

Review Article

Value Engineering Strategies for Cost Optimization in Heavy-Duty Trucks and Buses

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Received Date: 13 March 2026

Revised Date: 22 March 2026

Accepted Date: 11 April 2026

Abstract: Value engineering has become a core strategic tool for cost optimization in heavy-duty trucks and buses, as commercial vehicle development is shaped by demanding payload requirements, durability expectations, safety regulations, fuel-economy targets, and increasing pressure related to emissions compliance and electrification. Within that environment, cost reduction is no longer an isolated exercise of price reduction; instead, it must be pursued through process discipline, rationalizing platforms, modular architecture, lightweight structural redesign, life-cycle costing, simplification of manufacturing, and operation optimization using data. This paper reviews the academic literature covering value engineering strategies applied in heavy-duty trucks and buses, design-to-cost logic, target costing, modular product architecture, structural optimization, life-cycle inventory and cost evaluation, electrified powertrain economics, and maintenance-focused decision models. Key themes throughout the literature suggest that the most effective cost optimization approaches in which engineering decisions are associated with the total value of ownership as opposed to the cost of acquisition only. Simultaneously, some gaps continue to be apparent, such as deficient integration of capital and operating expenses, inadequate cross-comparison of diesel and electrified architectures under real operating conditions, and lack of supplier, manufacturing, in-service feedback influences on initial design choices. This remains an important field because future competition in commercial vehicles will depend on reducing costs without compromising safety, reliability, manufacturability, or fleet-level economic performance.

Keywords: Cost optimization, Heavy-duty trucks, Life-cycle cost, Modular design, Value engineering.

I. INTRODUCTION

Value engineering in the development of commercial vehicles involves the disciplined alignment of product function, technical performance, and cost. This is an especially difficult undertaking in heavy-duty trucks and buses, since every design choice has system-wide implications on all performance areas simultaneously, including structural integrity, payload efficiency, ride behavior, maintenance burden, fuel or energy demand, regulatory compliance, and manufacturing feasibility. The conventional cost-cutting strategies of late-phase procurement stress or the identification of a solitary part replacement hardly generate sustained benefits in this industry, because the costs often reappear in the form of warranty claims, increased service burden, or reduced fleet efficiency. That is why value engineering has evolved from a narrow cost-saving method into a broader engineering-management approach which links target cost, customer value, and design choice through early development phases [1].

A second background theme is that design-to-cost systems provide a way to present economic constraints in engineering terms. In the case of complex vehicle programs, decisions made during early concept stages determine a large proportion of downstream cost, but detailed manufacturing information appears long after the decision has been made. In response to this mismatch, design-to-cost strategies incorporate cost modelling, material-selection logic, and manufacturability and assembly assessment into concept generation and body design during embodiment design. These are of particular concern to commercial vehicles, in which frame systems, cabin structures, suspension designs, body modules and powertrain packages establish high levels of interdependence between functionality and expenditure. A cost-optimization strategy that is not integrated into engineering design tends to be reactive rather than strategic [2].

The third line of research space has to do with the growing maturity of the design-for-cost scholarship as a discipline in itself. It has been demonstrated in the literature that the cost is not a downstream accounting variable, but one determined by geometry, tolerancing, joining processes, process routing, number of parts, standardization, material flows and verification requirements. This point is particularly relevant to heavy-duty trucks and buses because commercial vehicles often have low-to-medium production volumes and a high-level of pressure for customization, which may further increase engineering complexity, which may exacerbate the engineering overhead and variant complexity. In this scenario cost control is not limited to lower component costs but is also required based on the systematic elimination of unwarranted complexity in the product and process architecture [3].



The emergence of platform strategies and modular architecture in the automotive industry is another major development. Platform logic allows common underbody, chassis, electrical and subsystem interfaces to be used across multiple products and modularization allows selective differentiation without complete redesign. In the case of heavy-duty trucks and buses, the same can be used to reduce engineering repetition, tooling duplication, difficult supplier coordination, and shortened lead time. However, platforming in commercial vehicles is more challenging than in passenger cars since duty cycles, axle format, body format, body payload groups, and regulatory environments are diverse. Nonetheless, there is an indication in the literature that smart standardization of the selected interfaces and modules can yield significant benefits in terms of cost leverage when paired with a mixed regimen of variant control [4].

