Decision Quality for an Electromechanical Startup

Abstract

Background: The demand for high-quality electromechanical parts is growing at an unprecedented rate. The growth demand can be seen more prevalent in the aerospace, telecommunications and defense industries. The quality of the electromechanical components is a stringent factor which drives up costs and ultimately increases delivery time due to the need to meet regulations. These electromechanical components include but are not limited to terminal connectors, fuse panels, peripheral component interconnect (PCI) board, power distribution boards (PDB), and printed circuit board (PCB).

Purpose: This paper aims to study how a structured decision-making framework can influence the manufacturing outcome in terms of cost, quality, and delivery of the product development for a startup. This is done by integrating knowledge from different fields such as business, engineering, and academia to put in place the best decision-making practices that result in quality innovation and production. The curiosity principle from Kern Entrepreneurial Engineering Network (KEEN) will be the driving factor integrated with the process outlined in the International Council on Systems Engineering (INCOSE) to showcase the structured approach to make strategic choices.

Method: The decision quality framework from INCOSE which includes the use of influence diagrams and decision trees are implemented to better evaluate the strategic alternatives and the impact of the decision made. Lean Six Sigma methodologies as defined in the INCOSE handbook are used as a foundation to the decisions affecting production processes

Results: Each research question was answered using a decision tree based on scenarios. In terms of quality improvements (RQ1), component redesign and material upgrades are a viable option but come at a higher cost. In terms of reduction in cost (RQ2), automation and Lean Six Sigma methodologies reduce material waste and cost of labor. In terms of speed of delivery (RQ3), optimization in logistics and coordination between suppliers shows an improvement in production and market responsiveness.

Conclusion: This study shows how structured decision-making helps balance quality, cost, and delivery in manufacturing. By using decision trees, companies can see trade-offs and make better choices. The findings confirm that improving materials ensures high quality but raises costs. Automating production lowers costs but requires upfront investment. Streamlining logistics speeds up delivery but depends on suppliers. No single approach is perfect, and companies must adapt to their needs**.**

Keywords: Decision Trees, KEEN, PCBs, INCOSE

1.1 Background

The demand for high-quality electromechanical components is increasing due to their ability to reshape the aerospace and defense industry. These industries require components to comply with strict quality and reliability standards, resulting in the electromechanical components being both high cost and longer delivery time. Modern electrical and electromechanical systems heavily rely on terminal

blocks, fuse panels, PCI boards, power distribution boards, FPGA modules, and PCBs. As technology advances in these industries, a drive for producing components at a higher efficiency ultimately results in the need for a structured decision-making approach for the manufacturing of electromechanical components.

The quality and economic viability of the production of electromechanical components relies on the decision-making process. This decision-making process is optimized through the integration of business, engineering, and academic viewpoints, resulting in a comprehensive approach. A structured decision-making framework addresses challenges of a startup by balancing the cost of production, quality of production, and delivery of products. Leveraging the Curiosity principle from the KEEN framework and the decision-making process from INCOSE, an innovative solution can be curated to not only improve the quality of the part but do so in a cost-efficient manner. The integration of these two frameworks allows for the systematic evaluation of alternatives revolving around a continuous improvement mindset.

1.2 Literature Review

1.2.1 KEEN

According to KEEN, three principles make up the framework which includes connections, curiosity, and creating value. For this paper, we will be focusing on the curiosity principle. The curiosity principle is foundational to foster an entrepreneurial mindset to adapt to the world that is rapidly evolving. With a curiosity mindset, individuals can explore trends that are emerging and use the findings to challenge traditional solutions, replacing them with innovative solutions. Proactive engagement between engineers not only allows for the adaptation towards newer technologies but also improves personal growth in addition to creating future engineers that can positively contribute to their respective fields [1].

Psychology and neuroscience research shows that curiosity is an important factor in decision-making where individuals are motivated to develop solutions to existing problems. As a foundation of cognitive aspect, individuals who have a curiosity mindset are motivated in seeking new information to develop themselves in a healthy manner. Individuals' problem-solving ability are improved as they have instilled in themselves the desire to explore and understand the world around them, allowing them to be competent engineers who are adaptable in the face of continuous evolution and challenges in industry [2].

