

The Hidden Cost of Scope Ambiguity: Why OFCI vs. CFCI Delineation Breaks Data Center Budgets

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ABSTRACT

An under-researched, but material, cause of cost increase in the delivery of data centers is scope ambiguity. This paper examines how ambiguous separation of the Owner-Furnished Contractor-Installed (OFCI) and Contractor-Furnished Contractor-Installed (CFCI) duties creates systemic inefficiencies at the procurement, integration and execution stages. Combining the concepts of cost modeling, strategic ambiguity theory and infrastructure delivery frameworks, the analysis shows that ambiguous ownership boundary creates a set of hidden costs by causing coordination overhead, change orders, schedule delays, and suboptimal system performance.

This paper conceptualizes the ambiguity of the OFCI/CFCI of the firm as a multidimensional risk factor in the capital expenditure structures and lifecycle cost models. It defines major failure modes, such as interface mismatch, fragmented responsibility and procurement breaks, and traces them to financial consequences that are quantifiable, such as cost variance, schedule slippage, and inefficiency of operations. An organized system is suggested to measure these effects and the ambiguity as a risk-corrected variable to total cost of ownership (TCO) and a payback model (return on investment (ROI)).

The results highlight that the scope clarity is not only a formal aspect of the contract but a very important factor of financial predictability in high-density and intricate data center settings. Mitigation needs to be well defined to ensure that technical and commercial tasks are aligned by adopting stringent scope definition, combined delivery plans, and better coordination systems.

Keywords: Scope Ambiguity; OFCI; CFCI; Data Center Economics; CAPEX Overrun; Cost Modeling; Procurement Strategy; Project Risk; Total Cost of Ownership; Infrastructure Delivery.

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INTRODUCTION

The increasing rates of scaling of hyperscale and enterprise data centers infrastructure have exacerbated the necessity of more accurate cost management solutions both at the design, at the procurement and construction levels. Even with the progress in financial modeling and optimization of operations, cost overruns are widespread, and they are often explained by aspects that are not related to the traditional engineering explanation or the fluctuations of the market. Of these, the scope ambiguity, especially between the Owner-Furnished Contractor-Installed (OFCI) and Contractor-Furnished Contractor-Installed (CFCI) scopes, stands out as a key, but not well-known, factor predetermining budget instability. In more complicated data center projects, with electrical and mechanical systems closely integrating with IT systems, even the slightest uncertainties in the task division may spill over into serious cost and performance wastes.

The cost structure of data centers is a complex structure that combines capital expenditure (CAPEX), operational

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expenditure (OPEX), and longevity in terms of total cost of ownership (TCO). The established models underline the significance of cost optimization throughout the lifecycle, with variables that include the level of energy efficiency, the utilization, and the ability to scale the infrastructure (Newcombe, 2021; Wu and Buyya, 2015). These models however tend to make assumptions that the project boundaries are very clear and never explicitly mention how

the distortions created by ambiguous scope definitions can come in. Consequently, there are often differences between forecasted and actual financial performance, which negatively affect the anticipation of return on investment (ROI) and strategic planning (Newcombe, 2014).

The difference between the OFCI and CFCI procurement models essentially defines the way the risks, responsibilities and costs are spread among the stakeholders of the project. Although the owners of the equipment have more control over equipment choice and supply chains with the help of the OFCI, it also brings fragmentation in terms of accountability of executions. On the other hand, CFCI centralizes the accountability among the contractors, however, it can reduce the flexibility and augment the price bundling. Failure to have clearly defined boundaries between these models lead to coordination problems, overlapping tasks, and contractual conflicts, all of which lead to hidden costs, which are often not reflected in original budgets.

In theory, ambiguity has been known to be a cause of inefficiency in strategic and organizational set ups. Ambiguous constructs allow interpreting the construct in different ways, which results in inappropriate expectations and non-optimal decision-making (Arend, 2022; Frankenhuis *et al.*, 2023). These effects are exacerbated in operational environments that are highly complex, as with data center construction. The study of the hidden costs in distributed and outsourced systems points to the interplay of complexity, the design of the organization, and lack of experiential learning to generate unexpected costs (Larsen *et al.*, 2013). On the same note, research on regulatory and environmental costs estimation reveals that indirect and frequently unquantified costs can be much higher than original estimates in case of poor management of uncertainty (Joshi *et al.*, 2001).