Recent developments have further extended this rationale to include sustainability and optimization on a systems level in the construction of the modular platforms. Rather than regarding cost, performance, and environmental impact as distinct goals, more recent models treat vehicle architecture as a multi-criteria decision problem. This change is important due to the fact that heavy-duty trucks and buses are currently being redesigned under the conditions of electrification, lightweighting, digital diagnostics, and pressures of circularity. The purely acquisition cost approach is becoming too flawed. The main theme of the current review is, therefore, to study the conceptualization, implementation, and tests of value engineering strategies on heavy-duty trucks and buses in the literature. Significant studies, trends in the methodology, reported results, unresolved inconsistencies, and future research requirements are addressed in the following paragraphs with particular consideration on cost optimization routes that do not compromise functional integrity and long-term fleet value [5].

II. LITERATURE REVIEW

The literature on value engineering in heavy-duty trucks and buses can be categorized into four broad themes, namely modularization and product architecture, structural lightweighting and chassis optimization, life-cycle and total-cost assessment, and operation or control-oriented cost reduction. Early commercial vehicle projects focused on modularity emphasized high organizational and process efficiency and not necessarily component reuse. The product modularization in a bus manufacturing process was linked to a quantifiable increase in product engineering efficiency and production performance which implies cost optimization can start with simplification of the architecture before any change in material or process is introduced [6]. A related study on production-process efficiency in bus manufacturing revealed that modularity enhanced productivity and produced a stronger causal relationship between the rationalization of architecture and performance of operation [8]. Combined, these studies suggest that platform and module decisions do not consist of abstract design preferences; in commercial vehicles, they change engineering workload, the stability of production, and the cost of managing variants.

A second body of literature deals with lightweighting and structural optimization. Chassis and bus body experiments have repeatedly shown that significant mass savings can improve energy economy and reduce operating cost without exceeding acceptable limits for stiffness, crashworthiness, rollover resistance and durability. The literature in bus superstructure optimization shows that topology and gauge optimization have the ability to minimize the mass of the structural component but maintain rollover and stiffness requirements [7]. Through numerical modelling, finite-element, and multi-objective optimization, similar exercises have been conducted on heavy-vehicle chassis systems to minimize weight and balance stress, and deformation responses [9]. Further development of the heavy chassis design to include multi-axle configurations has incorporated hierarchical optimization schemes of both the ride comfort and the handling stability, where it is well noted that cost optimization of commercial vehicles often comes at the expense of commercial structural economy and dynamic response [10].

The third theme is related to operational energy efficiency and economics of an alternative propulsion. Research on electric and hybrid bus systems has typically focused on speed trajectory, control logic, or route-sensitive operation rather than straightforward hardware redesign. The control studies with genetic algorithms have demonstrated that using optimized driving profiles could efficiently decrease energy requirements, which can directly reduce operating costs in transit fleets [11]. This is further elaborated by life-cycle inventory and manufacturing analysis since careful decisions that consider cost are made far earlier than operation, particularly where alternative powertrains alter the material contents and new manufacturing burdens [12]. This has been supported by studies on medium and heavy truck life cycle in the United States, which have compared manufacturing and operational implications of diesel, hybrid, battery-electric, and fuel-cell systems, thereby shifting the focus to system-level considerations, rather than single component considerations [13].

The fourth theme concerns total cost of ownership and long-horizon decision support. Empirical investigations of the comparative economics of ownership of conventional and battery-electric heavy vehicles have demonstrated that distance travelled, topography, vehicle scale, and automation assumptions may have a significant influence on comparative ownership economies [14]. Life-cycle emissions and externality analyses of Class 8 trucks also suggest that high initial-cost

technologies can be made attractive to the point where energy consumption, maintenance, and externalities are factored in [15]. Comparisons of the applicability of hydrogen, electricity, and diesel in heavy-duty on road and off-road applications demonstrate that no single propulsion route is dominant across all application scenarios; cost competitiveness is dependent on duty cycle, infrastructure consideration and the sensitivity to payload [16]. In the case of freight pickup and delivery systems, regional modelling has also demonstrated that battery cost, energy tariffs, road user charges and utilization of these assets is very strong to define the net ownership [17].

