Journal of Economics, Business and Management, Vol. 14, No. 1, 2026

Economic Optimization Approach to Integrating Value Engineering in Complex System Prototype Development: A Managerial Perspective

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Manuscript received November 2, 2025; accepted December 2, 2025; published February 5, 2026.

***Abstract*—The prototype development of complex systems, while effective for design validation and performance optimization, often suffers from insufficient consideration of cost factors, leading to economic inefficiencies throughout the product lifecycle. This study addresses this critical management challenge by proposing and validating an economic optimization approach that integrates Value Engineering (VE) into the prototype development phase. Through systematic case studies of leading complex system manufacturers (e.g., Boeing, Raytheon, Lockheed Martin), we demonstrate how VE serves as a strategic management tool for achieving cost-effectiveness without compromising essential functionalities. The findings reveal that VE application during prototype design enables significant cost savings and value enhancement by optimizing material selection, manufacturing processes, and functional configurations. The discussion further establishes the feasibility of this integration, outlining a managerial framework that employs functional analysis and cost-benefit assessment to guide prototype optimization and subsequent product derivation. We conclude that embedding Value Engineering into prototype development is not merely a cost-cutting tactic, but a comprehensive strategy for maximizing resource utility, enhancing project value, and securing a competitive economic advantage in complex system acquisition. This research provides a actionable managerial perspective and a practical pathway for organizations aiming to balance technological ambition with fiscal responsibility.**

***Keywords*—value engineering, prototype development, economic optimization, cost management, managerial decision-making**

I. INTRODUCTION

Value Engineering (VE) is a process involving a systematic approach to identifying and analyzing products, systems, or services that can maintain or improve performance and quality while reducing unnecessary costs. Value engineering is a problem-solving approach that aims to increase the value of a product, system, or service by identifying and eliminating unnecessary costs; value engineering is a team-based approach that involves different stakeholders, including designers, engineers, project managers and end users, who work together to identify and evaluate cost-saving alternatives that meet product or service requirements; value engineering is a data-driven approach that relies on collecting and analyzing factual information to support decision-making; value engineering is a continuous improvement process that aims to optimize the design and performance of a product or service over time.

Value engineering is not a simple cost reduction work, because it will not make products or services "cheap" or "cut corners". Value engineering is a process of exploring "better ways to achieve the products, services or processes that the organization is studying" with the help of a series of process-based work (as shown in Fig. 1), and continuously optimizing product functions through trade-off analysis with value. It can be linked to any alternative design work aimed at reducing project costs.

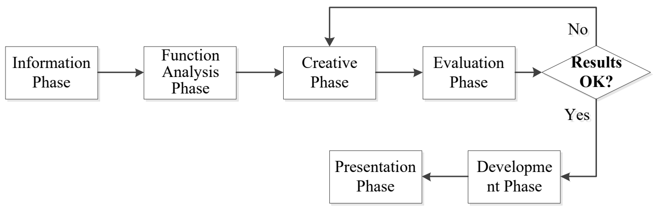

Fig. 1. Value engineering process.

The prototype is purposefully designed to be a prototype of a certain type of product with an advanced level, which is composed of "fixed parts", "quasi-variable parts" and "variable parts" during development. People optimize the product to provide different functions based on the "fixed parts" of the prototype, thereby deriving new products to meet various complex system needs, as shown in

In Fig. 2, with the dramatic changes in the world pattern, the development of military-civilian integration, and the prosperity of commercial shelf products, cost has become an increasingly key performance indicator to be considered in complex system procurement. How to obtain a high-performance, high-reliability, but low-cost complex system has become a new challenge for complex system construction to many countries. Therefore, in the development process of the prototype of a complex system, the balance between function and value should be taken seriously, and value engineering is a good solution.

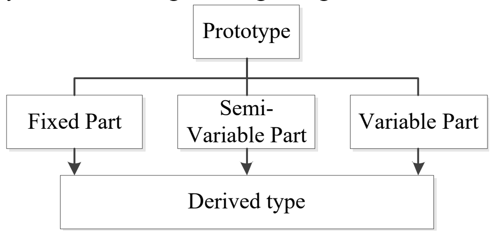

Fig. 2. The relationship between the concepts in prototype development.

