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Strategic Product Mix Decisions Through Route-Level Costing: A Case Study in the Polypropylene Manufacturing Industry

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Abstract: Polypropylene manufacturers are impacted by volatile costs for raw materials (feedstocks), price competition from the marketplace, and their own plant capacities. As such, product mix decision-making is becoming increasingly reliant upon the accuracy of margins. This study was conducted to create a Route Level Costing Framework to aid in Margin-Informed Product Mix Planning within a Polypropylene Manufacturing Company. The methodology used for this research project involved a Quantitative Descriptive Case Study. Secondary Internal Data were collected from PT PRP, including Production Data, Grade-Formula-Route Mapping, Bill of materials (BOM) listings, Utility Consumption information, Costs and Selling Price Data. The developed framework will integrate both BOM-based cost calculations and Activity-Based Costing (ABC) Logic to Recalculate Production Costs at each Grade-Formula-Route combination. Additionally, it will compare the recalculated production cost with the Selling Price to determine Contribution Margin. The results indicate that grade-level costing may mask differences in costs and margins across different production routes. There exists a wide variation in Contribution Margin between the Current Costing Methodology and the proposed ABC-BOM Route-Level Cost Visibility framework. A total of 36 combinations of grades-formula-routes have been analyzed, and as a result there exist variations ranging from less than 1 USD/ton to greater than 17 USD/ton.

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INTRODUCTION

Polypropylene is one of the most popular materials in the downstream industry. This includes use in a wide variety of applications such as packaging, houseware, automotive parts, medical devices, and fiber applications (Hossain et al., 2024). As a commodity product, polypropylene is very sensitive to market pricing pressure, feedstock cost volatility, and import competition (Blazy and Blazy, 2021; Nwaokete et al., 2025). For manufacturers who have limited capacity, product mix planning requires reliable cost and margin information so that management can evaluate which production alternatives are more feasible and profitable (Genis, 2017).

PT PRP, a polypropylene manufacturer, faces a specific product mix planning challenge due to its production configuration and cost visibility limitations (Ihenyen and Michael, 2025). In PT PRP's manufacturing context, product mix decisions are not limited

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to determining which product grades should be produced (Muanmeevit and Pankham, 2025). According to Luo et al. (2023), a single grade may be produced using different formulas or processed through different downstream production routes, depending on product specifications, equipment availability, production planning requirements, and operational constraints. These differences may affect raw material consumption, additive usage, utility consumption, and route-sensitive production costs. Therefore, cost and margin visibility in this case need to reflect not only product grade, but also formula and production route (Mangngenre et al., 2025; Pasaribu and Hasanuh, 2021).

PT PRP's production process begins with propylene processing in the polymerization reactor. The intermediate product is then transferred to downstream processing units, namely Extruder 1, Extruder 2, and Granule. In this production configuration, Extruder 1 functions as the main processing unit that determines the primary grade, while Extruder 2 and Granule may produce corresponding downstream grade options depending on the primary grade being processed. This case-specific configuration creates grade-formula-route complexity because one production decision may generate several feasible production alternatives across different processing units (Attar et al., 2025).

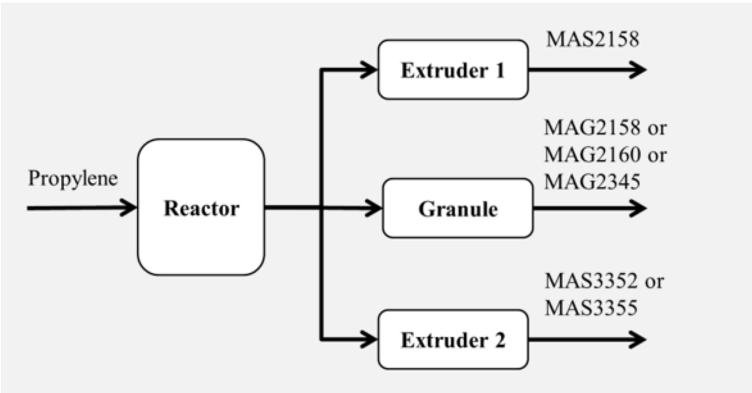

Figure 1. Grade-Formula-Route Complexity in PT PRP's Production Process
Source: PT PRP's Internal Information (2026)

