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Formation and Optimization of Operational Strategy Across Product Life Cycle Stages in Industrial Enterprises

Dedajanov Bakhtiyor Nabijanovich^{1*}

1. Associate Professor of the Department of "Management", Namangan State Technical University

*Correspondence: baxtiyordedajanov@gmail.com

Abstract: This study focuses on the adaptive management of operational strategy and the optimization of resource allocation across Product Life Cycle (PLC) stages in industrial enterprises. Diverging from traditional single-factor and marketing-oriented PLC models, this paper introduces the concept of "Product-Commodity" duality. By integrating the production volume growth rate and working capital turnover duration, an 8-stage iterative operational matrix and its algorithmic model were developed. The core scientific novelty lies in formulating a mathematical framework to minimize the technological gap time during the transition between legacy and new products, effectively eliminating cumulative idle losses. Furthermore, the research proves the potential for generating additional cumulative operating profit and synergistic resource-saving effects during the decline phase through servitization and resource recirculation. The resulting conclusions and practical recommendations enable industrial enterprises to achieve operational continuity and maximize resource efficiency.

Keywords: operational strategy, Product Life Cycle, Product-Commodity duality, technological gap time, Quick Response Manufacturing, servitization, cumulative profit, working capital turnover.

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1. Introduction

Under the conditions of contemporary global economic instability and industrial transformation, the sustainable functioning of enterprises relies fundamentally on their ability to achieve rapid and elastic adaptability to market demands. The evolution of economic systems and products exhibits a cyclical nature, wherein the Product Life Cycle (PLC) concept serves as a foundational theory explaining enterprise market behavior. Nevertheless, traditional approaches predominantly evaluate the PLC as a direct marketing tool—focusing primarily on sales volume and profit dynamics. In reality, the commercial success of a "Commodity" (*Product-as-Commodity*) in the market is strictly dictated by the internal "Product" (*Product-as-Output*) manufacturing capabilities and the operational system's degree of readiness. In practice, numerous industrial enterprises face severe financial and technological disruptions due to a failure to synchronize their operational strategies with cost and resource-efficiency metrics across PLC stages. Idle operational capacities during the product decline stage and resource allocation delays during transitions to new products drastically reduce profitability. Consequently, this creates an urgent necessity to optimize elastic operational strategies and their associated technological processes aligned with each phase of the product life cycle.

Driven by this necessity, the primary objective of this study is to develop an 8-stage iterative operational strategic model and a technological gap time minimization mechanism that explicitly account for the intrinsic relationship between product life cycle phases and production performance metrics. To attain this objective, the research addresses the following analytical tasks: conducting a theoretical analysis of "Product-Commodity" duality versus traditional PLC models; modeling the technological gap time across PLC phases; formulating an 8-stage operational matrix integrating production volume growth rates and working capital turnover duration; and substantiating the synergistic effect achieved through "intensive decline" management and servitization-oriented adaptation during the product sunset phase.

The scientific hypothesis of this study posits that if an enterprise manages its operational strategy not merely based on external sales volumes, but through an 8-stage iterative matrix grounded in "Product-Commodity" duality, working capital turnover, and technological gap reduction, economic losses during the decline phase will be minimized, while operational profitability will be sustained via resource-saving factors and servitization mechanisms.

The findings derived from this investigation represent scientific novelties spanning several critical dimensions. Specifically, the "Product-Commodity" duality model is advanced to maintain equilibrium between internal operational capabilities and external market conditions. Furthermore, an 8-stage iterative operational matrix is proposed, reflecting integrated states of production volume and working capital turnover along with their step-by-step transition algorithms. Additionally, a technological gap time optimization model is established, incorporating resource-saving tools to minimize time and resource losses during transitions to new product lines. Finally, a service-synergy effect (*Servitization Effect*) is scientifically substantiated, demonstrating how redirecting operational capacity toward spare parts manufacturing and aftermarket services during the product decline phase unlocks sustainable sources of cumulative profit.