However, Fig. 3 shows people's interest in "value engineering (blue)", "prototype (red)" and "value engineering + prototype (yellow)". It can be seen that since value engineering was proposed and continuously developed in the 1940s, there have been relatively rich studies on it, and prototype development, as a relatively mature theoretical method in complex system development activities, has also received a certain amount of attention, but there are very few studies that combine them. This situation leads to the prototype development, a design optimization technology that has not fully considered cost optimization in the past, now becoming even less supportive of cost management. Moreover, it will reduce the synergy between production management and cost management, leading to potential losses for the company. This study will start from the connotation and practice of value engineering and prototype development, analyze the significance of the combination of them, and give the feasibility and path analysis of the combination of the two technologies, to provide inspiration for complex system development under the new situation.

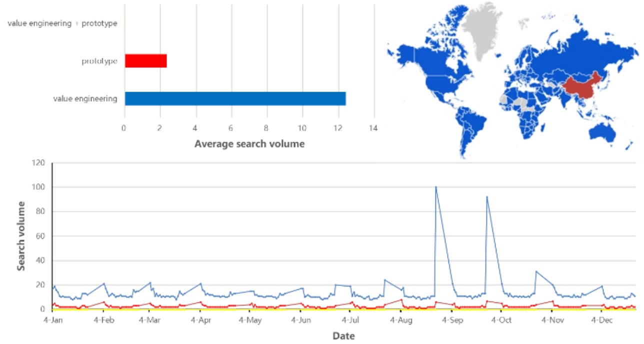

Fig. 3. The trend of different search terms' popularity over time on Google trend[1].

II. Literature Review

A prototype is a prototype or sample used to describe, evaluate, and optimize a product or system during the design and development process. It is a model with typical features and functions that can be used to measure and evaluate the performance and quality of other specific examples or products.

Its concepts and applications play a key role in promoting innovation and continuous improvement in many fields, including engineering design, software development, product manufacturing, etc. In these fields, prototypes can help engineers, designers, and developers better understand and define the required products or systems. In engineering design, the prototype refers to the earliest design model, which is used to verify the design concept, evaluate the design parameters, and test the design function. The prototype at this stage is usually a simplified model or sample to verify the feasibility and reliability of the design. The design and testing process of the prototype can help the design team find and solve problems that may arise in the subsequent stages, thereby reducing development costs and time.

Through research and analysis of literature, we can find that looking at the development of complex systems in major countries around the world, most of them are based on the upgrading and transformation of mature model platforms and the improvement of the overall performance of the system. Chen (2013) *et al*. believe that this development model helps to improve the level of commonality, serialization, and combination of complex system products, shorten the development cycle, and reduce the development cost and risk of the entire life cycle. It has become the basic trend of the development of complex system products in major countries around the world (Parcels, 2019).

Tang (2021) *et al*. believes that the quality of complex system product design seriously affects its performance and reliability, and the quality of complex system product system design often depends on the design of the prototype. Therefore, the prototype must be fully scientifically demonstrated before it can be used in the development and decision-making of complex systems. According to the actual technical level and economic strength of complex systems in various countries, the relationship between technological advancement and inheritance should be properly handled. While fully considering the advancement and technical and economic feasibility of the complex system, the extensibility of the development of the complex system should be fully considered, leaving enough development space and technical interfaces. The prototype of a complex system should have a technical prospect for serial development. After the prototype of a complex system is selected, Neitz (2013) believes that should take effective technical approaches according to the actual requirements of customers and the real-time needs of the task, such as tapping the potential of the prototype of a complex system, applying single scientific research results, replacing subsystems, changing launch platforms and other technical measures, so as to develop more diverse and serialized products, thereby effectively accelerating the vigorous development of complex system development and greatly saving development funds.

The concept of prototypes plays an important role in modern design and development. Through prototype development, engineers, designers, and developers can find the most cost-effective production method from aspects such as materials and number of parts, production technology, assembly time, and so on. Prototype development can also bring benefits in improving product reliability and practicality, strengthening communication and understanding, and promoting innovation and improvement. In short, introducing prototype development into complex system development has many advantages(GX Group, 2024):

- Validate design;
- Deepen communication and collaboration;
- Strengthen quality assurance;
- Mitigate risk;
- Increase opportunities for customization options prior to full production;
- Increase potential for identifying cost savings in design.