1.2.2 INCOSE

According to INCOSE, to guarantee that the best choice is made, a structured approach where a decision is made based on clear objectives, well-framed problems, and a comprehensive analysis of alternatives. To optimize cost, quality, and delivery, a high-quality decision is made through a structured approach where a problem is clearly identified and framed, a list of alternatives is created to solve the identified problem where the alternatives will then undergo an analysis involving trade-off study, influence diagrams, and decision trees before reaching the final step of execution. Engineers are required to find a balance between technical, operational, and financial factors to decide based on the objective criteria and probabilistic risk assessment, ensuring that the decision is sustainable and

effective at that point in time [3].

An important factor of quality decision making within the context of system engineering is the ability to incorporate and manage uncertainty and risk. Engineers are required to go through a risk and opportunity management process where all the potential failure modes are identified, the impact of the identified failure modes are then assessed before developing a mitigation plan for risks. Engineers are then able to make informed choices under uncertainty by integrating and implementing quantitative risk models, expected utility theory, Bayesian analysis, and sensitivity analysis based on readily available data at the point in time of making the decision. This structured approach is necessary for engineers, preventing them from making less than ideal solutions and avoiding premature convergence [3].

By taking the entire system lifecycle into consideration, a holistic and interdisciplinary approach allows engineers to seek out interdependencies, feedback loops, and emergent behaviors that may not arise during linear analysis. This is a form of tradespace exploration where engineers examine alternative solution against numerous dimensions to come up with an adaptable design along with the help of scenario simulation and decision trees [3].

1.3 Problem Statement

In the highly competitive home appliance market, the efficiency and reliability of terminal blocks are critical for ensuring product performance and customer satisfaction. Current terminal blocks, while functional, face challenges in terms of cost, quality, and delivery speed. To generate a competitive edge, we need to design and analyze a new terminal block product that meets the following criteria:

1. ***Acceptable Quality***: The new terminal block must meet or exceed industry standards for durability, safety, and performance.
2. ***Lower Cost***: The production cost of the new terminal block must be reduced without compromising quality.
3. ***Faster Delivery***: The time from order to delivery must be shortened to improve customer satisfaction and market responsiveness.

To achieve these goals, we will employ Lean Six Sigma methodologies and selected process automation to avoid inefficiencies in our production processes before making our first product.

1.4 Research Question

RQ1: Can the new terminal block meet or exceed industry standards

RQ2: Can the new terminal block production cost be reduced without affecting quality

RQ3: Can the delivery time be reduced to improve customer satisfaction

2.0 Methodology

This study aims to build an economic model for an electromechanical startup.

2.1 Decision Quality Steps: The first step is to understand the decision quality framework. This involves six elements: a useful frame, creative alternatives, meaningful information, clear values and trade-offs, sound reasoning, and commitment to action. These elements help in making better decisions.

2.1.1 Framing the Decision: We start by defining the problem and setting the context. This helps in understanding what needs to be decided and why it is important. A clear frame ensures that the decision is focused and relevant [4].

2.1.2 Generating Alternatives: Next, we brainstorm different options. This step is crucial as it provides multiple paths to achieve the goal. More alternatives mean a higher chance of finding the best solution [5].

2.1.3 Gathering Information: We collect data that is relevant to the decision. This includes market trends, financial reports, and technical specifications. Accurate and up-to-date information is vital for making informed decisions [6].

2.1.4 Clarifying Values and Trade-offs: We identify what is important to the stakeholders. This involves understanding their values and the trade-offs they are willing to make. Clear values help in prioritizing options [7].

2.1.5 Applying Sound Reasoning: We use logical methods to evaluate the alternatives. This includes creating influence diagrams and decision trees. These tools help in visualizing the decision process and the potential outcomes [8][9].

2.1.6 Committing to Action: Finally, we decide and plan the implementation. Commitment to action ensures that the decision is executed effectively [10].

2.2 Influence Diagrams and Decision Trees

Once our decision has been properly framed, the researchers created Influence diagrams and associated decision trees. Influence diagrams are used to map out the decision process. They show the relationships between different variables. Decision trees help in evaluating the alternatives by showing the possible outcomes and their probabilities. These tools are essential for visualizing and analyzing the decision-making process [11][12].

3.0 Results

3.1 Results for RQ1

Decision trees showed that to best ensure the terminal block production meets industry quality, improvement in material was the most strategic choice to make even though at a higher cost.

Scenario for a Decision Tree of Acceptable Quality

A manufacturing company specializing in terminal blocks is looking to improve product quality to meet or exceed industry standards. The company has three strategic options to achieve this goal:

1) **Improve Materials**: Upgrade raw materials to increase durability and safety compliance.
- High-cost investment but significantly improves performance.
- Moderate cost increase ensures long-term reliability.
- Minimal changes to materials to test market response.

