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ACCELERATING THE PROCUREMENT PROCESS THROUGH BUNDLING SCHEMES FOR TRANSMISSION AND SUBSTATION INFRASTRUCTURES

Suroso Isnandar[1], Djoko Nugroho[2], Endi Novaris Syamsudin[3], Aan Ridhoana Fitriaji[4], Ramadhani Wahono[5], Mohamad Toha[6], Dedi Apriadi[7]*, Muhammad Iqbal Faruqi[8], Agus Budiyono[9]

[1,2,3,4,5]PLN, Jakarta, Indonesia.
suroso.isnandar@pln.co.id[1], 0009-0001-9191-1891[1]
djoko.nugroho@pln.co.id[2], 0009-0003-2219-0992[2]
endi.novaris@plnindonesiapower.co.id[3], 0009-0004-0089-3352[3]
aan.fitriaji@pln.co.id[4], 0009-0001-3304-9746[4]
ramadhani12@pln.co.id[5], 0009-0004-1159-442X[5]
[6]Faculty of Engineering, President University, Bekasi, Indonesia. E-mail: mohamad.toha@president.ac.id. ORCID: 0009-0006-4266-0156
*[7]*Lapi Ganesha Utama, Bandung, Indonesia. E-mail: dedia@itb.ac.id. ORCID: 0009-0001-3779-6896*
[8]Independent Researcher, Jakarta, Indonesia. E-mail: iqbal@faruqi.org. ORCID: 0009-0008-7472-9714
[9]CAP Solutions, Jakarta, Indonesia. E-mail: budiyono@alum.mit.edu. ORCID: 0000-0002-1337-9684

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Corresponding author: Dedi Apriadi
(dedia@itb.ac.id)

ABSTRACT

The Electricity Supply Business Plan (RUPTL) sets increased targets for the development of power infrastructure through 2034, particularly for transmission and substation facilities, the escalation of these targets results in a higher number of projects that must be delivered within a relatively constrained timeframe. At the same time, PT PLN (Persero)'s procurement and project control capacities are subject to organizational and resource limitations, which may affect the speed and effectiveness of procurement execution. In this context, the application of bundling schemes in procurement is considered as an alternative approach to improve efficiency and accelerate the procurement process. This paper examines the application of bundling schemes in the procurement of engineering, procurement, and construction (EPC) projects for transmission and substation infrastructure, with the objective of supporting procurement acceleration and the achievement of RUPTL targets. The study focuses on identifying key constraints arising from existing bundling practices and developing alternative procurement programs to either mitigate or leverage these constraints under both bundling and non-bundling scenarios. A comparative evaluation is then conducted to determine the procurement approach that is most appropriate for different project characteristics. The research adopts a combined methodology of the Theory of Constraints (TOC) and Strategic Assumption Surfacing and Testing (SAST). This approach is used to identify systemic bottlenecks in procurement processes and to test the strategic assumptions underlying procurement decisions. The results indicate that, when applied selectively and in a project-specific context, bundling schemes demonstrate a higher degree of alignment with schedule acceleration, cost control, and risk management objectives as defined in the RUPTL, compared to non-bundling approaches. This framework is aimed at promoting opportunities within PLN to the global investment market in power industry. The bundling strategy is also envisaged to improve RUPTL execution in support of the targeted national economic growth.

KEYWORDS: bundling schemes, theory of constraints, strategic assumption surfacing and testing, procurement, project management.

1. INTRODUCTION

1.1. Background and Motivation

Indonesia's electricity sector is undergoing a large-scale expansion to support economic growth, regional development, and national energy policy objectives. The Electricity Supply Business Plan (*Rencana Usaha Penyediaan Tenaga Listrik* – RUPTL) sets ambitious targets for the development of power infrastructure up to 2034, with a substantial portion of these targets allocated to transmission and substation facilities. Achieving these targets requires the execution of hundreds of engineering, procurement, and construction (EPC) projects within relatively constrained timeframes.

While the scale of infrastructure development continues to increase, the institutional capacity of the utility responsible for implementation—PT PLN (Persero)—remains subject to organizational, financial, and procedural limitations. In practice, procurement and project execution processes face growing pressure due to the rising number of contracts, increased coordination complexity, and heightened exposure to schedule, cost, and risk uncertainties. Under conventional procurement schemes, transmission and substation projects are typically tendered and executed as separate packages, resulting in fragmented coordination among contractors, duplicated procurement activities, and limited synchronization across interconnected facilities.

These challenges indicate that procurement acceleration is not solely a matter of improving individual contract performance, but rather a systemic issue rooted in the structure of the procurement and project delivery system itself. As the number of projects increases, incremental improvements—such as additional recruitment or minor procedural adjustments—are often insufficient to meet RUPTL timelines. Consequently, alternative procurement strategies capable of restructuring the system and alleviating structural bottlenecks are required.

One such strategy is the application of bundling schemes in procurement. Bundling consolidates multiple infrastructure components or project packages into a single procurement and execution framework. For transmission and substation infrastructure, bundling has the potential to reduce transaction volumes, improve coordination between interdependent facilities, and better align engineering, procurement, and construction activities. However, bundling also introduces new forms of complexity related to vendor capability, financing capacity, policy alignment, and risk allocation. As a result, its effectiveness cannot be assumed a priori and must be evaluated within the specific constraints of the organizational and regulatory environment in which it is applied.

1.2. Problem Statement

Despite its potential benefits, the implementation of bundling schemes in large-scale transmission and substation procurement remains contested. In PLN's operational context, procurement challenges arise not only from technical considerations, but from a combination of internal and external constraints. Internally, limitations in planning capacity, procurement manpower, financing approval processes, and project monitoring capabilities can impede the timely execution of bundled or non-bundled projects alike. Externally, vendor technical capability, financial strength, consortium readiness, and supply chain reliability further influence procurement outcomes. In addition, policy and regulatory frameworks may not be fully adapted to support large-scale bundled procurement, creating uncertainty in implementation.

Under existing (non-bundled) procurement schemes, attempts to meet accelerated RUPTL targets often imply a substantial increase in the number of contracts that must be processed annually. In practice, this would require capacity expansion at a scale that may be infeasible within the available timeframe, such as significant recruitment, training, and system upgrades. Conversely, while bundling schemes may reduce the total number of procurement packages and simplify coordination, they also shift constraints toward vendor capability, financing arrangements, and policy clarity.

The central problem, therefore, is not whether bundling is theoretically superior to non-bundling, but whether bundling can restructure the constraint system in a way that makes accelerated procurement practically achievable. Without a structured approach to identifying and managing constraints, procurement decisions risk being based on assumptions that are misaligned with organizational realities, leading to implementation failure even when the chosen strategy appears optimal on paper.

1.3. Research Objectives and Research Questions

This study aims to address the procurement acceleration problem by adopting a constraint-driven evaluation of bundling schemes for transmission and substation infrastructure projects. Rather than focusing solely on comparative performance metrics, the study emphasizes

feasibility, execution capability, and probability of success under real-world constraints.

The specific objectives of this research are to:

1. Identify the dominant internal, external, policy, and demand-related constraints affecting procurement and project execution of transmission and substation infrastructure.
2. Examine how different bundling configurations interact with these constraints compared to existing non-bundled procurement schemes.
3. Develop and evaluate alternative procurement programs designed to exploit or mitigate identified constraints.
4. Select procurement schemes with the highest probability of success in supporting accelerated delivery of RUPTL targets.

Based on these objectives, the study is guided by the following research questions:

1. What systemic constraints limit the ability of existing procurement schemes to achieve accelerated transmission and substation development?
2. How does the application of bundling schemes alter the structure and severity of these constraints?
3. Which types of bundling configurations provide the most feasible pathway for procurement acceleration under PLN's operational conditions?

1.4. Contribution of the Study

This study contributes to the literature on infrastructure procurement and project delivery in three principal ways.

First, the study reframes procurement scheme selection as a system-level execution problem, rather than a purely contractual or cost-optimization exercise. By explicitly positioning procurement decisions within the context of PLN's challenge of implementing the RUPTL according to schedule, the research highlights how alternative implementation paths reshape coordination requirements, organizational workloads, and execution risks. This perspective extends existing procurement studies that primarily focus on efficiency, pricing, or contractual structure, by emphasizing feasibility under real organizational constraints.

Second, the study introduces an integrated analytical framework combining the Theory of Constraints (TOC) and Strategic Assumption Surfacing and Testing (SAST) for evaluating procurement alternatives in large-scale infrastructure programs. As illustrated in Figure X, the framework contrasts bundling-based and conventional (non-bundled) construction approaches, systematically examines the impacts and challenges arising from each, and applies SAST to identify feasible options that enable timely project delivery. This approach contributes methodologically by providing a structured means to assess procurement schemes under uncertainty, limited capacity, and institutional constraints—conditions that are often decisive in practice but underrepresented in conventional evaluation models.