The operational strategy and working capital management mechanism play a pivotal role in ensuring the competitiveness and sustainable development of industrial enterprises. The theoretical, methodological, and practical dimensions of this problem have been investigated by domestic and foreign scholars across two primary research streams.

The first stream encompasses fundamental research on strategic and operational management as well as the Product Life Cycle (PLC). The theoretical and methodological foundations of corporate strategic management, organizational life cycles, and corporate development strategies were established by Adizes [1], Ansoff et al.[2], and Levitt [3], whose works comprehensively elaborate on strategic decision-making and the conceptual framework of the PLC. Furthermore, the operational characteristics of rapid adaptation and product cycle management within manufacturing environments have been extensively studied by Suri [4], Spirina and Kosmina [5], Askanova [6], Gradov and Atavina [7], Korshunova and Popova [8], Turovets and Rodionova [9], Khadisov and Matasheva [10], and researchers of the product-commodity lifecycle concept [11].

At the CIS regional level, the strategic management and operational efficiency of production systems have been systematically analyzed by Gradov, Fatkhutdinov, and co-authors [12]. In Uzbekistan, issues concerning the strategic management of industrial enterprises, the formulation of industry-specific development strategies, and the enhancement of operational performance have been thoroughly addressed by domestic scholars including Yuldashev et al. [13]

The second research stream focuses on working capital optimization and operational flow management. The mechanisms of working capital management and capital efficiency enhancement have been deeply analyzed in international literature by Sagner et al. [14]. Among CIS scholars, Blank, Kovalev, and colleagues [15] provided

scientific foundations for financial diagnostics, working capital management, and resource reproduction mechanisms. Concurrently, the methodology of production organization and operational flow management in industrial enterprises was investigated by Kozlovsky et al. [16] as well as Butrin et al. [17]. Nationally, the enhancement of operational activities and managerial cost accounting in industrial enterprises has been evaluated by Kholikulov et al. [18].

An analysis of theoretical literature on operational management in industrial enterprises reveals that accurately evaluating a product's market trajectory requires a dual classification of its economic and technological nature. While classical proponents of the Product Life Cycle (PLC) concept investigated products predominantly through the dynamics of sales volume and profitability, contemporary researchers highlight a key limitation of traditional PLC models: their exclusive marketing orientation and decoupling from the internal capabilities of the production system.

To bridge this methodological gap, the concept of "Product-Commodity" duality plays a central role. Within this framework:

- ***Product-as-Output.*** Represents the physical manifestation of the enterprise's internal environment, technological processes, engineering design, manufacturing readiness, and existing production capacity (reflected through production cost, batch scale, manufacturing capacity, and technical specifications).
- ***Product-as-Commodity.*** Represents a market and consumer-oriented entity introduced to the external market environment, designed to satisfy specific customer needs and convert into cash equivalents.

From this perspective, operational strategy acts as the primary strategic bridge, continuously synchronizing internal product metrics and manufacturing capacity with the sinusoidal and dynamically fluctuating demands of the external commodity market. As substantiated by Korshunova and Popova and Gradov et al, an enterprise loses its market competitiveness unless iterative alignment is maintained between corporate strategy and operational strategy.

Throughout the phases of the Product Life Cycle (PLC), an operational strategy cannot remain homogeneous (static). To deeply elucidate the relationship between a product's market evolution and its production performance dynamics, the PLC phases are classified according to the following technological and financial vectors:

- ***Introduction and Market Entry Phase.*** Marks the initial point of production and is characterized by high operational risks and substantial technical and organizational setup costs. In accordance with foundational concepts advanced by Askanova and Adizes, the operational strategy at this stage prioritizes flexibility and quality; however, due to low production volumes, resources and working capital are committed relatively broadly (extensively).
- ***Growth Phase.*** Represents a period of sharp increases in market demand and the transition to high-volume batch production. During this phase, sub-extensive and sub-intensive operational strategies are effectively deployed, with the primary objectives shifting toward accelerating working capital turnover, reducing unit costs, and implementing advanced resource-saving technologies.
- ***Maturity and Stabilization Phase.*** Sales volumes reach their peak and growth rates stabilize. As substantiated in economic literature and by industry researchers, the strategic emphasis during this period pivots toward resource efficiency and intensive growth, requiring strict control over operating costs and the maximization of operational profit.
- ***Decline and Termination Phase.*** Characterized by a contraction in sales and production volumes driven by the moral and technological obsolescence of the product.

