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# A Proposed Blue Ocean Strategy for the Metal Sheet Processing Industry

Leveraging a Funding Proposal for Sustainable Growth

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**Thesis abstract <sup>1</sup>**

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This thesis delves into a strategic approach for sustainable growth within the metal sheet processing industry. It emphasizes the development of innovative projects that prioritize cutting-edge solutions while simultaneously securing a competitive advantage for participating companies.

The study includes an analysis of the current trends and potential risks facing the sector. The analysis incorporates benchmarking the sustainability efforts of key players against their competitors. Drawing on this comprehensive analysis, the thesis uses the Blue Ocean Strategy as main framework for active companies to find innovative approach to find their way through sustainability. By applying this framework, the results propose focusing on three key areas. The first is product portfolio redesign; this may involve the development of innovative products or services that cater to emerging market needs. The second one is pre-owned machinery upgrades by incorporating Industry 4.0 solutions: companies can optimize production processes and improve overall efficiency. The third one is carbon footprint reduction, which emphasizes implementing circular economy principles to minimize environmental impact throughout the entire value chain of the product.

By strategically utilizing the findings of the thesis and focusing on these three key areas, companies in the metal sheet processing industry can achieve sustainable growth. This comprehensive approach promises a trifecta of benefits: fostering cutting-edge innovation, promoting environmental responsibility, and securing a competitive edge in the marketplace. All these features may result in export capability, employment, and sustainable growth for companies in this industry. These features are the main aims of most funding calls in EU and specially inside Finland.

<sup>1</sup> Keywords: Sustainability, Carbon footprint, Blue Ocean Strategy, industry 4.0, Circular economy



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## Terms and Abbreviations

<b>AM</b>	Additive Manufacturing
<b>ASEAN</b>	Association of Southeast Asian Nations
<b>BEC</b>	Buyer Experience Cycle
<b>BOS</b>	Blue Ocean Strategy
<b>CNC</b>	Computer Numerical Control
<b>CAGR</b>	Compound Annual Growth Rate.
<b>ERRC</b>	Eliminate-Reduce-Raise-Create
<b>EU ETS</b>	EU Emissions Trading System
<b>ESG</b>	Environmental, Social, and Governance
<b>GRI</b>	Global Reporting Initiative
<b>GHG</b>	Greenhouse Gas
<b>IEA</b>	International Energy Agency
<b>IMS</b>	Intelligent Manufacturing Systems
<b>IPCC</b>	Intergovernmental Panel on Climate Change
<b>MFCA</b>	Material Flow Cost Accounting
<b>PPC</b>	Production planning and control
<b>LCA</b>	Life Cycle Assessment
<b>NZE 2050</b>	Net Zero Emissions by 2050
<b>R&amp;D</b>	Research and development
<b>SWOT</b>	Strengths, Weaknesses, Opportunities, and Threats
<b>WAAM</b>	Wire Arc Additive Manufacturing

# 1. INTRODUCTION

## 1.1 Sheet metal industry background

Sheet metal fabrication is a manufacturing process that involves the transformation of raw metal materials into intricate parts or structures through various techniques such as cutting, bending, and welding.

According to FSM manufacturing (n.d.) the magic of sheet metal fabrication lies in its ability to breathe life into various shapes and objects. It starts with plain metal sheets, which are then meticulously cut, bent, and joined to create the final product. From everyday tools to heavy-duty machinery, the possibilities are endless. This versatility is further amplified by a diverse range of tools employed in the process, including computer-aided design software for precise planning, laser cutters for efficient cutting, and sophisticated CNC punching and forming machines that handle intricate shaping (op. cit.). Welding technology and other precision equipment round out this impressive arsenal, allowing for the creation of robust and complex metal structures.

## 1.2 The metal fabrication process: from design to completion

The metal fabrication process transforms a client's vision into a tangible reality. As stated by FSM manufacturing (n.d.), the journey begins with a collaborative design phase. Here, clients work alongside experts to craft a precise metal solution tailored to their specific needs. High-powered lasers then take center stage, meticulously cutting the metal sheet with unmatched accuracy by following a programmed design. For intricate features, CNC punching machines utilize specialized tooling to create precise holes and shapes. The process then moves to bending the metal into the desired form. CNC folding machines achieve this by applying pressure between a top tool and die. Findings of Hajili (2017, p. 46) defined that a variety of welding techniques, such as MIG and TIG, join the components to create a robust and cohesive structure. To achieve the perfect finish, a comprehensive service is offered through partners, including powder coating, polishing, blasting, anodizing, and plating, depending on the specific needs of the project. Additionally, in-house polishing capabilities provide a touch of personalization. Finally, the process culminates in the assembly stage, where the components are brought together to form the final product. This assembly stage can range from simple welded

assemblies to complex electro-mechanical integrations, all dependent on the project's requirements.

### **1.3 Sustainability issues in sheet metal forming processes**

According to Ingarao et al. (2011, p.1) in sheet metal forming processes, there's a knowledge gap regarding sustainability, primarily due to the lack of a comprehensive model that considers all relevant factors. This thesis aims to address this gap by reviewing the current state of the art in forming processes, highlighting their sustainability contributions throughout a product's life cycle.

The thesis points out the scarcity of holistic approaches in existing literature and through using blue ocean strategy as main thesis framework propose a broader perspective to identify potential solutions for improving sustainability across all phases of a formed metal product's life cycle. Thesis primary focus is on sheet metal forming technologies. The thesis provides an overview of key topics related to energy and resource efficiency in sheet metal forming, emphasizing the potential environmental benefits these processes can offer in manufacturing.

### **1.4 Research question and objectives**

**Research question:** How can companies in the sheet metal processing industry further integrate sustainable practices into their product development and manufacturing processes? (This will allow them to maintain a competitive edge and contribute to a more sustainable future for the industry as a whole.)

#### **Research objectives:**

1. **Identify opportunities for innovation in sustainable products:** This objective focuses on identifying areas where companies in the metal sheet industry can develop new technologies or solutions that minimize waste, energy consumption, and environmental footprint throughout a product's life cycle.
2. **Evaluate potential funding opportunities:** This objective involves researching and identifying potential funding programs offered by organizations like Business Finland

or the European Commission that support the development of sustainable technologies in the manufacturing sector, specifically within the metal sheet industry.

3. **Develop a sustainable product development roadmap:** Based on the findings from the previous objectives, this objective focuses on creating a roadmap that outlines specific steps companies in the metal sheet industry can take to integrate sustainable practices into their product development processes.
4. **Assess the impact of sustainable practices on customer value proposition:** This objective involves analyzing how adopting sustainable practices can enhance the value proposition for environmentally conscious customers within the metal sheet industry.

### **1.5 Scope and structure of the thesis**

This thesis explores the integration of sustainable practices into both manufacturing and product development processes within the global sheet metal fabrication industry. This focus aligns with the international reach of many companies operating in this sector. The thesis structure is as below:

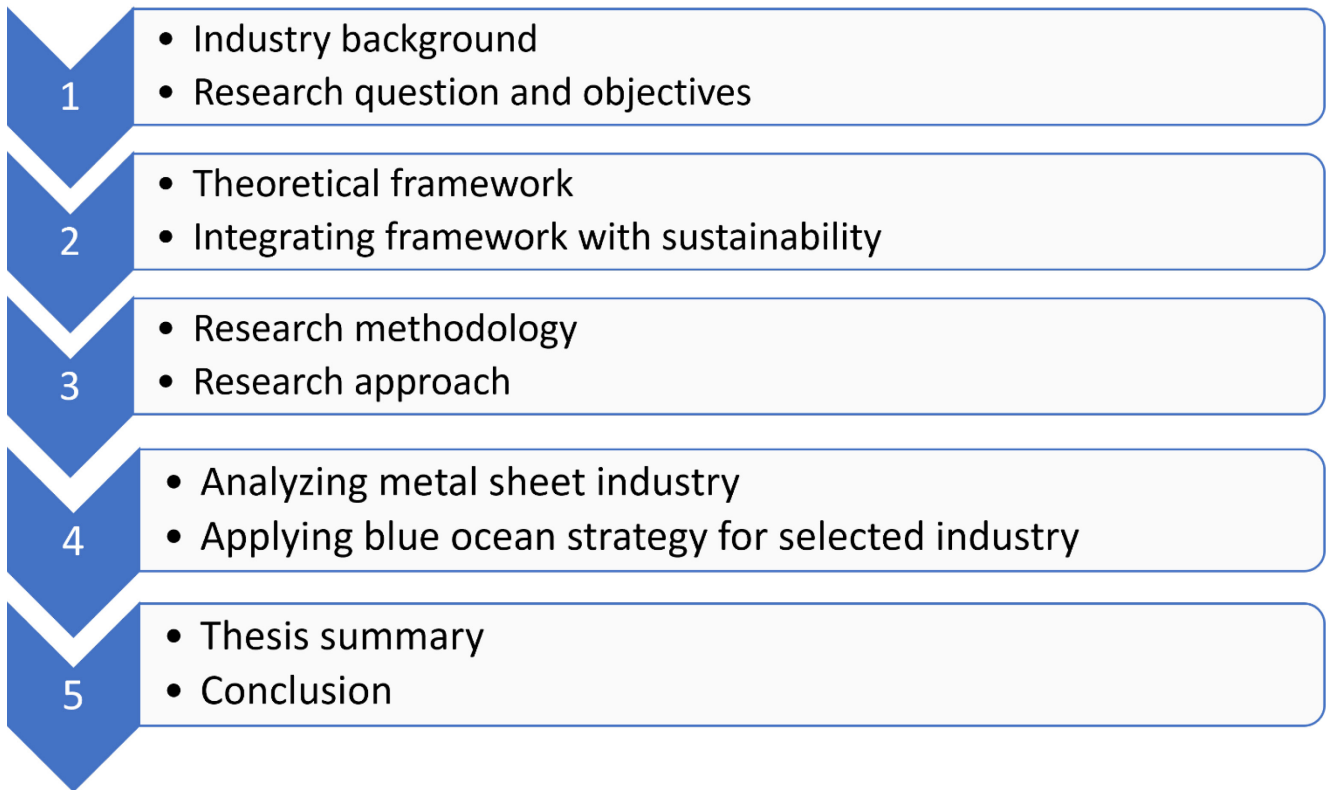


Figure 1. Structure of Thesis.

## **2 THEORETICAL PERSPECTIVE TOWARD SUSTAINABLE DEVELOPMENT**

Before diving into blue ocean strategy, it's crucial to understand its counterpart – red oceans. These represent existing, well-established industries where competition is fierce. Imagine a crowded marketplace where businesses fight for a limited pool of customers.

Red oceans are characterized by defined industry boundaries, established competitive norms, and a focus on outperforming rivals to secure a larger share of existing demand. According to Bretcu (2018) when competition intensifies, profit margins shrink, and products become increasingly commoditized. This cutthroat battle environment is why "red ocean" imagery is used.

Red ocean strategy essentially boils down to structuring company approach around the existing competitive landscape. Bretcu (2018) explore that companies conduct industry and competitor analyses to identify weaknesses they can exploit or strengths they can emulate. They then, strive for a competitive advantage through differentiation (offering unique value propositions) or cost leadership (providing the most affordable option).

According to Blue Ocean strategy (n.d.-a), in red ocean strategy, structure shapes the strategy.

### **2.1 Blue ocean strategy**

In stark contrast to red ocean strategies, blue ocean strategy argues that a company's success isn't solely dictated by the existing competition. Bretcu (2018) revealed that it focuses on breaking the traditional trade-off between value and cost, thereby creating entirely new market spaces. This approach allows companies to pursue both differentiation (offering unique value) and low cost simultaneously.

Blue ocean strategy, a framework developed by W. Chan Kim and Renée Mauborgne (Kim & Mauborgne, 2004), emphasizes moving beyond existing competition. It's about creating innovative value propositions that are not only novel but also highly appealing to customers.

In other words, in blue ocean strategy, strategy can shape structure (Blue ocean strategy, n.d.-c).

## 2.2 Red ocean versus blue ocean

According to blue ocean strategy (n.d.-c) the optimal strategy depends on several factors. Consider industry's attractiveness (growth potential, profitability), internal resources and capabilities (innovation capacity, financial strength), and organization's overall strategic focus (competition vs. innovation). Diversified companies may even utilize both approaches simultaneously.

According to Bretcu (2018) regardless of the chosen strategy (red or blue ocean), success hinges on aligning company strategic propositions with three critical stakeholder groups:

- Buyers: Ensure company offerings provide clear value propositions that resonate with target customers.
- Shareholders: Deliver financial performance that meets investor expectations.
- Employees: Engage company workforce by providing them with a purpose and the tools to contribute to company strategy.

