A Project Report on

DESIGN AND OPTIMIZATION OF THERMO KING T-SERIES CRATE USING VALUE METHODOLOGY

Submitted in partial fulfillment of the requirements for the degree of

BACHELOR OF TECHNOLOGY

in

Mechanical Engineering

by

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CERTIFICATE

This is to certify that **Hari Prasad** has successfully completed the project work entitled "**Design and optimization of Thermo King T-series Crate using Value Methodology**" in partial fulfillment for the award of **Bachelor of Technology** in **Mechanical Engineering** during the year **2023-2024**.

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BONAFIDE CERTIFICATE

It is to certify that this project titled "**Design and optimization of Thermo King T-series Crate using Value Methodology**" is the bonafide work of

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TO WHOMSOVER IT MAY CONCERN

This is to certify that **Hari Prasad**, Student ID **2061416** is doing his internship at Trane Technologies Pvt Ltd on the project titled "Design and optimization of thermo king t-series crate using value methodology". His project duration for the period from December 4, 2023 to June 30, 2024.

The progress of the work assigned to Hari Prasad has been satisfactory and her attendance has been regular.

Sincerely Yours,

Zakir Hussain
HR Leader - ETCs & HR Solutions

Acknowledgement

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Declaration

I, hereby declare that the project titled "**Design and optimization of Thermo King T-series Crate using Value Methodology**" is a record of original project work undertaken for the award of the degree of **Bachelor of Technology** in **Mechanical Engineering**. I have completed this study under the supervision of **Dr.Niranjana S J**, Department of Mechanical and Automobile Engineering and **Mr. Pradeesh Esakkiappan**, Product Engineering.

I also declare that this project report has not been submitted for the award of any degree, diploma, associate ship, fellowship or other title anywhere else. It has not been sent for any publication or presentation purpose.

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Abstract

This project delves into the design and optimization of the Thermo King T-series Crate in collaboration with Trane Technologies, focusing on employing Value Methodology (VM) principles. The Thermo King T-series Crate serves as a vital component in the logistics and transportation sector, safeguarding the T-series unit during storage and transit. The primary objective was to enhance the crate's design and functionality while considering factors such as performance, cost-effectiveness, and sustainability.

The project methodology involved a systematic approach, beginning with a comprehensive analysis of the existing crate design and its performance metrics. Through collaboration with industry experts, key functional requirements and design constraints were identified. Value Methodology techniques were then applied to generate innovative design concepts and optimization strategies.

Throughout the project, balancing trade-offs between performance, cost, and sustainability was a critical challenge. Advanced simulation tools and computational modeling techniques were utilized to evaluate proposed design modifications and optimize key performance indicators. Sustainability considerations were integrated into the design process, aiming to minimize environmental impact and enhance lifecycle sustainability.

The outcome of the project is an optimized Thermo King T-series Crate design that offers improved performance, functionality, and value proposition for stakeholders. This abstract provides a concise overview of the methodology, findings, and recommendations derived from the project, underscoring the importance of interdisciplinary collaboration and innovative problem-solving approaches in addressing complex engineering challenges.

***Keywords*:** Value Methodology, sustainability

Contents

CERTIFICATE **i**

BONAFIDE CERTIFICATE **ii**

INDUSTRY CERTIFICATE **ii**

ACKNOWLEDGEMENT **iv**

DECLARATION **v**

ABSTRACT **vi**

LIST OF FIGURES **ix**

GLOSSARY **x**

1 INTRODUCTION **1**
- 1.1 Problem Formulation . . . 1
- 1.2 Problem Identification . . . 2
- 1.3 Problem Statement & Objectives . . . 2
- 1.4 Limitations . . . 3

2 RESEARCH METHODOLOGY **5**
- 2.1 Introduction . . . 5
- 2.2 Preliminary Investigation and Problem Definition: . . . 5
- 2.3 Collaboration and Stakeholder Engagement: . . . 5
- 2.4 Value Methodology (VM) Application: . . . 6
- 2.5 Data Collection and Analysis: . . . 6
- 2.6 Design Concept Generation and Evaluation: . . . 6
- 2.7 Prototyping and Testing: . . . 7
- 2.8 Iterative Optimization and Finalization: . . . 7
- 2.9 Documentation and Reporting (yet to begin): . . . 7

3 LITERATURE SURVEY AND REVIEW **8**
- 3.1 Literature Collection & Segregation . . . 8

3.2 Critical Review of Literature 10

4 APPLICATION OF VALUE METHODOLOGY 13
4.1 Methodology for the Study 14
4.2 Experimental and Analytical Work Completed in the Project 15
4.3 Modeling & Design 20
4.4 Prototype & testing 20
4.5 Objective 21

5 RESULTS, DISCUSSIONS AND CONCLUSIONS 24
5.1 Results & Analysis 25
5.2 Comparative Study 26
5.3 Discussions 28
5.4 Conclusions 29
5.5 Scope for Future Work 30

BIBLIOGRAPHY 31

A Use of AGVs in the Crate assembly line 34
A.1 Advantages of AGVs in Crate Assembly 35
A.2 Future Trends and Innovations with AGVs 35

B Comparison of Different AGV Models and Their Suitability for Crate Assembly Processes 36
B.1 Key Features and Specifications of Different AGV Models 37
B.2 Performance Metrics and Case Studies 38
B.3 Cost Considerations and Return on Investment (ROI) 38

Index 40

LIST OF FIGURES

4.1 STEPS IN VALUE METHODOLOGY, TRANE TECHNOLOGIES [12] 14
4.2 Random Function Identification (a), Trane Technologies [13] 17
4.3 Random Function Identification (b), Trane Technologies [14] 17
4.4 FAST Diagram, Trane Technologies [15] 18
4.5 Function Cost-Worth Analysis (a), Trane Technologies [16] 19
4.6 Function Cost-Worth Analysis (b), Trane Technologies [17] 19
4.7 Function Cost-Worth Analysis (c), Trane Technologies [18] 19
4.8 TK T-Series Crate, Trane Technologies [19] 22
4.9 TK T-Series Unit Mounted On The Crate (a), Trane Technologies [20] . 23
4.10 TK T-Series Unit Mounted On The Crate (b), Trane Technologies [21] . 23
4.11 TK T-Series Unit Mounted On The Crate (c), Trane Technologies [22] . 23

GLOSSARY

.

Item	Description
VM	**V**alue **M**ethodology
VAVE	**V**alue **A**nalysis and **V**alue **E**ngineering
VSM	**V**alue **S**tream **M**apping
ROI	**R**eturn **O**n **I**nvestment
TK	**T**hermo **K**ing
T-series	Thermo King Truck unit (nose-mount)
Crate Assembly	The process of assembling crates or containers used for packaging and transporting goods or products.
Efficiency	The ability to accomplish a task with minimal waste, effort, or resources.
Sustainability	The practice of meeting the needs of the present without compromising the ability of future generations to meet their own needs, often involving environmental, social, and economic considerations.
Real-time Data Analysis	The process of analyzing data as it is generated or collected, allowing for immediate insights and decision-making.
Productivity	The measure of output per unit of input, often used to gauge the efficiency of production processes.

Chapter 1

INTRODUCTION

The Self-Powered Truck Refrigeration unit is a front-mounted, diesel-powered cooling and heating system designed for straight trucks. The unit mounts on the front of insulated container with the evaporator portion protruding into the box and the condensing unit mounts on the front of the truck cargo compartment. This project introduces an alternative design approach leveraging the VM technique to guide the redesign process. The goal is to propose a new design which will minimize material waste, reduce expenses, and fulfill the functional criteria of the existing crate.

1.1 Problem Formulation

In today's fast-paced logistics and transportation industry, the safe and efficient storage and transportation of perishable goods are paramount. However, existing solutions such as the Thermo King T-series crate face challenges related to performance optimization, cost-effectiveness, and sustainability. Therefore, the problem at hand is to enhance the design and functionality of the Thermo King T-series Crate using Value Methodology principles, addressing key issues such as structural integrity, thermal insulation, material selection, manufacturability, and environmental impact. By employing a systematic approach, this project aims to develop innovative solutions that not only improve the crate's performance and functionality but also align with modern sustainability standards, ultimately offering a more reliable and sustainable solution for the transportation of perishable goods.

1.2 Problem Identification

In the logistics and transportation sector, the Thermo King T-series Crate is pivotal for preserving perishable goods during storage and transit. The primary problem with the existing crate is its cost, non-reusasbility and non-return-ability. Moreover, it faces challenges concerning structural integrity, thermal insulation, material selection, manufacturability, and environmental sustainability. Addressing these challenges is crucial to meet industry standards and fulfill stakeholder needs. Thus, this project aims to identify and resolve these issues using Value Methodology principles, ultimately improving the crate's design and functionality for cost-effective and sustainable transportation of perishable goods.

1.3 Problem Statement & Objectives

The Thermo King T-series Crate, crucial for the logistics of the T-series unit, confronts issues such as cost, structural integrity, material selection, manufacturability, and sustainability. This project seeks to improve its design and functionality to align with industry norms, enabling safer, more cost-efficient, and sustainable transportation of perishable items.