2) **Enhance Testing**: Implement a more rigorous testing framework.
- Adopt AI-based testing for efficiency.
- Increase manual inspection points for quality control.
- Rely on standard compliance tests.

3) **Redesign Component**: Modify the terminal block design for better performance.
- Introduce a modular design for ease of customization.
- Improve insulation and heat resistance.
- Reduce the number of components to simplify assembly.

Each of these decisions will impact production cost, customer satisfaction, and regulatory compliance as shown in figure 1.

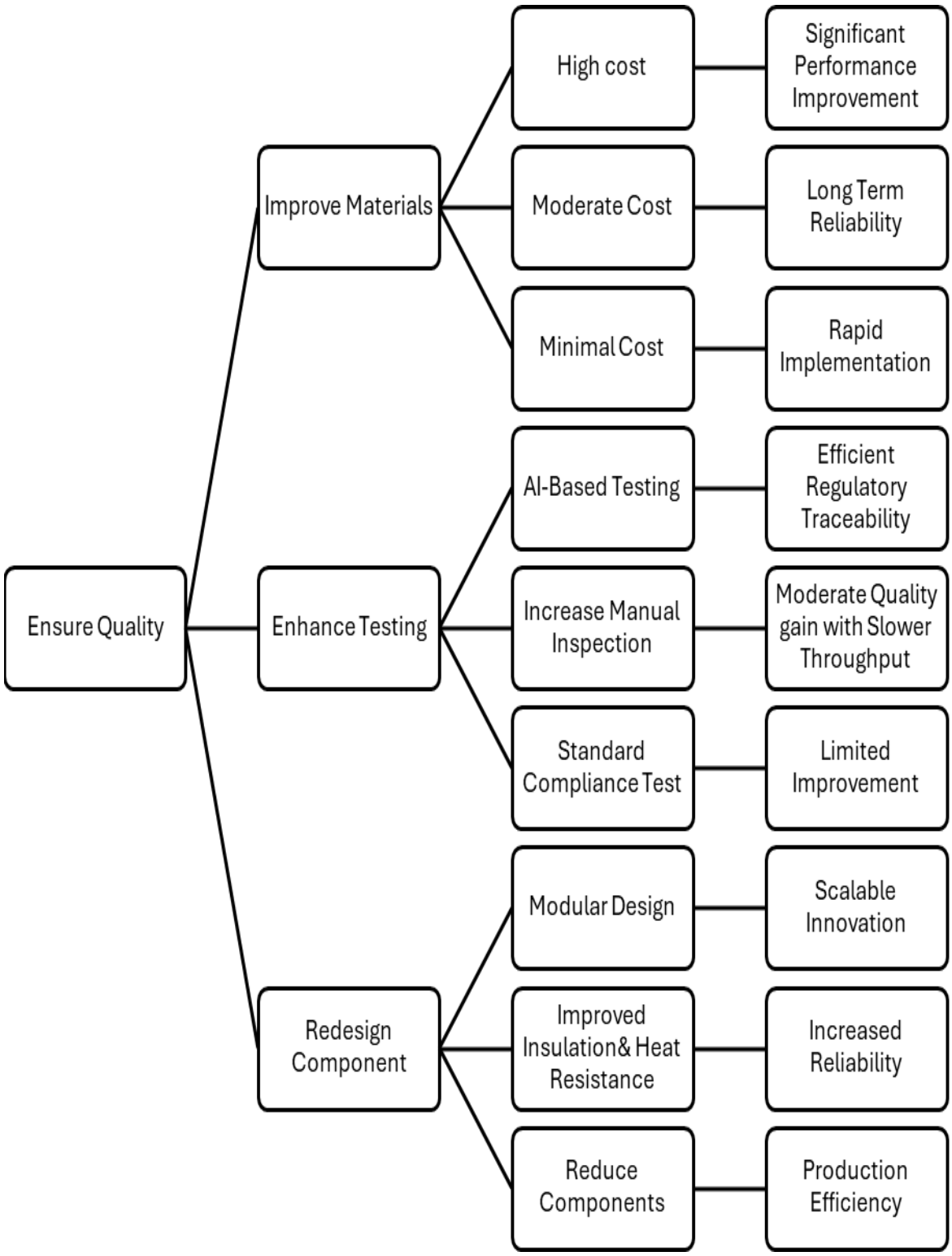

Figure 1: Decision Tree of Acceptable Quality

3.2 Results for RQ2

Decision trees shows that production automation provided the most effective way to reduce cost given the available information at hand. Other options are viable but usually come with hidden costs that are difficult to quantify due to the ambiguous nature of the market conditions.