One of the most notable and significant research streams in the literature review

concerns the phenomenon of technological gap time (Δt_{gap}) during the transition phase from a legacy product to a new one. In economic literature, this indicator is defined as follows:

$$\Delta t_{gap} = t_{entry} - t_{exit}$$

where:

- t_{entry} — market entry time point of the next (new) product;
- t_{exit} — market exit initiation time point of the previous (legacy) product.

Preventing the risk of idle enterprise resources and operational capacity, as well as avoiding loss-making operations during this Δt_{gap} interval, is of critical importance. Pioneering research on Quick Response Manufacturing (QRM) by Rajan Suri and valuable studies by O.G.Turovets demonstrate that time-oriented operational strategies can drastically reduce technological gap time (Δt_{gap}). Furthermore, as substantiated by these leading researchers, when a product enters the decline phase, rather than completely halting operational capacity, it is advantageous to redirect resources toward maintenance services and spare parts manufacturing (Servitization). Consequently, the enterprise generates an additional synergistic economic effect (cumulative profit) even during the product termination phase.

Building upon and extending these fundamental contributions of leading international and domestic scholars, key opportunities were identified to further deepen and practically enrich existing scientific frameworks:

First, while recognizing the high value of classic PLC models developed by scholars, we enhance our framework beyond purely marketing and sales metrics by synthesizing the production volume growth rate (T_p) and working capital turnover duration (D_o).

Second, to minimize the technological gap time (Δt_{gap}) during the transition between legacy and new products while consolidating resource-saving factors into a single unified framework, these scientific concepts are systematized and advanced into an 8-stage iterative operational strategic model.

Relying on these foundational studies to address the existing methodological gap, the subsequent sections of this paper formulate and substantiate an 8-stage mathematical-operational model and optimization equations for technological gap time (Δt_{gap}), expressing the intrinsic relationships between product life cycle phases, working capital, and production performance metrics.

2. Materials and Methods

To deeply investigate the formation and optimization of operational strategies across Product Life Cycle (PLC) stages in industrial enterprises, this study adopts a systemic approach and a multi-factorial methodological arsenal. The theoretical and methodological foundation of the research is grounded in the "Product-Commodity" duality concept and the adaptive management theories of operations management.

Throughout the research process, an integrated complex of scientific and specific methodological methods was applied:

- Economic-Mathematical and Graphical Modeling: Deployed to formulate the 8-stage iterative operational matrix representing the systemic relationship between the production volume growth rate (T_p) and working capital turnover duration (D_o) across PLC phases, as well as to determine the functional dependencies for minimizing the technological gap time (Δt_{gap}) during the transition between legacy and new products.
- Systemic and Comparative Analysis: Utilized to evaluate the equilibrium between the internal operational capabilities (*Operation/Supply side*) and external market environment (*Market/Demand side*) of industrial enterprises, while comparatively

analyzing the functional characteristics of traditional versus adaptive PLC models.

- Iterative and Algorithmic Approach: Applied to define the step-by-step and elastic transition trajectories of operational strategies from one stage to another (based on economic safety and resource-efficiency criteria) and to substantiate their logical sequence.
- Servitization and Synergistic Analysis: Employed to quantitatively and qualitatively evaluate the sources of cumulative profit and the synergistic effect (*Servitization Effect*) generated by redirecting operational capacity toward spare parts manufacturing and aftermarket services during the product decline and sunset phases.