Third, the study offers practically actionable insights for policymakers and infrastructure owners, particularly in the context of time-critical national development programs. By shifting attention from post hoc performance evaluation to ex ante problem anticipation, the framework supports more informed procurement policy design and strategic decision-making. The results demonstrate how appropriate procurement structuring can function as a lever for mitigating execution bottlenecks, improving coordination, and enhancing delivery robustness without relying solely on internal capacity expansion.

Fourth, the study serves as a strategic vehicle for institutional knowledge management and industry–academia synergy. By codifying structured problem-solving practices within PLN's operational framework, the research translates complex execution challenges into formalized inquiry and transferable knowledge outputs. This orientation is consistent with recent scholarship that frames academic papers as strategic tools for partnership governance and organizational learning, rather than as purely scholarly artifacts (Budiyono et al., 2024a). Moreover, the study advances an ecosystem-based perspective on innovation, emphasizing that sustained improvements in project delivery depend on the coordinated interaction of talent, technology, and institutional structures across diverse stakeholders (Apriadi et al., 2024; Budiyono et al., 2024b).

Overall, the study contributes by linking procurement system design, constraint-based reasoning, and strategic assumption testing into a coherent decision-support framework that is directly applicable to complex infrastructure programs such as the RUPTL. **Error! Reference source not found.** illustrates the study's contribution through the application of Strategic Assumption Surfacing and Testing (SAST) to evaluate alternative procurement implementation paths for achieving timely delivery of the RUPTL. The framework contrasts bundling-based and conventional (non-bundled) construction approaches, examines their respective impacts and

challenges, and supports anticipatory identification of execution risks and system constraints.

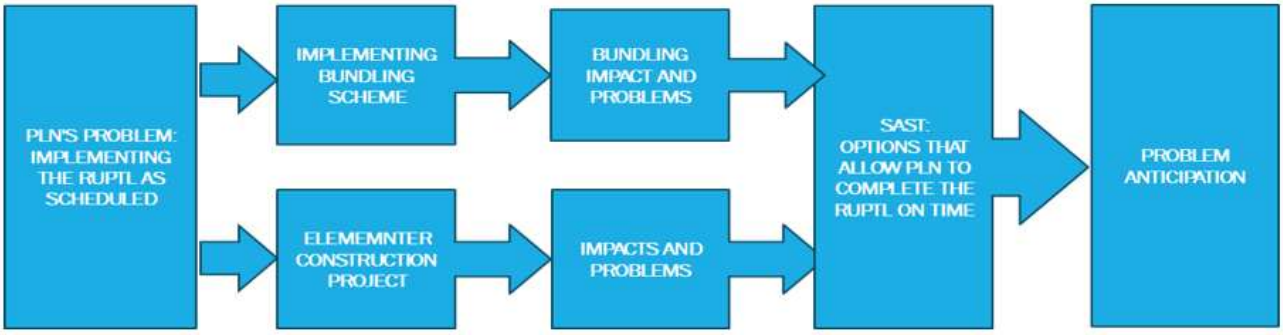

Figure 1: Research Flow and Contribution Framework

2. LITERATURE REVIEW AND CONCEPTUAL BACKGROUND

2.1. Project Procurement Management in Large Infrastructure Programs

Project procurement management plays a critical role in determining the performance of large-scale infrastructure projects, particularly in contexts characterized by high complexity, multiple stakeholders, and strict delivery timelines. Araújo, Alencar, and Mota (2017) provide a comprehensive structured review of the project procurement management literature, highlighting procurement as a strategic function that extends beyond contractual arrangements to include coordination, risk allocation, and decision-making under uncertainty. Their review emphasizes that procurement choices influence not only cost and schedule outcomes but also organizational workload, information flows, and governance effectiveness.

In large infrastructure programs, procurement systems must accommodate fragmented scopes, regulatory constraints, and limited internal capacity. The literature suggests that traditional procurement approaches, while offering clarity and control at the component level, often struggle to manage systemic complexity and interface risks when projects scale up. This limitation is particularly pronounced in public-sector infrastructure programs, where procurement decisions are frequently constrained by policy mandates and institutional rigidities (Araújo et al. 2017).

2.2. Bundling and Integrated Procurement Approaches

Procurement bundling has been widely studied as a mechanism for improving coordination and reducing transaction costs in complex procurement environments. Bundling involves aggregating multiple project components or contracts into a single procurement package, thereby shifting coordination responsibilities from the owner to the contractor or consortium. Schoenherr and Mabert (2008) show that bundling in business-to-business procurement settings can improve efficiency and reduce opportunistic behavior when appropriately designed, particularly in auction-based environments.

From a procurement design perspective, bundling affects competitive dynamics, supplier participation, and risk distribution. Day and Raghavan (2008) analyze combinatorial procurement auctions and demonstrate that bundle-based bidding mechanisms can mitigate free-riding and enable more efficient price discovery when interdependence across components exist. Their findings underscore that bundling is not merely an administrative decision but a structural choice that shapes supplier incentives and system performance.

In infrastructure contexts, bundling is often operationalized through integrated delivery models such as Engineering–Procurement–Construction (EPC). Huang et al. (2024), through a bibliometric review of EPC supply chain management, highlight that integrated procurement models can enhance coordination, reduce interface risks, and improve schedule performance. However, they also note that such models introduce new dependencies on contractor capability and governance mechanisms, making procurement design a trade-off rather than a universally superior solution.

2.3. Theory of Constraints in Project and Procurement Management

The Theory of Constraints (TOC) provides a system-level framework for managing performance by identifying and addressing the most critical limiting factor within a system. Izmailov, Korneva, and Kozhemiakin (2016) demonstrate the applicability of TOC principles in project management, showing that project delays and inefficiencies often stem from a small number of dominant constraints rather than from generalized resource shortages. Their work reinforces the

relevance of TOC for environments characterized by interdependent tasks and limited organizational capacity.

In the context of project procurement and delivery, TOC shifts analytical focus from local optimization to global system performance. Jacob and McClelland (2001) extend TOC concepts to project management, emphasizing the importance of subordinating all activities to the system's primary objective. This perspective is particularly relevant for procurement decisions, as procurement schemes directly influence where constraints emerge—whether within owner organizations, contractor interfaces, or supply chains.

By framing procurement schemes as alternative system designs, TOC enables decision-makers to assess how different procurement structures redistribute constraints across organizational boundaries. Rather than assuming that increased integration or fragmentation is inherently beneficial, TOC encourages evaluation based on whether dominant constraints can be effectively exploited and elevated within the chosen procurement arrangement.

2.4. Strategic Assumption Surfacing and Testing (SAST)

While TOC provides a powerful lens for identifying and managing constraints, it does not explicitly address the validity of the strategic assumptions underlying major design choices. Strategic Assumption Surfacing and Testing (SAST) addresses this gap by offering a structured method for identifying, challenging, and evaluating the assumptions embedded in strategic decisions. Barabba and Mitroff (2023) describe SAST as a participatory and systematic approach that enhances decision robustness by making implicit assumptions explicit and subject to scrutiny.

In procurement and infrastructure policy contexts, strategic assumptions often concern contractor capability, market readiness, regulatory flexibility, and organizational coordination capacity. These assumptions are rarely tested explicitly, yet they critically determine the success or failure of procurement schemes. SAST provides a mechanism to assess whether the assumptions required for a given procurement approach are plausible under real-world conditions, thereby complementing analytical frameworks such as TOC.

2.5. Conceptual Integration: Constraint Management and Assumption Testing

Taken together, the literature indicates that effective procurement decision-making in large infrastructure programs requires both constraint-based analysis and explicit examination of strategic assumptions. Procurement bundling and integrated delivery models offer potential advantages in coordination and efficiency, but they also redistribute constraints across organizational, contractual, and supply-chain boundaries. While the Theory of Constraints (TOC) provides a structured approach for identifying and prioritizing dominant constraints, it does not by itself assess whether the strategic assumptions required by alternative procurement schemes are valid under real-world conditions. Strategic Assumption Surfacing and Testing (SAST) addresses this limitation by enabling systematic identification and evaluation of such assumptions.

Error! Reference source not found. presents the conceptual framework developed in this study by integrating TOC and SAST into a unified decision-support logic for procurement scheme evaluation. The framework adapts the classical TOC five focusing steps—identifying the constraint, exploiting the constraint, subordinating all resources to the global decision, elevating the constraint, and overcoming inertia—by embedding SAST as a critical evaluative stage prior to procurement scheme selection. In this integration, TOC is used to reveal where dominant constraints emerge under alternative procurement structures, while SAST is employed to surface and test the strategic assumptions concerning organizational capacity, contractor capability, market readiness, and coordination feasibility.

By positioning SAST within the constraint management cycle, the framework shifts procurement analysis from post hoc performance assessment to ex ante feasibility evaluation. Rather than if a particular procurement model—such as bundling or conventional disaggregated contracting—is inherently superior, the integrated approach enables decision-makers to assess whether the constraints associated with each option can be effectively addressed within prevailing institutional and operational conditions. Procurement schemes are thus evaluated not only on their theoretical efficiency, but on the plausibility of the assumptions required for their successful implementation.