The later literature has been getting more explicit on multi-objective optimization. A recent study of heavy-duty trucks using electricity-powered trailers examined based on the joint minimization of fuel consumption and overall cost of ownership and shows that the future generation of value engineering in commercial automotive is entering the realm of multivariate optimization [18]. An additional life-cycle cost orientation is present in literature on battery sizing in long-haul electric trucks, where the aim is not to maximize technical specifications but to identify an economically viable trade-off between battery weight, charging policy, and maximum range [19]. Life-cycle cost studies of urban buses show similar tensions: hybrid or other alternative powertrains may trim down certain operating burdens; however, the cost of capital and site- and context-dependent energy assumptions continue to dominate the economic feasibility assessment [20].

Significant improvement in literature thus appears, but a number of gaps still exist. First, most studies continue to research one decision layer, including that of body structure, control strategy, or ownership economics, without linking that layer to a complete value-engineering chain between the analysis of functions and service-life performance. Second, cross-study comparability is low since measures differ in terms of the reduction of weight, saving of energy, stiffness retention, greenhouse-gas performance and total cost of ownership. Third, The integration of supplier strategy, manufacturing system design, and feedback of field maintenance have not been explored within the heavy-duty vehicle literature. Such gaps warrant a wider conceptual examination that has the potential of connecting technical optimization with value engineering logic.

Table 1. Summary of key findings

Ref	Focus	Key Findings
[6]	Bus product modularization and engineering efficiency	Modular product architecture improved engineering and production efficiency, indicating that architecture simplification can reduce indirect cost and process waste.
[7]	Bus superstructure lightweight optimization for rollover safety	Iterative topology and gauge optimization reduced structural weight while preserving bending stiffness, torsional stiffness, and ECE-R66 rollover compliance.
[8]	Product modularity and bus production-process efficiency	Longitudinal assessment showed positive and statistically significant productivity gains after modular implementation in bus manufacturing.
[9]	Heavy-vehicle chassis numerical modelling and multi-objective optimization	Weight reduction was achieved while controlling stress and deformation, supporting chassis redesign as a viable route for cost-sensitive structural improvement.
[10]	Analytical target cascading for multi-axle heavy-duty chassis design	Hierarchical optimization improved ride and handling metrics, showing that complex chassis systems benefit from decomposed multi-level decision structures.
[11]	Energy minimization in electric bus operation	Optimized speed profiles lowered energy demand, revealing that operational control can contribute to cost reduction without major hardware change.
[12]	Scalable life-cycle inventory for heavy-duty vehicle production	Component-level inventory modelling enabled comparison of alternative powertrain concepts at the early design stage, strengthening life-cycle-oriented decision support.
[13]	Vehicle-cycle and life-cycle analysis of medium- and heavy-duty trucks	Comparative modelling showed that manufacturing burdens and operational benefits differ markedly across diesel, hybrid, battery-electric, and fuel-cell platforms.
[14]	Ownership-cost dataset for conventional and battery-electric heavy vehicles	Distance, topography, vehicle size, and automation assumptions materially shifted total cost competitiveness across heavy-vehicle concepts.
[15]	Life-cycle emissions, costs, and externalities of Class 8 trucks	Battery-electric heavy trucks showed strong environmental advantages and competitive economics under suitable operating conditions despite higher initial investment.

Another trend is that bus-focused studies have emphasized modularity and body engineering, whereas truck-focused studies have placed greater emphasis on powertrain economics and life-cycle analysis of product architecture, structures, operations, and fleet economics. The key trend is that cost optimization becomes more effective when decisions are made at the system level rather than at the component level. Another trend is that bus-focused studies have emphasized modularity and body engineering, whereas truck-focused studies have placed greater emphasis on powertrain economics and life-cycle analysis. This thematic divide indicates the need for integrated frameworks applicable to both product categories.

