

# The Role of Design-to-Cost Technique in Cost Reduction

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**Abstract:** This study examines the effectiveness of integrating Design-to-Cost (DTC) methodology with Activity-Based Costing (ABC) to enhance cost efficiency in industrial product design. A case study approach is applied to a 120-liter electric heater manufactured by the General Company for Electrical and Electronic Industries in Iraq. The proposed framework evaluates cost reduction opportunities during the conceptual design stage through material substitution, labor optimization, and overhead cost restructuring. A comparative analysis between traditional costing and the DTC-based model is conducted to assess performance differences in terms of cost and resource efficiency. The results show that the optimized design reduces unit cost from 108,965 IQD to 89,098 IQD, achieving a cost saving of 19,867 IQD per unit while maintaining product functionality and quality. The study demonstrates that early-stage cost integration significantly improves resource allocation efficiency and supports more informed engineering decisions. The findings highlight the practical value of combining DTC and ABC as a structured approach for cost-driven product development in manufacturing environments.

## 1 INTRODUCTION

Cost control has become a critical competitive priority for economic units operating in highly competitive markets. Although cost reduction during the production phase is often constrained, empirical evidence suggests that 60–80% of total product cost is determined at the design stage, highlighting the strategic importance of early-stage cost management [1]. In this context, Design-to-Cost (DTC) has emerged as a systematic approach that integrates cost considerations into the product development process from its initial stages. DTC evaluates materials, processes, and design alternatives to achieve cost-efficient solutions while maintaining required levels of quality and functionality. It also promotes cross-functional collaboration among design, engineering, and production teams, thereby supporting the achievement of predefined financial objectives and improving overall operational efficiency. Through continuous cost evaluation and iterative design improvement, DTC contributes to waste reduction and enhances responsiveness to market requirements [2].

Design-to-Cost is particularly relevant in the conceptual design phase, where alternative solutions can be assessed before production commitments are made. This enables organizations to select optimal design configurations that balance cost, performance, and quality, thereby increasing competitiveness in dynamic market environments. However, traditional cost and management accounting systems are increasingly inadequate for supporting such decisions, particularly in developing economies such as Iraq, where firms face rapid technological change, globalization pressures, and shifting customer preferences. These challenges necessitate the adoption of modern strategic cost management techniques capable of controlling costs at the design stage without compromising product quality.

Accordingly, this study addresses the following research problem: whether the Design-to-Cost technique can effectively reduce costs in economic units. The study aims to: 1) examine the conceptual and methodological foundations of DTC, including its objectives and implementation process, and 2) evaluate its potential contribution to cost reduction in practice. The significance of the research lies in its focus on DTC as a strategic framework for integrating

cost control into product design, thereby achieving an optimal balance between cost efficiency and product quality. This approach supports the development of competitive products that meet market expectations while minimizing total cost exposure at early stages of development.

## 2 RELATED WORKS

The concept of design-to-cost (DTC) first appeared in the US Department of Defense literature after World War II in response to the urgent need to quickly reduce the costs of producing weapons and military equipment [3]. The 1972 DTC was systematically adopted across all major US Army purchases, with DTC requirements incorporated into all major manufacturing activities [3]. In 1973, designer Rodenacker of Howlett Packed, a military equipment manufacturer, suggested moving from an engineer-based design to a team-based design that combines design and cost efficiency, reflecting the need to remain competitive [4].

In 1974, William B. Pagonis published his book "Design to Cost," which provided an integrated vision for integrating cost management into design, making it an essential reference, especially in the military and heavy industries. In Germany, the first book on DTC was published by researchers Pahi & Beitz, titled "Design," which presented the design-to-cost philosophy, and it became a basic reference for teaching design processes based on cost information [5]. With the development of technology and its impact on the product life cycle, the DTC philosophy emerged in 2004 as a motivational tool to provide innovative solutions to meet increasing challenges. This concept involves analyzing cost elements (materials, wages, indirect costs) and designing products based on these elements to ensure a balance between quality and cost [6]. Both Jain (2016) and Kopacek (2018) agree that DTC technology helps define measurable cost standards and bridges the communication gap between designers and decision-makers. It also helps reduce the total cost by enhancing the ability to generate alternative ideas to regain control of costs and achieve what is required for economic units in the future [7], [8].