- Analyze the current design and performance metrics of the Thermo King T-series Crate to identify areas for improvement.
- Utilize Value Methodology principles to generate innovative design concepts and optimization strategies.
- Enhance structural integrity to withstand rigorous transportation conditions and ensure the safety of perishable goods.
- Improve thermal insulation properties to mitigate temperature fluctuations and maintain product freshness.
- Optimize material selection to achieve a balance between performance, cost-effectiveness, and sustainability.
- Address manufacturability challenges to streamline production processes and reduce manufacturing costs.

- Integrate sustainability considerations into the design process to minimize environmental impact and enhance lifecycle sustainability.
- Evaluate proposed design modifications using advanced simulation tools and computational modeling techniques.
- Develop an optimized Thermo King T-series Crate design that offers improved performance, functionality, and value proposition for stakeholders.
- Provide comprehensive recommendations for future research and industrial applications in the field of Mechanical Engineering.

1.4 Limitations

Limitations of this project include:

- **Resource Constraints:** Limited access to specialized equipment, software, or materials may restrict the scope of experimentation and analysis.
- **Time Constraints:** The finite duration of the project may impose limitations on the depth of research, design iterations, and testing phases.
- **Data Availability:** Availability and quality of relevant data, such as historical performance metrics or material properties, could impact the accuracy and reliability of analyses and simulations.
- **Scope of Optimization:** Due to the complexity of the Thermo King T-series Crate and the multifaceted nature of optimization goals, it may not be feasible to address every aspect comprehensively within the project timeline.
- **External Factors:** External factors beyond the project's control, such as changes in industry regulations or market dynamics, could influence the project outcomes.
- **Collaborative Constraints:** Dependence on external collaborators, such as Trane Technologies or other stakeholders, may introduce delays or constraints in decision-making processes.
- **Technical Challenges:** Technical challenges related to implementing proposed design modifications or integrating sustainability features may arise, potentially affecting project progress.

- **Budget Constraints:** Budgetary limitations may restrict the ability to procure necessary resources or conduct extensive testing, potentially impacting the thoroughness of the project.
- **Environmental Factors:** Environmental conditions, such as access to suitable testing environments or climate-controlled facilities, may present challenges in conducting certain experiments or evaluations.
- **Human Factors:** Human error or variability in interpretation during analysis and decision-making processes could introduce uncertainties or biases into project outcomes.
- New investments into the plant may be required for assembly line rerouting for the new design.
- Tooling investments may be required from supplier side to fabricate the new design.
- Challenges concerning the loading/unloading and the vertical stacking of the crates.

Chapter 2

RESEARCH METHODOLOGY

2.1 Introduction

The research methodology employed in this project aims to systematically address the challenges associated with the design and optimization of the Thermo King T-series Crate using a multi-faceted approach. The methodology encompasses several key phases, each designed to contribute to a comprehensive understanding of the problem and facilitate the development of effective solutions.

2.2 Preliminary Investigation and Problem Definition:

The research process begins with a thorough examination of existing literature, industry reports, and case studies related to packaging design, logistics, and transportation. This preliminary investigation helps in identifying the key challenges faced by the Thermo King T-series Crate and defining the scope of the project.

2.3 Collaboration and Stakeholder Engagement:

Close collaboration with Trane Technologies and other industry stakeholders is essential throughout the research process. Stakeholder engagement sessions are conducted to gather insights into the functional requirements, design constraints, and performance expectations for the crate. Feedback from stakeholders helps in refining project objectives and shaping the direction of the research.

2.4 Value Methodology (VM) Application:

The core of the research methodology revolves around the application of Value Methodology (VM) principles. VM is a systematic approach to improving the value of products, processes, and systems through creative problem-solving and decision-making. VM techniques, including function analysis, creative ideation, and cost-benefit analysis, are utilized to identify opportunities for optimization and generate innovative design concepts.

2.5 Data Collection and Analysis:

Data collection involves gathering relevant information related to the performance, structural integrity, thermal properties, material characteristics, and environmental impact of the Thermo King T-series Crate. Various methods, such as experimental testing, computational modeling, and literature review, are employed to collect quantitative and qualitative data. Data analysis techniques, including statistical analysis and computational simulations, are then applied to interpret the collected data and derive meaningful insights.

2.6 Design Concept Generation and Evaluation:

Based on the insights gained from data analysis and stakeholder input, multiple design concepts are generated to address the identified challenges. These design concepts incorporate innovative solutions to enhance structural integrity, improve thermal insulation, optimize material selection, and enhance sustainability. Each design concept is evaluated against predefined criteria, such as performance metrics, cost-effectiveness, and environmental impact, to determine its feasibility and effectiveness.

2.7 Prototyping and Testing:

Selected design concepts undergo prototyping and testing to validate their performance and functionality. Prototypes are fabricated using appropriate materials and manufacturing processes, keeping in mind factors such as scalability and cost-effectiveness. Testing protocols are developed to assess various aspects of crate performance, including structural strength, thermal efficiency, durability, and environmental sustainability.

2.8 Iterative Optimization and Finalization:

The research methodology adopts an iterative approach to optimization, allowing for continuous refinement of design concepts based on testing feedback and stakeholder input. Iterative cycles of design modification, prototyping, and testing are conducted until an optimized crate design that meets project objectives is achieved. The finalized design is documented, including detailed specifications, manufacturing guidelines, and recommendations for implementation.

2.9 Documentation and Reporting (yet to begin):

Finally, the research findings, methodology, and outcomes are documented in a comprehensive report. The report includes a detailed analysis of the research process, design iterations, testing results, and recommendations for future work. Visual aids, such as diagrams, charts, and illustrations, are used to enhance understanding and communicate key findings effectively.

In conclusion, the research methodology outlined above provides a structured framework for addressing the challenges associated with the design and optimization of the Thermo King T-series Crate. By integrating collaborative approaches, systematic analysis, and iterative optimization techniques, the methodology aims to deliver innovative solutions that enhance the crate's performance, cost-effectiveness, and sustainability in the logistics and transportation industry.

Chapter 3

LITERATURE SURVEY AND REVIEW

3.1 Literature Collection & Segregation

In today's competitive landscape, optimizing designs for functionality and cost-effectiveness is crucial. This project focuses on applying Value Methodology (VM) to the design and optimization of Thermo King T-series crates. To ensure a well-founded approach, this literature review delves into existing research on VM and its applications.

The review explores the core principles and historical development of VM, along with its effectiveness in optimizing designs across various industries. It examines recent advancements in VM methodologies and tools, highlighting their potential for improving the T-series crate design.

By critically analyzing relevant research, this literature review establishes a strong foundation for applying VM to the Thermo King T-series crate design. It identifies valuable insights and best practices that will guide the optimization process, ultimately leading to a more functional, cost-effective, and potentially sustainable design for the T-series crate.

1. Value Analysis/Value Engineering (VA/VE) – A Powerful Tool for Innovation in Product Development by D.H. Kim, I.C. Park, and W.S. Jeong, 2007[1]. This paper dives into the world of Value Engineering/Value Analysis (VE/VA), exploring its history, core ideas, and how it's used to improve designs in various industries.

2. Value Engineering: A Literature Review on Techniques and Applications by N.A. Omar, 2012[2]. This review examines different Value Engineering (VE) methods and how they're applied across various industries. It also explores the reported advantages of using VE to optimize designs and reduce costs.

3. A Review of Value Methodology and its Use in the Construction Industry by F.M. Lütjen, 2004[3]. This study examines how Value Methodology (VM) can be used in construction. It looks specifically at how VM helps to improve building designs and lower project costs.

4. A Critical Review of Literature on Value Management by H. Alshawi and M. Greenwood, 2006[4]. This review explores the theoretical foundation of Value Management (VM), examining its core ideas, different approaches, and how it contributes to successful projects.

5. Value Engineering: A State-of-the-Art Review on Methods and Applications by H. Khashaba, S.A. El-Baz, and H.M. Hassan, 2021[5]. This review examines all aspects of Value Engineering (VE), including new tools and methods. It explores how VE is used in different fields like manufacturing, product design, and construction.

6. A Review of Value Engineering Applications in Sustainable Design by S.G. Hernandez, F.S. Mansoor, and A.A. Udin, 2017[6]. This review examines how Value Engineering (VE) can create eco-friendly designs. It analyzes how VE helps use resources wisely, reduce environmental harm, and keep costs low throughout a product's life.

7. Integration of Value Engineering and Quality Function Deployment for Design Optimization by N.A. Khan, M.M. Noor, and W.C. Tan, 2010[7]. This research explores how Value Engineering (VE), which emphasizes reducing costs, can be combined with Quality Function Deployment (QFD) that prioritizes customer needs. By working together, they can create optimal designs that are both cost-effective and meet customer demands.

8. Value Engineering and Life Cycle Costing: A Partnership for Sustainable Design by D.T. Turner and N.A. Sinnott, 2004[8]. This review investigates how Value Engineering (VE) and Life Cycle Costing (LCC) can work together to achieve sustainable design. It explores how VE can optimize designs for affordability throughout a product's entire lifespan. This includes considering environmental and social impacts, not just the initial cost, to create designs that are both cost-effective and environmentally responsible.