The key difference between red and blue ocean strategies lies in how they achieve this alignment. Red ocean strategies rely on traditional methods within existing competitive landscapes, while blue ocean strategies focus on creating entirely new markets and value propositions. Figure 2 below summarizes the key conceptual differences between red ocean strategy and blue ocean strategy:

RED OCEAN STRATEGY	BLUE OCEAN STRATEGY
Compete in <b>existing</b> market space	Create <b>uncontested</b> market space
<b>Beat</b> the competition	Make the competition <b>irrelevant</b>
Exploit <b>existing</b> demand	Create and capture <b>new</b> demand
<b>Make</b> the value-cost trade-off	<b>Break</b> the value-cost trade-off
Align the whole system of a firm's activities with its <b>strategic choice of differentiation or low cost</b>	Align the whole system of a firm's activities in <b>pursuit of differentiation and low cost</b>

Figure 2. Differences between red ocean strategy and blue ocean strategy. (Kim & Mauborgne, 2004)

### Blue ocean shift

The blue ocean shift offers a clear path for individuals, teams, and organizations to achieve remarkable growth and market creation. As highlighted by Pateman (2019, p. 355) this roadmap is designed to be accessible to any entity, regardless of size or resources – from bootstrapped startups to established corporations, non-profits, and even governments. This shift outlines a straightforward five-step process that empowers company to actively participate in and champion the journey from fierce competition (red oceans) to vast, untapped markets.

### 2.3 Five steps to making a blue ocean shift

According to study by Weaven et al. (2021, p.111) a staggering 90% of businesses fail within a decade. This alarming statistic seems strangely normalized within the entrepreneurial world. However, what if there was a way to reduce the element of chance and minimize trial-and-error in building new markets?

Blue Ocean Strategy (n.d.-a) suggests a solution, a systematic five-step process to jump into new market, preventing business failure. By following these steps, businesses can

significantly increase their odds of achieving success and hitting the bullseye in market creation endeavors.

### **Step one - select the right scope**

The journey begins with identifying strategic sweet spot. The pioneer-migrator-settler map, developed by Chan Kim and Renée Mauborgne (Blue Ocean Strategy, n.d.-b), categorizes products offerings based on the level of innovative value they deliver to customers.

- **Settlers:** represent "me-too" businesses facing stiff competition and limited growth. While they might be profitable now, their long-term prospects are vulnerable.
- **Migrators:** are offerings that are better than most in the market, but still compete within existing boundaries. They can achieve moderate growth, but risk being overshadowed by truly innovative companies.
- **Pioneers:** are the game-changers. They create entirely new market space through value innovation, attracting large and loyal customer bases, and driving significant growth.

By plotting company's current product map and planned portfolio on this map (Figure. 3), then it is possible to identify areas with the most potential for a blue ocean strategy.

Remember, a balanced portfolio is key. While settlers provide current cash flow, a portfolio dominated by them signifies low growth potential. This guide encourages (Blue Ocean Strategy, n.d.-b) a strategic shift towards "blue ocean" creation, where value innovation leads to sustained growth. Don't just manage existing products (settlers). Allocate resources towards building pioneers, the true drivers of long-term success.

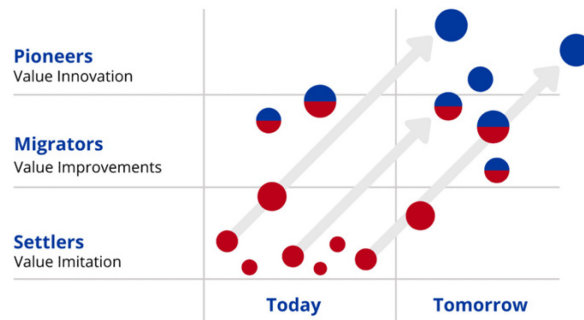


Figure 3. Pioneers, migrators and settler's map. (Kim & Mauborgne, 2004)

### Step two - understand current situation through strategy canvas

According to (Blue Ocean Strategy, n.d.-c) strategy canvas a one-page tool, developed by Chan Kim and Renée Mauborgne, acts as a diagnostic aid and an action framework for crafting a winning blue ocean strategy. It offers a clear picture of several key aspects as below:

- **Factors of competition:** These are the areas where intended industry focuses its efforts and investments.
- **Offering level:** This reflects how well current offerings deliver on these competitive factors.
- **Strategic profiles:** This visualizes how both company and competitors position themselves within the industry.

According to blue ocean strategy (n.d.-c) the strategy canvas tells a compelling story detailed in below items:

- It reveals how similar current company product offerings are to competitors, highlighting the red ocean dynamics at play.
- It exposes where industry players are currently investing and the types of products, services, and delivery options offered.
- It clarifies what value existing offerings provide to customers.

### How to draw a strategy canvas

According to blue ocean strategy (n.d.-c) the strategy canvas has two axes. The horizontal axis shows the key factors of competition, starting with price. Horizontal axis lists the key factors in the related industry.

The vertical axis, by contrast, shows the offering level that buyers receive for a given factor. A higher-level means that an industry player offers more, and hence buyers receive more.

By plotting the offering level delivered by the market leaders across each factor, and connecting the dots as it shown in figure 4, Now the strategic profile or value curve of each player is clear.

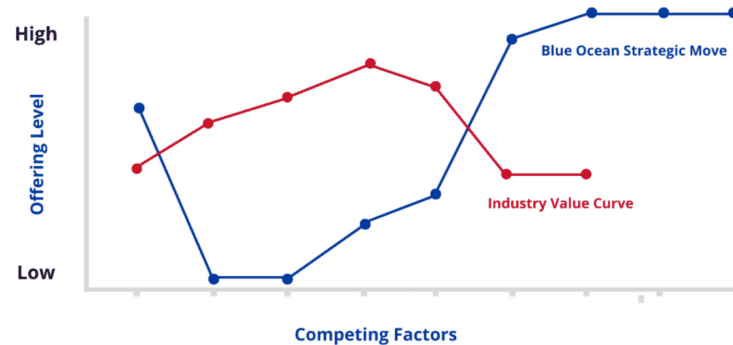


Figure 4. Strategy canvas. (Kim & Mauborgne, 2004)

### Step-by-step tutorial on how to draw a strategy canvas

1. Name the intended industry.
2. For selected businesses or chosen product/service offering, identify the key competitive factors for related industry.
3. Rate the relative offering level of each factor on the vertical axis using a 5-point scale. A relatively low offering level should be plotted lower on the axis, and a relatively high offering level should be plotted higher.
4. Connect the dots to create as-is strategic profile or value curve.

5. Decide on the best player to plot offering against and repeat the process. Select the industry leader or strongest competitor.

### **Characteristics of an effective blue ocean strategy**

Now planning an effective blue ocean strategy isn't magic; it's a carefully crafted approach. According to Blue Ocean Strategy (n.d.-d) with three key characteristics, evident when visualized through a value curve:

- **Focus:** A clearly defined strategic profile avoids the trap of being "all things to all people." This focus ensures that company resources are directed towards creating a truly differentiated offering.
- **Divergence:** Breaking away from the industry standard is crucial. A blue ocean strategy diverges from the existing value curve, offering something entirely different and appealing to a new set of customers.
- **Compelling Tagline:** A clear and truthful message that captures the essence of company strategic profile is a good way to test the effectiveness of selected strategy. It should accurately reflect the unique value proposition of the proposed offer.

### **Step three - buyer utility map**

The buyer utility map, created by Kim and Mauborgne (2004), encourages managers to consider things from the customer's viewpoint. It maps out all the ways a company can create value for buyers (utility levers) across the entire customer journey (buyer experience cycle). This approach helps managers see the big picture and identify all the potential ways their product or service can be useful to customers.

In simpler terms, as it is shown in figure. 5, it's a tool that combines the different stages a customer goes through when interacting with a product or service (buying it, using it, maintaining it, etc.) with the various features or aspects a company can improve to make that experience better for the customer.

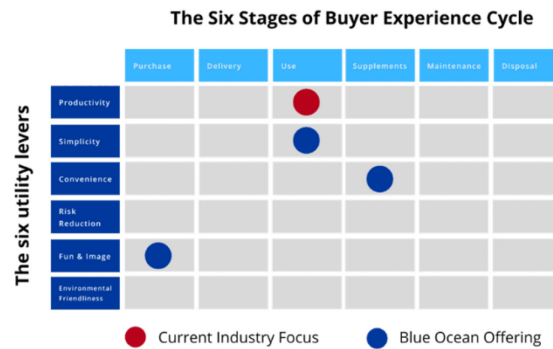


Figure 5. Buyer utility map (Kim & Mauborgne, 2004)

In other words, the buyer utility map is a tool designed to help businesses see things from their customers' perspective. Developed by Kim and Mauborgne (2004), it combines two key concepts:

- Buyer Experience Cycle (BEC): This cycle maps out the six stages a customer typically goes through when interacting with a product or service, from purchase to disposal.
- Utility Levers: These are the different ways a company can create value for customers at each stage of the BEC.

By using this map, managers can identify all the potential ways to improve the customer experience and unlock greater value for them.

This approach goes beyond simply adding more features at each stage of the customer journey. It encourages a more holistic view, prompting managers to consider how to remove the biggest obstacles (pain points) that prevent customers from getting the most out of the product or service.

This can be particularly valuable in established industries where simply adding more of the same isn't likely to create a breakthrough strategy.

## Value Innovation

The blue ocean strategy (n.d.-d) defines value innovation as creating a leap in value for both customers and the company simultaneously. Developed by Chan Kim and Renée Mauborgne (2004), it's the cornerstone of market creation. This powerful concept involves the

simultaneous pursuit of differentiation (standing out) and low cost, ultimately creating a leap in value for both buyers and the company.

Here's why it works:

- Value for buyers: It's the difference between what they get (utility) and what they pay (price).
- Value for the company: It's the difference between the selling price and the cost to produce.

By aligning all three elements (utility, price, and cost), value innovation unlocks a win-win scenario.

### Breaking the value-cost trade-off

According to blue ocean strategy (n.d.-d) traditional thinking suggests a trade-off as it is indicated in figure 6:

- **High value = High cost:** Companies can offer superior features but at a premium price.
- **Low cost = Lower value:** Companies can offer basic features at a lower price.

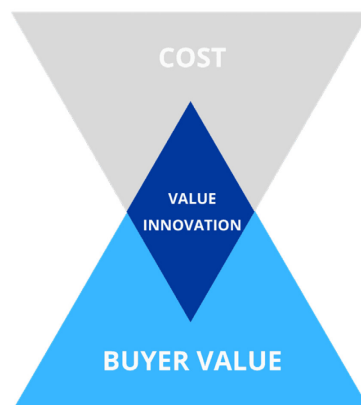


Figure 6. Value innovation. (Kim & Mauborgne, 2004)

Value innovation challenges this notion. It allows companies to pursue both differentiation and low cost simultaneously, creating entirely new market space where existing competitors haven't ventured.

### **Achieving value innovation:**

According to blue ocean strategy (n.d.-d), achieving value innovation goes beyond incremental improvements (just making things slightly better). It focuses on:

- **Eliminating** unnecessary industry features.
- **Reducing** features well below industry standards.
- **Raising** key features far above industry standards.
- **Creating** entirely new features the industry hasn't offered.

By asking strategic questions about these areas, companies can break the value-cost trade-off and unlock the potential for blue ocean creation.

### **Three tiers of noncustomers**

The three tiers of noncustomers are an analytic framework developed by Chan Kim and Renée Mauborgne (2004) to help companies gain insight into the latent demand they can tap into to create blue oceans. Typically, to grow their share of a market, companies strive to retain and expand their existing customer base.

Although the universe of noncustomers typically offers blue ocean opportunities, few companies have keen insight into who noncustomers are and how to unlock them. To convert this huge latent demand into real demand in the form of new customers, companies need to deepen their understanding of the universe of noncustomers.

The traditional approach to customers often overlooks a valuable segment: non-customers. This section dives into three distinct categories of non-customers indicated in figure 7, each with unique characteristics and potential:

### **1. First-tier non-customers: the ready-to-switch crowd**

These non-customers are closest to be company or business customer, already making minimal purchases. However, they're on the lookout for a better alternative and wouldn't hesitate to jump ship if one emerged.

Think of credit cards or health insurance - purchases driven by necessity, not desire. These customers represent an opportunity to significantly increase usage and create new demand by addressing their pain points.

### **2. Second-tier non-customers: the considered and refused**

These non-customers have consciously considered about company offering but ultimately rejected it. Reasons for rejection can vary:

- Better existing options: Another offering might fulfill their needs more effectively.
- Cost concerns: Current offering may be outside their budget.
- Complexity or lack of value proposition: These non-customers might find current offering confusing or lacking in perceived value.

This group represents a potentially low-hanging fruit. By understanding why, they refuse current company's offerings, shared pain points can be identified and then develop solutions to capture them.

### **3. Third-tier non-customers: the unexplored territory**

These non-customers are the furthest from selected industry, never even considering current products as a solution. The industry as a whole might overlook them, assuming their needs belong elsewhere.

This tier presents the largest pool of potential customers. They might benefit from company products or services but simply haven't considered it due to lack of awareness.