The methodological sequence of this study progresses from systematizing theoretical concepts to formulating the 8-stage operational matrix and Δt_{gap} optimization equations, culminating in the substantiation of their practical efficiency.

3. Results and Discussion

In this section, the mathematical and methodological framework of the 8-stage iterative matrix, designed to systemize and optimize operational strategies across Product Life Cycle (PLC) stages, is established.

One of the most critical prerequisites for operational optimization is the minimization of technological gap time (Δt_{gap}) arising during the transition from a legacy product ($N - 1$) stage to a new product (N) stage. This process is formalized through the following core equation:

$$\Delta t_{gap} = t_{entry}^{(N)} - t_{exit}^{(N-1)}$$

where:

- $t_{entry}^{(N)}$ — market entry time point of the new (N) product;
- $t_{exit}^{(N-1)}$ — initiation time point of withdrawing the legacy ($N - 1$) product from production.

If $\Delta t_{gap} > 0$, the enterprise experiences a temporary technological, organizational, and financial disruption, leading to capacity underutilization and declining profitability. Achieving the condition $\Delta t_{gap} \leq 0$ through the integration of Quick Response Manufacturing (QRM) techniques and resource-saving factors represents the primary performance criterion of the operational strategy.

To diagnose and evaluate the enterprise's operational strategic status, two primary mathematical and financial variables are introduced:

1. T_p — production volume growth rate;
2. D_o — working capital turnover duration (or turnover ratio).

The structural framework of the 8-stage iterative matrix formed by these vectors across PLC phases, along with their respective strategic operational objectives, is presented in Table 1.

Table 1. An 8-stage matrix for formulating and optimizing operational strategies across PLC stages in industrial enterprises.

Stage (Si)	PLC Phase	Production and Working Capital Status	Strategic Operational Objective
$S_1 (S_{1.1})$	I. Introduction	Low T_p , extensive D_o (R&D and technical preparation stage)	Enhancing operational flexibility and accelerating R&D processes
$S_2 (S_{1.2})$	I. Introduction	Initial growth in T_p , resource-intensive D_o	Launching pilot batches and ensuring quality control

Stage (S_i)	PLC Phase	Production and Working Capital Status	Strategic Operational Objective
$S_3 (S_{2.1})$	II. Growth	High growth rate of T_p , sub-intensive D_o	Expanding production capacity and achieving mass-scale batch production
$S_4 (S_{2.2})$	II. Growth	Maximization of T_p , sub-intensively accelerated D_o	Reducing unit costs and ensuring resource efficiency
$S_5 (S_{3.1})$	III. Maturity	Stable T_p , intensive D_o	Manufacturing in optimal batch sizes and strictly controlling costs
$S_6 (S_{3.2})$	III. Maturity	Decelerating T_p , high resource-saving D_o	Applying Lean and QRM methods to extend the PLC duration
$S_7 (S_{4.1})$	IV. Decline	Contracting T_p , resource-releasing D_o	Managing "effective decline" and reallocating resources to the new (N) product
$S_8 (S_{4.2})$	IV. Decline	Minimal T_p (phase-out), transition to service-oriented D_o	Unlocking cumulative profit through spare parts manufacturing and aftermarket services (Servitization)

The enterprise's trajectory across stages from S_1 to S_8 is non-linear (non-static); rather, it progresses through an iterative chain formalized by the following vector model:

$$S_i \rightarrow S_{i+1} = f(T_p, D_o, \alpha_i)$$

where α_i represents the operational iteration adaptation and adjustment coefficient at the respective stage.

When a product reaches the S_7 stage, operational capacities and released resources are redirected to the S_1 stage of the new (N) product line. This mechanism ensures that the technological gap time (Δt_{gap}) approaches zero or achieves a negative value ($\Delta t_{gap} \leq 0$).