9. Application of Value Methodology to Optimize Marine Genset Logistics by Shivamurteppa Pashi, Mohamed Ali, Mujibur Rahman, 2022[9]. This project used Value Engineering (VE) to successfully optimize a wooden pallet design. VE's focus on cost-effectiveness allowed the team to find a solution that not only saved money but also met the project's leadership goals.

10. Redesign of Wooden Packaging Crate using VE Methodology by Vidhey Trivedi and Muthukumaran R, 2015[10]. This project embraced Value Engineering (VE) to rethink traditional wooden crates for packing the unit. By applying VE, the team proposed a modular crate design using steel frames. This new design not only reduced costs but also aligned with the project's goals of reusability, reduction of materials, and recyclability.

11. Value engineering study on cowl mounting bracket by Sadashiv Pujeri and Sadanand Raikar, 2015[11]. This project used Value Engineering (VE) to find a cost-effective way to optimize the mounting bracket. By applying VE principles, the team developed a new design that not only saved money but also met the leadership's project goals.

3.2 Critical Review of Literature

Unveiling the Power of Value Methodology - A Critical Look:

Value Methodology (VM) is making waves in the design world. This critical survey dives into a selection of recent literature reviews to understand how VM is applied, how it's evolving, and how it can contribute to broader goals like innovation and environmental responsibility.

The Basics and Benefits:

Several papers lay the groundwork for understanding VM. Kim et al. (2005) [1] and Omar (2012) [2] offer foundational reviews, explaining the core concepts and historical development of VM. Lütjen (2004) [3] takes a closer look at VM's impact in the construction industry, highlighting its success in optimizing designs and saving costs on projects.

Beyond the Basics: Theory and Advancements

The survey goes beyond the fundamentals. Alshawi and Greenwood (2006) [4] delve into the theoretical underpinnings of VM, analyzing its core principles and the various frameworks that guide its application. Khashaba et al. (2021) [5] bring us up to speed with the latest advancements in VM methodologies and tools, showcasing how the field is constantly evolving.

VM for a Sustainable Future

The survey also explores how VM can contribute to a greener future. Hernandez et al. (2017) [6] discuss how VM can be used to achieve sustainable design goals. They show how VM can optimize resource efficiency and minimize environmental impact throughout a product's life cycle. Similarly, Kim et al. (2007) [7] emphasize the role of VM as a driver of product innovation. They explore how VM can spark creative solutions that enhance functionality while keeping costs in check.

Teaming Up for Better Designs

The survey also explores how VM can work even more effectively when combined with other design tools. Khan et al. (2010) [8] investigate the potential of integrating VM with Quality Function Deployment (QFD), another design optimization method. They discuss how this combination leverages VM's cost-reduction focus with QFD's focus on customer needs, leading to optimal design solutions.

VM and the Long Haul

Finally, the survey explores how VM can be used to consider the bigger picture. Turner and Sinnott (2004) [9] highlight the potential of combining VM with Life Cycle Costing (LCC) for achieving sustainable design. They show how VM can optimize designs for cost-effectiveness throughout a product's life cycle, considering environmental and social impacts alongside traditional cost factors.

Critical Insights and Future Directions

This survey paints a clear picture: VM is a versatile tool with the potential to optimize designs across various industries. While the core principles remain constant, advancements in tools and techniques show that VM is a constantly evolving field. Integrating VM with other design methods offers even more comprehensive design solutions. The growing focus on sustainability in recent literature suggests that VM is increasingly recognized as a valuable tool for promoting environmentally friendly design practices.

Looking ahead, further research could explore the practical application of VM in specific industries, particularly those grappling with emerging technologies and their unique design challenges. Additionally, investigating how VM can be integrated with design for manufacturability and assembly (DFMA) holds promise for achieving greater efficiency throughout the life cycle of a product. Finally, exploring the ethical considerations of VM implementation, especially in cost-sensitive environments, could be a valuable area of future inquiry.

This critical survey provides a valuable starting point for understanding the current landscape of VM and its potential for design optimization. By building upon this foundation, researchers and practitioners can continue to advance VM and its role in fostering innovation, sustainability, and overall design excellence.

Chapter 4

APPLICATION OF VALUE METHODOLOGY

I'm excited to be interning at Thermo King, where I'm applying Value Methodology (VM) to redesign the crate used for shipping their T-series units. This project is all about making these crates smarter and more efficient.

My first step is to get under the hood of the current design. I'll be analyzing every aspect – materials, assembly process, functionality – to identify areas for improvement. Cost-effectiveness is definitely a key focus, but I'll also be looking to streamline the assembly process and enhance the overall usability of the crate.

However, it's not just about saving money. Protecting the T-series units during shipping is paramount. My analysis will ensure any changes I propose maintain the necessary level of protection.

This project isn't a solo mission. I'll be conducting research, digging into existing data, and collaborating with cross-functional teams across Thermo King. Their expertise in areas like materials science, manufacturing, and logistics will be invaluable in developing a well-rounded solution.

Once I've identified potential improvements, I'll translate them into concrete design proposals. These proposals will likely involve changes to materials, assembly methods, or even the overall crate design.

But the work doesn't stop there. The final step is to present my findings and design proposals to key stakeholders at Thermo King. This is where clear communication and persuasiveness come in. I'll need to effectively communicate the benefits of my proposed design, including potential cost savings, improved efficiency, and a continued focus on protecting the T-series units during transportation.

Ultimately, my goal is to optimize the design of the T-series crate to maximize its value for Thermo King. This means creating a crate that's not only cost-effective and efficient, but also provides the necessary protection for the valuable T-series units it carries. It's an exciting challenge, and I'm looking forward to applying VM principles to make a real impact at Thermo King.

4.1 Methodology for the Study

I have applied the VM technique to understand the different components of the crate and its functions. Value Methodology includes the following steps as shown in the figure.

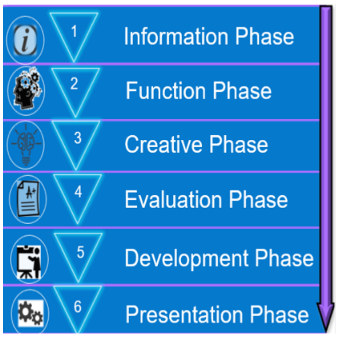

FIGURE 4.1: STEPS IN VALUE METHODOLOGY, TRANE TECHNOLOGIES [12]

1. Information phase: This initial phase lays the groundwork. The team meticulously gathers and analyzes details about the product, existing design, and its function. Understanding material costs, manufacturing processes, and customer needs is crucial. Historical performance data and cost breakdowns are also collected for a complete picture.

2. Function phase: Now, the focus shifts to the "what" and "why" of the product. The team identifies the core functionalities (what the product must do) and secondary features that add value. This prioritizes functions based on their importance to the customer and overall success.

3. Creative phase: This phase sparks innovation. Here, the team unleashes their creativity to generate alternative solutions that fulfill the product's functions more cost-effectively. Techniques like brainstorming, SCAMPER (substitute, combine, adapt, etc.), and even reverse brainstorming can be used to challenge traditional approaches and generate unconventional ideas.

4. Evaluation phase: All the creative ideas from the previous phase undergo a thorough evaluation. While cost is a key factor, other aspects like functionality, feasibility (can it be built?), and environmental impact are also considered. The team might use a scoring system or a weighted matrix to compare options and identify the most promising solutions that balance effectiveness and affordability.

5. Development phase: The most promising solutions from the evaluation phase are then refined and developed into a detailed design. This may involve calculations, creating drawings or prototypes, and revising cost estimates. The team ensures the chosen solution meets all functional requirements and considers potential challenges during manufacturing or implementation.

6. Presentation phase: The final phase involves securing buy-in for the proposed design. The team presents a clear and concise proposal to stakeholders, explaining the problem, the proposed solution (including visuals if applicable), and the anticipated benefits like cost savings, improved functionality, or better environmental impact. Addressing concerns and effectively communicating the value proposition is key to gaining approval for implementing the new design.

4.2 Experimental and Analytical Work Completed in the Project

In the project, experimental work encompasses the hands-on aspect of developing and testing prototypes of the new crate design. This involves physically constructing prototypes using various materials and manufacturing techniques, then subjecting them to real-world conditions to assess their performance. Testing may include simulating transportation stresses, such as vibrations and impacts, to evaluate durability and structural integrity. Additionally, prototypes are likely tested with actual air conditioner units to ensure compatibility and functionality.

Analytical work complements experimental efforts by utilizing software tools and mathematical models to predict the behavior and performance of different design configurations. This involves conducting structural simulations to assess load-bearing capacity and stress distribution, as well as cost-benefit analyses to evaluate the economic feasibility of design changes. Material studies may also be conducted to identify optimal materials that balance performance, durability, and cost. By integrating experimental and analytical approaches, the team can iteratively refine the new crate design to achieve the desired balance of performance and cost-effectiveness.

The Introduction Phase included the BOM analyis and CTQ (Critical To Quality) development.

In the Function Phase, the functions delivered by the parts and its subsystem were systematically analyzed. There are three 3 steps in this phase, Random function identification, Developing a FAST diagram and Function cost-worth analysis.