However, to realize the above advantages, its performance and functions need to be fully evaluated during the prototype production process to verify its design and identify any potential problems. By making necessary modifications to improve the design, function, or manufacturability of the complex system, engineers need to conduct comprehensive testing and evaluation before mass production to ensure that the prototype meets the required

[1] Data sourced from https://trends.google.com, which is due by Oct., 2025.

standards and specifications.

The prototype is not the final product or system, it is just a starting point and reference. The design and testing process of the prototype is an iterative process that requires continuous optimization and improvement. Through feedback and repetition, the prototype can gradually evolve into the final product or system. An important solution for product optimization is value engineering, which can run through the entire process and most stages of product development (as shown in Table 1). Li (1997) *et al*. consider it a systematic process that involves identifying and refining design elements to achieve the best results while minimizing overall costs. The process includes evaluating options and selecting the most optimized option that meets project requirements. The importance of value engineering in the product optimization process can be viewed from different perspectives, such as cost-effectiveness, optimizing functions, and promoting collaboration:

- Cost-effectiveness: Value engineering can help save costs by reducing material usage, minimizing waste, and improving the efficiency of the construction process;
- Optimizing functionality: Value engineering helps improve the functionality and usability of the project;
- Facilitating collaboration: Value engineering facilitates collaboration between different stakeholders such as designers, engineers, and contractors;
- Flexibility: Value engineering should also be flexible enough to adapt to changes in project requirements.

Table 1. Techniques for cost reduction over the development cycle

	Product Definition	Conceptual Design	Detailed Design	Production
R&D, design, and test and evaluation	▪Multi-year product plan: trade-off features, accept high one-time costs for future cost reduction ▪Cost deployment flowcharts ▪Reverse engineering/tear-down analysis			
Manufacturing and acquisition	▪Reverse engineering/tear-down analysis ▪Trade-offs ▪QFD	▪Value Engineering ▪QFD ▪Supplier Value Engineering ▪Supplier benchmarking	▪Value Engineering ▪Design for manufacturing and assembly ▪QFD ▪Supplier Value Engineering ▪Negotiation with supplier	▪Value analysis ▪Continuous improvement
Sales and marketing	▪Benchmarking ▪QFD			
Distribution	▪Trade-offs ▪QFD	▪Value Engineering ▪Design for distribution ▪Coordination with suppliers	▪Value Engineering ▪Design for distribution ▪Coordination with suppliers	▪Value analysis ▪Continuous improvement
Service	▪Trade-offs ▪QFD	▪Value Engineering ▪Design for maintenance	▪Value Engineering ▪Design for maintenance	▪Value analysis ▪Continuous improvement
Operations and support	▪Trade-offs ▪QFD	▪Value Engineering ▪Design for use	▪Value Engineering ▪Design for use	▪Value analysis ▪Continuous improvement
Disposal	▪Trade-offs ▪QFD	▪Value Engineering ▪Design for disposal ▪QFD	▪Value Engineering ▪Design for disposal ▪QFD	▪Value analysis ▪Continuous improvement

Considering the cost element in the prototype development process is very similar to the idea of value engineering: whereas value engineering is an activity that seeks to achieve the necessary functionality of a product at the lowest possible cost, considering the cost element in the prototype development process is a way to achieve dual control of functionality and cost, using price as a constraint. INCOSE Affordability Working Group (2013) takes value engineering as a tool that methodically documents the decision process by which the design and evaluation of the system solution is executed. It formally sets forth the functions and their relationship to cost. It also allows the engineer to determine how well and at what cost does a particular design alternative meets the requirements as set forth by the stakeholders. Moreover, value engineering can assist the decision-maker in managing the development and ultimate performance of the system he/she is developing. By identifying and analyzing complex system products with similar requirements through value engineering, streamlining additional functions, sorting out basic functions, identifying common functions, and using standardized means to carry out a series of unification within the system, it will play a positive role in controlling the technical status, conducting technical coordination, and ensuring the technical unification of the system and product quality. He (2004) *et al*. believe that it aims at improving value, takes functional analysis as the core and scientific methods as the tool, organically connects the technical level of products of complex systems with economic benefits, and searches for ways and means to improve the value of products of complex systems and reduce their costs through the functional analysis of products of complex system. In conclusion, the research and analysis of the literature show that applying value engineering to the prototype development of complex system models can transform scientific and technological achievements and experimental products obtained through invention, innovation, research, and development into products with reliable quality and stable repeatable production. With universalization, serialization, and combination as the internal core and market demand as the driving force, a sound complex system product system can be formed through mature application.