As illustrated in Figure 1, when propylene is processed through the reactor, the intermediate product may be directed into different downstream processing units. In the example shown, Extruder 1 produces MAS2158 as the primary grade. At the same time, the Granule unit may produce several corresponding downstream grade options, namely MAG2158, MAG2160, or MAG2345, while Extruder 2 may produce MAS3352 or MAS3355. This illustrates that one production configuration may create several feasible grade-route alternatives, rather than only one single product output.

This condition shows that product mix planning in PT PRP is not merely a grade selection decision (Shirolkar, 2024). The same production run may involve a primary grade and several downstream grade options across different processing units. Each route may have different formulas, additive requirements, utility consumption, and route-sensitive production costs. However, PT PRP's current cost visibility is still largely evaluated at the grade level, while formula-level material consumption and route-sensitive production costs are not fully reflected in contribution margin analysis (Shirolkar, 2024). When cost information is aggregated mainly at the grade level, differences caused by formula and route variation may not be fully visible. This condition may obscure the actual profitability of each production alternative and reduce the usefulness of cost information for product mix planning (Dragomir et al., 2024; Shirolkar, 2024).

The need for more detailed cost and margin visibility becomes more important because PT PRP operates in a market environment where revenue per ton fluctuates and may differ from the annual corporate work plan and budget/RKAP. In a commodity-based industry, changes in selling price, feedstock cost, and import competition can directly affect profitability. Therefore, product mix planning cannot rely only on demand fulfillment or production volume. According to Ghareeb (2024), management also needs to understand whether each feasible production alternative contributes sufficient margin after considering its formula and route-level cost behavior.

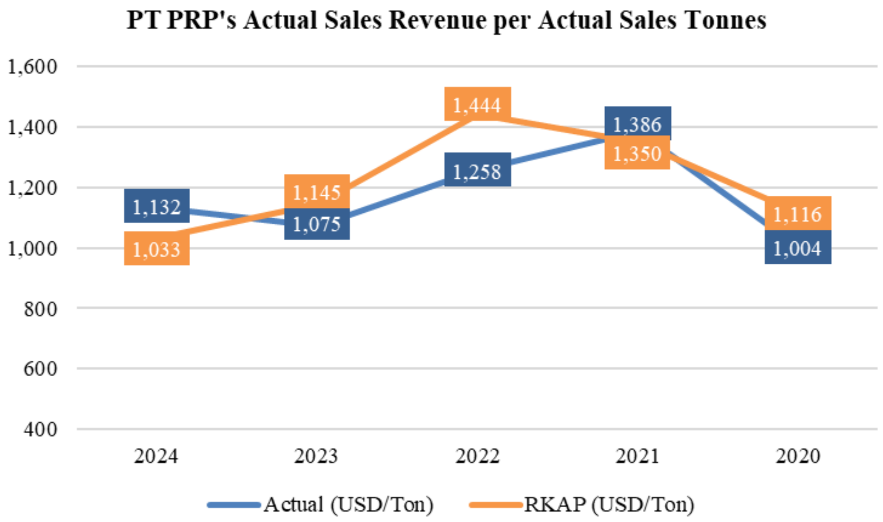

Figure 2. Sales Revenue in USD per Ton of PT PRP
Source: PT PRP's Annual Report (2020-2024)

Figure 2 shows the fluctuation of PT PRP's actual sales revenue per actual sales tons compared with the company's RKAP from 2020 to 2024. Actual revenue per ton reached USD 1,386 per ton in 2021, decreased to USD 1,258 per ton in 2022, and declined further to USD 1,075 per ton in 2023 before increasing to USD 1,132 per ton in 2024. This pattern indicates that revenue per ton is not stable across periods and may deviate from planned assumptions. Under this condition, product mix planning cannot rely only on sales volume or budgeted benchmark values. It requires more detailed cost and contribution margin visibility to support decision-making under changing market conditions.