Scenario for a Decision Tree to Lower Cost

A manufacturing firm producing electromechanical terminal blocks is looking to reduce production costs while maintaining quality. Three strategic alternatives are considered:

1) **Optimize Supply Chain**: Streamline procurement and logistics.
- Negotiate better pricing with suppliers.
- Identify alternative suppliers with lower costs.
- Implement just-in-time inventory management.

2) **Reduce Material Waste**: Improve production efficiency and minimize waste.
- Implement Lean Six Sigma to optimize raw material use.
- Invest in recycling initiatives for scrap reduction.
- Introduce automation to improve precision cutting.

3) **Automate Production**: Invest in process automation.
- Install robotic assembly lines for increased efficiency.
- Upgrade existing machinery to reduce human error.
- Use predictive maintenance to avoid downtime.

Each option involves trade-offs related to cost savings, implementation complexity, and operational efficiency as shown in figure 2.

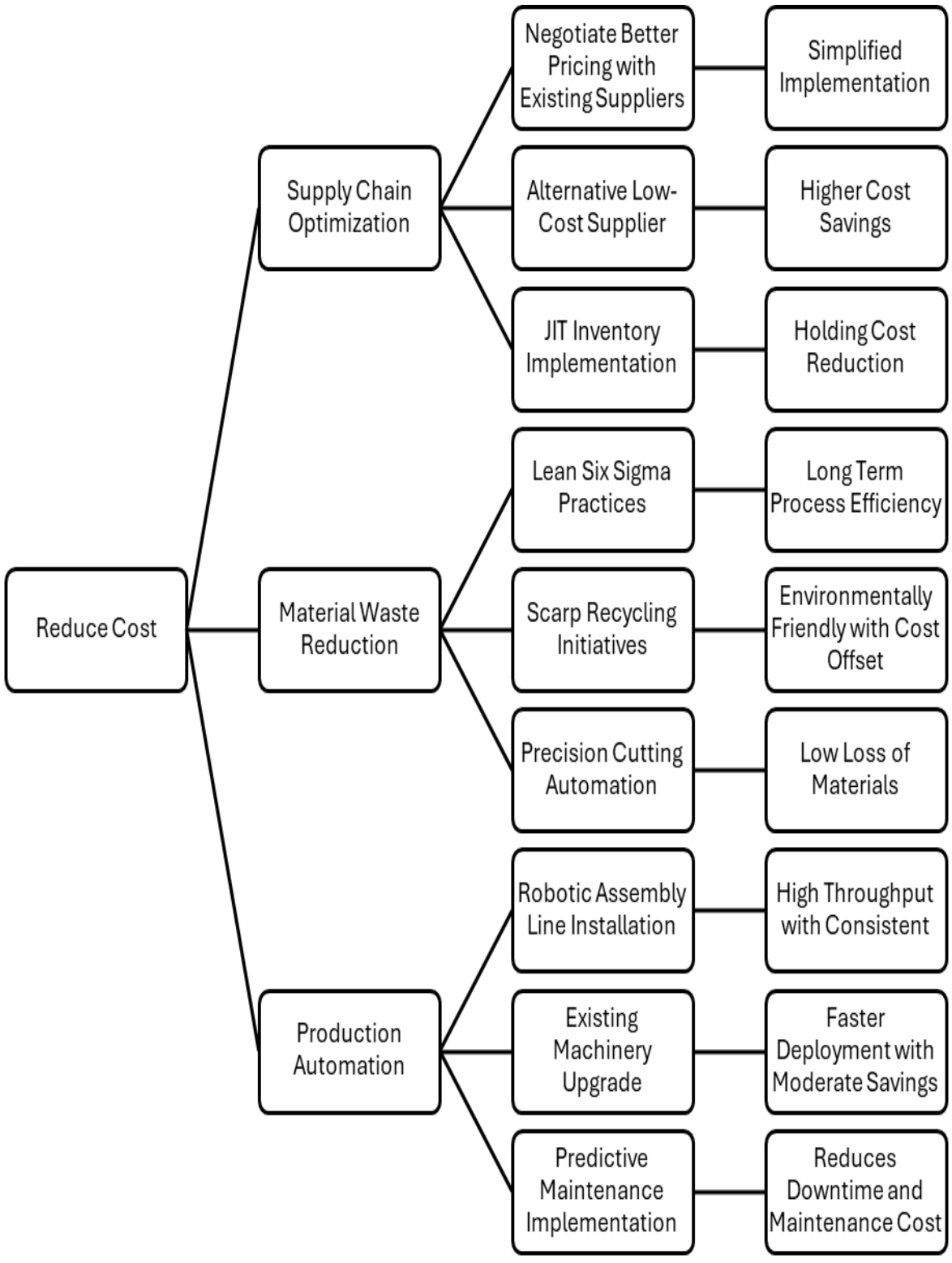

Figure 2: Decision Tree to Lower Cost

3.3 Results for RQ3

The decision trees shows that streamlining logistics provides the best results compared to other options with the least amount of negative effects compared to the other choices even though the benefits of the other choices are weighed. The decision can change at any given point in time depending on the goals of the company or the condition of the company.

Scenario for a Decision Tree for Faster Delivery

A company manufacturing terminal blocks is facing increased market demand and needs to shorten delivery lead times. The following alternatives are evaluated:

1) **Streamline Logistics:** Optimize warehousing and distribution.
- Implement a centralized distribution hub.
- Reduce handling time by optimizing packaging.
- Utilize direct shipping methods.

2) **Increase Production Capacity**: Expand manufacturing throughput.
- Invest in additional production lines.
- Optimize shift scheduling to maximize machine utilization.
- Outsource peak demand production.

3) **Improve Supplier Coordination**: Enhance supply chain responsiveness.
- Implement real-time inventory tracking with suppliers.
- Negotiate faster lead times with critical suppliers.
- Consolidate supplier relationships to improve consistency.

Each strategy affects operational flexibility, cost efficiency, and market competitiveness as shown in figure 3.