III. METHOD

The method used in this paper is a literature review study about cases. This paper presents several works of literature on complex systems with value engineering. The kinds of collected cases are works of literature discussing the application of value engineering in the development of complex systems and focus on the optimization of cost indicators of complex systems in the case after applying value engineering to development work, and provide certain data comparisons in forms and charts to prove the conclusions. These literatures were collected through the Google Scholar website and the official websites of major companies.

IV. FINDINGS

Value engineering is a process that uses a systematic approach to identify and analyze products, systems, or services to reduce unnecessary costs while maintaining or improving performance and quality. Understanding the value engineering process is essential when optimizing design solutions. The process provides an opportunity to determine how to save costs without sacrificing the quality of the product or service. To understand the value engineering process, it is important to consider its different aspects and perspectives.

Many complex system manufacturers in the world have carried out work related to value engineering. China has set requirements and guidance for complex system contractors to carry out value engineering through standard “Value Engineering and Cost Analysis Report”. The United States also stipulated in Part 48 of the “Federal Acquisition Regulations” promulgated in 1984 that value engineering technology should be used in defense contracts, and subsequently promulgated a series of relevant directives and standards. Based on this, value engineering has formed many practical cases in the field of complex system development in the United States.

A. Case Study on Boeing

When aerospace engineers select fasteners, their first considerations are often their technical requirements (such as strength, corrosion resistance, etc.) and the stacking of different components - choosing the screw length that is most suitable for stacking the required fasteners to minimize weight. This approach to selecting a screw size that is used less frequently results in an increase in cost (high installation costs and low marginal production costs) compared to standard components with significant economies of scale. Through research, Boeing’s value engineering organization determined that purchasing requirements were grouped around certain lead screw lengths, resulting in uneven lead screw pricing (as shown in Fig. 4).

Fig. 4. Price pattern for a family of screws.

Boeing’s value engineering organization identified costly lead screw lengths on the Boeing 787 aircraft as well as lead screw lengths that would provide significant cost savings. As long as the technology permits, although increasing the screw length increases the weight, the reduction in total cost far exceeds the increase in weight. It is self-evident which solution is more cost-effective at this time. Any design team with access to pricing data should understand the impact of volume on cost and develop more cost-effective solutions (such as avoiding low-volume lead screws), and Boeing’s failure to do value engineering in the first place left the design team Unable to obtain cost-related information, the more expensive option was chosen.

Also in the Boeing 787 project, Boeing engineers changed the material of two major fuselage parts from aluminum to an alloy (the design team assumed that its price was comparable to aluminum) early in the project to reduce the weight of the aircraft, but the value engineering organization later discovered that this alloy was much more expensive than aluminum due to insufficient supply and more difficult processing. For this reason, Boeing had to change the material of these parts back to the original aluminum. Although this change reintroduced the initial weight savings, the cost reduction far offset the weight increase. If the original design team responsible for the first change had conducted value engineering at the beginning, it would not have initiated this change that would inevitably be reworked later.

Boeing has demonstrated the benefits of cross-functional coordination during the development of the 777 program, helping to reduce changes, errors, and rework and lower program costs (Burns, 1994). The value engineering organization in the 787 program took this advantage even further, in which designers were placed among financial personnel, supplier managers, and Boeing partners. With this configuration, engineers are able to quickly and efficiently coordinate with other teams to significantly reduce 787 production costs. The above case study demonstrates that if Boeing engineers were more aligned with finance and supplier management through value engineering, they might better understand the financial impact of material selections, design changes, etc., and thus choose to eliminate design huge cost implications.