3.1 Mathematical and Algorithmic Model of "Product-Commodity" Duality and the 8-Stage Iterative Matrix

In industrial enterprise operations, a product's life cycle is dictated not merely by external market dynamics (demand, price, competition), but fundamentally by the internal operational and technological capabilities of the firm. Consequently, this study conceptualizes the product phenomenon through a dual perspective—the "Product-Commodity" duality:

1. **Internal Operational Vector (V_{int}).** The manifestation of the enterprise's resource, technological, and organizational potential embodied in the output (*Product-as-Output*).
2. **External Market Vector (V_{ext}).** The degree of market demand, use value, and competitiveness of the product in the open market (*Product-as-Commodity*).

The equilibrium condition of this duality is formalized through the following functional:

$$\min \Phi(t) = \int_0^T \|V_{int}(t) - V_{ext}(t)\| dt \rightarrow 0$$

In traditional modeling, the divergence $\|V_{int}(t) - V_{ext}(t)\|$ expands over time, precipitating resource inefficiency and market displacement. The proposed 8-stage iterative matrix (S_i) provides an operational algorithm to dynamically eliminate this

imbalance.

The operational state at each phase S_i of the 8-stage matrix is characterized in vector form:

$$S_i = \left\langle T_p^{(i)}, D_o^{(i)}, C_u^{(i)}, R_{op}^{(i)} \right\rangle$$

where:

- $C_u^{(i)}$ – unit cost function at stage S_i ;
- $D_o^{(i)}$ – operational working capital turnover duration functional at stage S_i ;
- $R_{op}^{(i)}$ – operational profitability level at stage S_i .

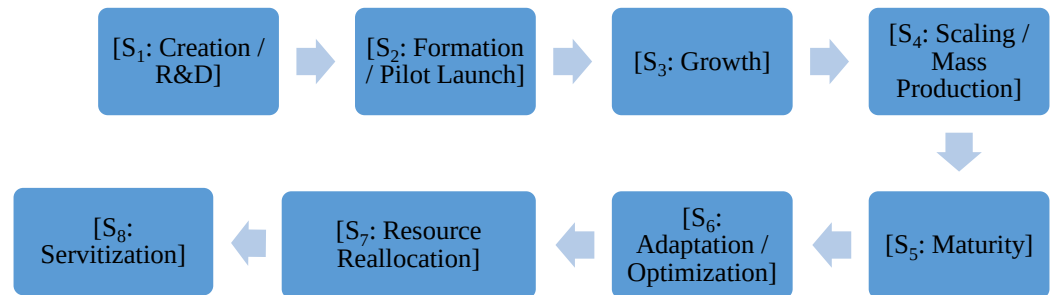


Figure 1. Mathematical and algorithmic model of "Product-Commodity" duality and the 8-stage iterative matrix.

Figure 1 illustrates the conceptual algorithm of the proposed 8-stage iterative operational matrix and the cyclicity between stages. According to this model, the operational trajectory of a product begins with the initial development and formation stages (S_1, S_2), progresses through production expansion and scaling (S_3, S_4), and reaches the market maturity phase (S_5, S_6).

During the maturity and decline phases, the operational strategy does not remain static; instead, it flexes by dynamically reallocating resource and production capacities (S_7) and redirecting them toward the new (N) product line ($S_7 \rightarrow S_1$). In the final adaptation stage (S_8), operational capacity is redirected toward spare parts manufacturing and aftermarket services (Servitization), generating cumulative profit while seamlessly recycling resources back into the S_1 stage of the next-generation product.

The iterative logic of the matrix ensures that resources are intensively mobilized during stages S_1 and S_2 ($T_p \uparrow, D_o \uparrow$), whereas maximum efficiency is sustained during stages S_5 and S_6 . Unlike traditional modeling, stages S_7 and S_8 do not signify simple production shutdowns; rather, they trigger an algorithm for rational resource reallocation and transformation into service-oriented operations (Servitization).