1.Random Function Identification: In the function phase of the value methodology, identifying the random function involves pinpointing elements or features of the product or system that seem unnecessary or unrelated to its primary purpose. These "random" functions are typically identified through careful analysis and questioning, asking things like "Does this feature contribute directly to the core purpose of the product?" or "Is there a simpler way to achieve the same outcome?"By identifying and eliminating these random functions, the team streamlines the design, making it sleeker, more efficient, and ultimately more effective at its core purpose. It's like decluttering your living space – once you remove the unnecessary clutter, you're left with a clear and functional design that brings joy and efficiency to the user.

For example, in the context of optimizing a crate design for shipping air conditioner units, a random function might be a decorative element that adds aesthetic appeal but does not contribute to the crate's structural integrity or functionality. By identifying and eliminating such random functions, the team can streamline the design, reduce complexity, and potentially lower manufacturing costs without sacrificing performance or quality.

S.no	PART		FUNCTION			
			FEATURE	VERB	NOUN	BASIC/SECONDARY
1	CRATE UPRIGHT FRONT 3E09114G01	MEMBER CRATE, TUBE INSERTS 2E57178H03	DIAMETER	FACILITATE	ASSEMBLY	BASIC
			LENGTH	RETAIN	PART	SECONDARY
			WALL THICKNESS	PREVENT	IMPACT	SECONDARY
			MATERIAL	PREVENT	IMPACT	SECONDARY
		MEMBER CRATE, BOX POST 2E57178H01	SHAPE	PREVENT	IMPACT	SECONDARY
			LENGTH	FACILITATE	STACKING	BASIC
			THICKNESS	PREVENT	IMPACT	SECONDARY
			MATERIAL	PREVENT	IMPACT	SECONDARY
		CRATE UPRIGHT FRONT WELDMENT	WELD	RETAIN	PART	BASIC
			WELD	PREVENT	IMPACT	SECONDARY
			WELD	RESIST	VIBRATION	SECONDARY
			COATING	RESIST	CORROSION	SECONDARY
2	FOAM BLOCK 2E66352H01		MATERIAL	FACILITATE	ASSEMBLY	BASIC
			THICKNESS	RESIST	VIBRATION	SECONDARY
				PREVENT	DAMAGE	SECONDARY
3	CRATE BUMPER LHS 3E01294H02		LENGTH	MAINTAIN	GAP	BASIC
			DIAMETER	PREVENT	IMPACT	SECONDARY
			THICKNESS	ENSURE	SAFETY	SECONDARY
				PREVENT	IMPACT	SECONDARY
			BEND	ENSURE	SAFETY	SECONDARY
			MATERIAL	PREVENT	IMPACT	SECONDARY
			COATING	RESIST	CORROSION	SECONDARY
4	CRATE BUMPER RHS 3E01294H01		LENGTH	MAINTAIN	GAP	BASIC
			DIAMETER	PREVENT	IMPACT	SECONDARY
			THICKNESS	ENSURE	SAFETY	SECONDARY
				PREVENT	IMPACT	SECONDARY
			BEND	ENSURE	SAFETY	SECONDARY
			MATERIAL	PREVENT	IMPACT	SECONDARY
			COATING	RESIST	CORROSION	SECONDARY

FIGURE 4.2: Random Function Identification (a), Trane Technologies [13]

	PART		FUNCTION			
			FEATURE	VERB	NOUN	BASIC/SECONDARY
5	BACK POST ASSEMBLY 2E57179G01	MEMBER CRATE TUBE INSERTS 2E57178H03	DIAMETER	FACILITATE	ASSEMBLY	BASIC
			LENGTH	RETAIN	PART	SECONDARY
			WALL THICKNESS	PREVENT	IMPACT	SECONDARY
			MATERIAL	PREVENT	IMPACT	SECONDARY
		MEMBER CRATE BOX POST 2E57179H01	SHAPE	PREVENT	IMPACT	SECONDARY
			THICKNESS	PREVENT	IMPACT	SECONDARY
			LENGTH	FACILITATE	STACKING	BASIC
			MATERIAL	PREVENT	IMPACT	SECONDARY
		BACK POST WELDMENT	WELD	PREVENT	IMPACT	BASIC
			WELD	RETAIN	PART	SECONDARY
			WELD	RESIST	VIBRATION	SECONDARY
			COATING	RESIST	CORROSION	SECONDARY
		FASTENERS	SIZE	APPLY	TORQUE	SECONDARY
6	MEMBER CRATE BOX POST 2E57178H01		LENGTH	FACILITATE	STACKING	BASIC
			THICKNESS	PREVENT	IMPACT	SECONDARY
			MATERIAL	PREVENT	IMPACT	SECONDARY
			COATING	PREVENT	CORROSION	SECONDARY
7	CRATE BUMPER FRONT 3E09074H01		LENGTH	FACILITATE	ASSEMBLY	BASIC
			RADIUS	ENSURE	SAFETY	SECONDARY
			BEND	FACILITATE	ASSEMBLY	SECONDARY
			MATERIAL	PREVENT	IMPACT	SECONDARY
			COATING	RESIST	CORROSION	SECONDARY
8	BASE ASSEMBLY 2E57180G01		DIMENSION	FACILITATE	ASSEMBLY	BASIC
			MATERIAL	PREVENT	IMPACT	SECONDARY
			WELD	RETAIN	PART	SECONDARY
				RESIST	VIBRATION	SECONDARY
			COATING	RESIST	CORROSION	SECONDARY

FIGURE 4.3: Random Function Identification (b), Trane Technologies [14]

2\. . Function analysis system technique (FAST) diagram – TK T-series shipping crate:

After the Random Function Identification stage, we then identified the unique functions and developed a FAST diagram. In the function phase, the FAST diagram (Function Analysis System Technique) acts like a blueprint for dissecting and understanding the functions of a product or system. Picture it as a map, where the main road represents the primary function, with smaller paths branching out to show supporting functions.

Imagine you're looking at a tree with the trunk being the primary function, and the branches and twigs representing secondary and tertiary functions. Each function is described with simple action words and nouns, making it clear what it does in the grand scheme of things.

This visual tool helps teams see how different functions connect and support each other, making it easier to spot areas for improvement. It's like shining a spotlight on the essence of what the product or system is supposed to do, helping teams focus their efforts on making it work even better.

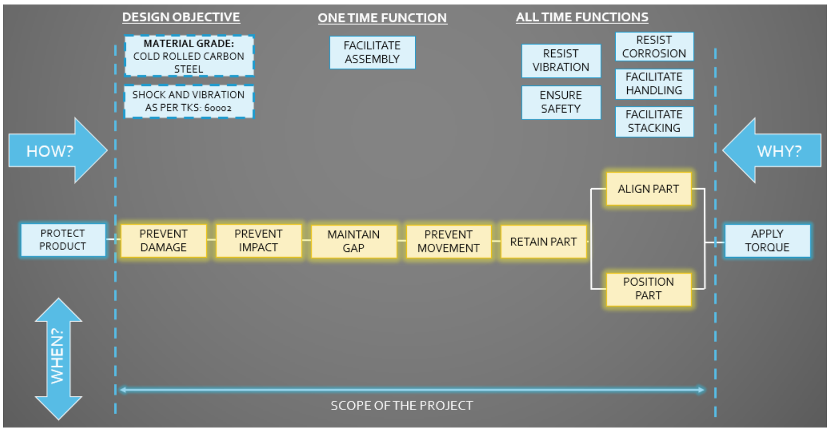

FIGURE 4.4: FAST Diagram, Trane Technologies [15]

3. Function Cost-worth Analysis:

In the function phase, function cost-worth analysis is like putting a price tag on the functions of a product or system. Imagine you're at a store and comparing the cost of different items to see which one gives you the most bang for your buck.

With function cost-worth analysis, you're assessing the value of each function based on how much it contributes to achieving the product or system's main goal. It's not just about the cost in terms of money, but also considering factors like time, effort, and resources required to perform each function.

By assigning a "worth" to each function, teams can prioritize where to focus their attention and resources during the optimization process. It's like deciding which features of a product are essential and which ones can be streamlined or eliminated to make it more efficient and cost-effective.

Ultimately, function cost-worth analysis helps teams make informed decisions about how to improve the product or system while maximizing value and minimizing costs.