This notion of scope ambiguity also has analogs in the field of linguistic theory since one and the same structure can have a number of correct interpretations in different situations (Scontras *et al.*, 2017; Hurum, 1988). Applying this analogy to data center delivery, vague language in the contract or missing interface specifications enable the stakeholders to perceive responsibilities and execute them in a way that is not aligned. The misalignment is especially damaging in systems where a high level of accuracy is required in coordinating the performance and efficiency like in power distribution and thermal management. The sensitivity of data center processes to accuracy in integration and coherence of the system has been highlighted by prior research on the paramount importance of power budgeting and energy optimization (Verma *et al.*, 2010; Islam *et al.*, 2015).

Moreover, the optimization efforts of large-scale data centers have continuously reported problems of governance, coordination, and accountability as the challenges in meeting

the cost savings goals (Powner, 2017). Such predicaments tend to be symptomatic to underlying structural ambiguities entrenched in project scopes. Lack of alignment between ownership of critical components, including uninterruptible power supply (UPS), cooling, or rack infrastructure, and installation and commissioning duties leads to the gaps between the two, which are reflected in delays, work re-work, and performance inefficiencies.

In this paper, it is argued that the ambiguity in the definition of OFCI and CFCI plays the role of a systemic risk multiplier in the data center projects and warps the financial forecasts as well as the operational results. Investigating the mechanisms where scope ambiguity adds hidden costs, the study will close the divide between theoretical understanding of ambiguity and the real issues in infrastructure delivery. It also places the clarity of scope as a primary prerequisite to attaining predictable cost performance, as opposed to a contractual consideration.

Conceptual Foundations of Scope Ambiguity

Scope ambiguity is a situation whereby the limits of the responsibility, deliverables and system interfaces are not well established and therefore there are multiple possible interpretations when executing the project. This ambiguity is not just semantic in capital-intensive and highly integrated settings like data centers; it also has operational and financial implications, having a direct impact on the cost predictability, coordination efficiency and system performance outcomes. In contrast to explicit risks which can be estimated in advance, scope ambiguity is a latent variable that exists in the contractual framework and specifications and is usually only realised in the implementation.

Strategically, ambiguity has been found to incur quantifiable, economic costs in distorting the decision-making process, diffusing accountability, and promoting the risk of misaligned incentives (Arend, 2022; Frankenhuis *et al.*, 2023). With interdependencies between actors and processes in complex organizational systems, these effects are magnified. The environment of data center delivery typified by a number of vendors, closely integrated levels of infrastructure (power, cooling, IT) and high reliability demands reflects exactly these conditions. As a result, the slightest issues in delineation of scopes may spread into disproportionately big cost effects.

The idea of hidden costs is a helpful mode of analysis. Hidden costs were originally formulated in the framework of offshoring and regulatory economics, and they are indirect, unexpected costs related to the coordination complexity, gaps in governance, and adaptation costs (Larsen *et al.*, 2013; Joshi *et al.*, 2001). When used in data center projects, the scope ambiguity is a major source of such costs. As an example, the ambiguity of installation between the responsibilities of the components of the two companies (OFCI and CFCI) may spur rework or duplication of effort or delays in commissioning that are not generally reflected in the baseline CAPEX models

(Newcombe, 2021; Wu and Buyya, 2015).

An analogous conceptual analogy can be likened to linguistic theory where scope ambiguity can be explained when a statement can be interpreted in a number of ways contingent on the structural or contextual information (Scontras *et al.*, 2017). In engineering and contractual contexts, a similar phenomenon occurs: specifications that lack precise boundary conditions allow stakeholders to interpret scope differently, leading to execution divergence. Early work on ambiguity resolution highlights that even small syntactic or definitional gaps can cascade into significant misunderstandings when multiple agents interact (Hurum, 1988). Translating this to data center delivery, ambiguity at the interface level such as between electrical distribution and mechanical cooling systems creates systemic coordination risk.