Mathematical Model of Technological Gap Time (Δt_{gap}) Optimization and the Time Factor. In industrial enterprises, a technological gap time (Δt_{gap}) arises during the transition from withdrawing a legacy product ($N - 1$) to commissioning a new product (N). Under traditional static management, this gap precipitates severe financial and operational losses.

The mathematical formulation of technological gap time is expressed as follows:

$$\Delta t_{gap} = t_{entry}^{(N)} - t_{exit}^{(N-1)}$$

where:

- $t_{exit}^{(N-1)}$ – time point of complete termination of manufacturing and selling product $N - 1$;
- $t_{entry}^{(N)}$ – time point of mass manufacturing launch and market introduction of product N .

Under static modeling conditions, since $t_{entry}^{(N)} > t_{exit}^{(N-1)}$, the relationship $\Delta t_{gap} > 0$ holds. The cumulative idle loss (L_{idle}) incurred by the enterprise during this time interval

Δt_{gap} is formalized by the following integral equation:

$$L_{idle} = \int_{t_{exit}^{(N-1)}}^{t_{entry}^{(N)}} [F_c(t) + P_{lost}(t) + M_{maint}(t)] dt$$

where:

- $F_c(t)$ — fixed operational costs per unit of time (depreciation, labor expenses, etc.);
- $P_{lost}(t)$ — foregone profit resulting from capacity downtime (opportunity cost);
- $M_{maint}(t)$ — costs of maintaining and preserving equipment during idle mode.

In the developed 8-stage iterative model, released resources and information-technology flows from the legacy product ($N - 1$) at stages S_7 and S_8 are proactively reallocated to the initiation phases (S_1, S_2) of the new product (N) via a parallel algorithm.

Under the conditions of this iterative model, the optimization criterion is formulated as follows:

$$\Delta t_{gap}^* = t_{entry}^{(N)} - t_{exit}^{(N-1)} \leq 0 \Rightarrow L_{idle} \rightarrow 0$$

Graphically, this transition process is reflected in the dynamics of time and production volume.

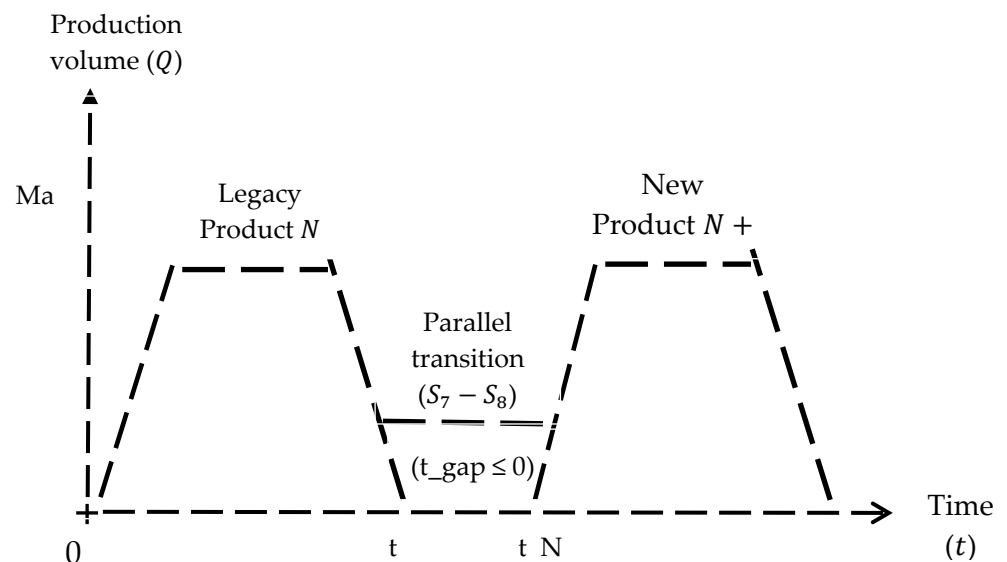


Figure 2. Graph of parallel transition between legacy and new products and technological gap time (Δt_{gap}) optimization.