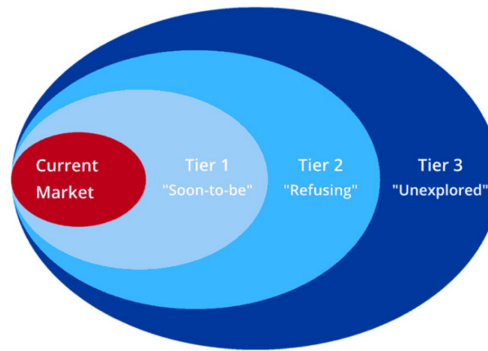


Figure 7. Three customer layers (Kim & Mauborgne, 2004)

### **The key takeaway of three layers of non-customers**

Don't just focus on existing customers. By understanding the motivations and pain points of all three non-customer tiers, Active players in the market can unlock new market opportunities and tap into a vast pool of potential users. By looking beyond each tier individually, explore commonalities across them to develop strategies that capture non-customers at all levels.

### **Step four - reconstructing market boundaries-six path framework**

Companies can use the six paths framework introduced by Kim & Mauborgne (Blue Ocean Strategy. n.d.-e) to identify blue ocean opportunities. the six paths framework is a tool designed to help businesses systematically discover and create blue ocean markets. It tackles the challenge of finding truly innovative ideas by guiding business owners through six distinct perspectives to deconstruct existing industry boundaries. The six paths framework is a powerful tool that helps businesses see markets in a whole new light. It provides six different ways to shift company's strategic perspective and explore opportunities beyond current industry's boundaries.

Traditionally, companies focus on competing within their industry. This framework encourages them to break free from that limited view. By looking across these six paths as shown in figure 8, companies can gain valuable insights into how to reconstruct existing market boundaries and unlock entirely new possibilities.

Regard to Kim & Mauborgne (Blue Ocean Strategy. n.d.-e) suggested below breakdown for the six paths:

1. Look across alternative industries: Don't just focus on company direct competitors. Explore how similar needs are fulfilled in entirely different industries. This can spark ideas for innovative offerings that cater to the same core need but in a completely new way.
2. Look across strategic groups: Within current industry, there might be different strategic groups targeting specific customer segments. Analyze how these groups compete and identify potential opportunities to serve a broader audience or create a new value proposition that appeals to a currently underserved niche.
3. Look across buyer groups: Consider the entire buyer ecosystem. Who influences buying decisions? Who actually uses the product or service? By expanding view beyond the immediate customer, company might uncover hidden needs or pain points that can be addressed through a new kind of offering.
4. Look across complementary product and service offerings: What products or services are typically used alongside company products? How can company create a more integrated or holistic solution by bundling offerings or designing products to seamlessly complement existing products?
5. Look across the functional-emotional orientation: Most industries tend to focus on either the functional aspects (performance, efficiency) or the emotional aspects (experience, aesthetics) of their offerings. Challenge this norm. Can company create an offering that delivers on both functional needs and emotional desires?
6. Look across time: Considering the evolution of company's industry and anticipate future trends. How company can get ahead of the curve by creating an offering that solves emerging problems or caters to changing customer preferences?

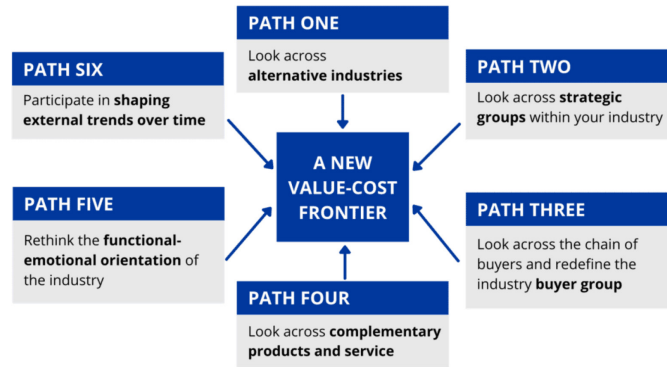


Figure 8. Six path frameworks (Kim & Mauborgne, 2004)

By applying these six paths, company can break free from the traditional way of seeing current industry and identify opportunities to create blue oceans - uncontested market space with high growth potential.

### Step five - the elimination-reduction-raising-creation grid

The Eliminate-Reduce-Raise-Create (ERRC) Grid is an essential tool of blue ocean strategy developed by Chan Kim and Renée Mauborgne. (Blue ocean strategy. n.d.-f). It goes beyond simply asking the questions, it pushes companies to take action on all four aspects to create a brand-new value proposition and unlock blue ocean markets. Here's how the ERRC Grid benefits companies (op. cit.):

1. **Breaking the cost-value trade-off:** By focusing on elimination and reduction alongside creation and elevation, companies can achieve both differentiation (standing out) and low cost, breaking the traditional barrier.
2. **Avoiding over-engineering:** The grid identifies companies that solely focus on raising and creating features. This can lead to over-engineered products and services that inflate costs without offering significant value.
3. **Accessibility and engagement:** The ERRC is designed to be easy to understand for managers at all levels, fostering high participation and a shared understanding of the strategic goals.

4. **Deep dive and innovation:** Completing the grid is a challenging but rewarding process. It forces companies to meticulously examine every factor they compete on, uncovering hidden assumptions and prompting innovative solutions.

### **Breaking Down the Four Actions:**

Based on what is provided by blue ocean strategy (n.d.-f), the ERRC Grid focuses on four key questions to guide companies towards blue ocean creation:

- **Eliminate:** Identify and remove factors that the industry takes for granted but no longer provide value, or may even detract from it.
- **Reduce:** Determine if existing features have been over-engineered in the competitive race. Can be simplified or reduce complexity without sacrificing value?
- **Raise:** Uncover the compromises buyers are forced to make due to industry standards. Redesigning can significantly improve key features to deliver greater value and eliminate existing trade-offs?
- **Create:** Discover entirely new value elements that haven't been offered in the industry before. This can help attract new customer segments and create entirely new demand.

As it demonstrates in figure 9 by tackling the first two questions (Eliminate & Reduce), companies gain insights into lowering their cost structure compared to competitors. The latter two questions (Raise & Create) focus on increasing buyer value and creating new demand.

Collectively, these four actions allow for a systematic exploration of how to reconstruct value propositions across industries. This empowers companies to offer buyers a completely new experience while maintaining a low-cost structure, setting the stage for success in blue ocean markets.

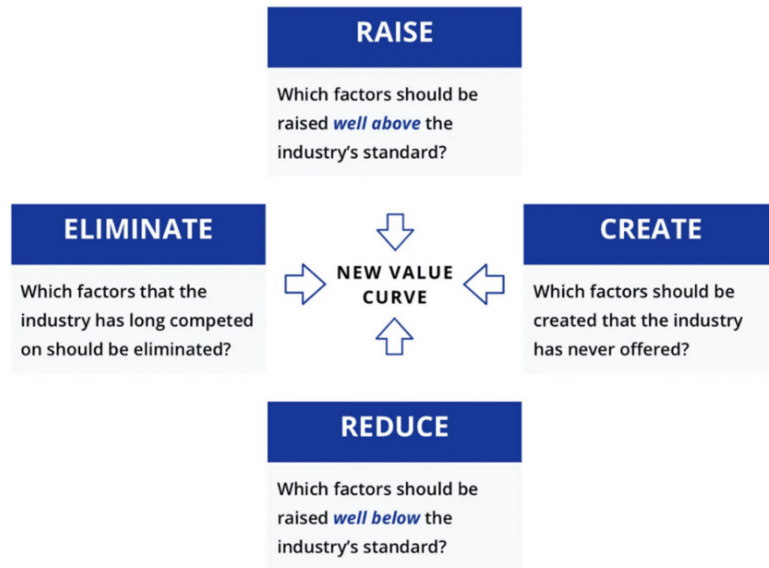


Figure 9. ERRC grid (Kim & Mauborgne, 2004)

## 2.4 Sustainability: a balancing act for our future

According to Greguš (2023, p.192), sustainability is a way of living and doing business that considers the well-being of our planet, society, and the economy. It's about making choices today that ensure a healthy and prosperous future for all, without compromising the ability of future generations to meet their own needs.

### Three pillars of sustainability

Consistent with Gomes Silva et al. (2022, p.1497) Imagine sustainability as a three-legged stool. Each leg represents a crucial aspect:

1. **Environmental sustainability:** This focuses on minimizing current negative impact on the environment. Today producers need to use resources wisely, reduce pollution,

and find eco-friendly solutions whenever possible. Think using less energy, conserving water, and opting for recycled materials.

2. **Social sustainability:** This considers the impact of our actions on people and society. It means treating workers fairly, ensuring safe working conditions, promoting diversity and inclusion, and sourcing materials responsibly.
3. **Economic sustainability:** This ensures businesses operate in a way that's financially healthy and creates long-term value. Sustainable businesses often find ways to save costs by minimizing waste and using resources efficiently.

### **Why is sustainability important?**

Sustainability is no longer a "nice to have" but a "must-have" for businesses. Here's why:

- Customers care: A study by Chuah et al. (2020) declare that consumers are increasingly concerned about the environmental and social impact of the products they buy. Companies with strong sustainability practices that prioritize a circular economy and biodegradable materials can attract and retain customers who share their values.
- Regulations are tightening: According to Kinderman (2020, p.681) governments are enacting stricter environmental and social regulations. Being proactive in sustainability helps businesses avoid future burdens and ensures they comply with evolving standards like those outlined in the sustainable development goals (SDGs).
- Risk management: Climate change, resource scarcity, and social unrest are all potential risks that can affect a company's bottom line. Hubbard (2020, p.150) states that sustainable practices, such as a focus on renewable energy and water stewardship, help mitigate these risks and ensure long-term business continuity.
- Innovation drives growth: Sustainability is not just about reducing negative impacts; it's also a driver of innovation. Nidumolu et al. (2009, p. 60) state that businesses that embrace sustainability can unlock new opportunities by developing eco-friendly products, services, and business models that contribute to a net positive impact. This

focus on innovation, like exploring impact investing, can lead to a competitive advantage in the marketplace while contributing to a more sustainable future.

In addition to the advantages mentioned earlier, Lozano (2015, pp. 34–38) emphasizes that a strong emphasis on sustainability signifies a company's dedication to a broader vision:

- **Fairness for all:** This includes ensuring fair trade practices throughout the supply chain, guaranteeing fair treatment for workers and producers.
- **Protecting our planet's diversity:** The company demonstrates a commitment to protecting biodiversity by implementing responsible sourcing and operating procedures.
- **Combating climate change:** Taking concrete climate action through initiatives that reduce greenhouse gas emissions showcases the company's role in addressing this global challenge.
- **Sustainable sourcing:** This emphasizes the company's commitment to sourcing materials responsibly, minimizing environmental and social impacts throughout the supply chain.

## 2.5 Blue ocean strategy and sustainability

Traditionally, businesses have viewed sustainability as a cost or a compliance burden. However, this thesis tried to use Blue Ocean Strategy (BOS) to offer a compelling alternative; using innovation to create new markets and competitive advantages while simultaneously addressing sustainability challenges. Shafiq (2019) found that BOS and innovation can drive business sustainability in following subjects:

1. Redefining market boundaries: BOS encourages businesses to look beyond existing industries and identify untapped market space where competition is irrelevant. This

can lead to innovative solutions that address environmental or social needs alongside traditional business goals.

2. Value innovation: BOS emphasizes creating value for both customers and the environment. Companies can achieve this through innovative products, services, or business models that reduce environmental impact while delivering superior benefits.
3. Cost reduction through innovation: Innovation can lead to cost savings that benefit both the company and the environment. This can involve finding ways to optimize resource use, reduce waste, or develop new energy-efficient technologies.
4. Disruptive technologies: BOS encourages businesses to embrace disruptive technologies that can revolutionize how they operate and how they approach sustainability challenges.
5. Collaboration and partnerships: BOS recognize the value of collaboration with external stakeholders like NGOs, research institutions, and other businesses. Partnerships can foster innovation and accelerate the development of sustainable solutions.

In conclusion, Blue Ocean Strategy provides a framework for businesses to move beyond a "business as usual" approach to sustainability. By fostering innovation and out-of-the-box thinking, companies can create new market opportunities, gain a competitive edge, and contribute to a more sustainable future.

## **3 RESEARCH METHODOLOGY**

### **3.1 Research approach**

This research takes a data-driven approach, focusing on analyzing existing documents. The researchers will examine company reports, industry standards, environmental reports, and articles to uncover successful strategies (best practices) and potential solutions. Our goal is to identify how companies in the metal sheet processing industry can integrate sustainable innovative practices into their product portfolio. Thesis will employ a mixed methods approach, primarily relying on document analysis. Here's a breakdown of our methodology:

#### **Document Analysis:**

Analyzing reports from various sources, including:

- Metal sheet processing companies
- Industry standard-setting bodies
- Environmental organizations

Through thematic analysis, it is appeared that:

- Best practices currently being implemented by companies in the industry.
- Potential solutions for metal sheet processing companies to adopt sustainable practices
- Gaps in the industry's current approach to sustainability

### **3.2 Benefits of this approach**

This mixed methods approach offers several advantages:

- **Comprehensiveness:** By analyzing documents from various sources, Company leaders can gain a broader understanding of existing practices in the industry.
- **Quantifiable insights (potential):** Quantitative data analysis, if applicable, can offer additional evidence to support the framework development.
- **Historical Perspective:** Insights into the historical development of sustainability practices within the industry can be achieved.
- **Data Triangulation:** Analyzing data from multiple sources strengthens the validity of findings.