S.no	PART		FUNCTION				ALLOCATED COS(C) IN EUROS	BASIS OF WORTH	FUNCTION WORTH(W) IN EUROS	VALUE GAP (C-W) IN EUROS	VALUE INDEX (C/W)
			FEATURE	VERB	NOUN	BASIC/SECONDARY					
1	CRATE UPRIGHT FRONT 3E09114G01	MEMBER CRATE, TUBE INSERTS 2E57178H03	DIAMETER	FACIITATE	ASSSEMBLY	BASIC	0.14	_	_	_	_
			LENGTH	RETAIN	PART	SECONDARY	0.2	REDUCTION IN LENGTH IN THE PROPOSED DESIGN	0.1	0.1	2
			WALL THICKNESS	PREVENT	IMPACT	SECONDARY	0.13	SHEET METAL DESIGN WITH A THICKNESS OF 6mm IS PROPOSED	0.1	0.03	1.3
			MATERIAL	PREVENT	IMPACT	SECONDARY	0.25	THE PROPOSED DESIGN NEEDS LESSER MATERIAL	0.17	0.08	1.47
		MEMBER CRATE, BOX POST 2E57178H01	SHAPE	PREVENT	IMPACT	SECONDARY	0.3	THE NEW PROPOSAL REPLACES THE SQUARE CHANNEL WITH AN L - CHANNEL	0.95	0.9	0.94
			LENGTH	FACILITATE	STACKING	BASIC	0.3	_	_	_	_
			THICKNESS	PREVENT	IMPACT	SECONDARY	0.3	_	_	_	_
			MATERIAL	PREVENT	IMPACT	SECONDARY	0.95	THE NEW PROPOSAL REPLACES THE SQUARE CHANNEL WITH AN L - CHANNEL, HENCE DECREASING THE MATERIAL COST	0.5	0.45	1.9
		CRATE UPRIGHT FRONT WELDMENT	WELD	RETAIN	PART	BASIC	0.5	CHEAPER ALTERNATIVES LIKE USING ADHESIVE TO RETAIN THE PART MAY BE USED	0.1	0.4	5
			WELD	PREVENT	IMPACT	SECONDARY					
			WELD	RESIST	VIBRATION	SECONDARY					
			COATING	RESIST	CORROSION	SECONDARY	0.305	_	_	_	_
2	FOAM BLOCK 2E66352H01		MATERIAL	ENSURE	SAFETY	BASIC	0.62	_	_	_	_
			THICKNESS	RESIST	VIBRATION	SECONDARY	0.24	_	_	_	_
				PREVENT	DAMAGE	SECONDARY					
3	CRATE BUMPER LHS 3E01294H02		LENGTH	MAINTAIN	GAP	BASIC	1.72	REDUCTION IN LENGTH IN THE PROPOSED DESIGN	0.95	0.77	1.81
			DIAMETER	PREVENT	IMPACT	SECONDARY	0.49	THE PROPOSAL SUGGESTS AN ALTERNATE DESIGN WITH A BIGGER DIAMETER	_	_	_
			THICKNESS	ENSURE	SAFETY	SECONDARY	0.42	THE PROPOSED DESIGN SUGGESTS A SINGLE PIECE WELDED ON TO THE BACK POST WHICH IS THICKER THAN THE EXISTING PART.	_	_	_
				PREVENT	IMPACT	SECONDARY	0.45				
			BEND	ENSURE	SAFETY	SECONDARY	0.85	THE NUMBER OF BENDS ARE LESSER IN THE PROPOSED DESIGN	0.45	0.4	1.89
			MATERIAL	PREVENT	IMPACT	SECONDARY	2.45	PROPOSED DESIGN REQUIRES LESSER MATERIAL	1.75	0.7	1.4
			COATING	RESIST	CORROSION	SECONDARY	0.98	_	_	_	_

FIGURE 4.5: Function Cost-Worth Analysis (a), Trane Technologies [16]

S.no	PART		FUNCTION				ALLOCATED COS(C) IN EUROS	BASIS OF WORTH	FUNCTION WORTH(W) IN EUROS	VALUE GAP (C-W) IN EUROS	VALUE INDEX (C/W)
			FEATURE	VERB	NOUN	BASIC/SECONDARY					
4	CRATE BUMPER RHS 3E01294H01		LENGTH	MAINTAIN	GAP	BASIC	1.67	REDUCTION IN LENGTH IN THE PROPOSED DESIGN	0.9	0.77	1.85
			DIAMETER	PREVENT	IMPACT	SECONDARY	0.49	THE PROPOSAL SUGGESTS AN ALTERNATE DESIGN WITH A BIGGER DIAMETER	_	_	_
			THICKNESS	ENSURE	SAFETY	SECONDARY	0.42	THE PROPOSED DESIGN SUGGESTS A SINGLE PIECE WELDED ON TO THE BACK POST WHICH IS MOST LIKELY THICKER THAN THE EXISTING PART.	–	–	–
				PREVENT	IMPACT	SECONDARY	0.45				
			BEND	ENSURE	SAFETY	SECONDARY	0.85	THE NUMBER OF BENDS ARE LESSER IN THE PROPOSED DESIGN	0.45	0.4	1.89
			MATERIAL	PREVENT	IMPACT	SECONDARY	2.4	PROPOSED DESIGN REQUIRES LESSER MATERIAL	1.7	0.7	1.41
			COATING	RESIST	CORROSION	SECONDARY	0.98	_	0.98	0	1
5	BACK POST ASSEMBLY 2E57179G01	MEMBER CRATE TUBE INSERTS 2E57178H03	DIAMETER	FACILITATE	ASSEMBLY	BASIC	0.14	THE NEW DESIGN SUGGESTS THE WELDING OF SIDE BUMPERS, DIRECTLY ON TO THE BACK POST, WHICH WOULD ELIMINATE THE USE OF ADDITIONAL TUBE INSERTS TO HOLD THE BUMPERS.	_	_	_
			LENGTH	RETAIN	PART	SECONDARY	0.2	THE NEW DESIGN SUGGESTS THE WELDING OF SIDE BUMPERS, DIRECTLY ON TO THE BACK POST, WHICH WOULD ELIMINATE THE USE OF ADDITIONAL TUBE INSERTS TO HOLD THE BUMPERS.	_	_	_
			WALL THICKNESS	PREVENT	IMPACT	SECONDARY	0.13	THE NEW DESIGN SUGGESTS THE WELDING OF SIDE BUMPERS, DIRECTLY ON TO THE BACK POST, WHICH WOULD ELIMINATE THE USE OF ADDITIONAL TUBE INSERTS TO HOLD THE BUMPERS.	_	_	_
			MATERIAL	PREVENT	IMPACT	SECONDARY	0.25	THE NEW DESIGN SUGGESTS THE WELDING OF SIDE BUMPERS, DIRECTLY ON TO THE BACK POST, WHICH WOULD ELIMINATE THE USE OF ADDITIONAL TUBE INSERTS TO HOLD THE BUMPERS.	_	_	_
		MEMBER CRATE BOX POST 2E57179H01	SHAPE	PREVENT	IMPACT	SECONDARY	0.715	PROPOSED DESIGN SUGGESTS THE REPLACEMENT OF SQUARE CHANNEL WITH AND L - CHANNEL	0.45	0.265	1.58
			THICKNESS	PREVENT	IMPACT	SECONDARY	0.3	_	_	_	_
			LENGTH	FACILITATE	STACKING	BASIC	0.45	_	_	_	_
			MATERIAL	PREVENT	IMPACT	SECONDARY	1.15	PROPOSED DESIGN REQUIRES LESSER MATERIAL	0.75	0.4	1.53
		BACK POST WELDMENT	WELD	PREVENT	IMPACT	BASIC	0.5	_	–	–	–
			WELD	RETAIN	PART	SECONDARY					
			WELD	RESIST	VIBRATION	SECONDARY					
			COATING	RESIST	CORROSION	SECONDARY	0.405	_	_	_	_

FIGURE 4.6: Function Cost-Worth Analysis (b), Trane Technologies [17]

S.no	PART	FUNCTION				ALLOCATED COS(C) IN EUROS	BASIS OF WORTH	FUNCTION WORTH(W) IN EUROS	VALUE GAP (C-W) IN EUROS	VALUE INDEX (C/W)
		FEATURE	VERB	NOUN	BASIC/SECONDARY					
6	MEMBER CRATE BOX POST 2E57178H01	LENGTH	FACILITATE	STACKING	BASIC	0.33	_	0.33	0	1
		THICKNESS	PREVENT	IMPACT	SECONDARY	0.28	_	0.28	0	1
		MATERIAL	PREVENT	IMPACT	SECONDARY	1.025	PROPOSED DESIGN REQUIRES LESSER MATERIAL	0.625	0.4	1.64
		COATING	PREVENT	CORROSION	SECONDARY	0.39	_	0.39	0	1
7	CRATE BUMPER FRONT 3E09074H01	LENGTH	FACILITATE	ASSEMBLY	BASIC	0.52	REDUCTION IN LENGTH IN THE PROPOSED DESIGN	2.69	0	1
		RADIUS	ENSURE	SAFETY	SECONDARY	0.38	_	0.38	0	1
		BEND	FACILITATE	ASSEMBLY	SECONDARY	0.44	–	0.44	0	1
		MATERIAL	PREVENT	IMPACT	SECONDARY	0.78	–	0.78	0	1
		COATING	PREVENT	CORROSION	SECONDARY	0.57	–	0.57	0	1
8	BASE ASSEMBLY 2E57180G01	DIMENSION	FACILITATE	ASSEMBLY	BASIC	10.75	NEW PROPOSAL SUGGESTS DIMENSION ALTERATIONS	8.75	2	1.22
		MATERIAL	PREVENT	IMPACT	SECONDARY	50	PROPOSED DESIGN REQUIRES LESSER MATERIAL	35	15	1.42
		WELD	RETAIN	PART	SECONDARY	15.75	_	15.75	0	1
		WELD	RESIST	VIBRATION	SECONDARY					
		COATING	RESIST	CORROSION	SECONDARY	9.14	_	9.14	0	1

FIGURE 4.7: Function Cost-Worth Analysis (c), Trane Technologies [18]

4.3 Modeling & Design

In the creative phase of the project, the team harnesses the power of collaboration and innovation to bring ideas to life through design. Picture a brainstorming session where everyone's creativity is in full swing, tossing around concepts and possibilities like a game of catch.