This conceptual integration bridges a gap in the existing literature, which has largely examined procurement design, constraint management, and strategic assumption testing as separate analytical domains. By combining TOC and SAST, the framework provides a coherent basis for anticipating

execution risks and supporting robust procurement decisions in time-critical infrastructure programs.

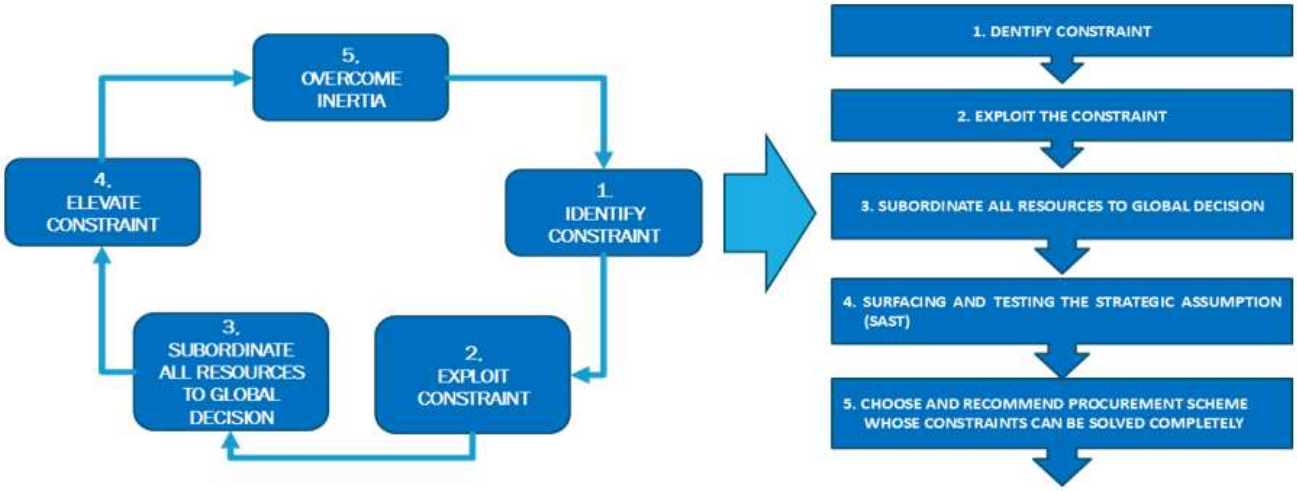

Figure 2: Integration of Theory of Constraints and Strategic Assumption Surfacing and Testing

3. RESEARCH METHODOLOGY

3.1. Research Framework and Analytical Approach

This study adopts a qualitative, theory-driven analytical approach to evaluate alternative procurement schemes for large-scale power transmission and substation infrastructure programs. The research methodology is grounded in the integrated Theory of Constraints (TOC)–Strategic Assumption Surfacing and Testing (SAST) framework developed from the literature and conceptually synthesized in Section 2.5. The framework is designed to support ex ante feasibility assessment, rather than post hoc performance evaluation or quantitative optimization.

Procurement schemes are treated as alternative system configurations that redistribute coordination responsibilities, organizational workloads, and execution risks across institutional and market actors. Rather than assuming that procurement challenges arise from generalized inefficiencies, the methodology focuses on identifying dominant constraints that govern system-level performance under each procurement structure.

Figure 3 presents the overall analytical framing of the study. Procurement and project execution problems are addressed by comparing two structurally distinct alternatives—full bundling and non-bundled procurement—and evaluating their feasibility under demand constraints, supply-side capabilities, internal organizational capacity, and policy conditions. Procurement success is defined in terms of schedule adherence, cost containment, and risk exposure, and the analytical objective is to identify the procurement scheme with the highest probability of success.

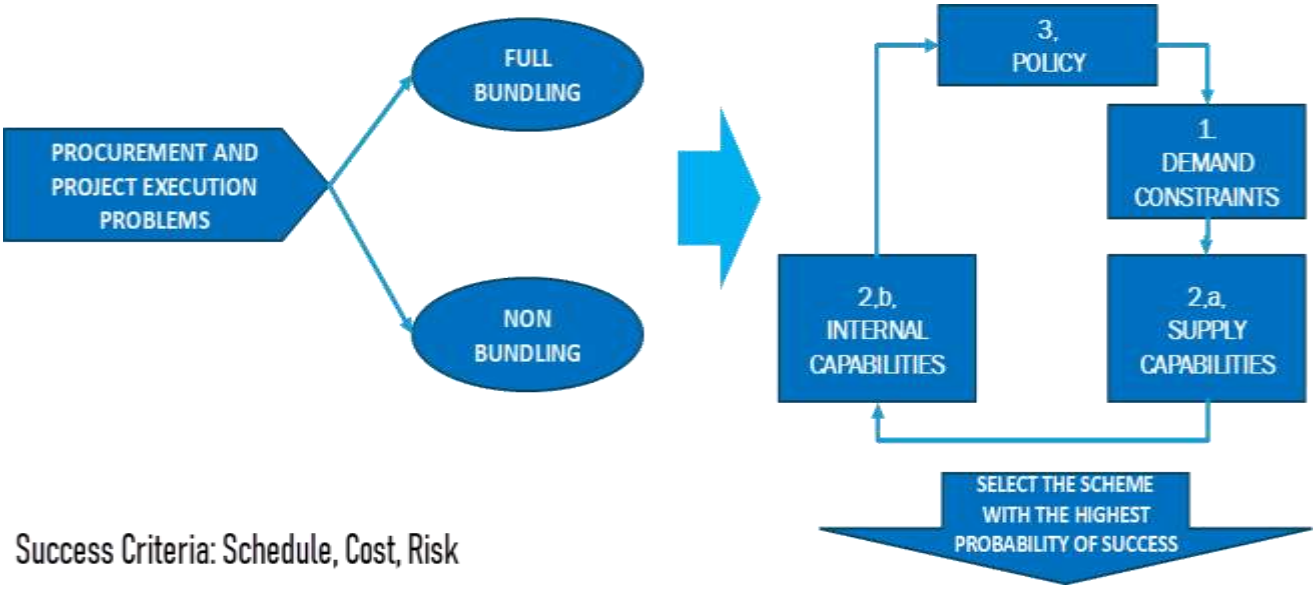

Figure 3: Procurement Alternatives and Constraint Logic

3.2. Identification and Structuring of Procurement Alternatives

The analysis focuses on two broad categories of procurement schemes commonly employed in large infrastructure programs: bundling-based procurement and conventional non-bundled procurement. Bundling-based procurement refers to arrangements in which multiple project components are aggregated into integrated contracts, including Engineering–Procurement–Construction (EPC)–type models. Conventional procurement refers to disaggregated approaches in which design, procurement, and construction activities are executed through separate contracts.

To avoid treating bundling as a homogeneous intervention, the study further differentiates procurement alternatives according to project functional characteristics.

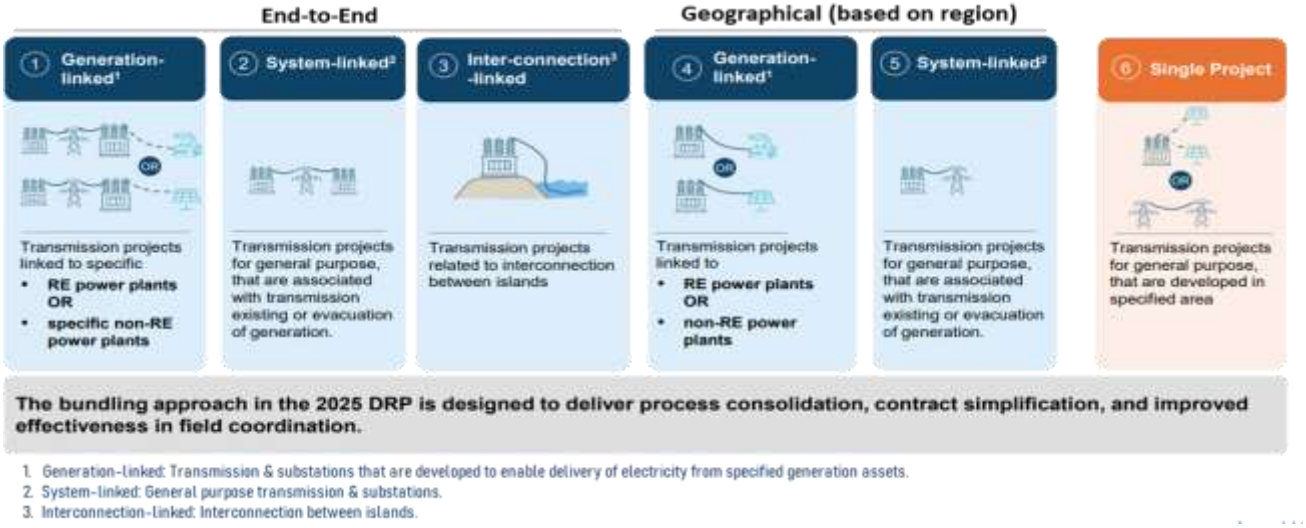

Figure 4: Classification of Bundling Contexts

Error! Reference source not found. presents a typology of transmission project contexts, distinguishing between generation-linked projects, system-linked projects, interconnection-linked projects, and geographically bounded single-project developments. This classification reflects differences in technical interdependence, coordination requirements, and exposure to external constraints. Table 1 shows the list of project examples for each of the package types