### 3.3 Limitations and considerations

Research method limitations and consideration are as below:

- **Reliance on existing data:** This approach relies on information already documented, which may not capture the full picture or the latest developments.
- **Lack of real-world nuance:** Document analysis may miss the practical challenges and complexities faced by companies in implementing sustainable practices.

Despite these limitations, document analysis offers a solid foundation for developing a framework for sustainable practices in the metal sheet processing industry. Future research could build upon this foundation by incorporating other methods, such as interviews or surveys, to gain a deeper understanding of real-world practices and challenges.

#### **Ethical consideration**

This research adheres to ethical principles by relying on publicly available reports and industry standards, respecting intellectual property, and ensuring anonymity of any identifiable data.

## 4 ANALYSING THE METAL SHEET PROCESSING INDUSTRY

### 4.1 Description of the industry

The metal sheet processing industry is a vital cog in the machine of modern manufacturing. It takes raw metal sheets and transforms them into the building blocks of countless products across various sectors. According to QuestTech (2021), through techniques like laser cutting, shearing, bending, and forming, metal sheets are shaped and sized to meet specific needs. From car parts and appliances to construction materials and electronic components, processed metal sheets find application in a wide array. The industry's importance lies in the versatility of metal sheets, allowing for precise customization and creation of durable products. Sustainability is also a growing focus, with practices like using recycled metal and minimizing waste gaining traction to reduce environmental impact. As technology continues to advance, the metal sheet processing industry will undoubtedly find new and innovative ways to shape the future of manufacturing.

#### Examples of metal sheet processing techniques:

According to QuestTech (2021) metal sheet processing techniques are as below:

- **Laser cutting:** Uses a focused laser beam to precisely cut intricate shapes from metal sheets.
- **Shearing:** Utilizes a shearing machine to cut straight lines in the metal sheet.
- **Punching:** Employs a punch and die to create specific holes or shapes in the sheet.
- **Pressing:** Involves applying pressure to bend the metal sheet into a desired angle or form.
- **Folding:** Uses a folding machine to create precise folds in the sheet.
- **Rolling:** Passes the metal sheet through rollers to achieve a desired thickness or create curved shapes.

- **Deep Drawing:** Stretches and shapes a metal sheet into a deeper, cup-like form.

The metal sheet processing industry is constantly evolving, with advancements in technology leading to more efficient and precise processing methods. This ensures the industry remains a vital part of the manufacturing landscape for a wide range of products.

## 4.2 Challenges and opportunities in metal sheet processing industry

The metal sheet industry is increasingly recognizing the importance of environmental sustainability. According to Kinderman (2020, p. 680) regulations like stricter emissions standards and consumer demand for eco-friendly products are pushing companies to adopt cleaner practices. Implementing eco-friendly solutions often requires upfront investments in new equipment or processes. However, these investments can lead to long-term cost savings through reduced energy consumption and improved material utilization. The metal sheet industry has the potential to become more environmentally friendly by embracing these solutions. As technology advances and their cost-effectiveness improves, eco-friendly solutions will likely play an increasingly important role in the future of the industry.

### Eco friendly solutions

The metal sheet industry plays a crucial role in various sectors, but its traditional processes can have a significant environmental impact. Here's a breakdown of the challenges and opportunities for eco-friendly solutions:

#### Challenges:

- **Energy consumption:** Ingarao (2017, p. 2880) highlights the high energy demands of metal manufacturing processes. Stamping, cutting, and bending rely heavily on energy, often from fossil fuels, contributing to carbon emissions.
- **Material waste:** Metal cutting processes can generate significant scrap, as noted by Cao et al. (2019, p. 620). This scrap needs proper recycling or disposal, adding to the environmental burden.

**Material impact:** According to life cycle study assessment study by Spitzer et al (2010, p. 105) provided that the production of certain sheet metals, like aluminum, has a larger environmental footprint compared to others.

#### **Eco-Friendly Solutions and Potential:**

- **Renewable Energy:** According to Ahmadi et al. (2009, p. 30) shifting towards renewable energy sources like solar or wind power to run fabrication equipment can significantly reduce the industry's carbon footprint.
- **Energy-Efficient Equipment:** Schuh et al. (2015, p. 277) examined that manufacturer are developing new, energy-efficient sheet metal fabrication equipment.
- **Minimizing Waste:** According to Gibbs et al. (2005, p.1) cutting techniques like laser cutting with minimal kerf waste and nesting software that optimizes material usage can help reduce scrap metal generation. Additionally, recycling scrap metal back into the manufacturing process reduces reliance on virgin materials.
- **Sustainable Materials:** According to Sharma et al. (2022) using recycled metals or exploring alternative, lower-impact sheet metal options like magnesium or aluminum alloys can contribute to a more sustainable industry.

**Additive Manufacturing (AM):** As DeBoer et al. (2021, p. 417) declares while still in its early stages for sheet metal applications, AM has the potential to reduce material waste compared to traditional subtractive manufacturing techniques.

#### **4.3 Traditional market (customer) segments**

Through understanding these market (Customer) segments and their specific requirements, sheet metal fabrication equipment manufacturers (Table. 1) can effectively tailor their products and marketing strategies to address the diverse needs of the industry.

Table 1. Traditional Market segments in metal sheet industry.

Segment	Description	Needs
Job Shops	Typically, small to medium-sized businesses specializing in custom metal fabrication projects.	Focus on flexibility, ease of use, and ability to handle a wide variety of materials and thicknesses. Multi-function machines preferred.
High-Volume Manufacturers	Large companies with mass production lines focused on producing large quantities of sheet metal parts.	Prioritize speed, efficiency, and automation to maximize output and minimize labor costs. Invest in dedicated, high-speed machines.
Sheet Metal Fabrication Subcontractors	Businesses specializing in sheet metal fabrication but work on behalf of other companies.	Similar to job shops; versatility, diverse projects, quick turnaround times, and competitive pricing.
Specialty Fabricators	Companies focused on specific niche applications within sheet metal fabrication, often requiring specialized equipment.	Needs vary; high precision (aerospace), ability to handle thick metals (heavy machinery), advanced laser cutting (medical devices).
Research & Development (R&D) Departments	Departments within companies dedicated to developing new sheet metal products or processes.	Smaller, more flexible machines suitable for prototyping and experimentation. Easy integration with design software and ability to handle a wider range of materials for testing.

#### 4.4 Market trends in metal sheet processing industry

According to (Mordor Intelligence, n.d.-a), the need for high accuracy, mass production efficiency, lower operating costs, and factory automation are some of the drivers propelling the machining centers market's significant expansion. One major factor is the rise of CNC machining centers, which offer increased control and transparency in production processes. The market is expanding due to technological breakthroughs in CNC programming and the integration of Industry 4.0 solutions. Significant growth is anticipated in the automobile, aerospace, and defense industries in the Asia-Pacific area. China, Germany, and Japan (Figure.10) are recognized as the top participants in the world market for machine tools. The market for machining

centers is expanding overall as a result of manufacturing's growing demands for automation and efficiency.

Machine Tool Producers' Market Share, in Percentage, by Country, 2021

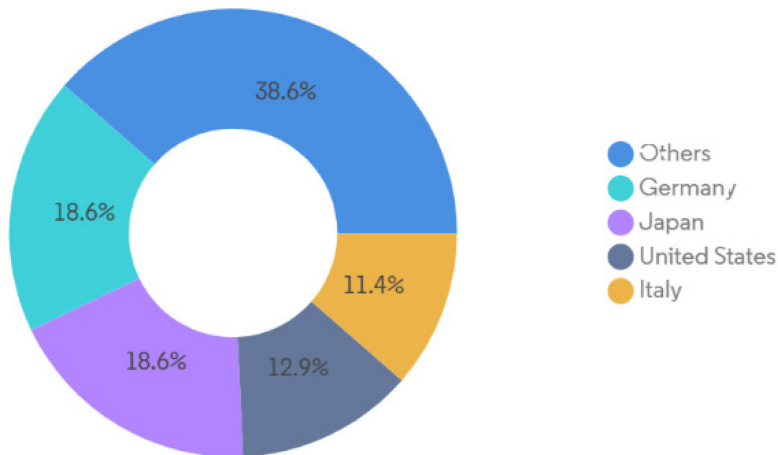


Figure 10. Machine tool producers market share (Mordor Intelligence, n.d.-a).

According to (Mordor Intelligence, n.d.-a), the market size of metal fabrication equipment industry, currently valued at USD 74.1 billion. The metal fabrication equipment market is projected to expand at a compound annual growth rate (CAGR) of more than 4.5% over the course of the forecast period. Due to manufacturing halts and disruptions in the supply chain, the COVID-19 pandemic had a negative impact on the market. The market is dominated by Asia-Pacific, largely due to the expansion of the manufacturing industries in nations like China, Indonesia, and India. Europe is the second-largest market, with Germany as its leader. (Op. Cit). The main forces behind this include the changing industrial environment, the need from major sectors like general and automotive production, industrialization, and energy use. High costs for raw materials are one of the challenges, but technical improvements and specially designed equipment present potential. However, obstacles, the market for metal fabrication equipment is expected to grow due to rising demand from various industries, particularly in developing economies, and the potential of technological advancements and customization.

## Market Trends

- **Growth of machining centers and the machine tools market source:** According to (Mordor Intelligence, n.d.-b), the machining center market is experiencing a surge due to factors like increased focus on worker safety, high-precision machining, real-time monitoring capabilities, and the need for more flexible and powerful machines. Additionally, the rise of Industry 4.0 solutions is driving demand for "smart" and interconnected machining centers equipped with advanced sensors and instruments. This trend is expected to further expand the market for linked machine centers. In 2021, China dominated the global machine tool market, accounting for a significant 31% share. Germany and Japan followed closely behind with 13% and 12% market share, respectively.
- **Focus on sustainability:** Chao et al. (2019, pp. 220–221) provided that environmental concerns are driving a demand for eco-friendly equipment and processes in sheet metal fabrication. This includes features like reduced energy consumption and use of recyclable materials. need to embrace sustainable practices and bring innovation in new redesigned products portfolio and pre owned machines (the whole value chain). Introducing new technological innovations to reduce dependency on fossil fuels.
- **Shifting Demand:** The Asia Pacific region is poised to be the most attractive market for metal fabrication during the forecast period. Mordor Intelligence (n.d.-a) reported that in 2021, it already held a commanding lead with a 41.5% share of the global market. This dominance is fueled by significant investments in infrastructure development across India, China, and ASEAN countries. While Asia Pacific takes the lead, North America and Europe remain established players. In 2021, they held substantial shares of the market at 20.6% and 25.1% respectively. These markets are also expected to see continued growth, albeit at a slower pace, with projected CAGRs of 4.6% for North America and 2.4% for Europe during the forecast period.

#### 4.5 Success factors for companies in metal sheet industry

**Advanced Technology:** Investing in modern machinery like laser cutting machines, CNC bending brakes, and automated processes can improve accuracy, speed, and reduce waste. According to Gyasi et al. (2022, p.640) traditional laser cutting, a mainstay in the automotive industry, utilizes flat-bed CNC machines, these machines struggle with flexibility and speed, limiting their application across broader industrial settings. However, the rise of Industry 4.0,

with its focus on automation and robotics, presents an opportunity for robot laser cutting systems. These systems (Figure. 11) offer significant advantages in flexibility, digitalization, and the ability to perform offline cutting.