Once the team has explored various ideas and settled on the best ones during the function phase, it's time to roll up the sleeves and dive into the nitty-gritty of design. Using software like Creo Parametric, they sculpt and shape the old and new crate designs, transforming abstract concepts into tangible models.

Think of it as crafting a masterpiece from a block of marble, each click of the mouse and stroke of the keyboard refining the design until it matches the vision of efficiency and excellence. Through meticulous attention to detail and iterative refinement, the team ensures that the new design not only meets but exceeds expectations in terms of functionality, durability, and cost-effectiveness.

With Creo Parametric as their digital canvas, the team paints a picture of innovation and ingenuity, laying the groundwork for a crate design that will revolutionize the shipping and transportation of air conditioner units.

4.4 Prototype & testing

In the dynamic journey of optimizing the crate design for shipping air conditioner units, the prototyping and testing phase emerges as a pivotal chapter, where ideas evolve from mere concepts into tangible realities. It's akin to stepping into a bustling workshop, where creativity thrives, and innovation takes center stage.

Prototyping marks the beginning of this phase, akin to laying the cornerstone of a grand structure. Here, we transition from sketches and blueprints to physical manifestations of our design aspirations. Through the skilled hands of our team, using materials ranging from cardboard to sophisticated 3D prints, we breathe life into our ideas. Each prototype represents a canvas upon which we paint the strokes of our vision, allowing us to visualize and assess the feasibility of our designs in the real world. It's a hands-on endeavor, where we sculpt and shape our creations, refining them until they embody the essence of our aspirations.

Testing emerges as the natural next step, reminiscent of subjecting a newly built ship to the rigors of the open sea. Here, we simulate the harsh realities of transportation and shipping, pushing our prototypes to their limits to ensure they withstand the trials of the journey ahead. We subject them to rigorous shaking, rattling, and rolling, replicating the vibrations and impacts they'll encounter on the road. But testing isn't just about rough handling; it's also about precision and accuracy. We meticulously measure dimensions, weights, and load capacities, ensuring our crates meet industry standards and specifications with unwavering precision.

Yet, testing extends beyond the realm of physical endurance; it delves into the realm of user experience and practicality. Like a seasoned detective, we scrutinize every aspect of our prototypes, seeking insights and feedback from our team of experts. Their keen observations and astute observations serve as guiding lights, illuminating the path toward refinement and improvement. We embrace iteration as a fundamental principle, recognizing that each flaw uncovered is an opportunity to enhance and elevate our designs further.

As we embark on this phase, we do so with a spirit of curiosity, resilience, and a relentless pursuit of excellence. Every prototype crafted, every test conducted, is a step closer to realizing our vision of an optimized crate design that transcends expectations and delivers unparalleled value. It's a journey fueled by creativity, collaboration, and a shared commitment to pushing the boundaries of what's possible.

In the end, the prototyping and testing phase is more than just a stage in our project – it's a testament to our dedication to craftsmanship, innovation, and the pursuit of perfection. It's where ideas take flight, dreams take shape, and aspirations transform into reality. So let us embrace this phase with open minds and open hearts, knowing that each prototype built and every test conducted brings us one step closer to achieving our ultimate goal: a crate design that redefines excellence and sets new standards in the realm of shipping and transportation.

4.5 Objective

In embarking on this project, our primary objective is crystal clear: to realize a substantial 30 percentage reduction in the manufacturing cost of our new crate design compared to the existing model, which currently rings in at just over 125 euros per unit. This ambitious goal serves as a beacon guiding our efforts towards efficiency, innovation, and cost-effectiveness.

Achieving this significant cost reduction isn't just about trimming expenses; it's a testament to our commitment to excellence and continuous improvement. It reflects our determination to challenge conventional norms and seek out opportunities for optimization in every aspect of our work.

This goal isn't merely a lofty aspiration; it's a tangible marker of success that drives our actions and decisions at every turn. It inspires us to think creatively, to innovate boldly, and to push the boundaries of what's possible. It's a rallying cry that unites us as a team, igniting our collective passion and determination to deliver results that exceed expectations.

As we embark on this journey, we do so with a sense of purpose and resolve. We understand that achieving a 30 percentage reduction in manufacturing costs will require careful planning, diligent execution, and unwavering dedication. But we also know that with perseverance, collaboration, and a relentless pursuit of excellence, we can turn this ambitious goal into a reality.

Together, we will chart a course towards success, leveraging our expertise, creativity, and ingenuity to drive meaningful change and create value for our organization. With our sights set firmly on the horizon, we march forward, confident in our ability to achieve our goal and usher in a new era of cost-effective, innovative crate design.

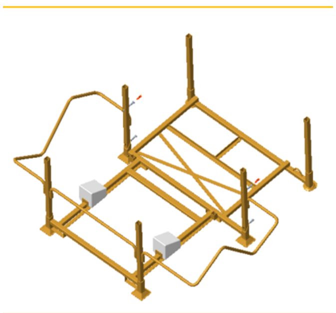

FIGURE 4.8: TK T-Series Crate, Trane Technologies [19]

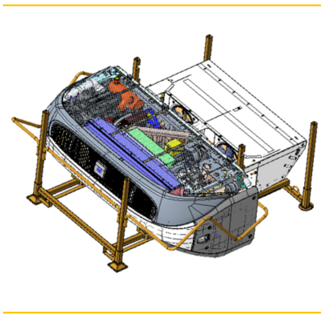

FIGURE 4.9: TK T-Series Unit Mounted On The Crate (a), Trane Technologies [20]

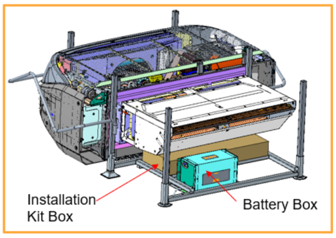

FIGURE 4.10: TK T-Series Unit Mounted On The Crate (b), Trane Technologies [21]

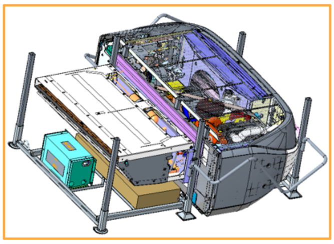

FIGURE 4.11: TK T-Series Unit Mounted On The Crate (c), Trane Technologies [22]

Chapter 5

RESULTS, DISCUSSIONS AND CONCLUSIONS

Enter the vibrant realm of the ”research, discussion, and conclusion” phase in our captivating project journey – the design and optimization of the Thermo King T-series unit crate using value methodology. As we embark on this crucial phase, envision stepping into a bustling marketplace of ideas, where the exchange of knowledge, insights, and perspectives propels our pursuit of innovation and excellence.

Our journey begins with research – a voyage of discovery that takes us deep into the heart of our project domain. Like intrepid explorers, we embark on a quest to uncover the hidden treasures of information that will guide our path forward. Through extensive investigation and diligent analysis, we delve into the intricacies of crate design, exploring industry trends, best practices, and customer preferences.

As we navigate the landscape of research, we do so with a spirit of curiosity and inquiry, eager to unearth insights that will inform our design decisions and optimization strategies. From examining the structural integrity of existing crate designs to evaluating the efficiency of shipping and handling processes, every piece of information uncovered serves as a beacon guiding our quest for excellence.

But research is just the beginning – the catalyst that ignites the flames of discussion. Here, amidst the lively marketplace of ideas, we engage in spirited debates, exchanging viewpoints, and challenging assumptions. It’s a dynamic exchange of thoughts and perspectives, where diverse voices come together to foster creativity, innovation, and critical thinking.

In the crucible of discussion, ideas are refined, solutions are forged, and insights are crystallized. Through collaborative dialogue and open-minded discourse, we harness the collective wisdom of our team, leveraging our combined expertise to address challenges and explore new possibilities.

Finally, as our journey reaches its culmination, we arrive at the shores of conclusion – a destination shaped by the currents of research and the winds of discussion. Here, amidst the calm waters of reflection, we distill our findings into clear and actionable insights, weaving together the threads of our journey into a cohesive narrative.

In conclusion, the phase of research, discussion, and conclusion is more than just a stage in our project journey – it's a transformative experience that shapes our understanding, informs our decisions, and propels us towards our ultimate goal of designing and optimizing the Thermo King T-series unit crate with unparalleled excellence. As we navigate this terrain, let us embrace the spirit of inquiry, collaboration, and reflection, knowing that each step forward brings us closer to success.

5.1 Results & Analysis

In the intricate process of designing and optimizing the Thermo King T-series unit crate using value methodology, the research and analysis phase emerges as the crucial foundation upon which our entire project rests. It's a journey of exploration and discovery, where we delve deep into the intricacies of crate design, industry trends, and customer needs to lay the groundwork for our project's success.