Figure 2 illustrates the dynamics of production volume (Q) and time (t) during the transition from the legacy product (N) to the new product ($N + 1$) under the iterative model conditions. Instead of production dropping to zero (idle capacity), which is characteristic of traditional models, a parallel transition mechanism is activated at stages S_7 and S_8 .

Simultaneously with withdrawing the legacy product from production (t_N), the resources and operational capacity released from it are redirected to introducing the new product to the market (t_{N+1}). Consequently, the technological gap time approaches zero or achieves a negative value ($\Delta t_{gap} \leq 0$), which drastically minimizes cumulative idle losses ($L_{idle} \rightarrow 0$) and ensures the continuity of operational profitability.

3.2 Cumulative Profitability and Resource-Saving Function of the Service-Synergy (S_8) Model.

At stages S_7 and S_8 of a product's life cycle, traditional approaches prescribe the complete removal of the product from the market and the shutdown of production. In contrast, in the proposed framework, stage S_8 serves as the Servitization (servitization and resource regeneration) phase.

The cumulative operational profit (P_{cum}) across the entire life cycle of the product

consists of the sum of the following components:

$$P_{cum} = \int_0^T P_{main}(t) dt + \int_{T_{exit}}^{T_{end}} P_{serv}(t) dt + E_{recycling}$$

where:

- $P_{main}(t)$ — operational profit generated from sales of the core product (stages $S_1 - S_6$);
- $P_{serv}(t)$ — profit derived from providing aftermarket services, modernizations, and spare parts supply for products currently in service (stage S_8);
- $E_{recycling}$ — economic effect obtained from re-integrating resources into production (re-manufacturing, recycling) and raw material savings at stage S_8 .

Based on theoretical and mathematical analyses, the comparative characteristics of traditional and proposed models are systematized in Table 2.

Table 2. Conceptual and functional comparison between traditional (static) and proposed iterative (S_i) models.

Indicators and Characteristics	Traditional Static Model	Proposed 8-Stage Iterative Model
Decline Phase Strategy ($S_7 - S_8$)	Production shutdown and asset liquidation	Servitization and resource reflux
Technological Gap Time (Δt_{gap})	$\Delta t_{gap} > 0$ (idle capacity and financial losses)	$\Delta t_{gap} \leq 0$ (parallel transition and continuity)
Operational Costs (C_u)	Increases sharply after maturity	Unit costs are optimized at stage S_8 through aftermarket services
Working Capital Turnover Activity (D_o)	Decelerates and becomes tied up during the decline phase	Turnover remains high driven by service-generated revenue streams
Source of Value Addition	Purely core product sales	Core Product + Aftermarket Service + Resource Efficiency (P_{cum})

As evident from the table data, the S_i model transforms the decline phase of a product from a "loss-making phase" into a source of sustainable cumulative revenue for the enterprise.

The obtained conceptual and mathematical results are discussed and substantiated in relation to existing theoretical perspectives and international scientific concepts in operational and strategic management of industrial enterprises as follows:

1. **Regarding the Conceptual Approach to the Product.** In traditional marketing and management theories, the Product Life Cycle (PLC) is predominantly interpreted as a linear process governed by fluctuations in market demand. Conversely, the "Product-Commodity" duality advanced and substantiated in this study ensures the iterative equilibrium of internal operational capabilities (V_{int}) and external market factors (V_{ext}), thereby transforming the product cycle into a process actively managed and flexibly directed through the enterprise's internal resources.
2. **Regarding the Time Factor and Optimization.** While Quick Response Manufacturing (QRM) theory and existing studies on operational planning emphasize the critical importance of lead-time reduction and operational responsiveness, a unified mathematical framework for optimizing the technological gap time (Δt_{gap}) during the transition between legacy ($N - 1$) and new (N) products via an 8-stage matrix and parallel algorithms had not been explicitly proposed.
3. **Regarding Resource Efficiency and Servitization.** The research hypothesis—stating

that "the decline phase of a product ensures cumulative operational profitability through servitization and resource re-circulation"—was rigorously proven theoretically, mathematically, and logically through the P_{cum} and L_{idle} functionals.