Many writers and researchers have presented various concepts addressing the cost design philosophy. Still, they did not agree on a specific idea. Jorgensen defined it as a more realistic strategy that uses cost as an objective means to improve product design by dividing the cost structure into basic costs.

Each process must achieve the goals within the specified cost [9]. Hari indicated that cost design is an administrative method for controlling costs through the design stage to achieve specific goals: stimulating creativity in product design and managing the cost of production/operation. Design for cost treats cost as a significant design factor, equally important to cost, performance, and schedule [3]. On the other hand, some see it as a cost management tool that provides an alternative framework, considered an approach to conducting innovation or enhancing the relationship between value and cost, by making cost and its data basic inputs to the design process rather than results of it [1].

Jain defined it as a technique that aims to reduce the life cycle of new products while ensuring quality, reliability, and other customer requirements by examining all cost-reduction ideas in the product planning and design process [7]. Sild defined it as a cost management principle that considers the costs of development, production, and service in the design phase. It aims to implement the necessary cost strategy throughout the project development cycle so that cost objectives become independent variables to guide decision-making. It is prevalent in improving costs and increasing performance [10]. The above shows that writers and researchers are diverse in their explanations of the design concept. Some see it as a strategy, method, tool, technique, or principle. Still, the idea that provides an objective description of the design-to-cost relationship is expressed as one of the strategic cost management techniques used in the early stages of product design. It aims to achieve a balance between performance and cost when designing or developing a new product by controlling cost factors in the conceptual design stage and before starting to physically manufacture/develop it to achieve a more accurate estimate of the cost to enhance profitability and perceived value without affecting the quality or performance of the product.

## 3 RESEARCH METHOD

DTC is an important technique that helps designers control costs and evaluate the manufacturing cost of available alternatives in the early stages of the design process [7]. Thus, economic units must modify the design to ensure that financial goals are achieved. This technique relies on frequent redesign to meet a specific budget, leading to less expensive and more competitive designs [11].

It is thus an effective way to shorten the "design/development/testing" cycle, allowing

multiple alternative solutions to be examined simultaneously and meeting customer needs while reducing resource use.

The impact of the current knowledge revolution on the cost of product design and the resulting resource restructuring, especially in cost elements such as materials, wages, and indirect costs. This development requires generating accounting techniques to accurately analyze the cost structure, especially with the diversity of materials and technological characteristics in product design [12]. The materials used in modern products differ from those in traditional ones due to technological developments, as material alternatives have multiplied and materials' functional and chemical properties have improved, thereby affecting production costs [13]. Shang (2019) believes that material cost management can be achieved by monitoring material alternatives throughout the product life cycle, contributing to an absolute reduction in total production costs. This can be achieved using a cost accounting system that provides accurate information on basic materials and their alternatives from the design stage. It is also preferable to use cost management techniques to clarify non-value-producing activities and resources and reduce the impact of idle energy on total costs [14].

With the acceleration of technological development, it has become challenging to classify materials directly or indirectly. Still, the strategic approach to cost management has provided solutions for classifying materials and allocating indirect costs objectively [15]. Technological development, Ostaev, and others have also significantly affected wages. (2019). Automation has reduced the number of workers, making it easier to track direct wages, which have become less important than during periods of large-scale production. To determine indirect costs and salaries, cost drivers such as features, functions, or time are used to allocate indirect costs, focusing on activities that add value and excluding those that do not. This is achieved by adopting modern technologies that communicate information to the design team, enabling them to choose the best alternative in terms of cost and quality [15].

## 4 PRACTICAL APPLICATION

This section presents the empirical application of the Design-to-Cost (DTC) methodology integrated with

Activity-Based Costing (ABC) for optimizing the production cost of a 120-liter electric heater. The case study is conducted at the General Company for Electrical and Electronic Industries. The objective is to evaluate cost reduction opportunities through early-stage design decisions and structured cost modeling.

### 4.1 Target Cost Determination

The first stage of the DTC approach involves defining the target cost based on market-driven pricing analysis. Target pricing is derived from competitive products available in the Iraqi and regional markets, reflecting customer willingness to pay for functionally comparable products.