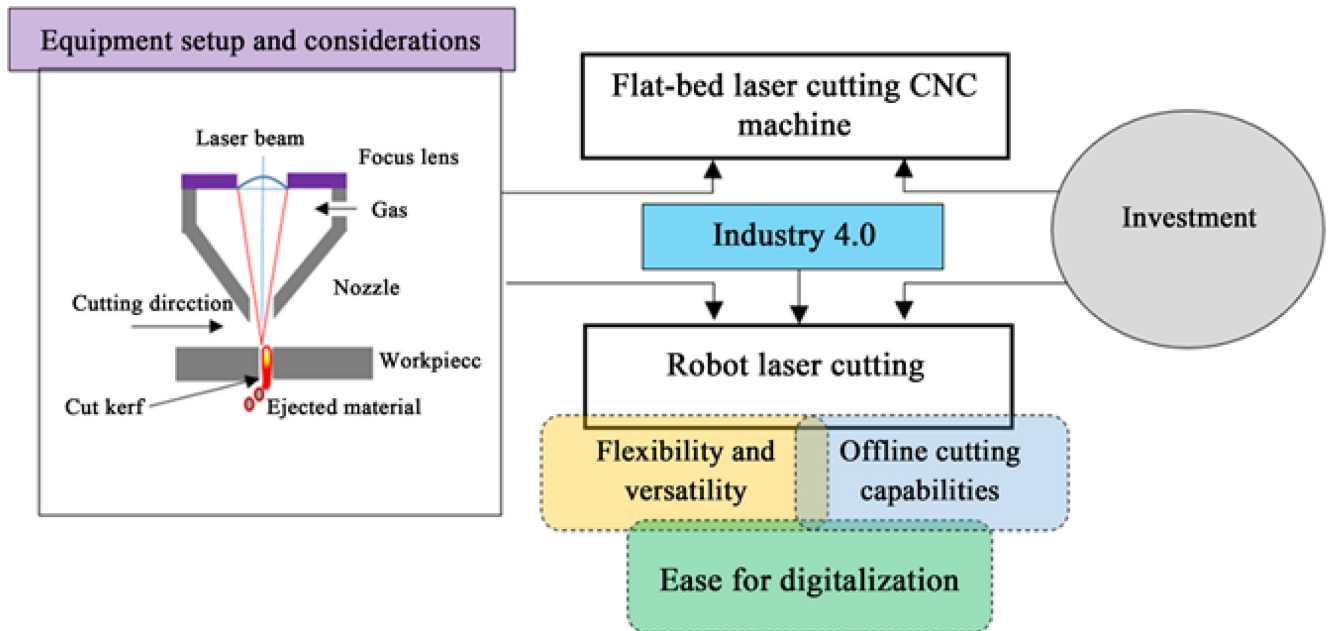


Figure 11. key variables in laser cutting, exploring robot laser cutting and Industry 4.0. (Gyasi et al. 2022)

According to Gyasi et al. (2022, p.642) in terms of market share, laser cutting is nowadays the most significant application in materials processing. In the metal industry, laser cutting is at the forefront of the production chain where pieces of parts and patterns are cut from sheet metals, metal plates or metal tubes for manufacturing of large volumes or low volumes of products to serve diverse industries. Laser cutting is a high-speed computer numeric control (CNC) process with cutting precision and accuracy of approximately 0,05 mm, and it delivers very low heat effects to the cut parts. Common metals which are laser cut include mild steel, stainless steel and aluminum. In laser cutting, the physical properties of metals, especially thickness and surface reflectiveness and chemical composition, and mechanical properties are significant characteristics that need to be considered. For mild steel and stainless steel, the thickness range suitable for laser cutting is between 0,5 - 20 mm while aluminum is between 0,5 - 8 mm.

**Process Optimization:** Streamlining workflows, minimizing downtime, and optimizing material usage led to increased efficiency and cost savings.

AMADA (n.d.) states that V-factory helps enterprises reduce downtime, which is one of the main cost items in manufacturing. As anticipated, the system detects setup and stand-by times, allowing production managers to identify causes and take proactive action to avoid future recurrences. In addition, the platform signals unexpected events through a system of real-time alarms, which are accurately categorized based on the cause and their impact on downtime. This allows them to activate prevention strategies and minimization of downtime.

AMADA (n.d.) also emphasizes that implementing preventative maintenance practices empowered by Industry 4.0 technologies, along with regular calibration, can significantly improve machine uptime, automate setup processes, and ultimately reduce production time.

**Quality Control:** Implementing robust quality control procedures throughout the process ensures consistent product quality and minimizes rework or scrap. Prima Power (n.d.) claims that Prima Power's Night Train system, minimize rework and scrap through two key strategies. Firstly, the system's capabilities enable efficient "nesting" of parts during production launch. This involves strategically combining various parts and even consumables onto a single sheet of metal, maximizing material utilization and aiming for an impressive 85% sheet filling rate. This clever nesting process significantly reduces leftover scrap material. Secondly, the Night Train system delivers a high-quality, clean cut with minimal to no burrs on the finished parts. By eliminating these burrs, the need for rework through sanding or grinding is minimized. This not only translates to faster production times but also reduces overall costs. While the text doesn't explicitly mention Prima Power's role in achieving clean cuts, this system attributing the reduction in rework to the Night Train system's "best finished cut" suggests the machine's cutting technology plays a crucial role in minimizing waste and rework. Overall, Prima Power's Night Train system contributes to a more efficient and cost-effective production process by enabling smart material usage and high-precision cutting, ultimately leading to greater customer satisfaction.

**Meeting customer needs:** Understanding customer requirements and offering customized solutions tailored to their specific needs. According to Helo and Hao (2017, p.524) new technologies like cloud computing are transforming how businesses operate. In manufacturing, a concept called "cloud manufacturing" is gaining traction. This approach aims to modernize the traditional manufacturing model.

According to QuestTech (2020) production planning and control (PPC) often involve solving optimization problems. These problems focus on creating plans that meet production demands while minimizing costs or maximizing profits. However, the ideal solution can change depending on the specific business phase and operation. To address this, cloud manufacturing offers a promising solution:

- **Decision Support as a Service (DSaaS):** Cloud platforms can act as a resource, providing data-driven recommendations to aid PPC decisions.
- **Improved Communication:** Cloud technology can facilitate better communication and collaboration across the entire supply chain.

**Value-added services:** Providing additional services beyond basic processing, such as assembly, finishing, or logistics, can enhance customer value. QuestTech (2020) declare that in the world of custom metal fabrication, going beyond just making parts offers a strategic advantage. Companies in construction, oil and gas, agriculture, and many others can benefit greatly from a wider range of services provided by their fabrication partners. These value-added services aim to streamline the entire production process, leading to faster time-to-market, lower costs, and reduced waste.

Fabrication shops can act as a one-stop shop, offering expertise and technology throughout the product lifecycle, from providing input on designs to producing prototypes and running on-demand production. QuestTech (2020) explore that this not only simplifies production but also reduces setup times compared to traditional methods. Additionally, these shops can help identify and eliminate unnecessary features in parts, making them easier to assemble and reducing the overall production chain complexity.

Furthermore, custom fabrication shops can handle various logistical tasks such as material handling, assembly, and export crating. According to Gregson et al. (2016, p 385), This eliminates the need for OEMs to manage multiple vendors, saving them both time and resources. By bringing all these services under one roof, fabrication shops can ensure superior quality, competitive pricing, and shorter lead times for their clients. In short, value-added services in custom metal fabrication are a win-win for both fabrication shops and their partner businesses.

**Cost Control:** Efficient resource management, proactive maintenance, and minimizing waste contribute to healthy profit margins. According to Rieckhof et al. (2015, p. 1266) Companies are increasingly pressured to adopt sustainable practices and use natural resources more efficiently. This research explores how to bridge the gap between strategy and action in achieving this goal. Material Flow Cost Accounting (MFCA) offers a valuable tool for developing a resource-efficient plan. However, for this plan to be successful, companies need a way to ensure everyone on board. Management Control Systems (MCS) come into play here, acting as the mechanism to translate strategy into action across all company levels.

Dittakavi (2021, p.48) explores various techniques to optimize resource usage and cost in cloud computing environments. It categorizes these techniques into three groups: Cloud/VM-focused, Workflow, and Resource Utilization/Efficiency. Cloud/VM techniques manage resource allocation and scheduling to find the right balance between cost and performance, while adapting to different cloud models. However, they can be complex due to their dynamic nature.

According to Dittakavi (2021, p.48), workflow techniques aim to optimize how tasks run in distributed cloud systems. They address quality of service inconsistencies and improve scheduling and reservation processes. While these techniques offer precise optimization, they can be computationally expensive for large problems.

Resource Utilization/Efficiency techniques focus on maximizing the use of available resources while being energy-efficient and cost-effective Dittakavi (2021, p.49). They consider current energy use and application needs to optimize performance without going over budget. However, these techniques might require constant monitoring, adding complexity.

Overall, these techniques provide a toolbox for cloud users to optimize resource usage and cost in cloud computing environments. They offer different approaches depending on the specific needs and priorities, but all contribute to a more efficient and cost-effective cloud experience.

**Supply Chain Management:** Building strong relationships with reliable suppliers ensures access to high-quality materials at competitive prices. According to Chien et al. (2022) Manufacturers of complex, custom-made equipment with high profit margins, like electric power transformers, are increasingly turning to intelligent manufacturing systems (IMS) to improve

customer service. IMS integrates supply chain data to make smarter decisions throughout the production process.

Chien et al. (2022) suggests two key IMS technologies:

1. **Smart supplier selection and component ordering:** This combines a decision-making method with multi-objective optimization to identify the best suppliers and order the right components. Unlike traditional methods, this module can handle complex constraints and identify multiple good options, making it a valuable tool for human decision-makers.
2. **Product quality prediction:** This module uses advanced statistical techniques to predict the quality of finished products before they are complete. This allows the manufacturer to quickly determine if components meet quality standards, reducing the risk of delays or wasted materials.

These technologies demonstrate the potential of IMS for manufacturers practicing mass customization of high-end equipment. The findings can be applied to other industries with heavy and big size products, that build complex, custom-made products.

#### 4.6 Innovation at the forefront

The main technological innovation trends in the manufacturing sector involve the following aspects.

**Digital transformation (Industry 4.0):** more efficient and intelligent machines. Complex systems that work with high flexibility and guarantee facility of use and “close to zero defect” manufacturing. As Mordor intelligence (n.d.-a) reports, the use of the Cloud (Figure .12), artificial

intelligence and cyber physical systems in the manufacturing sector are becoming more common.

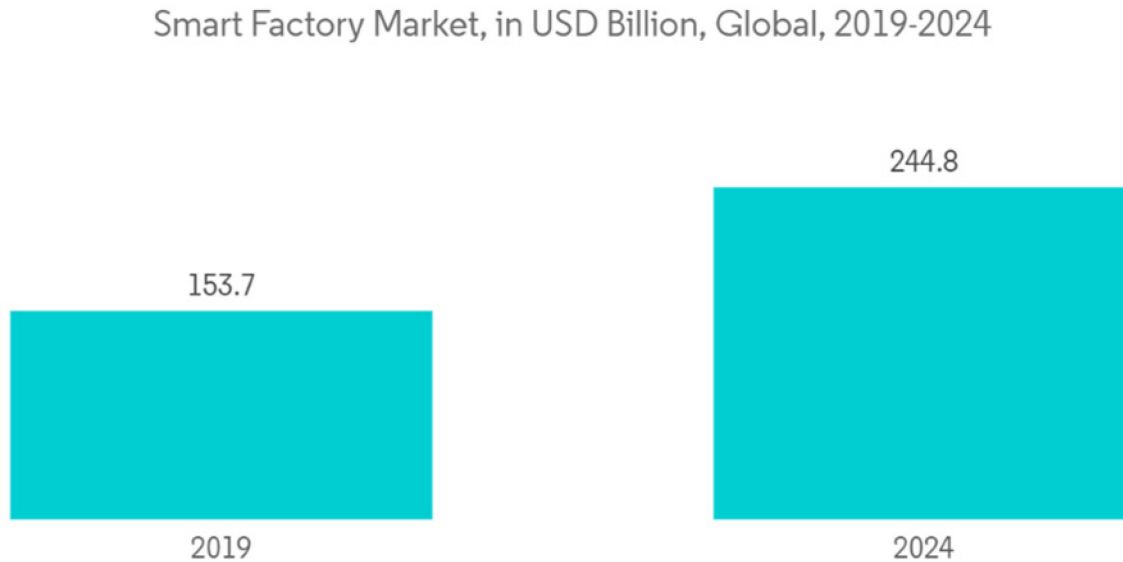


Figure 12. Smart Factory Market (Mordor Intelligence, n.d.-a).

**Circular economy:** According to Urbinati et al. (2020) circular economy is a technological trend where the manufacturing sector includes all technological integrations designed for recycling, energy savings, prolonging the life cycle of the product, and above all the functioning of the same components to improve performance in use.

**New business models for the manufacturing sector:** Urbinati et al. (2020) found that with the advent of digital transformation and industrial technologies 4.0, business models in the manufacturing sector are destined for drastic change to have costs that are more flexible and optimize the use of resources according to the demands of the market.

The manufacturing world is in the midst of a major revolution driven by Industry 4.0 and smart manufacturing concepts. Sheet metal fabrication, a cornerstone industry for many others, is jumping on board to reap the benefits of these advancements. This section dives into how Industry 4.0 and smart manufacturing principles are being integrated into sheet metal fabrication, exploring the positive impacts, advantages gained, and challenges encountered along the way.

According to Martinelli et al, (2021, p.162) Industry 4.0, often referred to as the fourth industrial revolution, is revolutionizing the manufacturing sector. It encompasses the integration of automation, data exchange, and digital technologies to create a more interconnected and intelligent manufacturing environment. In sheet metal fabrication, Industry 4.0 is reshaping processes, driving innovation, and optimizing production capabilities.

