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Cooperative Game Theory in the FPA Contract Mechanism for MRO Materials in the Mining Industry (Case Study of PT X)

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This study explores the implementation of Cooperative Game Theory in the context of the mining industry, particularly in the procurement of materials involving various parties such as Vendors, Business Users, and the Supply Chain Management Department. The primary focus is on the mechanism of the Forward Purchase Agreement (FPA), which plays a crucial role in routine activities such as maintenance, especially concerning MRO materials. In this research, it is found that the application of cooperative game theory in FPA can optimize expenditures by considering various cost scenarios. Through a cooperative strategy approach, the involved parties can reach a more optimal cost agreement, taking into account factors such as inventory costs and potential production loss that could lead to financial losses. A case study on PT X illustrates the success of using cooperative strategies in identifying unnecessary cost sources and formulating strategies with a tendency towards lower costs.

Keywords: Cooperative Game Theory, Forward Purchase Agreement (FPA), Contract Agreements, MRO.

1. Introduction

Supply Chain Management (SCM) stands as a pivotal driver in attaining Competitive Advantage. The swift evolution of SCM processes in the era of globalization presents notable challenges to the procurement of Maintenance, Repair, and Overhaul (MRO) goods. MRO materials encounter three primary challenges: volatile pricing and supply availability, intricate product specifications, and reliance on effective inventory management systems[1].

Forward Purchase Agreement (FPA) emerges as a strategic approach to contract agreements employed in MRO procurement across diverse industrial sectors. FPA contracts typically serve to ensure the uninterrupted availability of requisite MRO stock over defined time frames.

The application of cooperative game theory within supply chain management yields manifold benefits in facilitating business player interactions. Integrating cooperative game theory into SCM practices can enhance operational efficiency and effectiveness, foster joint profitability, mitigate conflicts, and bolster trust. However, MRO procurement contracts utilizing FPA within the mining industry encounter distinct challenges compared to other sectors due to the industry's unique MRO requirements and characteristics. These requirements exhibit variability stemming from diverse mining operation activities, thereby significantly impacting MRO needs and lead times[2]. MRO procurement contracts within the mining sector often extend over lengthier durations and necessitate comprehensive risk considerations.

2. Methodology

A. Research Focus

In this cooperative game theory case study, the focus lies on analyzing the Forward Purchase Agreement (FPA) material contract between PT X and Vendor PT Y. The objective is to optimize outcomes aligned with the mutual objectives of the involved parties: Business User PT X, Supply Chain Management PT X, and PT Y.

B. Procedure of Case Study

The study undertaken involves an examination of collaborative decision-making among multiple entities (players), focusing on the implications of the Forward Purchase Agreement (FPA) contract on these entities. The procedural steps employed to derive the study outcomes are outlined below:

Step 1: Identification of each player and their respective interests within the cooperative game theory framework. The involved players comprise Supply Chain Management PT X, Business User PT X, and PT Y as the material supplier. The objectives of each player are delineated as follows:

Supply Chain Management PT X: To minimize costs and mitigate production losses attributable to unavailability of materials.

Business User PT X: To minimize costs and prevent production disruptions.

PT Y: To minimize costs throughout the contract duration.

Step 2: Standardization of all player objectives into a unified measurement metric. All goals are quantified in terms of financial benefits, denominated in "Rupiah." The conversion process involves:

Estimating production loss in monetary terms, computed by determining the average production and its standard deviation. The total expected production loss is calculated based on the identified data distribution.

Total Expected Production Loss= $\sum_{Z_{min}}^{Z_{Before\ loss}} Z\ x\ Financial\ Loss\ per\ Production$

- Z_{min} is the Z value when production equals 0

- $Z_{Before\ loss}$ is the Z value when production can cause financial loss

Conversion of material storage considerations into financial terms, utilizing the assumption of a Holding Cost equivalent to 12% of the total material price per annum. This assumption encompasses various factors such as physical storage expenses, risk assessments, inventory management costs, and depreciation.

Step 3: Comparative analysis of total costs across various scenarios.

Step 4: Examination of coalition formations and their impact on total costs within each scenario, followed by a comparison of average costs associated with each coalition type.

C. Mathematical Model

Player Definitions:

• Business User PT X: BU

• Supply Chain Management PT X: SCM

• PT Y (Vendor): V

Permissible Activities:

• BU: Initiate material requests with specified quantities, set budget constraints, and outline expected deadlines.

• SCM: Engage in vendor negotiations, implement procurement strategies (via tendering, direct appointments, or ongoing contracts), and enforce penalties for inadequate performance.

• V: Offer terms (lead time, specifications, and quantity) and negotiate with Procurement.

Characteristic Function (v):

The characteristic function assigns a value to each potential player coalition. Seven possible coalitions are delineated as follows:

• v({BU}) = Avoided Production Loss (BU) + Cost (BU)

• v({SCM}) = Avoided Production Loss (SCM) + Cost (SCM)

• v({V}) = Profit (V)

• v({BU, SCM}) = - Avoided Production Loss (BU) + Cost (BU) + Avoided Production Loss (SCM) + Cost (SCM)

• v({SCM, V}) = Avoided Production Loss (SCM) + Cost (SCM) + Profit (V)

• v({BU, SCM, V}) = Avoided Production Loss (BU) + Cost (BU) + Avoided Production Loss (SCM) + Cost (SCM) + Profit (V)

Collaboration between the Vendor and Business User necessitates involvement from the Supply Chain Management team to adhere to ethical business practices.