This condition indicates that PT PRP requires a more granular costing structure to support product mix planning. The main concern is not only whether production costs are recorded, but whether the cost information is sufficiently detailed to distinguish the economic impact of different formulas and production routes. Without this visibility, management may have limited basis for identifying which feasible production alternatives provide stronger contribution margin under changing market conditions.

Accordingly, this study develops and evaluates an ABC-BOM route-level costing framework using the grade-formula-route combination as the unit of analysis. The study compares the proposed framework with the current grade-level costing method to assess whether cost disaggregation can improve contribution margin visibility. The contribution of this study is a practical managerial costing approach that supports product mix planning by linking operational feasibility, cost transparency, and margin-based decision support.

LITERATURE REVIEW

A product mix decision is the determination of combinations of products that a company will prioritize to serve market demand and optimize available resources. When

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multiple products are being produced, the product mix decisions should consider customer demand, production capability, cost efficiency, and profitability. (Kotler and armstrong (2018) explain the product mix reflects the structure of product variants and their relationship with market strategy and operational strategy. As each grade may have different formulas, routes, and applications for polypropylene manufacturing, planning a product mix becomes more complex. Therefore, accurate visibility into costs and margins must exist to make an effective product mix plan (Gutierrez and Ermita, 2023; Pedersen and Williams, 2024)

Activity-Based Costing (ABC) provides a relevant basis for improving cost visibility. ABC was developed to address the limitations of traditional cost systems by allocating costs to products or processes using broad allocation bases. Its core principle is that cost objects consume activities, and activities consume resources (Gosselin, 2006; Kaplan and Cooper, 1998). Therefore, costs should be assigned using drivers that reflect actual resource consumption. Previous studies show that ABC can improve cost accuracy, identify product profitability, and support product mix decisions in multi-product environments (Abeje et al., 2025; Diaz-Sanchez et al., 2025).

Previous studies show that ABC can improve cost accuracy, reveal hidden profitability differences, and support product mix decisions. Hartmann et al. (2025) applied ABC in the chicken processing industry and showed that ABC provides more accurate product cost allocation than conventional absorption costing. Majka (2024) demonstrated that ABC supports competitive pricing decisions by identifying differences between activity-based and volume-based product costs. Applied ABC in mining operations and found that the method could identify products with different profitability levels within a product mix. Correa et al. (2025) and Kennedy (2024) further integrated ABC with Theory of Constraints and optimization models to support product mix decisions under capacity, outsourcing, and environmental constraints. These studies confirm that ABC is useful for product mix decision-making because it provides more detailed cost information than traditional costing methods.

Bill of Materials (BOM) supports manufacturing cost analysis by identifying the materials and quantities required to produce a product or formula. Putra and Kitamura (2023) explain that material cost can be calculated by multiplying standard material quantities by relevant prices. BOM is also important for procurement, inventory management, production planning, and cost estimation (Mudunuri and Aragani, 2024). In this study, BOM is used to trace direct material and additive costs at the formula level, while ABC is used to allocate route-sensitive production costs. Thus, the integration of ABC and BOM provides a more complete costing logic for manufacturing settings where cost variation arises from both formula composition and production route.

Based on the above theoretical foundation, this study proposes an ABC-BOM route-level costing framework. The framework uses the grade-formula-route combination as the unit of analysis. BOM is applied to calculate formula-level material and additive costs, while ABC is applied to allocate route-sensitive production costs using relevant activity drivers. The resulting production cost is then compared with selling price to calculate contribution margin for each grade-formula-route combination. This framework is expected to improve contribution margin visibility and support margin-informed product mix planning.