III. MATERIALS AND METHODS

The methodology combines managerial cost frameworks with engineering optimization models. The management side involves target costing, function analysis, design to cost and platform strategy. Gauge optimization, topology optimization, finite-element analysis, life-cycle inventory construction, total cost of ownership modelling, and increasing multi-objective or hierarchical optimization also belong to the engineering side. Strongest studies do not treat these method families as substitutes. Rather, the problem is framed by cost targets, and engineering models define the possibility of reaching the target without significant functional loss [1][2]. In this context, value engineering in commercial vehicles can be understood as a structured approach that links economic objectives with technical implementation.

A common methodological divide exists between direct optimization and staged decomposition. In structural work, direct minimization is usually used where the goal is reduced mass or reduced expenses in the form of energy consumption, subject to stiffness, stress, durability, or safety constraints [7][9]. Platform design, modularization and target cascading studies more frequently exhibit stages of decomposition, as high-level goals are converted into subsystem requirements, and optimization at a lower level follows [4][10]. In the case of heavy-duty truck and bus, decomposition approaches are desirable since the systems of the vehicle, chassis and body, powertrain, and storage, axle system, cabin, and control architecture, are closely coupled, but can be designed by distributed teams and vendors.

The other significant methodological trend is the change in favor of the use of life-cycle evaluation to the previous minimization of the cost. Previous design-for-cost studies tended to optimize manufacturing or procurement cost but in modern business enterprise research studies, energy consumption, service, time to change, resale value and environmental impact have been included [3][12][13]. This change is important since cheaper design during the purchase process may prove more costly within the service life in case of increase in mass, downtime, charging time, and operational complexity. The case of transit buses and freight trucks is that operating and service costs tend to capture the bulk of total ownership value, so life-cycle frameworks are of particular importance here [17][20].

Asymmetry in the quality of data is also evident in the literature. High-fidelity deep simulation is commonly used in structural optimization studies, where it represents results with clearly defined modelling assumptions, whereas fleet-economic studies are based on assumptions about fuel price, battery cost, annual mileage, availability of charging, duty cycle, and policy incentives [14][16][19]. As a result, analytical rigor in one aspect can be accompanied by uncertainty in another. An advanced chassis design optimization may not result in actual financial gain if the redesigned component increases manufacturing or service complexity. Similarly, a good ownership-cost model can lose its credibility once it is not connected to engineering implementation. Integration and not specialization is the most promising direction in methodology.

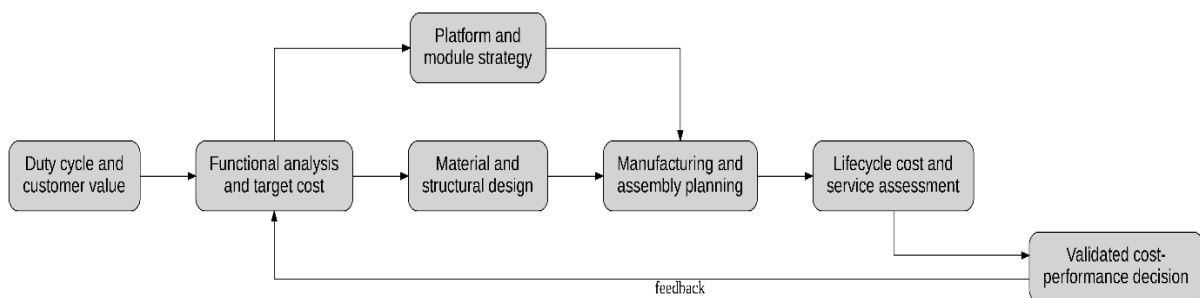


Figure 1. Conceptual framework for value engineering in heavy-duty trucks and buses

Figure 1 formulates literature as a conceptual pathway. It displays that value engineering of commercial vehicle design commences with duty-cycle and customer-value concepts, builds through functional breakdown and target-cost deployment, and then branches into module strategy, material and structural design, manufacturing simplification, and service-life feedback. This structure helps in making the case because it clarifies that cost optimization is not a single calculation, rather it is a closed-loop system of decision making.