3. Result

A. Game Scenarios

Within the game structure, each player is equipped with two strategic options, yielding a total of eight potential game scenarios arising from the amalgamation of strategies across all players, detailed as follows:

Table 1. Game Scenarios

No	Vendor (PT Y)	SCM PT X	Business User PT X
1	Stock Few Materials	Stock Materials	Stock Materials
2	Stock Few Materials	Stock Materials	Do Not Stock Materials
3	Stock Many Materials	Do Not Stock Materials	Stock Materials
4	Stock Many Materials	Do Not Stock Materials	Do Not Stock Materials
5	Stock Many Materials	Stock Materials	Stock Materials
6	Stock Few Materials	Do Not Stock Materials	Do Not Stock Materials
7	Stock Many Materials	Stock Materials	Do Not Stock Materials
8	Stock Few Materials	Do Not Stock Materials	Stock Materials

B. Game Scenarios

Within the framework of this game, conducting a comprehensive analysis of total costs entails considering several crucial components. The elements underlying the calculation of costs for scenarios outlined in Table 2, representing the Eight Game Scenarios, encompass:

1. Holding Cost incurred by SCM PT X
2. Holding Cost incurred by User PT X
3. Holding Cost incurred to Vendor/PT Y
4. Total Expected Production Loss Cost

Table 2. Total Cost for Each Scenario

Scenario	Cost (IDR)				
	Total Holding Cost SCM PT X	Total Holding Cost User PT X	Total Holding Cost PT Y	Total Cost of Air Production Losses	Total Cost
Scenario 1	1,455,185,080	2,439,432,689	7,288,680	96,125,785	3,998,032,234
Scenario 2	1,455,185,080	-	7,288,680	166,716,825	1,629,190,585
Scenario 3	-	2,439,432,689	1,133,709,370	1,322,427,615	4,895,569,674
Scenario 4	-	-	1,133,709,370	1,910,128,124	3,043,837,494
Scenario 5	1,455,185,080	2,439,432,689	1,133,709,370	-	5,028,327,139
Scenario 6	-	-	7,288,680	7,972,461,068	7,979,749,748
Scenario 7	1,455,185,080	-	1,133,709,370	1,058,010	2,589,952,460
Scenario 8	-	2,439,432,689	7,288,680	7,972,461,068	10,419,182,437

The total identified costs are allocated among the three Players involved. Breakdown of the expenses to be incurred by each player can be seen from table 3.

Table 3. Responsibility for Costs Incurred by Each Player

	Cost (IDR)			
	SCM PT X	Business User PT X	PT Y / Vendor	Total Cost
Scenario 1	1.503.247.973	2.487.495.581	7.288.680	3.998.032.234
Scenario 2	1.538.543.492	83.358.412	7.288.680	1.629.190.585
Scenario 3	661.213.808	3.100.646.496	1.133.709.370	4.895.569.674
Scenario 4	955.064.062	955.064.062	1.133.709.370	3.043.837.494
Scenario 5	1.455.185.080	2.439.432.689	1.133.709.370	5.028.327.139
Scenario 6	3.986.230.534	3.986.230.534	7.288.680	7.979.749.748
Scenario 7	1.455.714.085	529.005	1.133.709.370	2.589.952.460
Scenario 8	3.986.230.534	6.425.663.223	7.288.680	10.419.182.437

The potential coalitions derived from the characteristic function present four game scenarios, each exerting varying impacts on total costs. The following outlines these scenarios:

1. No Coalition Game ({BU}.{SCM}.{V}): Absence of coalition may result in disparate storage of materials among players, potentially leading to the formation of shadow warehouses. Conversely, scenarios may emerge where materials remain unallocated. Thus, the total cost scenarios encompass scenario 5 and scenario 6. The average total cost probability amounts to IDR 6,504,038,444.

2. User and SCM Coalition ({BU.SCM}.{V}): A coalition between the Business User and SCM effectively eliminates shadow warehouses and encourages SCM to offer alternative stock solutions. This yields total cost scenarios in scenario 2 and scenario 7, with an average total cost probability of IDR 2,109,571,522.

3. SCM and Vendor Coalition ({BU}.{SCM.V}): Collaboration between SCM and Vendor regulates material allocation, mitigating the risk of storage duplication. Therefore, the total cost scenarios encompass scenarios 1, 2, 3, and 4, with an average total cost probability of IDR 3,391,657,496.

4. All Coalition ({BU. SCM. V}): Comprehensive coalition among all parties eradicates shadow warehouses and ensures efficient material supply without duplication.

Hence, the total cost scenarios involve scenario 2 and scenario 4, with an average total cost probability of IDR 2,336,514,039.

4. Conclusion

Upon analyzing the application of cooperative game theory involving three players within supply chain and maintenance strategies, the following conclusions emerge:

1. The strategic adjustments made by each player exert direct influence on the total costs incurred by all three interconnected players. Through average calculations derived from potential scenarios, each coalition type exhibits a distinct value relative to others.

2. Scenario 2 emerges as the most cost-effective strategy, with total costs amounting to IDR 2,604,173,091. In this scenario, Business User PT X refrains from storing goods, SCM PT X handles storage, and the vendor stores only a minimal quantity. This strategic choice is based on simulations conducted utilizing the Gambit application detailed in Appendix A.

3. The coalition formed between Business User PT X and SCM PT X yields the lowest cost value, averaging IDR 2,109,571,522.

References

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