The conceptual framework presented in Figure 3 explains the relationship between the research questions, business issue, theoretical intervention, and expected output. The business issue begins with the current costing condition, where cost data is recorded mainly at the product grade level. This creates limited visibility because formula-level material consumption and route-sensitive production costs are not fully reflected in the cost calculation. As a result, product mix planning may be driven primarily by demand fulfillment and operational requirements, while profitability differences between production alternatives remain less visible. The theoretical positioning of this study is an applied managerial costing study in a process manufacturing context.

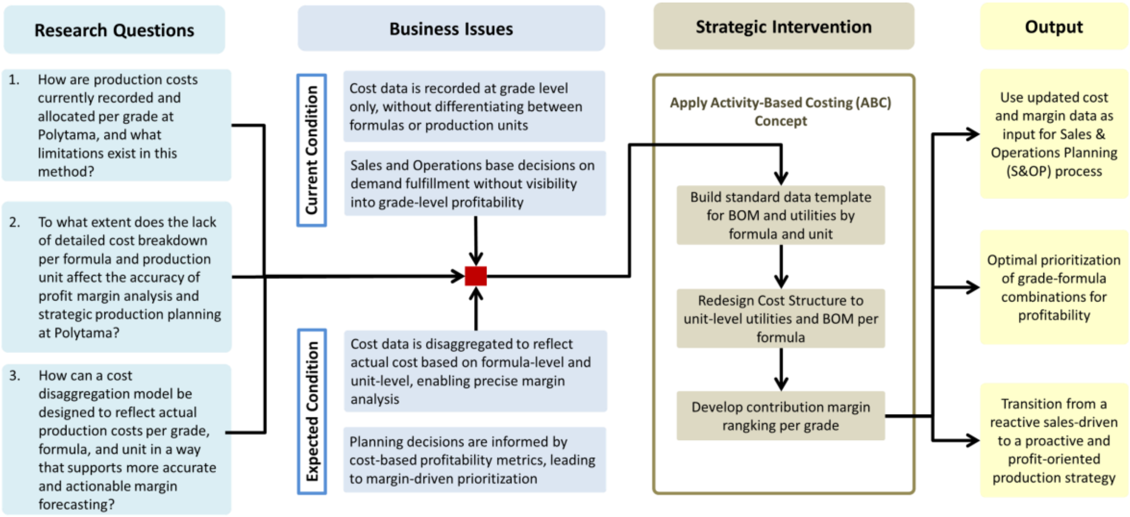

Figure 3. Conceptual Framework
Source*:* Data that has been processed by the author (2026)

This study does not seek to test causal relationships between independent and dependent variables. Instead, it develops and applies a costing framework using actual internal manufacturing data to evaluate whether cost disaggregation can improve contribution margin visibility.

This study contributes to the literature by extending the use of ABC and BOM into route-level contribution margin analysis for polypropylene manufacturing. While previous studies have demonstrated the usefulness of ABC in improving cost allocation and supporting product mix decisions, this study adds a more specific application by integrating formula-level BOM tracing and route-level ABC allocation. The novelty lies in using the grade-formula-route combination as the unit of analysis, which is particularly relevant for process manufacturing companies where the same product grade may have different cost outcomes depending on formula and production route. Therefore, the proposed framework provides both theoretical and practical contributions by linking cost disaggregation, contribution margin visibility, and product mix decision support.

METHODS

This study uses a quantitative descriptive case study approach at PT PRP, a polypropylene manufacturing company. The approach was selected because the research analyzes actual internal production and costing data to develop a route-level costing framework for product mix planning. The object of this study is the product costing and product mix planning process, while the unit of analysis is the grade-formula-route combination. A total of 36 feasible combinations were analyzed based on the company's operational and data scope.

The analysis focuses on variable and route-sensitive production costs rather than total full cost. The cost components analyzed include raw materials, additives, utilities, catalyst and other chemicals, and general chemicals that vary across formulas or production routes. Fixed costs are excluded because the objective of this study is to support contribution margin analysis for product mix planning, not to determine full product profitability or statutory cost of goods sold. Finished goods inventory cost is also excluded because it depends on post-production factors such as inventory level, storage duration, demand realization, and sales timing, rather than the grade-formula-route production process itself.