B. Case Study on Raytheon

Raytheon is an active participant in the joint government/contractor Value Engineering Integrated Product Team (VEIPT) to increase value engineering participation in its product lines. Participation in VEIPT will increase synergies across programs for each company and provide financial savings to the Department of Defense. According to the Program Executive Office of the U.S. Department of the Navy’s Theater Support Command, Raytheon’s Value Engineering Change Proposal (VECP) saved the U.S. Navy $117.3 million in fiscal year 2000, with a publicly demonstrated return on investment of 5.6:1 (Navy, 2024).

Similarly, the Standard Missile 2 (SM2) Block IV, which was successfully flight-tested against a subsonic target at White Sands Missile Range, New Mexico, after an upgrade to its control system was completed as part of Raytheon

Missile Systems' value engineering program. The upgrade enabled the Navy to increase performance at a lower cost and included a new steering control section, a new thrust vector actuator assembly for the booster rocket motor, and a new main missile battery, as well as an upgrade to the guidance and control software. Through the intervention of value engineering, this improvement will result in a significant reduction in the cost of the missile (Patterson, 2016).

By using value engineering technology, Raytheon not only provides value enhancement for customers but also reduces costs for itself as a complex system contractor.

According to the analysis of Raytheon's third quarter 2009 financial report (Wood, 2009), the operating income and operating profit margin in the three quarters of 2009 remained relatively consistent with the three quarters of 2008. Among them, the $27 million performance brought by the improvement project of the "Phalanx" model that implemented the Value Engineering Change Proposal (VECP) accounted for 6% of the operating income in the first nine months of 2009. This was mainly achieved by saving materials and improving labor efficiency through value engineering, thereby reducing production costs.

Table 2. Raytheon's 2009 Q3 financial report data

(In millions, except percentages)	Three Months Ended			Nine Months Ended		
	Sept. 27, 2009	Sept. 28, 2008	% Change	Sept. 27, 2009	Sept. 28, 2008	% Change
Net Sales	$ 1396	$ 1360	2.6%	$ 4148	$ 4042	2.6%
Total Operating Expenses	1251	1215	3.0%	3698	3600	2.7%
Operating Income	145	145	0.0%	450	442	1.8%
Operating Margin	10.4%	10.7%	-	10.8%	10.9%	-
Bookings	$ 1395	$ 1102	26.6%	$ 4210	$ 4685	−10.1%

C. Case Study on Lockheed Martin

Lockheed Martin Space Systems Company has included value engineering as an important design concept in its design manual (Martin, 2013), emphasizing that the design should ensure that the cost spent is maximized, and quality, safety, reliability, and maintainability should not be sacrificed for cost saving. The analysis and design methods should follow the established principles of professional engineering practice. In the design and development process of all systems, value engineering is encouraged, and the calculation of the life cycle cost is used as part of the value engineering proposal.

In the F-35 Joint Strike Fighter development and production project, Lockheed Martin selected a new cryogenic processing technology to cut titanium parts through value engineering (Creare LLC, 2019). This technology optimizes the performance, sustainability, and part quality of processed steel, aluminum, and other alloys and composites, significantly improving efficiency and reducing costs. Lockheed's value engineering team estimated that the project could save/avoid costs of more than $500 million.

V. Results

The cases in the FINDINGS part show the value of value engineering in the development of complex systems. The cases of screw and material selection at Boeing, missile design upgrade at Raytheon, and process design optimization at Lockheed Martin all demonstrate the usefulness and importance of value engineering in cost management - reducing costs and increasing profits.

The results achieved in the cases were all achieved by optimizing the initial development design. As a consequence, introducing value engineering into the development of complex systems to validate the design concepts, evaluate the design parameters, and improve the function design as required by prototype development, will help to optimize the design and save the cost in the prototype development of complex systems.

VI. Discussion

A. Feasibility of Value Engineering in the Prototype Development of Complex Systems

During its life cycle, a product goes through three stages (as shown in Fig. 5), namely development, growth, and maturity, before becoming obsolete(e-Yantrik, 2024). When the prototype of a complex system is developed, the entire product series is often still in the development stage. As more functions are added, changed, and optimized as needed, the value of the product will slowly increase during the development and growth stages until it reaches its peak in the mature stage, and then begin to slowly decrease due to competition, changes in customer demand, and other factors.