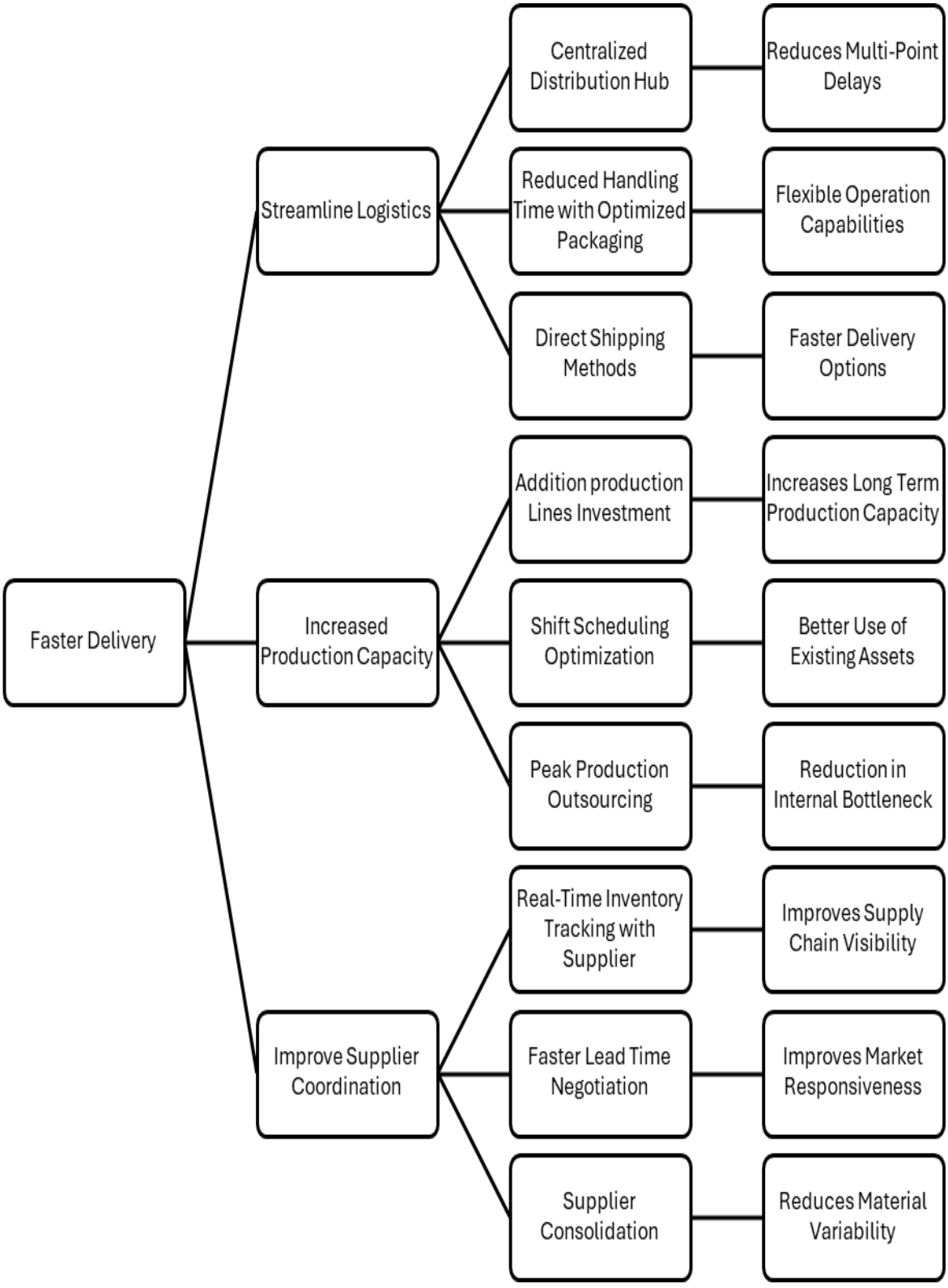

Figure 3: Decision Tree for Faster Delivery

4.0 Discussion

4.1 Interpretation of results

The study used decision trees to evaluate trade-offs between quality, cost, and delivery for a new terminal block. Results show that improving materials best ensures acceptable quality, but at a higher cost. Automating production lowers costs but may require upfront investment. Streamlining logistics speeds up delivery but depends on supplier reliability. The findings highlight that no single approach is best, and companies must balance these factors based on market needs. Decision trees helped visualize risks and rewards, guiding data-driven choices to improve manufacturing efficiency, meet industry standards, and enhance customer satisfaction.

4.2 Implications

4.2.1 Academia pedagogy & research

This study integrates engineering, business, and financial modeling to improve the decision-making process, fostering an interdisciplinary approach. This structured decision framework can cultivate an entrepreneurial mindset amongst the students of both engineering curriculum and business curriculum. University is also able to provide students with experiential learning experience that simulates the decision-making process involved within a startup through the application of sensitivity analysis, decision trees, and influence diagrams.

4.2.2 Industry

This study provides a high-quality decision framework allowing startup outside of the electromechanical industry to benefit from resulting in an optimized cost, quality, and delivery. Companies can strategically make decisions by carefully applying sensitivity analysis and influence diagram simultaneously with Lean Six Sigma methodologies to mitigate risk and comply with regulations, resulting in maintaining the company's competitiveness in their individual markets

4.2.3 Government