In the literature under review, this framework allows understanding why the isolated interventions can easily generate very little value. A mass-reduction program that is not assessed in terms of manufacturing and service implications may shift cost rather than reduce it. In comparison, an architecture that matches target cost, modular interfaces, verification effort and operational economics is more congruent with the strongest evidence discovered throughout the literature [5][12].

IV. RESULTS AND DISCUSSION

Cost optimization is most effective when both direct cost drivers and indirect system-level cost drivers are addressed. A clear example is provided by bus modularization studies. Product modularization enhanced engineering and production efficiency, which signifies that value engineering can lower the cost before production volume materially increases [6][8]. This is important in heavy-duty trucks and buses since propagation of engineering changes, the complexity of variants, and instability in the assembly process tend to consume resources that would not be apparent in part-price comparisons. A pure purchasing-led understanding of cost is likely to overlook this leverage.

A second significant outcome is with regard to lightweighting. This indicates that in both topology and gauge optimization as well as parameter optimization, structural optimization studies typically provide positive results when the weight reduction is done by optimization of topology, gauge, or parameter under the explicit performance requirements [7][9][10]. But even the literature hints that the reduction of masses does not necessarily correspond to the economic improvement. The cost benefits of the interaction effects are material cost, fabrication complexity, tooling implications, fatigue performance and operational savings. Lightweighting of the body and frame may be used to enhance the energy economy and increase passenger or payload efficiency of buses, although, increased structural complexity can offset some of the economic gains if the resulting design becomes difficult or costly to manufacture or maintain. Chassis and trailer optimization can generate significant operation savings in trucks, but the value of such change is heavily contingent on the intensity of the routes and the use of the assets.

A third big observation is that life-cycle framing often changes the comparative outcomes of alternatives. A cost analysis based only on manufacturing may favor the traditional architecture, yet the total ownership and life-cycle analysis normally improve the stance of the electrified or hybrid system in the right conditions of use in general [12][13][15][16]. This does not mean that any one of the technologies will always be superior. Instead, it demonstrates that value engineering in commercial vehicles needs to utilize the temporal distribution of cost. Battery-electric trucks will seem poor on the acquisition terms but will get better in the case of high-utilization duty cycles with available charging infrastructure and energy environments. Hydrogen-powered solutions can prove interesting in some long-haul or off-road applications, but infrastructure and the price of components are the final factors. This limits the possibility of broad generalization; instead, the literature advocates duty-cycle-specific optimization.

The fourth outcome concerns the increasingly significant role of the optimization hierarchy. Analytical target cascading, multi-objective optimization, or route-sensitive control represents a significant move away from single-metric design and suggests the use of the coordinated decision structure [10][11][18]. Commercial vehicles have numerous conflicting goals: smaller mass can decrease energy consumption but increase material costs, larger battery capacity can decrease charging load but reduce cargo and increase capital cost, higher module commonality can decrease engineering costs but limit marketability. Such conflicts are not removed in hierarchical methods but rather allow a systematic negotiation across levels of the system. This is closely aligned with the logic of value engineering, as in that case the function and cost have to be brought into line and not optimized individually.

One of the fifth outcomes is the fact that context dependence is an essential consideration when researching total cost of ownership. The economics of ownership of heavy-duty vehicles vary with annual distance, terrain, access to charging or refueling, tariffs on energy, maintenance history, and regulation [14][16][17][19]. This sensitivity makes the direct comparison between studies difficult but provides a methodological lesson as well: the value engineering of heavy-duty trucks and buses should not aim at the most cost-effective particular design. Instead, the aim should be adaptable, cost-efficient architecture that can be scaled to specific operating segments. Different value-engineering priorities may be needed even in the construction of a shared platform by a city bus, a regional coach, a distribution truck, and a long-haul tractor.