Table 1: Project Packaging Classification

Packaging Type	Project Names
A. Interconnection-linked	**Interconnection Sumatera – Bangka II** 1. GITT 150 kV Mariana (Arah LP Sumatera) Ext 2 LB 2. SUTT 150 kV Mariana – LP Sumatera LP 2 3. SKLTT 150 kV LP Sumatera LP 2 – LP Bangka Landing Point 2 4. SUTT 150 kV LP Tanjung Berani – Koba 5. GITT 150 kV Koba (Arah LP Bangka) Ext 2 LB
B. Geographical (regional based) – System linked	**GITET Madiun beserta Transmisi Incomer Terkait** 1. GITT 150/20 kV Madiun New, 60 MVA 2. GITET 500/150 kV Madiun New, 1000 MVA 3. SUTT 150 kV Madiun – Inc. (Ngawi – Manisrejo) New, 4 cct, 4 kms 4. SUTET 500 kV Madiun – Inc. (Pedan – Kediri) New, 4 cct, 2 kms
C. Geographical (regional based) – Generation linked	**Extension IBT GITET Indramayu, GI PLTU Indramayu / Sumur Adem (Ext.) dan SKTT PLTU Indramayu / Sumur Adem – Indramayu** 1. GITET 500/150 kV Indramayu Ext, 1 CB, 1 IBT 2. GITT 150 kV PLTU Indramayu / Sumur Adem Ext, 1 Dia, 3 CB 3. SKTT 150 kV PLTU Indramayu / Sumur Adem – Indramayu New, 1.5 kms
D. Single Package	1. GITT 150 kV Natal New, 4 LB, 1 TB, 1 BC, 1 TRF 30 MVA 2. SUTET 275 kV Pangkalan Susu – Arun New, 2 cct, 2 Zebra 3. SUTET 275 kV Arun – Sigli New, 2 cct, 2 Zebra

By explicitly structuring procurement alternatives in this manner, the methodology ensures that differences in feasibility outcomes are attributable to system-level procurement design, rather than to unobserved heterogeneity in project scope or function.

3.3. Constraint Identification and Analysis using The Theory of Constraints

The Theory of Constraints is employed as the primary analytical lens for identifying and prioritizing dominant constraints associated with each procurement alternative. In this study, constraints are defined broadly to include organizational, coordination, institutional, and market limitations that restrict the procurement system's ability to achieve its primary objective of timely and reliable project delivery.

Following TOC principles, the analysis seeks to identify the constraint that most strongly limits system performance under each procurement configuration. This includes examination of internal organizational capacity for planning, procurement execution, and project monitoring, as well as external supply-side constraints related to vendor technical capability, financial capacity, and delivery bandwidth.

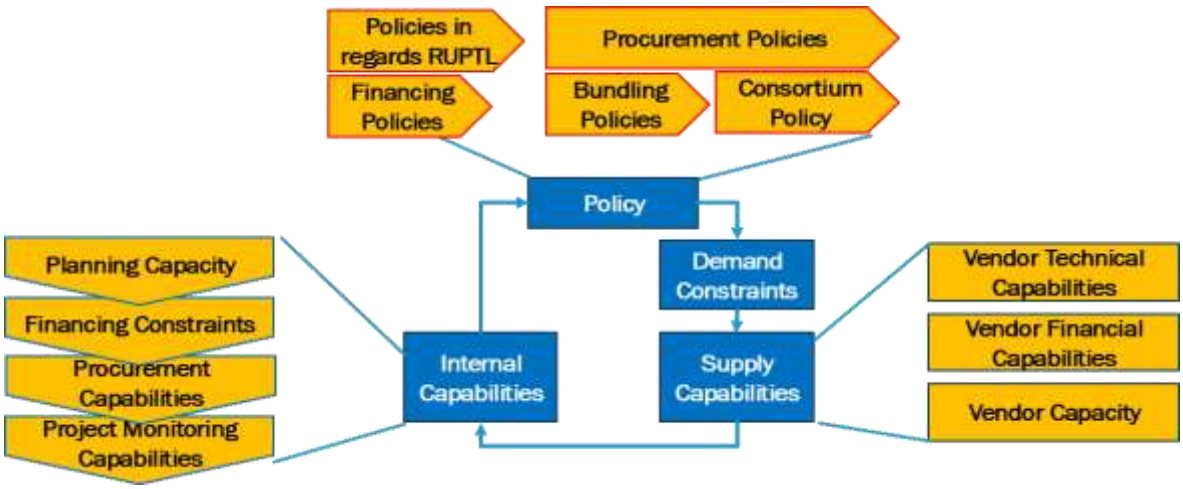

Figure 5: Constraint Taxonomy and Policy Linkages

Error! Reference source not found. summarizes the constraint taxonomy adopted in the analysis, illustrating the interaction between policy frameworks, internal organizational capabilities, and external vendor capacities. These constraints are not treated as independent variables, but as interrelated elements that jointly shape procurement feasibility.

The operational application of TOC within the procurement context is illustrated by **Error! Reference source not found.**, where it depicts the procedural logic of applying TOC to procurement decision-making. Procurement alternatives are first identified and treated as competing system designs. The dominant bottleneck or constraint is then identified for each alternative, followed by qualitative assessment of how that constraint could be exploited, subordinated to, or elevated through changes in coordination, responsibility allocation, or resource focus.

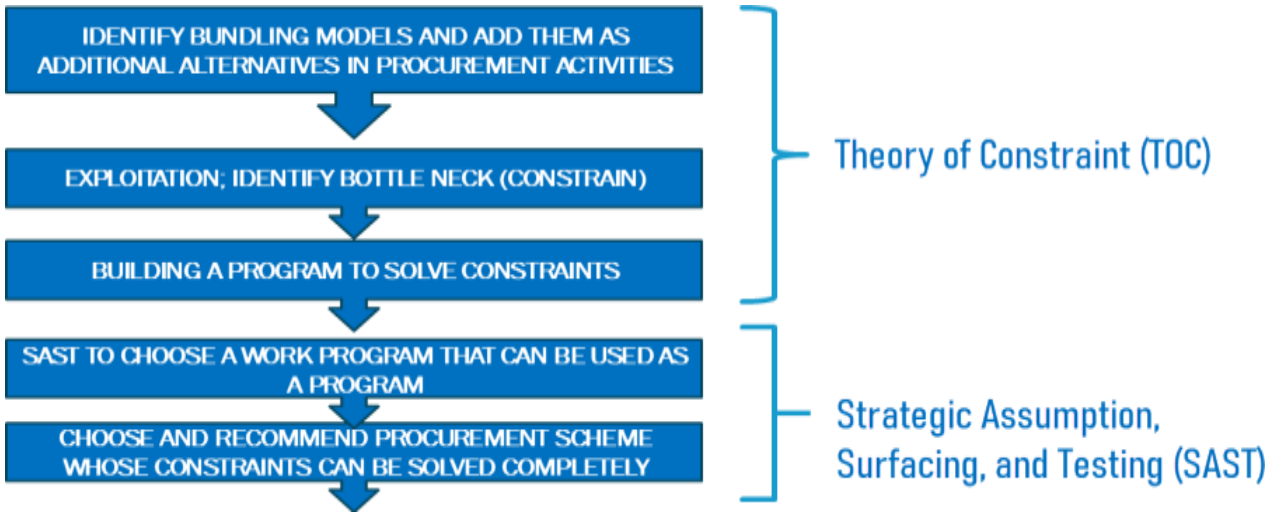

Figure 6: Operationalization of TOC and SAST

3.4. Strategic Assumption Surfacing and Testing (SAST)

While TOC enables systematic identification of dominant constraints, procurement decisions also depend on strategic assumptions regarding the feasibility of managing or alleviating those constraints. To explicitly evaluate these assumptions, the study incorporates Strategic Assumption Surfacing and Testing (SAST) as a complementary analytical tool.

SAST is used to identify the key assumptions embedded in each procurement alternative, including assumptions concerning internal organizational readiness, contractor capability, market competitiveness, financing availability, and regulatory flexibility. These assumptions are surfaced through structured analysis and evaluated in terms of their criticality to procurement success and their plausibility under prevailing conditions.

The integration of SAST within the analytical process is shown below.

As illustrated in Figure 6, SAST is embedded as a decision gate following constraint identification and preliminary resolution planning. Procurement schemes that rely on highly critical but weakly supported assumptions are treated as high-risk options, whereas schemes supported by more plausible and controllable assumptions are considered more robust.