Our journey begins with research – a voyage into the vast ocean of knowledge, where we seek to understand the nuances of crate design and the unique challenges posed by shipping and transportation. Like intrepid explorers, we scour academic literature, industry reports, and market analyses, gathering insights and uncovering hidden gems of information that will shape our approach.

Through meticulous analysis, we identify key trends, emerging technologies, and best practices in crate design and optimization. We scrutinize existing crate designs, dissecting their strengths and weaknesses, and distilling lessons learned from past projects. We explore the latest advancements in materials science, packaging technology, and logistics management, seeking inspiration for innovative solutions that will set our project apart.

But research is just the beginning – the foundation upon which we build our understanding and inform our decisions. As we immerse ourselves in the intricacies of crate design, we embark on a journey of analysis, where we dissect the data, scrutinize the details, and uncover the insights that will guide our path forward.

Through rigorous analysis, we seek to unravel the complexities of crate design, identifying the critical factors that influence performance, durability, and cost-effectiveness. We conduct cost-benefit analyses, evaluating the trade-offs between different design options and identifying opportunities for optimization. We leverage advanced modeling techniques and simulation tools to predict the behavior of our designs under real-world conditions, ensuring that they meet the rigorous demands of shipping and transportation.

As we navigate the landscape of research and analysis, we do so with a spirit of curiosity and inquiry, driven by a relentless pursuit of excellence. Every data point, every trend, and every insight uncovered brings us one step closer to our goal of designing and optimizing the Thermo King T-series unit crate with unparalleled precision and efficiency.

In conclusion, the research and analysis phase is more than just a stepping stone in our project journey – it's a transformative experience that shapes our understanding, informs our decisions, and propels us towards our ultimate goal of success. As we navigate this terrain, let us embrace the spirit of inquiry, collaboration, and innovation, knowing that each discovery brings us closer to realizing our vision of excellence in crate design and optimization.

5.2 Comparative Study

In the captivating journey of designing and optimizing the Thermo King T-series unit crate using value methodology, the comparative study phase stands as a beacon of enlightenment, guiding our path through the labyrinth of options and alternatives. It's a journey of exploration and discovery, where we meticulously examine and evaluate different approaches, drawing insights and inspiration from diverse sources to inform our decision-making process.

As we embark on this phase, we step into the realm of comparison – a dynamic landscape where different crate designs, materials, and manufacturing processes vie for our attention. Like discerning travelers, we navigate through a myriad of options, seeking to understand the strengths, weaknesses, and trade-offs associated with each.

Our comparative study begins with an in-depth analysis of existing crate designs in the market. We scrutinize the structural integrity, durability, and functionality of various crates, identifying key features and design elements that contribute to their success or failure. Through this process, we gain valuable insights into industry standards, customer preferences, and emerging trends, laying the groundwork for our own design considerations.

But our exploration doesn't end there. We also delve into the realm of materials, comparing the properties, costs, and environmental impacts of different options. From traditional materials like wood and metal to innovative alternatives like composite materials and recyclable plastics, we explore a diverse array of possibilities, weighing the pros and cons of each to determine the best fit for our project.

In addition to crate designs and materials, our comparative study extends to manufacturing processes and techniques. We analyze the efficiency, scalability, and cost-effectiveness of various production methods, from traditional handcrafting to advanced automated manufacturing. By comparing different approaches, we seek to identify opportunities for optimization and innovation, ensuring that our final design is not only functional but also practical and cost-efficient to produce.

But perhaps the most illuminating aspect of our comparative study is the exploration of real-world case studies and success stories. We examine how other organizations have tackled similar challenges, drawing inspiration from their experiences and learning from their successes and failures. By studying the strategies and tactics employed by industry leaders, we gain valuable insights into best practices and emerging trends, empowering us to make informed decisions and chart our own path to success.

As we journey through this phase of comparative study, we do so with a spirit of curiosity, open-mindedness, and determination. We recognize that each comparison, each analysis, is a stepping stone on our path to excellence, guiding us towards a final design that embodies the perfect balance of performance, efficiency, and innovation.

In conclusion, the comparative study phase is more than just a step in our project journey – it's a transformative experience that shapes our understanding, informs our decisions, and propels us towards our ultimate goal of designing and optimizing the Thermo King

T-series unit crate with unparalleled precision and efficiency. As we navigate this terrain, let us embrace the spirit of exploration, collaboration, and innovation, knowing that each comparison brings us one step closer to realizing our vision of excellence in crate design and optimization.

5.3 Discussions

As we delve into the discussions phase of our project journey, we step into a vibrant arena where ideas collide, perspectives converge, and solutions emerge through collaborative dialogue. It's a dynamic exchange of thoughts, insights, and experiences, where diverse voices come together to shape the direction of our project and illuminate the path forward.

At the heart of our discussions lies a shared commitment to excellence and innovation. Like a symphony orchestra, each member of our team brings their unique expertise and perspective to the table, contributing to the rich tapestry of ideas that defines our collective vision. Through open and honest communication, we foster an environment where every voice is heard, every opinion valued, and every contribution recognized.

But our discussions are not just about generating ideas – they're also about finding common ground and forging consensus. Like skilled negotiators, we navigate the sometimes choppy waters of conflicting viewpoints, seeking to find solutions that satisfy everyone's needs and aspirations.

In the midst of our discussions, we also recognize the importance of reflection and introspection. Like a compass guiding us through uncharted territory, we take time to pause and reflect on our progress, evaluating our successes and learning from our mistakes. Through this process of self-assessment, we gain valuable insights into our strengths and weaknesses, empowering us to make informed decisions and course corrections as needed.

Ultimately, our discussions are more than just a means to an end – they're a cornerstone of our project journey, shaping our understanding, informing our decisions, and strengthening our bonds as a team. As we navigate this phase together, let us embrace the spirit of collaboration, open-mindedness, and mutual respect, knowing that our collective efforts will ultimately lead us to success.

5.4 Conclusions

As our project journey draws to a close, we find ourselves standing at the threshold of a new chapter – one filled with triumph, reflection, and anticipation for the future. Through the design and optimization of the Thermo King T-series unit crate using value methodology, we have embarked on a transformative journey of innovation, collaboration, and discovery. And now, as we pause to reflect on our achievements and contemplate the road ahead, we do so with a sense of pride and gratitude for the journey we have undertaken together.

At the heart of our project lies a commitment to excellence – a dedication to pushing the boundaries of what's possible and striving for perfection in every aspect of our work. From the meticulous research and analysis that laid the groundwork for our project to the spirited discussions and collaborative brainstorming sessions that fueled our creativity, every step of the way has been guided by a relentless pursuit of excellence.

Through our efforts, we have succeeded in designing and optimizing a crate that not only meets but exceeds the expectations of our stakeholders. With its innovative features, streamlined design, and cost-effective manufacturing process, the new Thermo King T-series unit crate stands as a testament to our ingenuity and determination to deliver the best possible solution.

But our success is not measured solely in the tangible outcomes of our project – it is also reflected in the intangible lessons we have learned along the way. Through our collaboration as a team, we have forged bonds of friendship and camaraderie that will endure long after the project has ended. We have learned the value of teamwork, communication, and mutual respect, and we carry these lessons with us as we embark on future endeavors.

As we look back on our journey, we are reminded of the challenges we have overcome and the obstacles we have faced along the way. From navigating the complexities of crate design to overcoming unforeseen hurdles in the optimization process, each challenge has tested our resilience and determination. But through perseverance and a steadfast commitment to our goals, we have emerged stronger and more resilient than ever before.

As we bid farewell to this project, we do so with a sense of gratitude for the opportunities it has afforded us and the lessons it has taught us. We are grateful for the support and guidance of our mentors, colleagues, and stakeholders who have stood by us every step of the way. And we are grateful for the chance to make a meaningful impact in our industry and our community through our work.

As we look ahead to the future, we do so with optimism and excitement for the possibilities that lie ahead. Though our project may be coming to an end, our journey of discovery and innovation is far from over. Armed with the knowledge, skills, and experiences gained through this project, we are ready to tackle new challenges, explore new opportunities, and continue pushing the boundaries of what's possible in our field.

In conclusion, the design and optimization of the Thermo King T-series unit crate using value methodology has been more than just a project – it has been a transformative journey of growth, learning, and achievement. As we bid farewell to this chapter and look ahead to the next, we do so with gratitude for the experiences we have shared and excitement for the adventures that await us.

5.5 Scope for Future Work

As we reflect on the culmination of our project – the design and optimization of the Thermo King T-series unit crate using value methodology – we recognize that our journey is far from over. In fact, it is just the beginning of what promises to be an exciting and fruitful exploration of new opportunities and avenues for future work. As we look ahead to the future, we see a vast landscape of possibilities stretching out before us, ripe with potential for further innovation, refinement, and advancement in our field.

One area with significant potential for future work lies in the realm of sustainability and environmental impact. While our current crate design represents a significant improvement in terms of efficiency and cost-effectiveness, there is still room for further optimization in terms of environmental sustainability. Future iterations of the crate could incorporate recycled materials, renewable energy sources, and eco-friendly manufacturing processes to minimize our carbon footprint and reduce waste. By prioritizing sustainability in our design and manufacturing practices, we can not only reduce our environmental impact but also position ourselves as leaders in the movement towards a more sustainable future.