The research methodology is summarized in Figure 3. The research begins with the objective of developing a route-level costing framework for margin-informed product mix planning. The required data includes grade and route structure, formula data, utility consumption data, current cost data, and selling price data. These data are obtained from internal company sources and are then processed through BOM-based unit cost calculation, ABC-based unit cost allocation, total unit cost calculation, and contribution margin analysis.

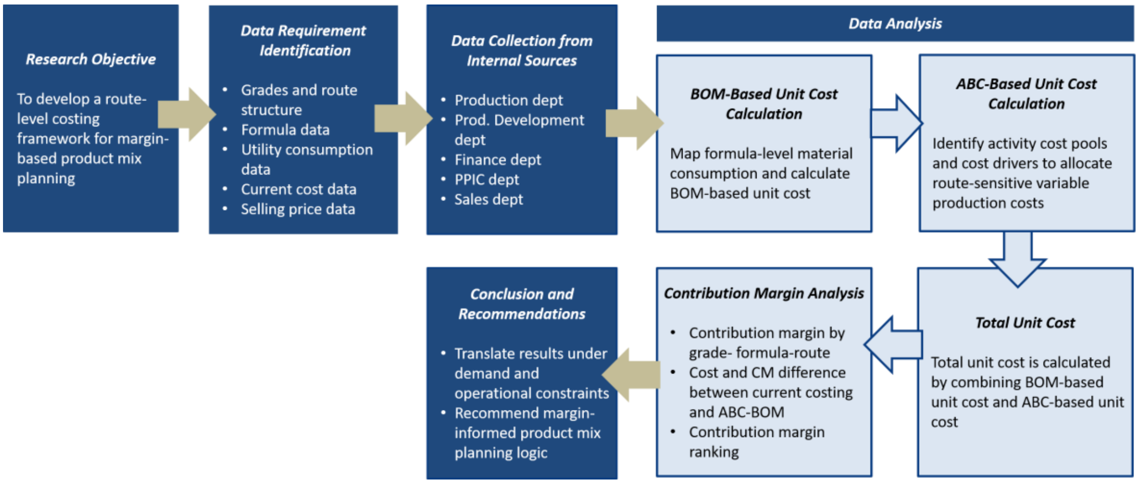

Figure 4. Research Design for ABC-BOM Route-Level Costing Framework Development
Source*:* Data that has been processed by the author (2026)

As shown in Figure 4, the first stage is identifying and collecting the required secondary data from internal company records. Production and route data were obtained from production and planning functions, BOM data from product development, cost data from finance, and selling price data from sales. The analysis period uses full-year 2024 actual data to provide a complete annual view and reduce the effect of monthly production fluctuations. The use of secondary internal data is appropriate because the study aims to analyze actual historical production and costing practices rather than perception-based primary responses.

The second stage is BOM-based unit cost calculation. BOM is used to trace material and additive costs that can be directly identified at the formula level. Rather than assuming one standard BOM per grade, this study recognizes that a single grade may have different BOM variants depending on the formula and processing unit. Therefore, the BOM-based unit cost is calculated by multiplying the formula-level material or additive consumption rate by the relevant material price. This step ensures that formula-specific differences in material and additive usage are reflected in the unit cost calculation.

The third stage is ABC-based unit cost allocation. ABC is used to allocate shared direct costs and indirect route-sensitive production costs that cannot be directly traced through the BOM. These costs include polymerization-related costs, catalyst and other chemical consumption, utility consumption, and general chemical consumption. The ABC allocation mechanism is conducted by grouping costs into activity cost pools based on the production unit where the activity occurs, namely Reactor, Extruder 1, Extruder 2, and Granule. Each activity cost pool is then allocated to the relevant grade-formula-route combination using cost drivers that reflect actual resource consumption.