3.5. Integrated TOC–SAST Evaluation Process

The integration of TOC and SAST follows the conceptual logic illustrated earlier and is applied at both project and program levels. TOC provides the diagnostic foundation by identifying where dominant constraints emerge under alternative procurement structures, while SAST enables explicit evaluation of whether the strategic assumptions required to manage those constraints are credible.

Figure 7 illustrates the application of this integrated framework at the program level, using a portfolio of funded transmission and substation projects. Bundled and non-bundled procurement schemes are evaluated against demand constraints, supply-side capabilities, internal organizational capacity, and policy conditions to assess their relative feasibility. The outcome of this process is not the identification of a universally optimal procurement solution, but a reasoned assessment of which procurement schemes exhibit the highest probability of success under existing constraints.

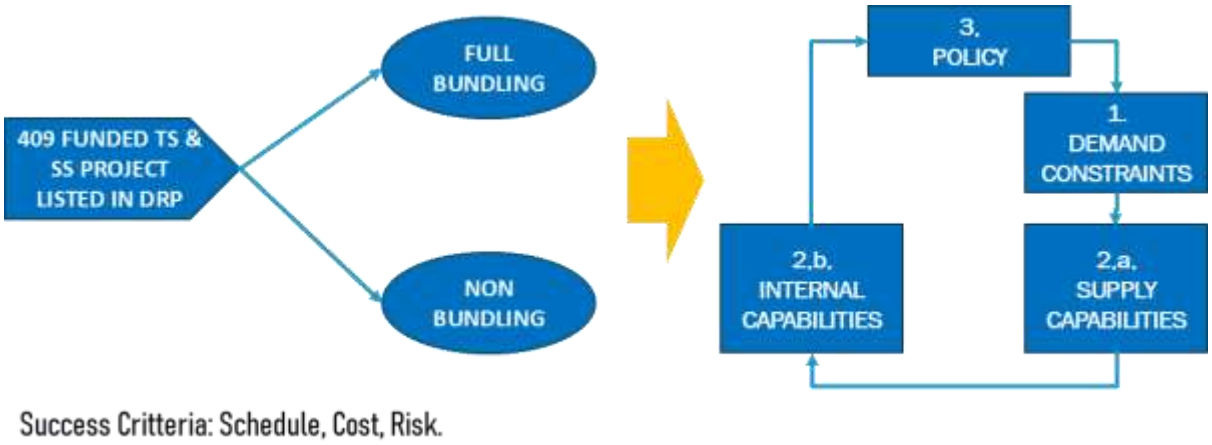

Figure 7: Application to the DRP Project Portfolio

By integrating constraint management with assumption testing, the methodology shifts procurement evaluation from post hoc performance comparison to anticipatory decision-making, enabling infrastructure owners to identify execution risks before procurement commitments are made.

3.6. Analytical Scope and Limitations

The methodology emphasizes qualitative, system-level analysis and is intended to complement, rather than replace, detailed financial, technical, or scheduling models. The integrated TOC–SAST framework is particularly suited to early-stage strategic decision-making, where uncertainty is high and institutional constraints play a decisive role.

The findings are context-sensitive and reflect the institutional, organizational, and market conditions associated with large public-sector infrastructure programs. While the framework is transferable in principle, its application in other sectors or regulatory environments requires careful contextual adaptation.

4. RESULTS AND ANALYSIS

4.1. Overview of Procurement Performance under Bundling and Non-Bundling

This section presents the empirical results of the TOC-based constraint analysis applied to alternative procurement schemes for accelerating the RUPTL program. The analysis compares bundled and non-bundled procurement configurations across internal organizational capacity, external market capability, institutional policy, and demand-side feasibility.

While bundled procurement demonstrates potential advantages in reducing contractual fragmentation and interface complexity, the results reveal that bundling also redistributes and intensifies constraints across multiple subsystems. The following subsections systematically identify, evaluate, and interpret these constraints using the Theory of Constraints (TOC) logic of identification, exploitation, and subordination.

4.2. Constraint Identification Using TOC

4.2.1. Internal Capacity Constraints

Internal capacity constraints relate to the organization's ability to plan, finance, procure, and govern bundled projects effectively.

4.2.1.1. Planning and Design Capacity

Bundled procurement places substantial demands on early-stage planning, including multidisciplinary coordination, permitting, design integration, and cost estimation.

INTERNAL: PLANNING CAPACITY CONSTRAINTS

CONSTRAINTS	LEVEL OF IMPORTANT								CONSTRAINTS EXPLOITATION AND SUBORDINATION OF ALL RESOURCES TO GLOBAL DECISION	C
	IL N-I	IL B-I	GSL N-L	GSL B-I	GGL N-I	GGL B-I	SP N-I	SP B-I		
Knowledge Integration and Project Complexity	3	5	3	5	3	5	3	5	1-a. Establishment Multi-discipline Planning Teams and Training for them	5
Delay in obtaining a construction permit	5	5	5	5	5	5	5	5	1-b. Standardization of Processes and Documents in obtaining construction permits:	4
Difficulties in Managing Risk:	4	5	4	5	4	5	4	5	1-c. Earlier Risk Identification and Mitigation	4
Delay in preparing Design	5	5	5	5	5	5	5	5	1-d. Establishment Multi-discipline Planning Teams and Training for them 1-e. Start Design Earlier	4 4
Difficulty in Estimating Costs	4	5	4	5	4	5	4	5	1-f. Establishment Multi-discipline Planning Teams and Training for them	4

Figure 8: Planning Capacity Constraints

Error! Reference source not found. shows that internal planning-related constraints reach the highest severity level under bundled schemes across all contract types. Knowledge integration, permitting readiness, and design preparation consistently score at the upper end of the constraint scale, indicating that bundling shifts complexity upstream into planning functions that may not be institutionally prepared to absorb it.

Beyond indicating high severity, the planning and design capacity constraints shown in Figure 8 represent a physical system bottleneck in the TOC sense. Planning determines the maximum rate at which projects can be transformed from investment intent into permit-ready, design-complete, and cost-certain packages eligible for procurement. When this capacity is exceeded, upstream queues form, delaying all downstream activities regardless of procurement efficiency gains.

Bundled procurement amplifies this bottleneck by increasing the volume and coupling of planning tasks that must be completed simultaneously. Multisite coordination, integrated design resolution, and parallel permitting requirements increase the effective workload imposed on planning units. As a result, even when construction or procurement execution capacity is available, overall system throughput remains constrained by the limited ability to complete early-stage project preparation.

This finding explains why improvements in contractual efficiency under bundling do not translate proportionally into accelerated project

delivery. The constraint is not eliminated; it is shifted upstream and intensified.

4.2.1.2. Financing Capacity

Bundled projects aggregate financial exposure, increasing capital requirements and tightening lender conditions.

INTERNAL: FINANCING CONSTRAINTS

CONSTRAINTS	LEVEL OF IMPORTANT								CONSTRAINTS EXPLOITATION AND SUBORDINATION OF ALL RESOURCES TO GLOBAL DECISION	C
	IL N-I	IL B-I	GSL N-L	GSL B-I	GGL N-I	GGL B-I	SP N-I	SP B-I		
Difficulty in meeting loan requirements	3	5	3	5	3	5	3	5	1-g. Conduct a comprehensive feasibility study and complete loan document, 1-h. Maintain financial ratios that show the ability to pay.	5 5
Delays in the approval process	5	5	5	5	5	5	5	5	1-i. Choose an experienced financial professional.:	5
Difficulty in meeting financial ratios	4	5	4	5	4	5	4	5	1-j. Consider ratios in the company's financial planning and implementation	5

Figure 9: Financing Constraints

As shown in **Error! Reference source not found.**, financing-related constraints—including loan qualification, approval timelines, and financial ratio compliance—are significantly more binding under bundled procurement. This suggests that while bundling reduces the number of contracts, it concentrates financial risk, making funding access a dominant bottleneck.

4.2.1.3. Procurement Execution Capacity

Bundling alters the workload distribution of procurement functions.

INTERNAL: PROCUREMENT CAPACITY CONSTRAINTS

CONSTRAINTS	LEVEL OF IMPORTANT								CONSTRAINTS EXPLOITATION AND SUBORDINATION OF ALL RESOURCES TO GLOBAL DECISION	C
	IL N-I	IL B-I	GSL N-L	GSL B-I	GGL N-I	GGL B-I	SP N-I	SP B-I		
Resource limitations for Existing Scheme Procurement	5	1	5	1	5	1	5	1	1-l. Conduct HR recruitment and conduct necessary training to perform 784 contracts per year 1-m. Increase capacity by reallocating internal company 's HR and conduct necessary training to perform 306 contracts per year	2
Resource limitations for Bundling Procurement	1	5	1	5	1	5	1	5		5
Infrastructure Limitations	4	4	4	4	4	4	4	4	1-n. Infrastructure investment for procurement activities	4
Limitations of (Information) Technology	5	4	5	4	5	4	5	4	1-k. Information technology investment to support procurement activities.	5
Delays in the procurement process	3	5	3	5	3	5	3	5	1-k. Proactively identify and meet the requirements for the implementation of the procurement process as early as possible.	5

Figure 10: Procurement Capacity Constraints

Error! Reference source not found. highlights a critical TOC insight: although bundling reduces the total number of procurement packages, it increases the complexity, risk concentration, and capability requirements of each package. As a result, procurement capacity constraints remain severe despite apparent transactional efficiency gains.