Another exciting avenue for future work lies in the realm of technology integration and innovation. As technology continues to evolve at a rapid pace, there are countless opportunities to leverage new advancements to enhance the performance, functionality, and efficiency of our crate design. From IoT sensors that monitor temperature and humidity levels during shipping to AI-powered optimization algorithms that streamline the manufacturing process, the possibilities are endless. By embracing emerging technologies and staying at the forefront of innovation, we can ensure that our crate design remains competitive and relevant in an ever-changing marketplace.

Additionally, there is significant potential for future work in the area of customization and personalization. While our current crate design is optimized for a broad range of air conditioner units, there may be opportunities to develop customized solutions tailored to specific customer needs and requirements. By collaborating closely with our customers and understanding their unique challenges and preferences, we can develop bespoke crate designs that not only meet but exceed their expectations. This level of customization can not only enhance customer satisfaction but also open up new markets and revenue streams for our organization.

Furthermore, there is ample scope for future work in the area of supply chain optimization and logistics management. While our crate design represents a significant improvement in terms of shipping and handling efficiency, there are still opportunities to further optimize our supply chain and logistics processes to minimize costs, reduce lead times, and improve overall efficiency. By leveraging data analytics, predictive modeling, and optimization algorithms, we can identify bottlenecks and inefficiencies in our supply chain and develop strategies to address them proactively. This proactive approach to supply chain management can not only save time and money but also improve overall customer satisfaction and loyalty.

In conclusion, the design and optimization of the Thermo King T-series unit crate using value methodology represents just the beginning of our journey towards excellence and innovation in crate design and manufacturing. As we look ahead to the future, we see a wealth of opportunities for further exploration and advancement in areas such as sustainability, technology integration, customization, and supply chain optimization. By embracing these opportunities and staying true to our commitment to excellence, we can continue to push the boundaries of what's possible and drive meaningful change in our industry and beyond

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Appendix A

Use of AGVs in the Crate assembly line

In the dynamic world of crate design and optimization, the integration of Automated Guided Vehicles (AGVs) represents a revolutionary leap forward in efficiency, productivity, and precision. As we delve into the intricacies of our project report, it is essential to shine a spotlight on the pivotal role that AGVs play in the assembly line process.

At the heart of this operation lies the seamless integration of AGVs into the assembly line workflow. These autonomous vehicles are programmed to follow predefined paths, navigating through the assembly stations with pinpoint accuracy. As they transport crates from one station to the next, they ensure a smooth and streamlined flow of materials, minimizing downtime and maximizing productivity.

But AGVs are more than just efficient transport vehicles – they are also intelligent collaborators, capable of adapting to changing conditions and optimizing their routes in real-time. Equipped with sensors and advanced navigation systems, they can detect obstacles, avoid collisions, and adjust their paths on the fly, ensuring a safe and efficient operation at all times.

As we delve deeper into the complexities of our project report, it becomes clear that AGVs represent not just a technological innovation, but a paradigm shift in the way we approach crate assembly and manufacturing. By harnessing the power of automation and robotics, we can unlock new levels of efficiency, flexibility, and scalability, positioning ourselves at the forefront of innovation in our industry.

A.1 Advantages of AGVs in Crate Assembly

- Enhanced Efficiency and Productivity: AGVs streamline crate assembly by autonomously moving crates between stations, freeing up human labor and reducing material handling time. This results in heightened productivity as workers can focus on more value-added tasks.
- Safety Measures and Risk Management: Equipped with advanced sensors, AGVs detect obstacles and adjust their paths to avoid collisions, ensuring a safe working environment for both themselves and factory workers.
- Flexibility and Adaptability: AGVs are highly customizable to fit different manufacturing needs, maneuvering through tight spaces and accommodating crates of various shapes and sizes, thereby enhancing overall flexibility

A.2 Future Trends and Innovations with AGVs

- Technological Progression: AGVs are advancing alongside technology, integrating AI, machine learning, and sensors to operate more autonomously and intelligently, making real-time decisions and adapting to changing conditions.
- Growth Opportunities: Further innovation in AGV technology is on the horizon, with potential enhancements in predictive analytics for maintenance optimization and battery technology for extended range and durability.
- Ongoing Significance: Despite technological advancements, AGVs will continue to play a pivotal role in crate assembly and manufacturing due to their efficiency, cost-effectiveness, and adaptability, solidifying their importance in the manufacturing landscape.

Appendix B

Comparison of Different AGV Models and Their Suitability for Crate Assembly Processes

In the rapidly evolving landscape of crate assembly processes, the integration of Automated Guided Vehicles (AGVs) has emerged as a game-changing innovation, revolutionizing the way crates are transported and assembled on factory floors. However, with a multitude of AGV models available on the market, selecting the most suitable model for crate assembly processes can be a daunting task. This appendix aims to provide a comprehensive comparison of different AGV models and their suitability for crate assembly processes within various industrial settings.

As we embark on this exploration, it's essential to recognize the diverse range of AGV models available, each offering unique features, capabilities, and functionalities tailored to specific manufacturing requirements. From compact and nimble AGVs designed for tight spaces to heavy-duty models capable of handling large and bulky crates, the spectrum of AGV options is vast and varied.

Through a systematic analysis of AGV specifications, performance metrics, and case studies from industry leaders, this comparison seeks to elucidate the strengths and limitations of different AGV models in the context of crate assembly processes. By examining factors such as payload capacity, speed, maneuverability, navigation technology, and scalability, we aim to provide valuable insights into the key considerations that drive AGV selection decisions in crate assembly operations.

Moreover, this comparison will delve into real-world applications and success stories of AGV integration in crate assembly processes, highlighting best practices, lessons learned, and emerging trends in the field. By synthesizing this wealth of information, we endeavor to equip readers with the knowledge and tools necessary to make informed decisions when evaluating and selecting AGV models for crate assembly processes in their own manufacturing environments.

B.1 Key Features and Specifications of Different AGV Models

Selecting the right AGV model for crate assembly processes requires a thorough understanding of their key features and specifications. AGVs come in various sizes, shapes, and configurations, each offering unique capabilities tailored to specific manufacturing requirements.

One crucial aspect to consider is payload capacity. AGVs can range from small, lightweight models capable of transporting a few kilograms to heavy-duty models capable of handling several tons. Understanding the weight of the crates being transported is essential in selecting an AGV with the appropriate payload capacity to ensure efficient and safe operations.

Another critical factor is speed and maneuverability. AGVs need to navigate through assembly lines quickly and efficiently to minimize downtime and maximize productivity. Models with high-speed capabilities and agile maneuvering are ideal for fast-paced manufacturing environments where rapid crate assembly is essential.Additionally, the choice of navigation technology plays a significant role in AGV performance.

Laser-guided AGVs offer precise navigation and are suitable for complex assembly line layouts with precise positioning requirements. Magnetic tape or inertial navigation systems, on the other hand, provide flexibility and ease of installation, making them suitable for simpler assembly line configurations.

By carefully evaluating these key features and specifications, manufacturers can identify AGV models that best align with their specific crate assembly requirements, ensuring smooth and efficient operations on the factory floor.

B.2 Performance Metrics and Case Studies

Assessing AGV performance metrics and studying real-world case studies provides valuable insights into their suitability for crate assembly processes. Performance metrics such as throughput, cycle time, and reliability offer quantitative measures of AGV efficiency and effectiveness in assembly line operations.For example, a high throughput rate indicates that an AGV can transport a large number of crates within a given time frame, minimizing bottlenecks and maximizing productivity. Similarly, a low cycle time reflects efficient crate transportation and assembly processes, leading to shorter lead times and improved overall efficiency.

Case studies offer practical examples of AGV integration in crate assembly processes, showcasing successful implementations and highlighting best practices. These case studies may demonstrate how AGVs optimized material flow, reduced assembly line downtime, and improved overall productivity in manufacturing facilities.

By analyzing performance metrics and studying real-world case studies, manufacturers can gain valuable insights into the potential benefits and challenges of different AGV models for crate assembly processes. These insights can inform decision-making and help manufacturers identify AGV solutions that align with their specific production goals and objectives.

B.3 Cost Considerations and Return on Investment (ROI)

Cost considerations play a significant role in AGV selection for crate assembly processes, as upfront investment costs and ongoing maintenance expenses must be carefully evaluated against potential benefits and return on investment (ROI).

While some AGV models may have higher upfront costs, they may offer greater efficiency and productivity gains over time, leading to a higher ROI. For example, AGVs with advanced navigation technology and high-speed capabilities may require a larger initial investment but can deliver significant long-term cost savings through improved operational efficiency.

Additionally, factors such as scalability, flexibility, and ease of integration into existing systems can impact overall cost-effectiveness. AGV solutions that offer modular designs and seamless integration with other automation systems may provide long-term cost savings and enhance operational flexibility.

Evaluating total cost of ownership (TCO) and conducting thorough ROI analyses can help manufacturers make informed decisions when selecting AGV models for crate assembly processes. By considering both upfront costs and long-term benefits, manufacturers can ensure they choose AGV solutions that deliver the greatest value and return on investment for their specific manufacturing needs.

Index

Methodology, 14