From a financial modeling standpoint, traditional Total Cost of Ownership (TCO) and Return on Investment (ROI) frameworks assume a relatively stable and well-defined scope baseline (Newcombe, 2014; Newcombe, 2021). However, scope ambiguity violates this assumption by introducing variability into both cost and schedule parameters. This variability is particularly critical in data centers, where energy efficiency, power allocation, and infrastructure utilization are tightly optimized. Studies on power budgeting and energy cost minimization demonstrate that even small deviations in system integration can lead to significant inefficiencies in operational expenditure (Verma *et al.*, 2010; Islam *et al.*, 2015). Thus, ambiguity

at the design or procurement stage can have long-term financial consequences extending beyond initial construction.

Furthermore, public-sector analyses of data center optimization efforts reveal that governance and coordination challenges often rooted in unclear scope definition are major barriers to achieving projected cost savings (Powner, 2017). This reinforces the argument that scope ambiguity is not an isolated contractual issue but a systemic factor affecting the entire lifecycle of data center assets.

To operationalize this concept, scope ambiguity in data center projects can be decomposed into distinct but interrelated categories, each associated with specific cost generation mechanisms.

OFCI vs. CFCI Delineation in Data Center Delivery

The distinction between Owner-Furnished Contractor-Installed (OFCI) and Contractor-Furnished Contractor-Installed (CFCI) is one of the fundamental choices in the model of data center delivery, as it directly affects the organization of procurement, the distribution of risks, and financial predictability. Although both methods are very common, the success of both methods relies on the demarcation of the scope and the level of integration between design, supply chain and installation processes.

In OFCI systems the owner reserves the right to purchase vital equipment, e.g. UPS systems, switchgear, or IT racks and to delegate the installation to a contractor. The model is commonly sought after in cases where the owners want to have a greater control over the technology standards, the choice of the vendor or the compatibility of the technology in the long term. Nevertheless, this control comes with fragmentation of accountability, which raises the complexity of the coordination, and the possibility of

Table 1: Types of Scope Ambiguity in Data Center Projects

Ambiguity Type	Description	Example in OFCI/CFCI Context	Cost Impact Mechanism
Ownership Ambiguity	Unclear asset responsibility	UPS supplied by owner but install scope undefined	Rework, duplicated effort, procurement delays
Interface Ambiguity	Undefined system integration boundaries	Cooling system integration with electrical distribution unclear	Coordination overhead, system mismatch
Specification Drift	Evolving or inconsistently interpreted requirements	Rack density or load assumptions change mid-project	Change orders, redesign costs
Accountability Gaps	Disputed liability for failures or defects	Commissioning failure with unclear responsible party	Claims, legal disputes, delay costs



Table 2: OFCI vs. CFCI Comparative Risk Profile

Dimension	OFCI	CFCI	Budget Risk Level
Procurement Control	Owner-driven	Contractor-driven	Medium vs Low
Cost Certainty	Lower (fragmented sourcing)	Higher (bundled contracts)	High vs Medium
Coordination Load	High due to multi-vendor interfaces	Moderate with centralized responsibility	High vs Medium
Flexibility	High (custom vendor selection)	Lower (contractor-defined supply chain)	Medium vs Low
Risk Transfer	Limited; retained by owner	Significant transfer to contractor	High vs Medium
Interface Clarity	Often ambiguous	Typically well-defined	High vs Low
Schedule Reliability	Vulnerable to delays	More predictable timelines	High vs Medium

interface mismatches. This fragmentation may skew capital expenditure predictions, and inflate indirect costs via delays and rework, which can be viewed through the cost modeling lens (Wu & Buyya, 2015; Newcombe, 2021).

On the other hand, CFCI structures concentrate the procurement and installation duties with the contractor and practically bundle the risk and make contractual interfaces less complex. This method increases cost predictability and lessens coordination expenses, with just one party responsible both to provide and carry out. Nonetheless, it can restrict the flexibility of the owner to choose vendors, and create pricing premiums that are linked to the risk transfer that is managed by the contractor. CFCI models are more likely to have less unpredictable results in Total Cost of Ownership (TCO) because of the less ambiguous definition of scopes (Newcombe, 2014; Newcombe, 2021).