The cost drivers are selected based on operational causality. Polymerization cost is allocated using tons of propylene per ton of PP because propylene consumption is directly related to reactor output. Catalyst and other chemical consumption are allocated using kilograms per ton of PP because these costs are driven by chemical usage intensity. Utility consumption is allocated using running hours because electricity and utility-related costs vary with the operating time of each production unit. General chemicals are allocated using kilograms per ton of PP because their consumption is related to production volume and processing requirements. These drivers are considered appropriate because they represent the way resources are consumed along each grade-formula-route combination.

The ABC allocation is conducted by calculating the unit cost rate for each activity cost pool. The unit cost rate is obtained by dividing the total cost of the activity pool by the total driver quantity within the observed period. The allocated ABC cost for each grade-formula-route combination is then calculated by multiplying the activity cost rate by the actual driver consumption of the related combination. ABC allocation is applied only to combinations that were actually produced during the observed period, not to all theoretical grade-route possibilities. This prevents cost distortion from allocating costs to combinations that did not consume resources during the period.

The fourth stage is total unit cost calculation. The total unit cost per ton is calculated by combining the BOM-based unit cost and the ABC-based unit cost using the following formula: Total Unit Cost per Ton = Unit Cost from BOM + Unit Cost from ABC. The unit cost from BOM represents direct material and additive costs that are traceable to the formula and processing unit. The unit cost from ABC represents shared direct costs and indirect route-sensitive costs allocated using activity cost pools and cost drivers. The recalculated total unit cost is then compared with the current grade-level costing method to identify whether the current method may overstate or understate the cost of certain grade-formula-route combinations.

The fifth stage is contribution margin analysis. After the total unit cost is obtained, contribution margin per ton is calculated using the following formula: Contribution Margin per Ton = Selling Price per Ton − Total Unit Cost per Ton. Selling price is treated as an input variable, not as an output controlled by the ABC-BOM framework. Therefore, the framework does not determine market price. Instead, it provides more detailed cost visibility to evaluate profitability under prevailing market price conditions. The contribution margin results are used to compare the current costing method and the proposed ABC-BOM route-level costing framework.

Data validation was conducted through cross-checking among internal data sources. Production volume and route data were checked against production and planning records. BOM data was checked against product development records to ensure that formula and additive information matched the relevant grade and processing unit. Cost data was checked against finance records, while selling price data was checked against sales records. The consistency among these internal documents was reviewed before the unit cost and contribution margin calculations were performed. This validation process was conducted to ensure that the framework was built using internally consistent production, costing, and commercial data.

The analysis is limited to PT PRP's operational context and is not intended to be statistically generalized to all polypropylene manufacturers or other industrial contexts.

The result is interpreted as a case-specific managerial insight into how cost disaggregation at the grade-formula-route level can improve cost transparency and contribution margin visibility for product mix planning.

RESULTS AND DISCUSSION

The analysis compares the current grade-level costing method with the proposed ABC-BOM framework. The comparison is based on variable and route-sensitive production costs, since the objective of the framework is to support contribution margin analysis rather than full-cost profitability measurement. The unit of analysis is the grade-formula-route combination, because production cost in PT PRP is affected not only by product grade, but also by formula and downstream processing route.

The first result shows that the ABC-BOM framework produces different unit cost values compared with the current costing method. Three representative grades are presented to reflect different cost behavior patterns. MAS2158 represents a single formula and single route case, MAS5637 represents a single formula with multiple routes, and MAS3352 represents multiple formula and multiple route combinations.