### **Smart machines and robotics**

Industry 4.0 is transforming sheet metal fabrication by introducing smart machines and robotics. Refer to Evjemo et al. (2020, p.37), these intelligent technologies automate repetitive and labor-intensive tasks, offering a multitude of benefits. Automating these tasks frees up human workers to focus on more specialized roles, ultimately increasing production speed and efficiency. Additionally, smart machines can perform complex operations with high precision, resulting in consistent, high-quality products. This translates to not only improved quality but also potentially lower costs due to less reliance on manual labor. Furthermore, by automating dangerous tasks, smart machines significantly enhance worker safety in sheet metal fabrication facilities.

### **Internet of things (IOT) connectivity**

In sheet metal fabrication, the Internet of Things (IoT) acts as a key driver for smart manufacturing. According to Qazi et al. (2022, p.20) with IoT connectivity, machines, sensors, and various devices can talk to each other and share data instantly. By incorporating this technology into the production process, manufacturers gain valuable real-time information on machine performance, maintenance requirements, and production analysis. This data-driven approach empowers them to make proactive decisions, perform predictive maintenance, and optimize production schedules, leading to a smarter and more efficient operation.

### **Data analytics and artificial intelligence (AI)**

Sheet metal fabrication is experiencing a revolution driven by data analytics and artificial intelligence (AI) alongside other Industry 4.0 advancements. Ladani (2021) declare that data analytics tools sift through massive amounts of data collected from sensors, machines, and production lines. This empowers manufacturers to identify trends, optimize processes, and make data-driven decisions for superior efficiency and quality control. AI takes it a step further. AI

algorithms can analyze sensor data to predict equipment failures before they happen, enabling proactive maintenance to prevent costly downtime. In the design phase, AI can analyze design data and predict potential issues during fabrication, allowing for design optimization and ensuring products meet quality standards. AI can even automate quality control by using AI-powered systems for visual inspection of sheet metal parts, identifying defects with high accuracy and speed, reducing the need for manual inspection and saving time and labor costs. (op. cit.) Finally, AI can be used to optimize production scheduling, material usage, and machine settings, minimizing waste, reducing production time, and improving overall efficiency. In conclusion, data analytics and AI are transforming sheet metal fabrication by enabling smarter decision-making, improved efficiency, and enhanced product quality.

### **Additive manufacturing and 3D printing**

Further innovation comes from additive manufacturing, Researchers are exploring a fascinating application of robotics in steel fabrication - Additive Manufacturing (AM) using Wire Arc Additive Manufacturing (WAAM) or 3D printing (Lange, 2020, p.146). This technology unlocks the creation of complex designs, facilitates mass customization, and minimizes material waste. It also enables rapid prototyping and cost-effective production of low-volume parts. Robots are now performing two key tasks: holding steel components (like stiffeners and end plates) and welding seams on beams and columns. But this isn't the only use for welding robots. The welding wire acts like a 3D printing filament, allowing robots to "print" metal directly onto steel beams. This technology opens doors for creating complex connecting elements and even complete structures like nodes for space frames and small bridges.

### **Benefits of industry 4.0 and smart manufacturing technology in sheet metal fabrication**

**Enhanced productivity and efficiency:** The rise of Industry 4.0 is revolutionizing sheet metal fabrication by automating repetitive tasks and streamlining workflows. This translates to a significant boost in productivity and overall efficiency. According to Qazi et al. (2022, p.22) smart machines take over repetitive tasks, freeing up human workers for more specialized roles. Additionally, machines communicate with each other through the Internet of Things (IoT), providing real-time data that feeds powerful AI analytics. These analytics empower manufacturers to identify and eliminate production bottlenecks, minimize downtime caused by equipment failures, and ultimately achieve higher output levels without sacrificing quality. In

essence, Industry 4.0 is transforming sheet metal fabrication into a smarter, more efficient, and productive industry.

**Improved quality and precision:** Industry 4.0 is bringing a quality revolution to sheet metal fabrication. Qazi et al. (2022, p.23) found that smart machines and robots take over repetitive tasks, minimizing human error and ensuring consistent, high-precision results. This automation also reduces variations in product quality. Additionally, real-time data monitoring and analytics become possible with these smart technologies. This allows manufacturers to catch defects early in the process, enabling them to take immediate corrective actions and ultimately deliver superior quality sheet metal components and products.

**Cost reduction and waste minimization:** Industry 4.0 technologies enable cost reduction and waste minimization in sheet metal fabrication. Lange (2020, p.149) explores that by automating processes and optimizing material usage, manufacturers can minimize scrap, reduce material waste, and optimize inventory management. Moreover, the predictive maintenance capabilities of smart machines help prevent unexpected breakdowns, reducing maintenance costs and downtime.

**Flexibility and customization:** Industry 4.0 facilitates greater flexibility and customization options in sheet metal fabrication. With additive manufacturing and 3D printing, manufacturers can produce highly complex and customized parts on demand. The ability to quickly iterate designs and adapt to changing customer requirements provides a competitive edge in the market.

**Real-time monitoring and predictive maintenance:** Qazi et al. (2022, p.27) states that smart manufacturing technologies allow real-time monitoring of machines, processes, and product quality. By collecting and analyzing data in real-time, manufacturers can detect anomalies, predict maintenance needs, and take proactive measures to avoid costly breakdowns. This predictive maintenance approach increases machine uptime, extends equipment lifespan, and reduces maintenance costs.

**Enhanced workplace safety:** According to Qazi et al. (2022, p.30), the integration of Industry 4.0 technologies in sheet metal fabrication enhances workplace safety. By automating hazardous tasks and providing real-time data on machine performance, manufacturers can minimize the risk of accidents and injuries. Smart machines also have built-in safety features,

such as collision detection and emergency stop mechanisms, further ensuring the well-being of workers.

**Implementing Industry 4.0 in sheet metal fabrication:** Implementing Industry 4.0 in sheet metal fabrication comes with its own set of challenges. According to Evjemo et al. (2020, p.39), these include high upfront costs, the need for specialized technical expertise, data security concerns, and potential resistance to change among the workforce. Overcoming these challenges requires careful planning, proper training, and a phased implementation approach.

The challenges in implementing Industry 4.0 in sheet metal fabrication include upfront costs, technical expertise requirements, data security concerns, and change management. However, the long-term benefits outweigh these challenges.

**Improve quality control in sheet metal fabrication by smart manufacturing:** Smart manufacturing in sheet metal fabrication enhances quality control through real-time monitoring, data analytics, and predictive maintenance. Following Evjemo et al. (2020, p.42), by continuously monitoring production parameters, manufacturers can detect deviations and anomalies, ensuring consistent quality. Predictive maintenance helps prevent machine failures, minimizing defects and rework.

Smart manufacturing improves quality control in sheet metal fabrication by enabling real-time monitoring, data analytics, and predictive maintenance. These capabilities ensure consistent quality and reduce defects.

**Increase production speed in sheet metal fabrication with industry 4.0 and smart manufacturing:** Industry 4.0 and smart manufacturing can significantly increase production speed in sheet metal fabrication. According to Evjemo et al. (2020, p.27), by automating processes, optimizing workflows, and leveraging real-time data insights, manufacturers can achieve faster turnaround times and meet increasing demand effectively. Industry 4.0 and smart manufacturing can enhance production speed in sheet metal fabrication by automating processes, optimizing workflows, and leveraging real-time data insights.

**Metal sheet fabrication companies adapt to embrace Industry 4.0:** To embrace Industry 4.0, sheet metal fabrication companies should invest in advanced technologies, such as

smart machines, IoT connectivity, data analytics, and additive manufacturing. Evjemo et al. (2020, p.39), suggest that they should also provide training to their workforce, establish strong data security measures, and foster a culture of innovation and continuous improvement. Sheet metal fabrication companies can adapt to embrace Industry 4.0 by investing in advanced technologies, providing training, ensuring data security, and promoting a culture of innovation.

#### **4.7 Emissions management - carbon footprint**

In the context of global climate change, greenhouse gas emissions have become increasingly serious. Metal processing companies make a great contribution to the annual CO<sub>2</sub> emissions, making this industry one of the key contributors to climate change. According to Zhang et al. (2021), many countries are paying high attention to the emission reduction technologies in the steel industry, and a trend has been established focusing on the reform and innovative changes of steel companies. Amidst this backdrop, the methods and technologies in the World regarding energy saving and emission reductions are reviewed in the article. Moreover, projects like the COURSE50 project in Japan, the FINEX-CEM project in Korea, the hydrogen metallurgy projects in China, the ULCOS project in Europe, the 'H<sub>2</sub> Future' project in Austria, the HYBRIT project in Sweden, the Carbon2Chem and SALCOS projects in Germany, molten oxide electrolysis and hydrogen flash smelting project in the US were selected, to optimize the current metal processing industry and to display the development direction and progresses that have been made.

Figure 13 below discusses the growing concern over CO<sub>2</sub> emissions from human industrialization, particularly in China and Korea (Fig. 13a). The steel industry is highlighted as a major contributor to CO<sub>2</sub> emissions due to its reliance on energy-intensive processes (e.g., blast furnaces) fueled by coal (Fig. 13b).

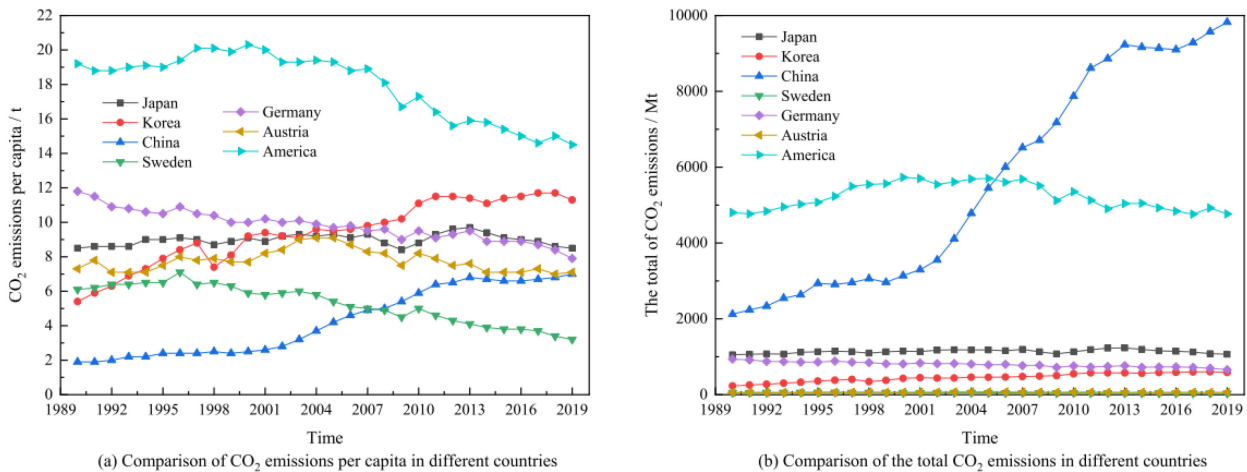


Figure 13. Comparison of the total and per capita CO2 emissions in different countries. Zhang et al. (2021)

While some technological advancements have improved energy efficiency, alternative steelmaking processes haven't been developed yet. Therefore, innovation is crucial for the steel industry to achieve significant reductions in CO<sub>2</sub> emissions.

**What is 2°C scenario?**

A 2°C scenario a global effort to limit warming to 2 degrees Celsius above pre-industrial levels by 2100 (IPCC, 2018). This ambitious goal, outlined by the Intergovernmental Panel on Climate Change (IPCC), aims to prevent the most catastrophic effects of climate change (IPCC, 2018). Achieving this scenario requires significant reductions in greenhouse gas emissions across all sectors.

**Financial impact from climate change risks in 2°C scenario**

In the 2°C scenarios, regarding the risk of a possible increase of carbon cost due to the future rise of carbon pricing, the total amount of carbon cost that a sample metal sheet industry like AMADA will cover is estimated in below table (Amada sustainability report, 2023). Based on assumption that by the 2030 carbon pricing being 80€-90€/ t-CO<sub>2</sub>, calculated from the EU Emissions Trading System (EU ETS-May 2024), under SDS scenario of the IEA (while some regional initiatives might have lower prices.)

Table 2. Carbon Pricing

Carbon Pricing	Intended Year	Estimated price
New designed Machines-Scope 1+2*	2030	€80-€90/t-CO <sub>2</sub>
Pre-Owned Machines-Scope 3**	2030	€80-€90/t- CO <sub>2</sub>

\*: scope 1+2: Direct and Indirect greenhouse gas (GHG) emissions from purchased electricity, heat, or cooling.

\*\* : scope 3: Indirect emissions that occur throughout the industry's value chain (often the most complex to quantify).