The difference between the two models becomes critical in the high density data center setting where closely integrated systems, which include power, cooling and IT infrastructure must be accurately integrated. Interference of the boundaries in the OFCI/CFCI usually results in interface ambiguity with neither party taking full accountability in case of interoperability of systems. This is a reflection of more general strategic ambiguity theories, in which ambiguous role definitions are driving up the transaction costs and lowering the efficiency of execution (Arend, 2022; Frankenhuys *et al.*, 2023). This ambiguity may spread through numerous layers in complex delivery ecosystems, increasing the coordination issues and the hidden costs (Larsen *et al.*, 2013).

From an operational standpoint, the implications extend beyond construction into performance optimization. Data center efficiency, particularly in power allocation and energy management, depends on cohesive system integration. Fragmented procurement under poorly defined OFCI

structures can hinder the implementation of unified energy budgeting strategies, leading to inefficiencies in power utilization and increased operational expenditure (Verma *et al.*, 2010; Islam *et al.*, 2015). This reinforces the need for alignment between procurement models and system-level design objectives.

Furthermore, ambiguity in OFCI/CFCI delineation introduces measurable hidden costs analogous to those identified in regulatory and organizational contexts, where indirect financial burdens arise from misaligned incentives and unclear responsibilities (Joshi *et al.*, 2001). These costs often remain unaccounted for in initial budgeting exercises, contributing to discrepancies between projected and actual project performance. Empirical observations in data center optimization initiatives highlight that unresolved scope boundaries are a recurring barrier to achieving targeted cost savings and efficiency gains (Powner, 2017).

At a conceptual level, the challenge of OFCI/CFCI delineation can be likened to scope ambiguity in linguistic systems, where multiple valid interpretations of a structure lead to divergent outcomes in execution (Scontras *et al.*, 2017; Hurum, 1988). In engineering and construction contexts, this manifests as inconsistent assumptions across stakeholders, resulting in misaligned deliverables and increased project risk.

The choice between OFCI and CFCI is not merely a procurement preference but a strategic determinant of cost structure and risk exposure. Without rigorous scope definition and interface governance, both models are susceptible to ambiguity-driven inefficiencies. However, OFCI arrangements, in particular, require heightened coordination discipline to prevent the erosion of anticipated cost advantages.

Mechanisms of Budget Breakdown

Data center project cost breakdowns caused by the ambiguity of the OFCI compared with that caused by the ambiguity of CFCI are not usually the consequence of one failure point, but

Table 3: Cost Breakdown of Scope Ambiguity Impact

Cost Category	Direct/Indirect	Description	Primary Trigger Mechanism	Typical Impact Range
Change Orders	Direct	Scope corrections and rework during construction and commissioning	Ownership and specification ambiguity	5–20% of CAPEX
Delay Costs	Indirect	Extended project timelines, idle resources, and rescheduling	Coordination failures, interface mismatches	10–30% schedule overrun
Coordination Costs	Indirect	Increased communication, management overhead, and integration effort	Multi-vendor fragmentation	3–10% of CAPEX
Performance Loss	Indirect	Reduced energy efficiency and system optimization	Poor integration of OFCI components	5–15% increase in OPEX
Legal and Claims	Direct	Dispute resolution, arbitration, and contractual claims	Accountability gaps	Variable (project-dependent)
Procurement Inefficiency	Direct/Indirect	Cost escalation due to fragmented sourcing and logistics misalignment	OFCI-driven supply chain discontinuity	5–12% of equipment cost

is the product of interacting cost leakages at procurement, integration and operational levels. These processes are systemic, increasing throughout the project life cycle and in many cases not wholly covered in the traditional financial models.

The fundamental one is the misalignment of the ownership where there is a lack of clarity as to who is supposed to supply equipments, install them and commission them, which results in the creation of the execution gaps. The owner of the structure in OFCI-heavy is taking over the procurement role but leaving the installation to the contractors, thus creating coordination discontinuities. This fragmentation enhances the chances of interface mismatches especially between closely integrated systems like power distribution, cooling systems and IT load integration. They often cause re-engineering loops and field changes, which are reflected in change orders and schedule slippage (Wu & Buyya, 2015; Newcombe, 2021).