Table 2. Method comparison

Ref	Method	Strengths	Limitations
[6]	Case study with DEA, ANOVA, causal impact	Captures process-level efficiency effects of modularization in an industrial context	Firm-specific evidence limits broad generalization
[7]	Topology optimization plus	Connects weight reduction to	High-fidelity simulation can be

	gauge optimization	stiffness and rollover safety constraints	computationally intensive
[9]	Finite-element modelling with multi-objective optimization	Suitable for balancing weight, stress, and deformation in chassis design	Economic interpretation depends on added manufacturing assumptions
[10]	Analytical target cascading	Handles subsystem coupling in multi-axle vehicle design	Requires careful coordination of upper- and lower-level objectives
[11]	Genetic algorithm for route-speed optimization	Reveals operational energy-saving potential without major hardware redesign	Results remain sensitive to route and control assumptions
[12]	Component-level life-cycle inventory modelling	Useful in early concept comparison across powertrain alternatives	Environmental inventory does not automatically capture service complexity
[13]	Vehicle-cycle and life-cycle comparative analysis	Links manufacturing and operation across multiple truck classes	Broad scope increases dependence on scenario assumptions
[14]	Ownership-cost dataset and sensitivity analysis	Makes distance, topography, and vehicle size effects explicit	Dataset structure may require adaptation before design use
[15]	Life-cycle emissions and cost analysis	Integrates environmental and economic comparison of alternative truck technologies	Externality assumptions vary by region and policy context
[18]	Joint fuel-consumption and TCO optimization	Aligns technical configuration with lifecycle economics	New architectures may face implementation and infrastructure barriers

Table 2 shows that no single method is sufficient on its own. Structural methods are strong in preserving functionality during redesign, whereas ownership-cost and life-cycle methods are stronger in assessing long-term economic feasibility. The most robust value-engineering practice is therefore to integrate both method families rather than choose between them

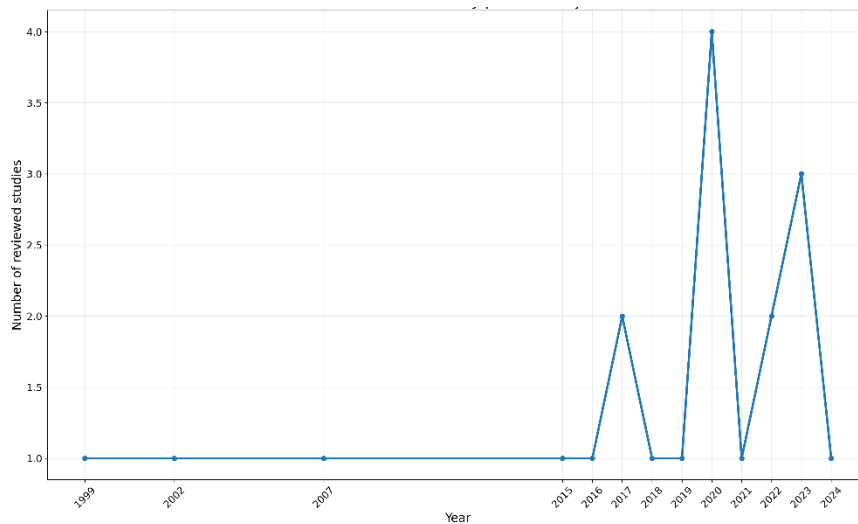


Figure 2: Distribution of reviewed studies by dominant strategy and publication year

Figure 2 converts the reviewed sample into a publication trend categorized by dominant strategy family. It depicts the expansion of the field from managerial cost structures toward life-cycle, optimization, and electrification-focused research. This supports the argument that value engineering in commercial vehicles has become increasingly systems-oriented.

The figure does not imply that the number of publications reflects maturity, but it reflects an apparent change of focus. However, earlier literature focused on cost systems, modularity, and platform logic, whereas later literature emphasizes vehicle engineering integrated with life-cycle and ownership economics.