4.2.1.4. Project Monitoring and Governance

Bundled contracts require stronger coordination, faster decision-making, and integrated monitoring systems.

INTERNAL: PROJECT MONITORING CAPABILITY CONSTRAINTS

CONSTRAINTS	LEVEL OF IMPORTANT								CONSTRAINTS EXPLOITATION AND SUBORDINATION OF ALL RESOURCES TO GLOBAL DECISION	C
	IL N-I	IL B-I	GSL N-L	GSL B-I	GGL N-I	GGL B-I	SP N-I	SP B-I		
Limited Human Resources	5	5	5	5	5	5	5	5	1-o. Use more suitable Information Technology 1-p. Standardize Reporting System 1-q. Adjust/increase the number of human resources 1-r. Conduct training for new employees	4 5 4 4
Difficulties in integrating monitoring systems	5	5	5	5	5	5	3	5		
Difficulties in coordination	5	5	5	5	5	5	5	5	1-s. Effective communication with vendors	5
Delays in the decision-making process	5	5	5	5	5	5	5	5	1-r. Create a realistic timeline for decision-making and make sure everyone understands the importance of time. 1-u. Hold regular coordination meetings to discuss project progress and address any difficulties that may arise.	5 5
Difficulties in managing quality	5	5	5	5	5	5	5	5	1-v. Standard-setting and quality control	5
Difficulties in managing risk	4	5	4	5	4	5	4	5	1-w. Identify, analyze, mitigate and monitor risks strictly.	5

Figure 11: Project Monitoring Capability Constraints

Figure 11 demonstrates that bundled procurement places maximum stress on project governance functions, including coordination, quality assurance, and risk management. Non-bundled schemes distribute monitoring responsibilities across more actors, reducing peak internal governance load.

4.2.2. External Market Constraints

External constraints arise from the technical and financial capabilities of vendors participating in bundled procurement.

4.2.2.1. Vendor Technical Capability

EXTERNAL: VENDOR TECHNICAL CONSTRAINTS

CONSTRAINTS	LEVEL OF IMPORTANT								CONSTRAINTS EXPLOITATION AND SUBORDINATION OF ALL RESOURCES TO GLOBAL DECISION	C
	IL N-I	IL B-I	GSL N-L	GSL B-I	GGL N-I	GGL B-I	SP N-I	SP B-I		
Limited total capacity of overall existing vendors .	5	5	5	5	5	5	5	5	2-a. Maintaining/leveraging existing vendors.	4
									2-b. Provide opportunities for new vendors.	5
Limitations of the vendor experience; a) Multidiscipline Bundling Scheme b) Existing Scheme	1	4	1	4	1	4	1	1	2-c. Vendors are asked to form consortiums.	4
	4	4	4	4	4	4	4	4	2-d. Using accumulated experience as criteria for selecting vendors/consortiums.	4
Some vendors have limitations in important technology	5	5	5	5	5	5	5	5	1-e. Using technological capabilities as criteria for selecting vendors/consortiums.	5
Some vendors have limited management capabilities	4	5	4	5	4	5	4	5	1-f. Using vendor management capabilities as criteria for selecting vendors/consortiums.	5
Some vendors have limited logistics capabilities	5	5	5	5	5	5	5	5	1-g. Using logistics capabilities as criteria for selecting vendors/consortiums	5
Limited quality control capabilities	4	5	4	5	4	5	4	5	1-g. Using Quality Control capabilities as criteria for selecting vendors/consortiums	5
Limitations in adaptability	4	5	4	5	4	5	4	5	2.e2-g. Using flexibility as criteria for selecting vendors/consortiums.	5

Figure 12: Vendor Technical Constraints

As shown in **Error! Reference source not found.**, bundled procurement requires vendors or consortia with advanced technical integration capabilities across engineering, logistics, quality control, and

adaptability. Such vendors are limited in number, increasing dependency risks and reducing competitive pressure.

4.2.2.2. Vendor Financial Capability

CONSTRAINTS	LEVEL OF IMPORTANT								CONSTRAINTS EXPLOITATION AND SUBORDINATION OF ALL RESOURCES TO GLOBAL DECISION	C
	IL N-I	IL B-I	GSL N-L	GSL B-I	GGL N-I	GGL B-I	SP N-I	SP B-I		
Some vendors have limited funding capabilities	1	5	1	5	1	5	1	5	2-h. Request vendors to conduct mutually complementary consortiums to meet the needs of funds and working capital.	4
Some vendors have limited working capital	5	5	5	5	5	5	5	5	2-i. Include accumulated funding capabilities as a criterion for selecting vendors/vendor consortiums.	4
Some vendors have limited ability to obtain collateral	4	5	4	5	4	5	4	5	2-j. Include accumulated working capital and liquidity in the vendor/consortium selection criteria.	4
Some vendors have limitations in managing liquidity	5	5	5	5	5	5	5	5	2-k. Include the accumulation of collateral ability as a criterion in the selection of vendors/ consortiums	4
Some vendors have limited ability to manage financial risk	4	5	4	5	4	5	4	5	2-l. Include risk management skills as a criterion in the selection of vendors/consortiums.	4

Figure 13: Vendor Financial Constraints

Error! Reference source not found. indicates that vendor financial constraints—such as limited funding capacity, liquidity management, and risk absorption—are universally severe under bundled schemes. TOC exploitation strategies therefore emphasize consortium formation, accumulation of working capital, and financial capability as explicit vendor selection criteria.

4.2.3. Institutional and Policy Constraints

Procurement policy plays a decisive role in enabling or constraining bundling strategies.

CONSTRAINTS	LEVEL OF IMPORTANT								CONSTRAINTS EXPLOITATION AND SUBORDINATION OF ALL RESOURCES TO GLOBAL DECISION	C
	IL N-I	IL B-I	GSL N-L	GSL B-I	GGL N-I	GGL B-I	SP N-I	SP B-I		
Procurement policies procedures that allow bundling procurement	1	5	1	5	1	5	1	5	4-a. Propose clear procurement policies for bundling projects in order to achieve RUPTL	5
									4-b. Compiling bundling procurement procedures:	5
Procurement policy need to be completed with vendor consortium policy	2	5	2	5	2	5	2	5	4-c. Develop the Company's policy regarding the procedures for the formation of a consortium of vendors to carry out bundling projects.	5
Policies related to project funding in achieving the RUPTL are needed	5	5	5	5	5	5	5	5	4-d. Establishment of project funding policies using various sources of selected funds	5

Figure 14: Purchasing policy

Error! Reference source not found. shows that unclear or incomplete procurement policies significantly constrain bundling implementation. The absence of standardized procedures for bundling, vendor consortium formation, and project financing creates institutional bottlenecks that cannot be resolved solely through market mechanisms.

4.2.4. Demand-Side Constraints

Demand-related constraints concern the alignment between project development and actual system demand.

CONSTRAINTS	LEVEL OF IMPORTANT								CONSTRAINTS EXPLOITATION AND SUBORDINATION OF ALL RESOURCES TO GLOBAL DECISION	C
	IL N-I	IL B-I	GSL N-L	GSL B-I	GGL N-I	GGL B-I	SP N-I	SP B-I		
Lack the demand prediction that leads mismatch of the real demand with prepared capacity	5	5	5	5	5	5	5	5	3-a. Forecasting demand that is close to realities. 3-b. Development based on accurate demand forecasts	4 4
Change the environment that change the real demand	5	5	5	5	5	5	5	5	3-c. Monitor demand and confirm before executing a build.	5

Figure 15: Demand constraints

As illustrated in Figure 15, inaccurate demand forecasting and misalignment with device or system bottlenecks impose severe constraints regardless of procurement scheme. TOC-based mitigation emphasizes development sequencing starting from bottleneck devices and improving demand forecast accuracy.

4.3. Constraint Exploitation and Subordination Strategies

Across Figures 8–15, the results demonstrate that bundled procurement does not eliminate constraints but reallocates them. Effective implementation therefore depends on exploiting the dominant constraint—typically internal planning or financing—and subordinating all other resources to that global decision.

This includes:

- Strengthening multidisciplinary planning capacity,
- Aligning financing structures with bundled risk profiles,
- Reforming procurement policy to explicitly support bundling,
- Sequencing development based on demand and system bottlenecks.

From a TOC perspective, these results indicate that planning capacity most frequently emerges as the dominant system constraint under bundled procurement schemes. Effective exploitation therefore requires prioritizing planning throughput over localized efficiency improvements in procurement or execution functions.

Subordination implies that downstream decisions—such as contract packaging, vendor selection, and execution sequencing—must be aligned with the realistic output capacity of planning units. When bundling decisions exceed this capacity, apparent efficiency gains at later stages are offset by prolonged system lead times.