With the help of value engineering, product value can be created from two aspects: reducing costs and extending the maturity period. The time and cost of value engineering for existing prototypes of products are much lower than designing new product series. If value engineering is used systematically, it will achieve huge economic benefits and higher efficiency.

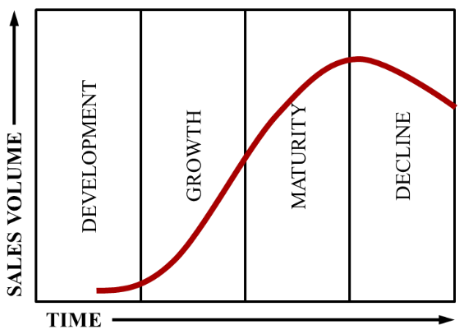

Fig. 5. The relationship between product value and life cycle.

In the process of building complex systems, countries around the world attach great importance to the research on prototypes and series. By streamlining basic functions, a mature prototype of complex systems is formed, additional functions are planned, product series are optimized and upgraded, system performance is comprehensively improved, product system spectrum is optimized, and a series development trend is formed, which will continue to maintain and improve the overall efficiency of complex systems. The practice has proved that this type of R&D model with a high level of technology sharing can effectively reduce R&D costs and risks, shorten the R&D cycle, and improve the overall benefits of complex system construction. The essence of the basic and serialized development ideas of foreign complex systems is technology sharing, that is, when designing a product series, as many shared technologies as possible are used, and additional functions are improved and upgraded according to different task requirements, in order to achieve a leap-forward improvement in overall performance at the lowest possible cost. China is also carrying out the unification of complex systems, and continuously improving the "three transformations" of the prototype of complex systems, thereby further ensuring the stability and coordination of the technical status of the complex system product series7. The above R&D ideas are often achieved by ensuring the necessary functions of the product and eliminating unnecessary functions in order to reduce costs and increase product value. The trade-off between basic functions, additional functions, costs, and expenses is the problem that value engineering focuses on solving.

Therefore, value engineering can be used as an important process in prototype development, so as to apply the experience and expertise accumulated in value engineering to the design of new products and upgrade and improve existing product lines; in the development stage of the prototype design process, design engineers can improve the function and form of the prototype by analyzing and optimizing the design.

It can be said that the main role of value engineering in prototype development is to optimize the design and create the best design at the lowest possible cost. Focus on how to create the most value for the product in all aspects, from materials and the number of parts to production technology, assembly time, and molds, to find the most cost-effective production method. By determining product performance and design scope, using cost-effective solutions, the growing economic pressure on new product development can be alleviated, thereby providing more support for the prototype development stage in the early stage of product series construction.

Therefore, applying value engineering to the prototype development of complex systems helps to achieve the optimal allocation of the entire resource, maximize cost savings, reduce the entire operating cost, and optimize the cost of the entire life cycle (Gao, 2020).

B. *The Approach of Value Engineering in the Prototype Development of Complex Systems*

The three elements involved in value engineering are value (V), function (F), and cost (C), and the relationship between the three elements refer to Eq. (1).

$$V = \frac{F}{C} \tag{1}$$

The above relationship can be used to determine the use strategy of value engineering. When V=1, it means that the required functions of the prototype being developed match the full life cycle cost, which is the best budget cost value. When $V>1$, it means that the functions of the prototype at this stage are greater than the budget of the full life cycle cost, and it is necessary to analyze and determine whether there are excess functions: if there are no excess functions, it means that this prototype has generated a higher value-added during the development process; if there are excess functions, it needs to be improved to avoid unnecessary waste. When V<1, it means that the full life cycle cost budget is difficult to support the functions expected to be achieved by the prototype, and the actual cost is high. Designers need to reduce unnecessary functions to avoid exceeding the project budget (Chen, 2011).

The above methods are used to determine: First, planning is carried out from the top level of the complex system, and the idea of pre-planning improvement is used to design the complex system spectrum and upgrade and improve it. When designing the prototype, the technical measures that may be taken for future improvement are considered in advance to maintain the flexibility and scalability of the prototype design plan. Based on the forecast of the situation and technology development direction faced by the future development of the complex system, an improvement plan for the prototype is formulated in advance, so that the performance of the complex system can be continuously and plannedly improved and enhanced, while shortening the improvement cycle and research and development costs, and enhancing the value of the overall product series based on the prototype.