In the third quarter of 2023, EU economy greenhouse gas emissions are estimated at 787 million tons (Eurostat report, 2024) of CO<sub>2</sub>-equivalents. While current sustainability efforts in Europe are making a positive difference, the potential for impact is far greater. Expanding these initiatives across all market countries would create a wider ripple effect. Additionally, applying these practices to new industries beyond current focus, would allow a broader range of companies to benefit and contribute to creating a more sustainable future. By implementing these combined strategies, metal sheet processing companies can achieve at least double the environmental and economic benefits that what they are currently generating. This broader geographic and industry focus will not only expand the positive impact of planned efforts, but also allow more companies to contribute to a more sustainable future.

Geopolitical issues change the dynamics in the global flow of goods and information, and macroeconomic changes cause overall economic uncertainty. Leveraging technology leadership through automated and digital solutions can help to survive situation. The landscape is shifting dramatically, with the transition towards carbon neutrality (NZE 2050 & EU Green Deal programs) becoming a significant driver. Rising carbon costs, pose a major threat to traditional production methods for companies and its customers in different industries. The International Energy Agency's World Energy Outlook report (IEA, n.d.) provides scenarios for future carbon pricing. Their sustainable development scenario estimates an average global carbon price of around USD 135 per tons of CO<sub>2</sub> by 2050 Also, another analysis by Goldman Sachs (2021, n.d.) predicted a potential global carbon price of USD 75 per tons by 2030 It

could be understood that to remain competitive in this evolving market, companies need to embrace sustainable practices and bring innovation in redesigned products portfolio and pre owned machines (the whole value chain), Introducing new technological innovations to reduce dependency on fossil fuels and respectively carbon cost.

Expanding the scope of analysis beyond the metal industry can significantly inflate its total Scope 3 emissions (indirect GHG emissions). According to Finkbeiner et al. (2016) applying Life Cycle Assessment (LCA) practices in other continents and related industries (construction, automotive) offer valuable insights. Upstream activities (raw material extraction, transportation) and downstream activities (product use, disposal) across the entire value chain contribute to Scope 3 emissions. For instance, understanding the environmental impact of mining practices in different regions or the recycling infrastructure in other countries can significantly impact the overall footprint. Similarly, data from related industries can illuminate industry-specific considerations, such as the embodied carbon in construction materials used with metal components. Furthermore, examining projects and lessons learned from global supply chains can identify areas for collaboration with suppliers across continents to implement more sustainable practices. Finally, studying successful projects and best practices used elsewhere can spark innovation within the metal industry, leading to the development and adoption of lower-impact materials and production processes. A comprehensive understanding of Scope 3 emissions across a broader scope is essential for developing effective reduction strategies and achieving sustainability goals.

### **Risks of Inaction toward reducing CO<sub>2</sub> emissions in metal sheet fabrication industry:**

- **Increased production costs:** According to Daehn et al. (2022, p.277) carbon pricing and emissions trading regulations and policies are likely to be implemented in the future. Without proactive emission reduction measures, major players face potential cost increases due to carbon pricing in industry value chain.
- **Rising Material Costs:** According to Daehn et al. (2022, p.279) decarbonization efforts in the metal industry may lead to higher crude steel prices. Additionally, the rise of renewable energy sources could lead to increased electricity prices.
- **Reputational Damage:** Daehn et al. (2022, p.280) also states that failure to address climate change can negatively impact reputation with investors, customers, and

potential employees. Stricter ESG (Environmental, Social, and Governance) disclosure standards could also impose additional costs.

### Opportunities for Leadership:

- **Developing Eco-Friendly Products:** A carbon footprint reduction project presents an opportunity to create redesigned products portfolio and innovative solutions that are energy-efficient and minimize environmental impact. This can lead to increased profits and market differentiation.
- **Innovation and Efficiency:** Efforts to reduce carbon footprint can drive innovation in areas like Energy-efficient machines, Automation, Fiber optic control technology, Application of Cloud, Artificial intelligence and machine learning, Sustainable materials, technology, and IoT-based energy savings. These advancements can further enhance product offerings and operational efficiency.

## 4.8 Customer (user) needs and pain points

Understanding customer needs and pain points, helps manufacturers of sheet metal fabrication equipment to develop solutions that are more targeted and address the real challenges faced by their customers.

The below Table 3 summarizes customer or user need and pain points of sheet metal fabrications equipment:

Table 3. Customer Needs

Category	Needs	Pain Points	References
Production	Increased Efficiency & Productivity	High Initial Investment	Choomlucksana. et al. (2015, p.109)
	Improved Quality & Precision	Complexity of Operation	
	Reduced Operating Costs	Maintenance Needs	

Versatility	Flexibility & Versatility	Lack of Automation	Cao et al. (2019, p.612)
		Difficulties Meeting Evolving Needs	
Integration	Integration with Existing Systems	Integration Challenges	
Safety	Safety for Workplace Surfaces	Complex rules & regulations	ANSI (2017)
Workforce	Skilled Workforce Availability	Competition	Macky and Boxall. (2008, p.13)
Environmental Concerns	Eco-Friendly products	Finding suitable solution	Sáez Martínez. et al. (2016, p.898)

#### **4.9 Meet business Finland funding calls**

According to Business Finland (n.d) Finnish businesses can gain a competitive edge worldwide by teaming up with research institutions through Business Finland's Co-Innovation program. This program fosters partnerships that drive innovation, boosting exports, creating jobs, and advancing technology.

Projects require collaboration with a research organization and a clear demonstration of how they'll significantly increase the company's international business. As it explained in Business Finland (n.d.) a group of at least two companies (or three with a research partner) is needed. While at least two companies must have funded research and development projects, others can contribute financially or with resources.

Funding from Business Finland is tailored to each project. Research projects can receive up to 80% of their costs, with a higher rate for those with international collaboration. Company R&D projects are assessed based on size, content, and goals.

The research findings should be broadly applicable, benefiting others beyond the initial partnership. Companies have first right to negotiate the use of results, but flexible agreements within the group are allowed. International collaboration in research projects is strongly encouraged.

Business Finland (n.d.) explain that interested Finnish companies should consult Business Finland's application instructions and explore potential alignment with the "leading companies' ecosystem" initiative for further opportunities. Co-Innovation funding empowers Finnish businesses to achieve global success through collaborative innovation.

#### **4.10 Blue ocean strategy toward selected industry**

This thesis explored the potential for metal sheet fabrication companies to create new value propositions in the sheet metal fabrication equipment industry. Insights were gathered through various sources.

These resources, along with an analysis of the existing product portfolio within the metal sheet fabrication equipment industry, led to the following findings:

- **Product utility map:** Understanding customer needs throughout the buying process, from initial purchase to equipment disposal, can reveal opportunities for differentiation. Figure 14 below shows that how companies can map customer needs, and identify areas where they can offer superior value compared to competitors.

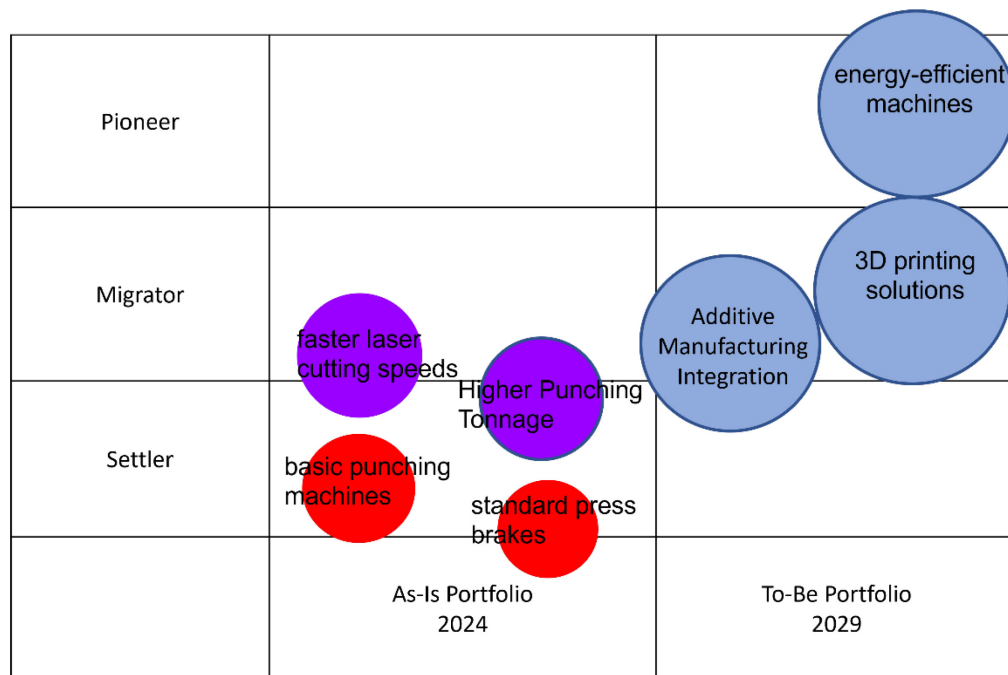


Figure 14. Pioneer, migrator, settler map.

- **Six paths framework:** As in shown in figure 15 this framework encourages exploring avenues for innovation by looking beyond the immediate industry. By analyzing:
  - **Alternative industries:** It is identifying that potential in areas like additive manufacturing and bio-based materials are capable areas to reduce waste.
  - **Strategic groups & buyer groups:** Targeting niche segments or developing user-friendly solutions for specific user groups can open new markets.
  - **Complementary products & services:** Offering bundled packages with design software or training on eco-friendly practices creates additional value propositions.

- **Functional-emotional aspects:** Sustainable design aesthetics and multilingual user interfaces can differentiate company in the global market.
- **Future trends:** Investing in R&D for AI-powered equipment and closed-loop material systems positions company for future market needs.

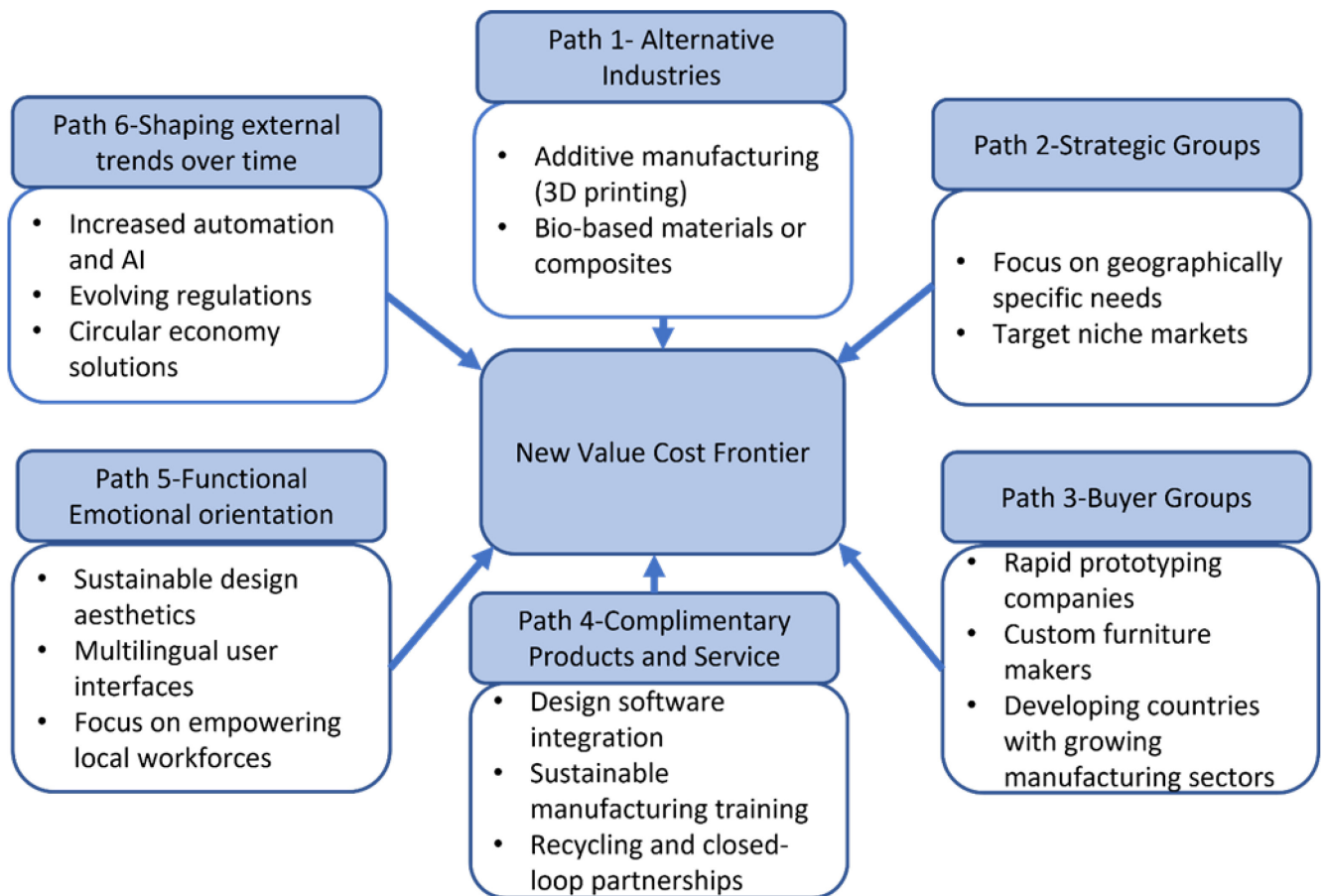


Figure 15. Metal sheet industry six path framework.