Accordingly, bundled procurement is viable only when accompanied by explicit measures to elevate planning capacity, including institutional coordination mechanisms, resource expansion, and sequencing strategies that reduce simultaneous workload demands. Absent such measures, bundling increases constraint severity and reduces overall throughput despite reduced transactional fragmentation.

4.4. Strategic Assumption Surfacing and Testing (SAST) Analysis

This section extends the TOC-based constraint analysis by applying Strategic Assumption Surfacing and Testing (SAST) to evaluate the robustness of procurement strategies under the identified constraint conditions. While Figure 8 – Figure 15 diagnose where constraints are most severe, SAST examines whether the assumptions required for bundled procurement to succeed are both important and sufficiently certain.

4.4.1. Single Package SAST Mapping

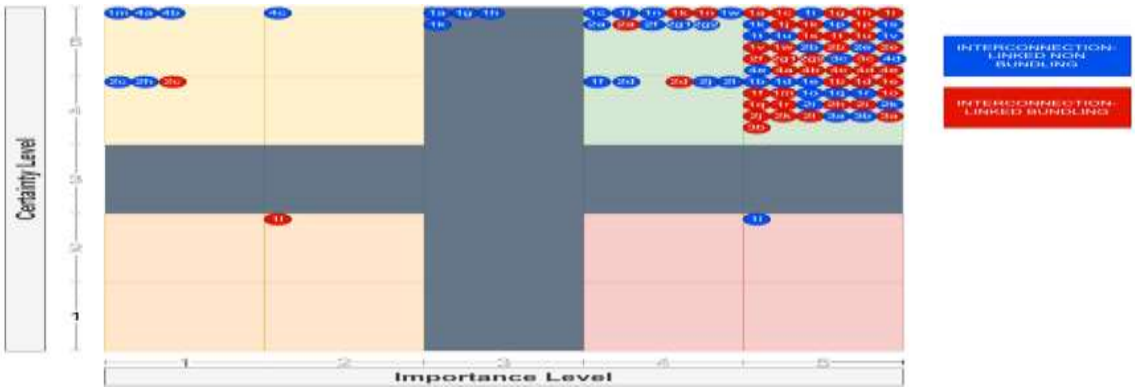

Figure 16: Single package SAST mapping

The single-package SAST mapping (Figure 16) shows that bundled procurement depends on a concentrated set of high-importance assumptions, particularly regarding internal planning readiness, vendor integration capability, and financing feasibility. While these assumptions are critical, their certainty remains moderate, reflecting institutional and market variability. This positioning places single-package bundling near the feasibility threshold, indicating vulnerability to assumption failure.

4.4.2. Interconnection-Linked SAST Mapping

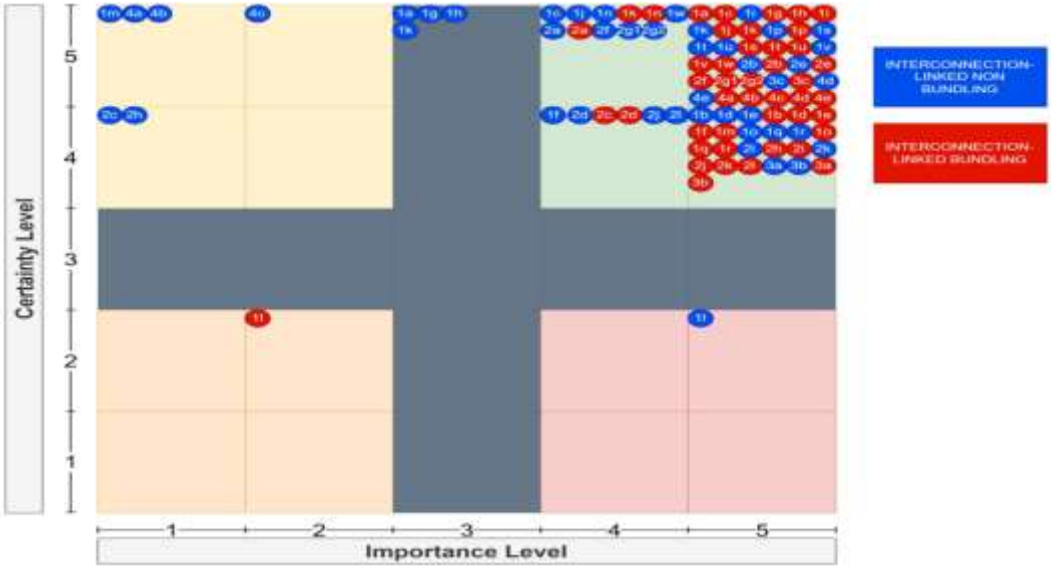

Figure 17: Interconnection-linked SAST mapping

Interconnection-linked SAST mapping (Figure 17) introduces cross-package dependency, increasing assumption coupling. The analysis shows that failures in permitting, financing, or coordination at one node propagate across the system, reducing overall robustness. As assumption interdependence increases, the feasibility of bundled procurement becomes constrained by the weakest link rather than average capability.

4.4.3. Geographical-System-Linked SAST Mapping

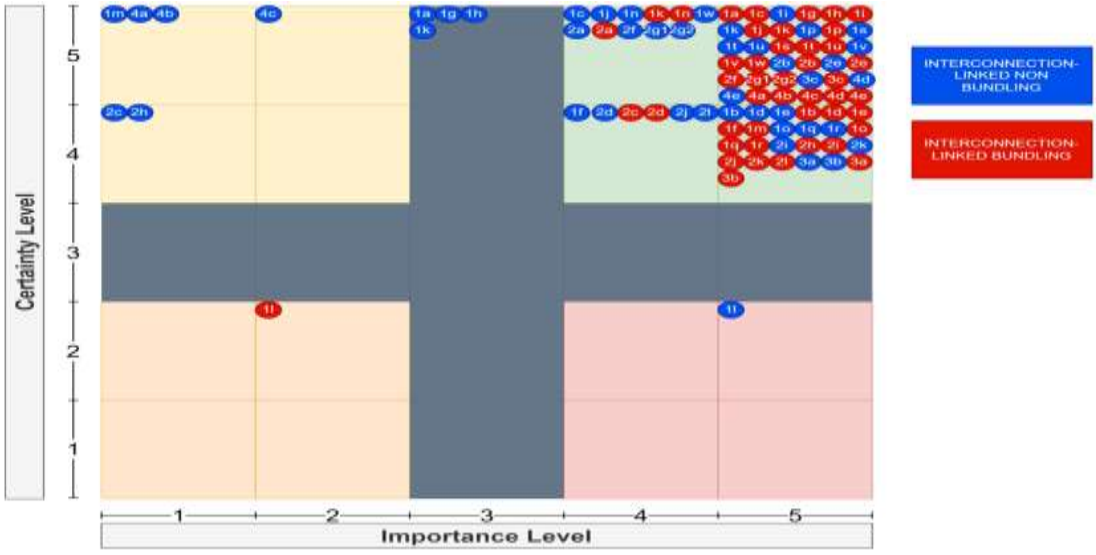

Figure 18: Geographical-system-linked SAST mapping

Geographical dispersion further reduces assumption certainty. Variability in local permitting regimes, stakeholder alignment, and site conditions shifts several high-importance assumptions into the low-certainty quadrant (see Figure 18). This confirms that spatial expansion magnifies planning capacity and institutional coordination constraints already identified in Figure 8 and Figure 14.

4.4.4. Geographical-Generation-Linked SAST Mapping

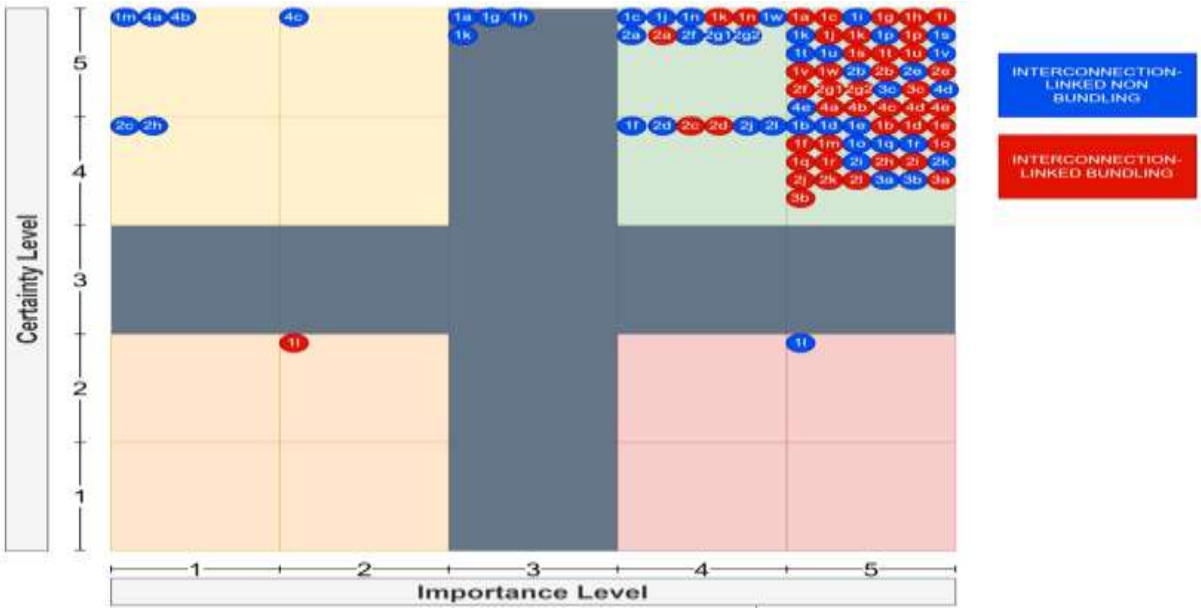

Figure 19: Geographical-generation-linked SAST mapping

The geographical-generation-linked configuration represents the most assumption-intensive case. Here, multiple high-importance assumptions cluster in low-certainty regions, indicating minimal strategic robustness. Bundled procurement under such conditions requires simultaneous satisfaction of numerous uncertain assumptions, significantly increasing the probability of system-wide delay.