Table 1 summarizes the observed market prices of competing electric heaters. Based on comparative analysis, the average market price is estimated at 100,000 IQD, which is considered the target selling price. In contrast, the current production price of the case product is 120,000 IQD, indicating a cost-price gap that requires optimization through design and process improvements.

Table 1: Price of competing products

Product name	the price	Origin
Al-Amin	80000	Iraq
Barfab	110000	Iran
George	90000	Italian
Hasawi	120000	Kuwaiti

### 4.2 Cost Model Specification

The study compares two cost allocation approaches: a traditional overhead allocation method and an ABC framework. The traditional system allocates indirect costs by uniformly distributing total overhead across production units, which may result in cost distortion.

In contrast, the ABC-based model allocates indirect costs according to product-specific cost drivers and design attributes, enabling a more accurate representation of resource consumption during production.

Application of the ABC-based model results in a reduction in unit cost from 109,000 IQD (traditional method) to 108,707 IQD, representing an initial improvement of 293 IQD per unit. This reduction reflects improved cost traceability and more precise allocation of overhead resources.

Table 2: Total cost of specifications for a 120-liter electric heater.

Specification	Volume-related costs	Activity-related costs	Energy-related costs	Decision-related costs	Total specification cost
Size	36709	5137	258	3129	45233
Durability	19575	2192	110	1849	23726
Safety	21633	3320	167	1565	26685
Appearance (Aesthetic)	11044	1380	70	569	13063
Total	88961	12029	605	7112	108707

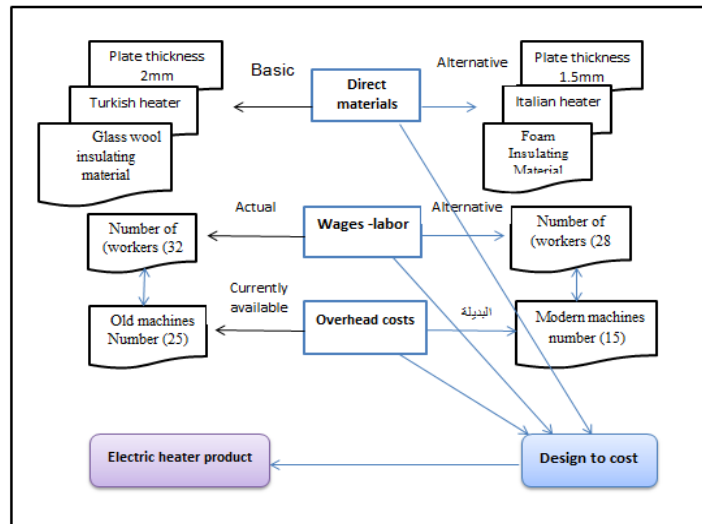


Figure 1: Building the conceptual diagram of the electric heater product.

### 4.3 Cost Elements and Design Alternatives

The actual cost structure of the electric heater components was derived from the official accounting records of the heater factory (Cost Division of the General Company for Electrical and Electronic Industries) under the unified accounting system (Table 3). Following structured interviews with the design and engineering team, it was identified that significant cost reduction opportunities could be achieved through the substitution of selected design elements without compromising product quality.

For direct materials, several alternative configurations were proposed. The external frame and heater cover, originally manufactured using 2 mm steel sheets, can be replaced with 1.5 mm sheets, as these components do not critically affect structural or functional performance. In addition, the existing Turkish heating element (14,000 IQD) can be substituted with an Italian alternative priced at 13,000 IQD, offering improved efficiency at a lower cost. Furthermore, fiberglass insulation (4,496 IQD) can be replaced with foam insulation (3,750 IQD), which

provides superior thermal and electrical insulation properties at a reduced cost.

Regarding direct labor, field analysis revealed that the production process employs 32 workers across different departments. Based on automation potential in machining and pressing operations, the workforce can be reduced to 28 employees without affecting production capacity.

For overhead costs, modernization of equipment from 24 to 15 machines enables significant efficiency gains. This results in reductions of 17% in fuel and oil consumption, 50% in spare parts usage, and 33% in maintenance expenses, reflecting improved operational efficiency and lower indirect cost intensity.

### 4.4 Conceptual Design and Cost Integration Framework

A conceptual design framework was developed to integrate product specifications with corresponding cost elements and their alternatives. This framework provides a structured representation of material, labor, and overhead cost drivers, enabling systematic comparison of alternative design configurations.