Table 1. Representative Unit Cost Comparison Between Current Costing and ABC-BOM

Grade	Formula	Production Route	ABC-BOM Unit Cost (USD/ton)	Current Unit Cost (USD/ton)	Cost Difference (USD/ton)
MAS2158	A	Reactor–Extruder 1	932.13	929.82	2.32
MAS5637	L	Reactor–Extruder 1	941.54	945.70	4.16
MAS5637	L	Reactor–Extruder 2	932.96	945.70	12.74
MAS3352	F	Reactor–Extruder 1	906.61	913.97	7.36
MAS3352	F	Reactor–Extruder 2	900.54	913.97	13.44
MAS3352	P	Reactor–Extruder 2	901.47	913.97	12.50

Source*:* Data that has been processed by the author (2026)

The results in Table 1 show that cost differences are relatively limited for MAS2158, which has only one formula and one production route. Under the ABC-BOM framework, MAS2158 has a total unit cost of 932.13 USD/ton compared with 929.82 USD/ton under the current costing method. The difference of 2.32 USD/ton indicates that when a grade has a single formula and a single production route, grade-level costing may still provide a relatively close approximation.

However, the difference becomes more material for grades with multiple routes or formula alternatives. Under the current costing method, MAS5637 has a single total unit cost of 945.70 USD/ton. However, under the ABC-BOM framework, MAS5637 Formula L produced through Reactor–Extruder1 has a total unit cost of 941.54 USD/ton, while the same formula produced through Reactor–Extruder2 has a lower total unit cost of 932.96 USD/ton. Since the BOM cost for MAS5637 remains the same at 31.47 USD/ton on both routes, and since using the same formula, the unit cost difference is mainly driven by activity-based cost differences between downstream processing units. This confirms that route-level cost behavior is a relevant source of cost variation.

A similar pattern is observed for MAS3352; the current costing method records a single total unit cost of 913.97 USD/ton. Under the ABC-BOM framework, MAS3352 Formula F produced through Reactor–Extruder1 has a total unit cost of 906.61 USD/ton, while the same formula produced through Reactor–Extruder2 has a lower unit cost of 900.54 USD/ton. MAS3352 Formula P produced through Reactor–Extruder2 has a total unit cost of 901.47 USD/ton. This indicates that the current costing method may overstate the cost of certain MAS3352 route alternatives because it does not distinguish the cost behavior of each formula-route combination.

The larger margin differences in multi-route grades can be explained by three cost behavior patterns. First, reactor-related costs dominate the cost structure because all grades pass through the polymerization process. However, after the reactor stage, each downstream processing unit consumes different levels of utilities, general chemicals, and operating time. Second, grades that can be produced in more than one downstream unit may have different route-sensitive costs even when the same formula is used. Third, grades with more than one formula may have different BOM-based material and additive costs, creating additional variation beyond route cost. Therefore, higher cost and margin differences occur when both formula variation and route variation are present.

The ABC allocation breakdown supports this interpretation. Reactor activity costs include polymerization, catalyst and other chemical consumption, electricity, and other utilities. Downstream activity costs include electricity and general chemicals in Extruder 1, Extruder 2, or Granule. These cost pools are allocated using relevant cost drivers such as tons of propylene per ton of PP, kilograms of catalyst or chemicals per ton of PP, and running hours. As a result, the ABC-BOM framework captures differences in resource consumption that are hidden when all costs are aggregated at the grade level.

The contribution margin analysis further confirms the managerial importance of route-level costing. Because selling price is treated as the same input under both methods, the contribution margin difference moves directly in line with unit cost differences. This finding shows that grade-level costing may be sufficient for simple production cases but becomes less reliable when the same grade can be produced through different formulas or routes.

Compared with previous ABC studies, the result is consistent with the argument that ABC improves cost accuracy by revealing resource consumption differences that traditional or volume-based costing systems may conceal. Prior studies in multi-product manufacturing have shown that ABC can identify differences in product profitability and support product mix decisions. This study extends that insight into a route-level process manufacturing context. The main distinction is that the cost object is not only the product grade, but the grade-formula-route combination. Therefore, the study contributes to ABC literature by showing that cost disaggregation is useful not only across products, but also within the same product grade when alternative formulas and production routes exist.