5. DISCUSSION AND POLICY IMPLICATIONS

5.1. Reinterpreting Bundled Procurement through a Constraint-Based Lens

The results presented in Section 4 confirm that bundled procurement is neither inherently superior nor inferior to non-bundled schemes. Its effectiveness is contingent on the ability of the system to correctly identify, prioritize, and manage dominant constraints. The TOC-based analysis demonstrates that bundling does not remove constraints but redistributes them—shifting the system bottleneck away from transactional fragmentation toward upstream planning capacity, financing readiness, and institutional preparedness.

Figure 8–Figure 12 illustrate that internal and external capacity constraints intensify under bundled procurement. Among these, planning and design capacity emerges as the dominant upstream constraint, shaping the feasibility of all subsequent activities. Bundling concentrates complexity into early-stage decision-making, requiring a level of coordination, integration, and readiness that exceeds routine project preparation practices. When this constraint is not explicitly recognized and exploited, downstream efficiencies offered by bundling fail to materialize.

Figure 13–Figure 15 further indicate that many observed constraints are not purely operational but are embedded in financial structures, institutional policies, and demand uncertainty. These constraints cannot be resolved at the project level alone. Instead, they require policy-level interventions that address assumption risk and systemic readiness. From this perspective, procurement performance depends less on the contractual form itself and more on the alignment between procurement strategy and the system's true limiting factors.

5.2. Vendor Financial Constraints and Market Structuring

Figure 13 highlights vendor financial capability as a binding external constraint under bundled procurement. Large contract values, extended cash-flow exposure, and elevated risk transfer significantly narrow the pool of qualified vendors. As a result, bundled procurement may inadvertently reduce competition and increase procurement delays, despite its intended efficiency gains.

However, the findings also suggest that vendor financial constraints should be interpreted as a secondary constraint, subordinate to upstream planning and institutional readiness. Market-structuring mechanisms—such as encouraging vendor consortia, assessing accumulated financial capacity at the consortium level, and evaluating financial risk management capabilities—can only be effective if projects are supported by robust planning and clear institutional frameworks.

Without such upstream readiness, bundling effectively transfers financial risk to vendors without enabling conditions for risk absorption, thereby undermining project bankability and execution feasibility.

5.3. Institutional and Purchasing Policy Reform

Figure 14 underscores procurement policy itself as a dominant institutional constraint. Although bundling is permitted in principle, the absence of standardized procedures governing bundled procurement, consortium formation, and financing arrangements introduces uncertainty that delays implementation and discourages participation.

The results indicate that policy reform must move beyond enabling provisions and function explicitly as a constraint-exploitation mechanism. Procedural clarity is required to reduce assumption risk embedded in procurement decisions, including:

- Clear definitions of bundling scopes and thresholds,
- Standardized procurement workflows for bundled projects,
- Formal guidelines for consortium formation, governance, and financial coordination.

By reducing ambiguity at the institutional level, procurement policy can support the exploitation of dominant constraints rather than amplifying them. In this sense, policy design becomes an active component of system optimization rather than a neutral regulatory backdrop.

5.4. Demand Alignment and System Bottlenecks

Figure 15 demonstrates that demand-side misalignment remains a severe constraint regardless of procurement scheme. Inaccurate demand forecasting and weak alignment with critical system devices reduce the effectiveness of both bundled and non-bundled approaches.

From a TOC perspective, demand alignment represents a downstream constraint that must be subordinated to upstream planning and institutional decisions. Development sequencing should therefore begin at system bottlenecks—such as critical devices or network limitations—rather than being driven by contractual convenience or volume aggregation.

Policy implications include prioritizing demand forecasting accuracy as a strategic input to procurement decisions, aligning project sequencing with system bottlenecks, and avoiding premature bundling of projects whose demand readiness is uncertain. This shifts procurement planning from a volume-driven approach toward a flow-oriented development strategy consistent with TOC principles.

5.5. Integrating TOC into National Infrastructure Procurement Policy

Taken together, Figure 13–Figure 15 demonstrate that successful bundling requires coordinated action across planning capacity, market design, procurement policy, and demand alignment. Bundling should therefore be treated as a conditional strategy, deployed selectively when dominant constraints—particularly upstream planning capacity—can be effectively exploited and all other resources subordinated accordingly.

Integrating TOC with assumption-focused decision tools such as SAST strengthens this approach by making underlying policy assumptions explicit and testable. High-impact procurement decisions often rely on assumptions regarding institutional readiness, vendor capability, and demand certainty. When these assumptions are both critical and uncertain, procurement strategies become fragile. Embedding constraint diagnosis and assumption testing into policy formulation improves robustness and reduces the risk of systemic failure.

For national infrastructure programs such as the RUPTL, this implies:

- Using TOC as a diagnostic tool prior to selecting procurement schemes,
- Applying assumption-testing logic to evaluate policy readiness for bundling,
- Aligning procurement reforms with identified system constraints,
- Institutionalizing constraint-based thinking in long-term infrastructure planning.

Rather than prescribing bundling as a universal solution, the findings support a contingent, system-aware procurement strategy that prioritizes flow, resilience, and institutional capability over contractual form.

Taken together, the results and interpretations presented in Sections 4 and 5 demonstrate that procurement strategy cannot be evaluated independently of system constraints and institutional readiness. Bundling emerges not as a universal efficiency mechanism, but as a conditional policy choice whose success depends on the explicit identification and management of dominant constraints—particularly upstream planning capacity—and the robustness of underlying assumptions. The concluding section synthesizes these insights, highlights the study's contributions to constraint-based infrastructure procurement theory, and outlines implications for future research and policy application.

6. CONCLUSION

This study examined the effectiveness of bundled procurement as a strategy for accelerating large-scale infrastructure delivery under the RUPTL program, using a Theory of Constraints (TOC) framework complemented by assumption-focused analysis. Rather than treating bundling as an inherently superior procurement form, the analysis demonstrated that its performance is contingent on the configuration and management of dominant system constraints.

The empirical results showed that bundling does not eliminate constraints but reallocates them. While non-bundled procurement disperses complexity across multiple contracts, bundled procurement concentrates it upstream—most notably in planning and design capacity, financing readiness, and institutional coordination. Among these, internal planning capacity emerged as the dominant gating constraint, shaping the feasibility and effectiveness of all subsequent procurement and execution activities. When this constraint is not explicitly identified and exploited, the anticipated efficiency gains from bundling fail to materialize.

The study further demonstrated that external market capabilities, procurement policy frameworks, and demand alignment function as subordinate but critical constraints. Vendor financial capacity, institutional purchasing rules, and demand forecasting accuracy influence whether bundled procurement can be successfully executed, but their effectiveness depends on upstream readiness. These findings highlight that procurement outcomes are driven less by contractual form than by system-wide alignment between strategy, capacity, and institutional design.

By integrating TOC with structured assumption testing, the study contributes a system-aware decision framework for infrastructure procurement. This approach enables policymakers to distinguish between constraints that can be managed operationally and those that require institutional or policy-level intervention. Bundling, in this context, becomes a conditional strategy—appropriate only when dominant constraints are understood, assumptions are sufficiently robust, and supporting capacities are in place.

For national infrastructure programs such as the RUPTL, the findings imply that procurement policy should prioritize constraint diagnosis and flow optimization over standardization of contractual mechanisms. Embedding constraint-based logic into procurement planning can improve decision robustness, reduce systemic risk, and enhance the likelihood that acceleration strategies achieve their intended outcomes.

Future research may extend this framework by applying constraint-based and assumption-aware procurement analysis to other infrastructure sectors or by quantitatively testing the dynamic interaction between planning capacity, market structure, and institutional reform over time. Such extensions would further strengthen the evidence base for system-oriented procurement policy in complex infrastructure environments.

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