Table 3. Results comparison

Ref	System	Metric	Outcome
[6]	Bus product architecture	Engineering and production efficiency	Significant efficiency improvement after modularization
[7]	Bus superstructure	Structural weight; stiffness; rollover compliance	Weight reduction achieved while retaining safety and stiffness requirements
[8]	Bus production process	Process efficiency	Positive causal effect of modularity on production performance
[9]	Heavy-vehicle chassis	Weight; stress; deformation	Optimized chassis achieved lower weight with acceptable structural response
[10]	Multi-axle heavy-duty chassis	Ride comfort; handling stability	Coordinated subsystem optimization improved dynamic performance indicators
[11]	Electric bus operation	Energy consumption	Optimized speed profile reduced route-level energy demand
[14]	Conventional and BE heavy vehicles	Total cost of ownership	Competitiveness changed with distance, hilliness, vehicle size, and automation assumptions
[15]	Class 8 heavy-duty trucks	Life-cycle cost and emissions	Battery-electric option showed strong lifecycle advantages under suitable conditions
[17]	Freight pickup and delivery trucks	Whole-of-life emissions; TCO	Battery-electric truck lowered emissions; TCO remained sensitive to battery and charging assumptions
[18]	Heavy-duty truck with electric trailer	Fuel use; TCO	Joint optimization identified configurations that improved energy performance while moderating ownership cost

Table 3 supports the central finding that reported outcomes are multi-dimensional. A strategy that appears attractive under one metric may be less attractive under another. For this reason, value engineering should not be reduced to cost alone; cost optimization is meaningful only when the performance metrics of the relevant system are clearly defined.

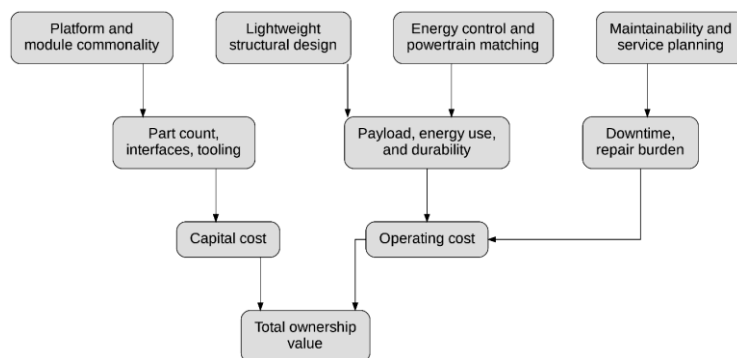


Figure 3: Relationship diagram linking engineering levers and economic outcomes

Figure 3 plots the key cause-and-effect relationships in the literature. It demonstrates the fact that platform modularity, lightweighting, control strategy and service planning have an impact on both capital and operating costs via intermediate variables like part count, payload efficiency, energy demand, maintainability and validation effort. This supports the analytical assertion that cost in commercial vehicles is determined by engineering structure rather than by late-stage purchasing decisions.

The major inference about Figure 3 is that the corresponding design lever can influence capital and operating costs in different, and sometimes opposing, ways. As an example, new materials can increase the capital cost and payload or energy efficiency; modular interfaces may increase upfront costs but reduce engineering effort and maintenance time. It is repeatedly confirmed in the literature that considering only the one side of the relationship would lead to incomplete decisions [13][16][19].

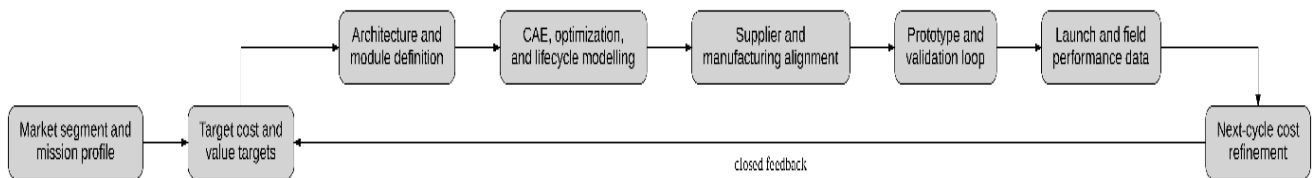


Figure 4: Integrated model for value-engineering deployment in commercial vehicle programs

The fourth figure gives a combined implementation model based on the evidence that has been reviewed. It connects market targeting, target cost, subsystems architecture, design with simulation, alignment of suppliers, prototype validation and field-data feedback into a single closed process. This figure supports the conclusion that value engineering of heavy-duty trucks and buses is best achieved when information from design, manufacturing, and service is connected early and iteratively.