The theoretical implication is that ABC can be strengthened when combined with BOM in a manufacturing context where both material structure and processing route influence cost behavior. BOM captures formula-level material and additive consumption, while ABC captures shared direct costs and indirect route-sensitive costs. The integration of these two approaches provides a more complete cost visibility framework. This supports the principle that cost objects consume activities and activities consume resources, while also recognizing that formula composition determines material consumption. Therefore, the ABC-BOM framework provides more suitable costing logic for PT PRP's case than grade-level aggregation.

The practical implication is that PT PRP can use route-level contribution margin as a decision-support input in product mix planning. The framework allows management to compare feasible grade-formula-route alternatives and identify which routes generate stronger contribution margin.

However, contribution margin ranking should not be used as the only basis for production allocation. In a commodity industry like polypropylene, product mix planning must remain responsive to market demand, customer commitments, and consider operational feasibility. Therefore, this study proposes a three-layer decision hierarchy consisting of demand commitment, operational feasibility, and margin prioritization. The first layer is demand commitment, which includes contractual demand, strategic customer demand, and minimum market supply. The second layer is operational feasibility, which includes route availability, unit readiness, capacity and feedstock constraints, and transition requirements. The third layer is margin prioritization, where route-level contribution margins are compared and higher-margin alternatives are prioritized within feasible and marketable combinations.

Figure 5. Proposed Three-Layer Product Mix Decision Hierarchy
Source*:* Data that has been processed by the author (2026)

The three-layer hierarchy shown in Figure 5 clarifies that the ABC-BOM framework does not replace market-driven or operationally feasible planning with purely cost-driven decision-making. Instead, it provides margin visibility after demand and operational constraints are considered. This is important in PT PRP's context because a high-margin grade may not always be produced at the highest possible volume if market absorption is limited or if contractual commitments require other grades to be produced. For instance, even when a primary grade shows higher contribution margin, downstream grade selection must still consider customer demand and marketability.

The managerial implication is that route-level contribution margin should be embedded into PT PRP's formal Sales and Operations Planning process. In the short term, the company can use the ABC-BOM framework to support quarterly planning by updating selling price assumptions, raw material cost assumptions, BOM data, route assumptions, and activity cost drivers. In the long term, the framework can be developed into an optimization-based decision-support tool that maximizes total contribution margin subject to demand commitments, capacity constraints, route feasibility, and transition requirements.

The findings also indicate that contribution margin is not a static value. Since polypropylene is a commodity product, selling price and feedstock cost may change over time. Therefore, route-level contribution margin should be updated periodically rather than treated as a one-time analysis. This dynamic update is necessary so that production planning remains responsive to market changes while maintaining internal cost discipline. The ABC-BOM framework therefore functions as a living managerial tool rather than a one-off costing exercise.

The results demonstrate that the ABC-BOM route-level costing framework improves cost transparency and contribution margin visibility in PT PRP's product mix planning. The framework reveals cost and margin differences that are hidden under the current grade-level costing method, particularly for grades with multiple formulas and production routes. The findings strengthen the practical relevance of ABC by showing how activity-based allocation can be combined with BOM-based material tracing to support product mix decisions in a process manufacturing case. The framework also provides a structured basis for management to balance demand commitment, operational feasibility, and margin prioritization.

CONCLUSION

This study concludes that the ABC-BOM route-level costing framework can improve cost and contribution margin visibility in polypropylene product mix planning. By using the grade-formula-route combination as the unit of analysis, the framework provides more detailed cost information than the current grade-level costing method, particularly for products with different formulas and production routes. The findings indicate that grade-level costing may obscure route-level margin differences, while the proposed framework helps management evaluate production alternatives more accurately. However, the framework should not be interpreted as a purely cost-driven decision rule, since product mix planning should still consider demand commitment and operational feasibility before margin prioritization. Therefore, PT PRP is recommended to integrate route-level contribution margin analysis into its formal product mix planning process, use the framework as cross-functional input for management review and strategic production allocation decisions, support its implementation through top-down direction, and periodically update BOM data, cost drivers, routing assumptions, and market price inputs to maintain its relevance under changing operational and market conditions.

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