Second, we should attach importance to the analysis of the contribution of common technologies to complex system development, study the mapping rules of complex system and technology development from the perspective of cost-effectiveness, and provide a reference for adding the same common technologies to multiple prototypes, so as to improve the overall benefits of complex system development. From the perspective of foreign complex system development history, there is an imbalance in the development of common technologies in various product series, which often depends on the maturity of the technology and the degree of impact on the overall performance indicators of the complex system. Evaluate the marginal benefits obtained by improving a certain common technology under the existing technical level, compare it with the marginal cost of improving the technology level on the missile, study the contribution of common technologies from the perspective of cost-effectiveness, and determine the focus and priority of technology development in order to maximize the benefits of complex system development.

Integrating value engineering into the entire value chain, including product design, prototype development, production and manufacturing, and supply chain management, will reduce costs and increase product value. This is because the goal of value engineering services is to identify and eliminate high-cost areas in the value chain to ensure a balance between effective use of resources and reduced operating costs. Through top-level planning, the relationship between functions and costs is determined, and the functions required for the prototype are streamlined to maximize the value of the product series; at the same time, value analysis techniques such as FAST diagrams are used to analyze the most urgent and efficient shared technologies required for the subsequent development of the complex system, so that the complex system can achieve the lowest cost and the best performance.

VII. Conclusion

In the prototype development of a complex system, by introducing value engineering, resource utility improvement and project management optimization can be achieved in many ways. Especially when developing the prototype of the complex system series in the early stage, value engineering emphasizes cost-benefit analysis during the project design and implementation stages to ensure that each investment can generate the greatest value. It can help transform high-level design goals into specific system function goals, thereby achieving the development results of the prototype that meets all basic functions and has the least additional functions. This method not only focuses on technical performance but also includes sustainability considerations, so that the impact of different business configurations on resources can be evaluated and compared in the early design stage, thereby optimizing resource utilization and improving the overall value of the project.

Therefore, the application of value engineering in complex system development not only improves resource utility, but also provides support for the universalization, serialization, and combination of complex system series by integrating system engineering. Applying value engineering to the prototype development of complex systems can not only help solve the limitations of resources and funds but also optimize the performance variables and progress variables of complex systems through innovation and optimization of design solutions. In addition, value engineering also emphasizes increasing product functions and reducing product costs in product innovation design, which is particularly important for prototype development because it is directly related to the market competitiveness of the product (Chen, 2011).

In short, value engineering provides a comprehensive and systematic solution for prototype development through its unique methodology. It not only helps enterprises identify and eliminate unnecessary costs but also promotes product development and innovative design centered on customer needs, ultimately maximizing cost-effectiveness and significantly improving economic benefits.

There are two main contributions of this study. First, it proposes an idea to introduce value engineering technology with a unique methodology into the production management method of prototype development, thereby providing a comprehensive and systematic cost optimization solution for it. It can not only help companies identify and eliminate unnecessary costs, but also promote product development and innovative design centered on customer needs, and ultimately achieve cost-effectiveness maximization and significant improvement in economic benefits. Secondly, through the analysis of technical principles and case data, the feasibility of this idea is preliminarily confirmed, and some operational suggestions are given in the discussion section.

However, there are also several limitations in this study. First, the findings of the case data analysis in this study mainly link value engineering, design optimization, and cost management together, but their connection with prototype development is mainly through theoretical analysis and lacks data support. Moreover, the cases are mainly from the United States, which may have certain limitations. Therefore, the next step is to carry out pilot research and seek cooperative enterprises to collect and conduct more in-depth analysis of the cost-effectiveness data achieved by using value engineering for prototype development of complex systems.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Zhongyang Zhang and Chunfeng Jia conducted the research and analyzed the data; Chunfeng Jia and Zhili Zhao provides theoretical knowledge and data on prototype development of complex system; Panxiang Yue provided case study materials related to value engineering; Zhongyang Zhang wrote the paper; all authors had approved the final version.

Acknowledgment

The authors wish to thank Zhili Zhao and Xujiao Lu.

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