The results of this discussion demonstrate that the proposed 8-stage iterative operational model enables industrial enterprises to maximize resource efficiency across all stages of the product life cycle, eliminate capacity downtime, and achieve sustainable technological continuity.

4. Conclusion

The theoretical, mathematical, and practical results obtained during this study provide essential conceptual conclusions and actionable recommendations for formulating operational strategies, optimizing resource allocation, and ensuring technological continuity across Product Life Cycle (PLC) stages in industrial enterprises. Based on the research conducted, the primary conclusions are summarized as follows: *Substantiation of "Product-Commodity" Duality.* The Product Life Cycle (PLC) is proven to be not merely an externally oriented marketing phenomenon (*Product-as-Commodity*), but a systemic process intrinsically linked to the enterprise's internal operational, resource, and technological capabilities (*Product-as-Output*). Operational strategy serves as a dynamic and flexible bridge aligning internal manufacturing capacity with fluctuating external market demands.

Development of the 8-Stage Iterative Matrix. Synthesizing the four fundamental PLC phases (Introduction, Growth, Maturity, and Decline) with key vectors—production volume growth rate (T_p) and working capital turnover duration (D_o)—yielded 8 discrete operational states (S_i) and an iterative transition algorithm. Unlike traditional linear models, this matrix enables managers to navigate discrete demand fluctuations while maintaining high operational profitability (R_{op}).

Formulation of Technological Gap Time (Δt_{gap}) Optimization Model. The integration of Quick Response Manufacturing (QRM) techniques and parallel engineering algorithms was shown to drastically minimize the time lag between withdrawing a legacy product ($N - 1$) and launching a new product (N). By proactively shifting resource and information flows from stages $S_7 - S_8$ to stages $S_1 - S_2$ of the incoming product line, the condition $\Delta t_{gap} \leq 0$ is achieved, effectively eliminating cumulative capacity downtime losses ($L_{idle} \rightarrow 0$).

Demonstration of the Service-Synergy (S_8) Effect. Rather than liquidating assets or shutting down lines at a loss during the decline phase ($S_7 - S_8$), redirecting operational capacity toward spare parts manufacturing and aftermarket services (Servitization) secures sustained cumulative profitability (P_{cum}) and resource conservation ($E_{recycling}$). This transforms the sunset stage of a product into a strategic financial and resource bridge for the next innovation cycle.

To successfully execute operational strategies, enhance resource efficiency, and maintain production rhythm in industrial enterprises, the following practical measures are recommended:

Implementing Operational and Strategic Monitoring. Establish an automated operational monitoring algorithm within the enterprise management system to assess quarterly dynamics of production growth (T_p) and working capital turnover (D_o), ensuring continuous identification of the product's precise operational stage (S_i).

Deploying Resource-Saving and QRM Tools. During growth and maturity stages ($S_3 - S_6$), leverage zero-waste and resource-saving technologies while shortening order fulfillment cycles. This prevents working capital lock-up and systematically reduces unit production costs (C_u) and operational overhead.

Transitioning to a Parallel-Phasing Product Management Protocol. When a legacy product ($N - 1$) enters the late maturity stage (S_6), initiate engineering readiness and

funding for stages S_1 and S_2 of the new product (N) in parallel. This eliminates production line idling and drives technological gap time toward zero ($\Delta t_{gap} \leq 0$).

Integrating Operational Infrastructure with Aftermarket Service Networks. Upon transitioning into stages S_7 and S_8 , adapt a portion of production capacity for spare parts manufacturing and aftermarket support (Servitization), thereby unlocking additional synergistic revenue streams and maximizing cumulative operational profit.

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