Table 3: Cost and price of the 120-liter electric heater with the exchange rate.

S	Part Name	Exchange rate	Weighted price	Total price of the item
1	Inner Tank Cover	6.93	1410	9771.3
2	Inner Tank Body	10.22	1410	14410.2
3	Base	1.31	1410	1847.1
4	Heater/Thermostat	1	14000	14000
5	Heater Bushing 3/4	4	380	1520
6	Frame (External Structure)	7.713	1410	10875
7	Upper Cover Frame	1.225	4100	5022.5
8	Lower Cover Frame	1.225	4100	5022.5
9	Plastic Cover for Pipes	0.25	1351	337.75
10	Cable-Electric Wire	1.5	1000	1500
11	Pipes	1.3	2450	3185
12	Welding Wire	3.25	974	3165.5
13	Sealing Tape	2	105	210
14	Sodium Hydroxide	0.0723	300	21.69
15	Nitric Acid	0.1	12000	1200
16	Glass Wool (Insulation)	1	4496	4496
17	Screw	20	40	800
18	Iron Plug	2	300	600
19	Ton Nail	12	15	180
20	Lamp	1	105	105
21	Water Inlet Sign	1	100	100
22	Water Outlet Sign	1	100	100
23	Reverse Connection 3/4	1	500	500
24	Thermometer	1	250	250
25	Dyes	1.5	3000	4500
26	Brand	1	100	100
27	Raw Material Cost			83819.54
28	Wages			8381.954
29	Indirect Manufacturing Costs 13% of Raw Materials			10896.54
30	Marketing and Administrative Expenses 7%			5867.36
31	Total Cost (Manufacturing Cost + Marketing and Administrative Cost)			108965.39
32	Profit Margin 10%			10896.54
33	Suggested Selling Price			119861.9
34	Final Selling Price			120000

The model serves as a decision-support tool that links engineering specifications with cost implications, thereby facilitating early-stage evaluation of design alternatives. Figure 1 illustrates the integrated conceptual structure of the electric heater system, highlighting interdependencies between cost components and design specifications.

#### 4.5 Cost Evaluation and Optimization Results

The evaluation phase assessed all proposed alternatives in order to quantify their impact on total production cost and to identify the optimal design configuration.

For direct materials, replacing 2 mm sheets (20,646.6 IQD) with 1.5 mm sheets reduces the cost to 15,375.2 IQD, generating a saving of 5,271.4 IQD.

Substituting the Turkish heating element with an Italian alternative reduces cost by 1,000 IQD. Replacing fiberglass insulation with foam further reduces costs by 746 IQD. The total material cost reduction amounts to 7,017.4 IQD per unit.

For direct labor, the introduction of modern multifunctional machinery enables a reduction of four workers. Given an average monthly wage of 750,000 IQD, this translates into a labor cost reduction of 3,000,000 IQD per production batch, or approximately 2,000 IQD per unit based on 1,500 units.

For overhead costs, efficiency improvements generate total savings of 16,230,000 IQD per batch, corresponding to approximately 10,850 IQD per unit.

Overall, total cost savings amount to 19,867.4 IQD per unit, reducing unit production cost from 108,965.4 IQD to 89,098 IQD. The optimized cost structure demonstrates the effectiveness of

integrating design-to-cost principles in early-stage product development. Assuming a 10% profit margin, the revised pricing strategy enhances the competitive positioning of the product in the market.

## 5 CONCLUSIONS

The study demonstrates that applying Design-to-Cost (DTC) principles at the early design stage leads to a significant reduction in total production costs by enabling systematic identification of cost-saving opportunities prior to manufacturing, thereby lowering material, labor, and overhead expenditures. In addition, DTC reduces the need for expensive modifications during later production stages by ensuring that financial and performance targets are embedded in the product design from the outset, which minimizes redesign activities typically associated with higher costs. The approach also enhances resource utilization and operational efficiency through early evaluation of alternative materials and production methods, reducing waste of materials and production time while improving overall cost efficiency. Furthermore, DTC contributes to shortening the product development cycle by enabling simultaneous assessment of multiple design alternatives at the conceptual stage, which decreases resource consumption and improves responsiveness to customer requirements while reducing time and cost burdens in later stages of design and manufacturing.

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