The second mechanism is an escalation of the coordination overhead. The more the ambiguity, the more the cross-party alignment will be required, which may entail a host of vendors, contractors and consultants. This forms a non-linear increase in the complexity of communication, decision making time and administrative overhead. Empirical and theoretical literature on the hidden costs of complex organizational systems demonstrates that such coordination ineffectiveness are often not reflected in the base budgets, yet have significant impact on aggregate spending (Larsen *et al.*, 2013; Joshi *et al.*, 2001). This is enhanced in the context of data centers in which the dependency of subsystems leads to some delays in one component causing a ripple effect through the project timeline.

Another pathway that is critical is specification drift. Technical specifications (rack density, redundancy, thermal limits) are more likely to be re-interpreted in execution in ambiguous scope environments. This is reflective of other ambiguity studies that have established that there are more than two valid interpretations that result in implementation variance (Scontras *et al.*, 2017; Hurum, 1988). The economic effect is that it will lead to a growth of late-stage design changes, which are relatively costly in comparison to early-stage changes.

A further mechanism is risk misallocation and dispute generation. When contractual boundaries between OFCI

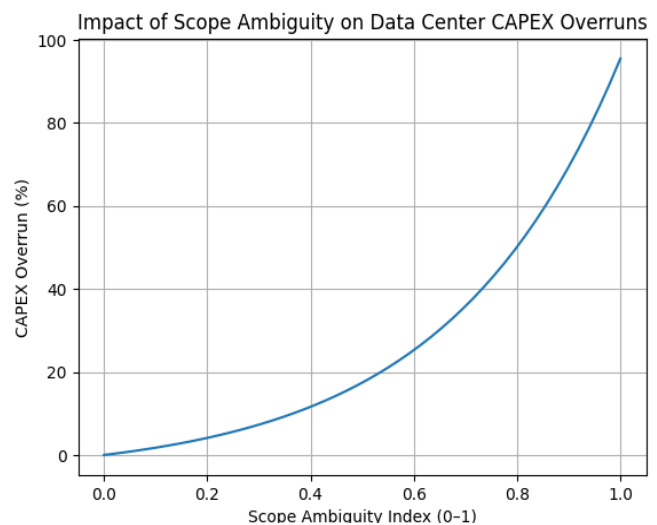


Figure 1: CAPEX overruns increase non-linearly as scope ambiguity rises, with disproportionately high cost escalation beyond mid-level ambiguity thresholds



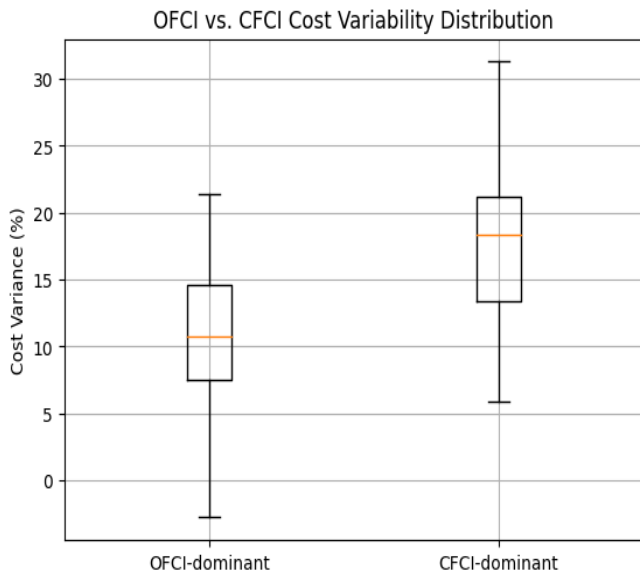


Figure 2: CFCI-dominant procurement models exhibit greater cost variability compared to OFCI-dominant models, indicating higher financial uncertainty.

and CFCI are not explicitly defined, accountability for failures particularly during testing and commissioning becomes contested. This aligns with strategic ambiguity theory, where unclear responsibility structures increase opportunistic behavior and dispute frequency (Arend, 2022; Frankenhuys *et al.*, 2023). The resulting claims, legal costs, and delays introduce both direct and indirect financial burdens.