This study contributes to policymakers by providing them with a framework that is data driven to support manufacturing startups, boosting the domestic manufacturing capability and improving regulatory compliance standards. Through the implementation of this framework, the assessment of grant applications, funding allocation, and industrial policy development can be streamlined by the government, creating a resilient supply chain domestically and internationally.

4.3 Limitations of the Study

4.3.1 Survivorship Bias

This study focuses on a structured decision-making process for a successful startup but does not consider the structured decision-making process for a failed startup. Startups that use structured decision-making processes may fail due to external factors outside of the scope of the model [14].

5.0 Summary and Conclusions

This study shows how structured decision-making helps balance quality, cost, and delivery in manufacturing. By using decision trees, companies can see trade-offs and make better choices. The findings confirm that improving materials ensures high quality but raises costs. Automating production lowers costs but requires upfront investment. Streamlining logistics speeds up delivery but depends on suppliers. No single approach is perfect, and companies must adapt to their needs. Using structured analysis, firms can reduce risk and increase efficiency. This approach helps businesses remain competitive while ensuring customer satisfaction and meeting industry standards.

Future research should explore long-term impacts of these decisions. Companies may need to adjust strategies as technology, market demand, and regulations change. Studying how firms combine quality, cost, and delivery improvements can reveal best practices for sustainable growth. Further analysis could also measure the financial impact of each strategy over time. By continuing to refine decision-making tools, manufacturers can improve operations, reduce waste, and enhance innovation. This study highlights the power of decision science in manufacturing, helping firms make informed, strategic choices in a complex, competitive industry.

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