating time and energy consumption. This study introduces BIM technology into the construction process of offshore platforms to reduce unnecessary standby and delays.

Table A1. The results of carbon emission.

Carbon Elements	Estimated Emissions (tCO ₂ e)
Raw materials	77,000
Transportation	5250
Machinery	311,838.48
Labor	941.88
Total	395,030.36

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