Operational inefficiencies also emerge as a downstream effect. Poorly coordinated installation of owner-furnished equipment can lead to suboptimal system integration, affecting energy efficiency and capacity utilization. Given that energy constitutes a major component of data center OPEX, even marginal inefficiencies can significantly inflate lifecycle costs (Islam *et al.*, 2015). Additionally, power budgeting constraints central to modern data center optimization are harder to enforce when infrastructure components are not cohesively specified and deployed (Verma *et al.*, 2010). These inefficiencies undermine long-term cost optimization objectives highlighted in data center performance studies (Powner, 2017).

Finally, financial modeling gaps exacerbate the issue. Traditional CAPEX and TCO models often assume well-defined scope boundaries and therefore fail to incorporate ambiguity as a probabilistic cost driver. This results in systematic underestimation of total project cost and overestimation of return on investment (Newcombe, 2014; Newcombe, 2021). As ambiguity-induced costs accumulate across categories, the divergence between projected and actual financial outcomes becomes significant.

Collectively, these mechanisms illustrate that scope ambiguity is not a marginal issue but a structural cost amplifier. Its effects propagate across technical, organizational, and financial dimensions, ultimately undermining the economic

viability of data center investments if not rigorously controlled.

Quantifying the Hidden Costs

Quantifying the financial impact of scope ambiguity in OFCI versus CFCI delineation requires extending traditional data center cost models to explicitly incorporate ambiguity-driven risk variables. Conventional frameworks such as Total Cost of Ownership (TCO) and Return on Investment (ROI) assume relatively stable scope boundaries; however, ambiguity introduces stochastic variability that manifests as both direct and indirect cost escalations (Newcombe, 2021; Wu & Buyya, 2015). To address this, scope ambiguity can be operationalized as a risk multiplier (α) applied across capital, schedule, and operational cost components.

1. Cost Modeling Framework with Ambiguity Factor

Let baseline cost be defined as:

$$C_0 = \text{CAPEX} + \text{OPEX (baseline, fully defined scope)}$$

Introduce ambiguity-adjusted cost:

$$C_a = C_0 \times (1 + \alpha_s + \alpha_c + \alpha_o)$$

Where:

α_s = scope interpretation variability (design/execution mismatch)

α_c = coordination overhead factor

α_o = operational inefficiency factor

This formulation aligns with ambiguity cost theory, where unclear boundaries increase transaction and coordination costs (Arend, 2022; Larsen *et al.*, 2013). In practice, α values are empirically observed through cost variance logs, change order frequency, and integration delays.

Decomposition of Hidden Cost Drivers

- Change Order Amplification

Ambiguous OFCI/CFCI boundaries frequently lead to mid-execution scope corrections. These corrections typically exhibit nonlinear cost growth, as late-stage modifications

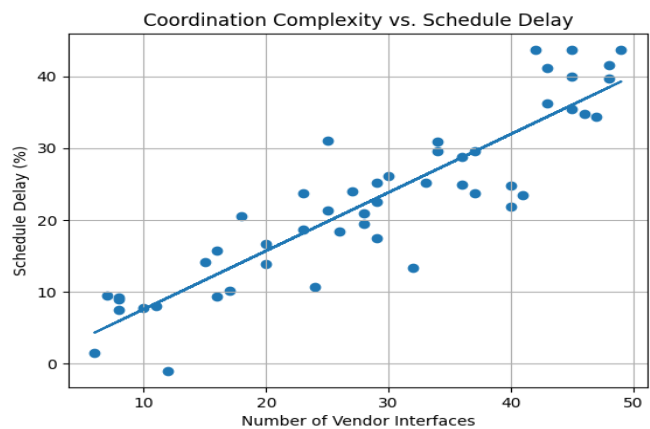


Figure 3: A positive correlation exists between vendor interface complexity and schedule delays, suggesting coordination overhead as a key driver of timeline slippage

affect already-installed systems. Empirical studies of infrastructure projects show that such hidden costs can exceed initial estimates due to compounding dependencies (Joshi *et al.*, 2001).

- **Coordination and Interface Costs**

Fragmentation across vendors increases communication pathways exponentially. For n stakeholders, coordination complexity approximates:

- $O(n^2)$ interaction overhead

This is particularly acute in OFCI-heavy models, where owner-supplied equipment must integrate seamlessly with contractor-installed systems. The resulting inefficiencies mirror ambiguity effects observed in organizational design and outsourcing contexts (Larsen *et al.*, 2013).