One insight revealed by the integrated model is that a weakness of many studies: feedback of service life is not as developed as the structural or ownership modelling. However, in heavy-duty trucks and buses, actual patterns of maintenance, downtime patterns, route severity, as well as timing of part replacement, are core determinants of value. In-service evidence is therefore a necessary part of a mature value-engineering process and not front-end optimization alone.

V. FUTURE DIRECTIONS

Future studies should focus not on isolated optimization, but on integrated commercial-vehicle value structures. The integration of target costing, finite-element design, life-cycle inventory, and the total cost of ownership into a shared digital decision environment is a priority. Available research usually undertakes such activities in a sequential fashion with dissimilar assumptions. A more consistent model would allow early assessment of how architecture and materials interact with manufacturing pathways, service requirements, and economic value across truck and bus platforms.

Another promising approach is duty-cycle-specific modular design. City delivery, regional passenger, long-haul, school bus, intercity passenger, or urban transit markets are driving the need for manufacturers to serve multiple markets using partially shared systems. Modularity studies have demonstrated efficient benefits in bus applications, but the next phase is more advanced: management of common interfaces alongside chassis-specific energy storage, body designs, mission-specific configurations, and maintenance access. The result of such work may be reduced engineering redundancy without the performance penalty of over-standardization.

An improvement of methodology is also required in the ownership-cost studies. Numerous TCO studies are based on assumed scenarios that are challenging to reconcile in different regions and vehicle categories. Future work must integrate actual telematics, maintenance data, route topography, charging or refueling behavior, and driver actions to develop more dependable economic techniques. In the case of heavy-duty trucks and buses, it is seldom a question of whether one technology is economically viable in the abstract; it is the question of what operating conditions, within what operating envelope, one technology is economically favorable. More solid empirical data would be considered a significant addition to the practical value of the further research.

Transdisciplinary efforts are going to find more significance. It is probable that because of its contributions to mechanical design, operations research, transport economics, data analytics, and industrial engineering, the most powerful future contributions will be nontrivial. Control Electrification, digital diagnostics, soft-defined controls and the use of circular materials are transforming the price architecture of the commercial vehicles. The value engineering studies, which are restricted to a single disciplinary perspective, run the risk of underestimating the significant interplay, in particular between manufacturing cost, uptime, residual value, and infrastructure dependence. Heavy-duty trucks and buses should therefore be viewed as techno-economic systems over their full life cycle rather than as isolated mechanical artefacts; this is the perspective that future research should adopt.

VI. CONCLUSION

The literature reviewed has indicated that value engineering of heavy-duty trucks and buses has evolved into a multi-layered discipline that bridges the engineering design, manufacturing logic, and the economics of ownership. Cost optimization is most credible when grounded in functional analysis and when evaluated at the system level rather than at the unit level. This position is supported by studies on target costing, design-to-cost, and platform strategy.

There is empirical evidence on buses and heavy-duty trucks that many measures can result in meaningful cost improvement: modular architecture can increase engineering and production efficiency; lightweight structural optimization can help reduce energy requirements and enhance the value of payloads; operational control can help reduce route-level

energy demand; and life-cycle models can help clarify the situations in which higher capital cost may be justified by lower operating load. None of these strategies are sufficient in isolation.

Persistent gaps remain. cross-study comparability remains limited, service-life feedback is not yet standard practice in early design methodologies, and many economic analyses contain assumptions that are highly market and duty cycle specific. Furthermore, the literature continues to discuss buses and trucks only independently, although both types of products would benefit from a shared value-engineering framework adapted to mission profile.

The academic significance of the field, in general, is that it redefines cost in terms of being a system property. In the next generation heavy-duty trucks and buses, the competitive edge will not be determined by low-cost parts but meticulous integration of architecture, structure, manufacturing, operation, and maintenance. In this broader sense, value engineering is still one of the most significant avenues of sustainable cost improvement in the development of commercial vehicles.

Interest Conflicts

The author declares that there is no conflict of interest concerning the publishing of this paper.

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