- **Schedule-Induced Cost Escalation**

Ambiguity-driven delays propagate into extended labor, equipment rental, and financing costs. Schedule variance (SV) can be expressed as:

$$SV = \text{Planned Duration} - \text{Actual Duration}$$

Cost impact follows:

$$\text{Delay Cost} \propto SV \times \text{Burn Rate}$$

Data center optimization studies highlight that delayed deployments significantly defer expected cost savings and revenue realization (Powner, 2017).

- **Energy and Operational Inefficiency**

Improperly scoped infrastructure (e.g., misaligned cooling or power provisioning responsibilities) results in suboptimal energy utilization, increasing long-term OPEX. Power budgeting inefficiencies and resource misallocation further amplify costs in high-density environments (Verma *et al.*, 2010; Islam *et al.*, 2015).

Integration into Financial Metrics

To embed ambiguity into financial decision-making:

T C O A d j u s t m e n t :

$$TCO_a = TCO \times (1 + \alpha_{total})$$

R O I D e g r a d a t i o n :

$$ROI_a = (\text{Net Benefit} - \text{Ambiguity Cost}) / \text{Total Investment}$$

Where ambiguity cost includes aggregated impacts from change orders, delays, and inefficiencies. This approach extends classical financial analysis models used in data center planning (Newcombe, 2014; Newcombe, 2021).

Empirical Measurement Indicators

Key measurable proxies for quantifying ambiguity include:

Change Order Frequency (COF)

Cost Variance (CV%)

Schedule Variance (SV%)

Power Usage Effectiveness (PUE) deviation

Vendor Interface Count

These indicators provide a data-driven basis for estimating a parameters and benchmarking project performance across OFCI and CFCI structures.

This quantification framework demonstrates that scope ambiguity is not merely qualitative but can be rigorously

modeled, measured, and incorporated into financial controls, enabling more predictable and optimized data center project outcomes.

Mitigation Strategies and Conclusion

To reduce the latent costs of the visage of the scope of the OFCI and CFCI ambiguity, a change in approach to the administration of contracts between reactive-based to proactive scope engineering and financial integration is necessary. The data point to the fact that ambiguity is not just a documentation deficiency but a structural inefficiency inherent in the project governance, procurement design and system integration. It thus requires concerted efforts in the technical, contractual and financial sectors to tackle it.

One of the major mitigation measures involves the deployment of granular scope definition models, with the aid of clear interface matrices and Responsibility Assignment (RACI) models. These tools should not be limited to the higher level delineation, but to subsystem level ownership, installation, testing and commissioning. Based on the ambiguity theory, run-to-run interpretive flexibility in interfaces can be reduced to reduce the number of different paths of execution and the rework expense (Arend, 2022; Scontras *et al.*, 2017; Hurum, 1988). In practice, it will involve the definition of scope into design documentation, procurement package and contractor bid package.

The use of integrated delivery models (like the Engineering, Procurement, and Construction (EPC) or design-build models) that centralizes accountability and creates less fragmentation is also essential. These models reduce the coordination overhead by ensuring that there are reduced contractual boundaries and reduce the spread of ambiguity amongst the stakeholders. This is in line with the results of those who suggest that organizational complexity and disaggregated responsibility systems increase the level of hidden costs in big projects (Larsen *et al.*, 2013). Where components of the OFCI are still required e.g. IT hardware that is under the control of the owner or specialized systems, then strict interface control protocols should be imposed within the framework of hybrid governance structures.

Financially, the uncertainty is to be clearly reflected in the cost model and investment analysis scheme. Conventional Total Cost of Ownership (TCO) and Return on Investment (ROI) approaches tend to undervalue risk, with deterministic scope limits. The inclusion of ambiguity as a risk-adjusted cost multiplier allows forecasting CAPEX variation more realistically, schedule risks, and lifecycle inefficiencies (Newcombe, 2021; Wu & Buyya, 2015). The experience of optimization programs in the past also indicates that the inability to consider these uncertainties negatively affect cost-saving goals and capital allocation choices (Powner, 2017; Newcombe, 2014).

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