#### – Metal sheet industry strategy canvas

Base on the information and product features that was gathered in last chapter, 8 different competing factors can be known for comparing current metal sheet industry:

1. Cost and value: Finding the best value for investment is key.

2. Machine capabilities: This includes aspects like material handling, cutting and bending precision, automation level, and flexibility for diverse jobs. Minimizing waste and software integration are also valued features.
3. Eco-friendliness: Energy efficiency, use of recycled materials, waste reduction strategies, and end-of-life recyclability are increasingly important.
4. Circular economy practices: Design for disassembly, upgradability, spare parts availability, refurbishment programs, and closed-loop material management are gaining traction.
5. Reliable support: adding value to existing products (Brownfield Innovation).
6. Innovation: Investment in R&D for sustainable and efficient technologies with a focus on circular economy principles is valued.
7. Reputation and market share: A strong brand reputation for quality, reliability, and environmental consciousness, along with experience and market share, influence buying decisions.
8. Delivery speed: Meeting deadlines through efficient order processing and equipment delivery is important.

Based in the different competitors' products analysis, figure 16 demonstrates the strategy canvas which active companies in this industry can expand their future roadmap products through it.

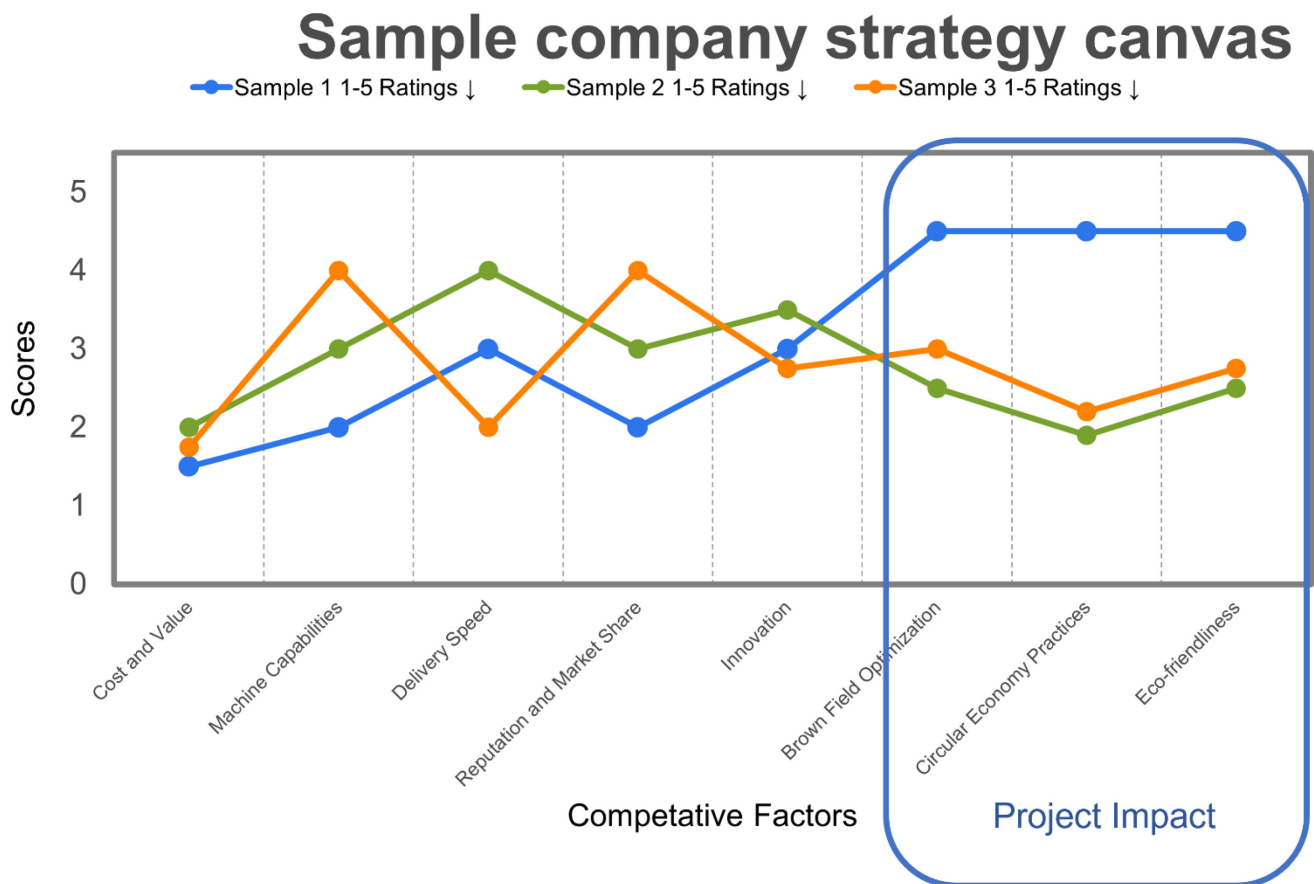


Figure 16. Sample metal sheet industry strategy canvas.

### – ERRC grid for sample metal sheet industry company

Sample metal sheet industry company's ERRC (Eliminate-Reduce-Raise-Create) Grid outlines a comprehensive strategy for achieving environmental sustainability, boosting export capabilities, and ultimately driving business growth. Here's a breakdown of the key elements:

#### Eliminate:

- **Unnecessary complexity:** Streamlining customization processes to avoid inefficiencies and wasted resources.
- **One-size-fits-all mindset:** Tailoring solutions to specific customer needs for better resource allocation and reduced waste.

#### Reduce:

- **Machine downtime:** Optimizing machine performance to minimize production disruptions and energy waste.
- **Energy consumption:** Implementing energy-efficient technologies and practices throughout the production process.
- **Material waste:** Minimizing material waste during fabrication through improved processes and design.
- **Packaging waste:** Utilizing recyclable or reusable packaging materials to lessen environmental impact.

#### **Raise:**

- **Eco-friendly materials:** Prioritizing sustainable materials in product design and manufacturing.
- **Remote service capabilities:** Enhancing remote service and troubleshooting features for improved customer support and reduced travel emissions.
- **Machine uptime and reliability:** Ensuring machine reliability and extended uptime to maximize productivity and efficiency.
- **User-friendliness and multilingual support:** Developing user-friendly interfaces with multilingual capabilities for a broader global market.

#### **Create:**

- **Subscription-based services:** Introducing subscription models that provide ongoing value to customers and promote resource optimization through industry 4.0 innovation solutions.
- **Carbon offsetting programs:** Offering carbon offsetting options to mitigate the environmental impact of company products operations and customer activities.

- **Export financing solutions:** Developing financing options to facilitate equipment acquisition for export markets, stimulating growth.
- **Educational programs:** Creating educational programs to raise awareness and promote sustainable manufacturing practices across the industry.

Figure 17 below demonstrates ERRC grid for current active companies in this industry.

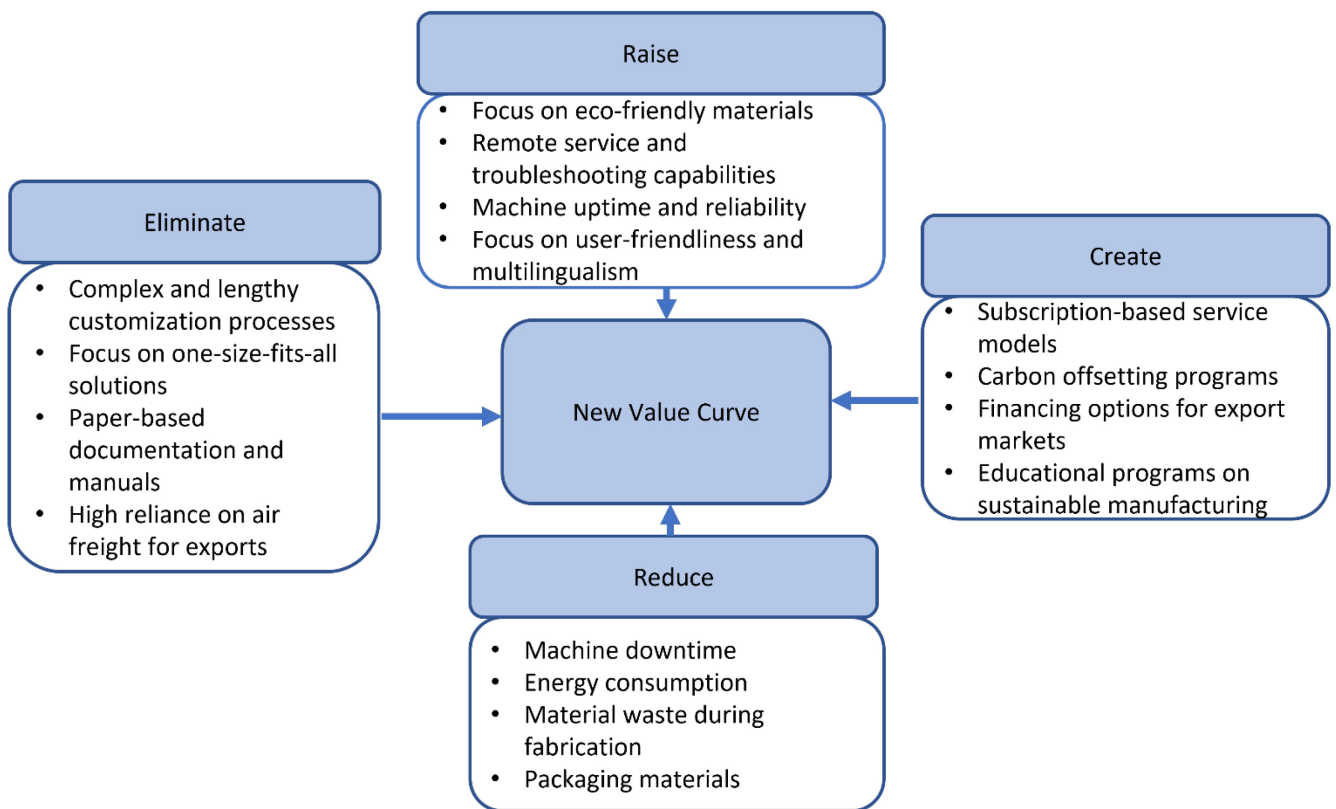


Figure 17. ERRC GRID for sample metal sheet industry company.

**Competitor Examples:**

Sustainability reports from industry leaders like Amada and Trumpf showcase real-world applications of BOS strategies:

- **Amada:** "Eco Edge Technology" program incorporates recycled materials into machine components, promoting resource efficiency (Amada Sustainability Report, 2023, p. 127).

- **Trumpf:** "TruMark Punch" system minimizes material waste by utilizing a more efficient punching process, reducing the need for rework (Trumpf Sustainability Report, 2023, p. 115).
- **Prima Power:** The Night Train is a game-changer for sheet metal fabrication (Prima Power, n.d.). It automates the entire process, integrating material handling, information systems, and individual manufacturing stages into one smooth, flexible workflow.

These benefits translate to cost savings, reduced environmental impact, and a more competitive industry. Further research is needed to explore the full potential of circular economy in sheet metal processing and identify barriers to implementation.

## 5 SUMMARY AND IMPLICATIONS

### 5.1 Summary of study

This thesis argues that metal sheet fabrication companies must take a proactive stance cope with technology trends and also carbon footprint reduction to secure their future success. Inaction poses significant risks, while a proactive approach offers substantial benefits including cost savings, market leadership, and brand reputation (WBCSD, 2020). Implementing a carbon footprint reduction project is presented as a strategic imperative for the long-term sustainability of metal sheet fabrication companies.

The opportunity lies in becoming a frontrunner in sustainable sheet metal fabrication through a comprehensive carbon footprint reduction project, inserting industry 4.0 technology in new product portfolio, reduce energy consumption in the whole value chain. This project aims to revolutionize the industry while achieving cost savings and market leadership.

Supposed project aligns with Business Finland's funding projects goals to boost leadership in the related industry. It focuses on collaboration between research groups, companies (various sizes), and metal sheet industry to develop innovative solutions for export growth. By targeting specific market needs and fostering international research, the project aims to make Finland a leader in this industry, creating jobs and boosting exports.

Building on identified opportunities, sustainable product development roadmap objective will create a practical roadmap for metal sheet fabrication companies. This roadmap will outline specific steps for integrating sustainable practices throughout the product development process. This might involve using recycled materials, designing energy-efficient products, and optimizing production to minimize waste. Industry 4.0 technologies, such as data analytics and digital twins, will be explored to further enhance this roadmap.

Customer value proposition analyzes how adopting sustainable practices can benefit environmentally conscious customers. Here, the project will explore how features like energy efficiency, reduced waste generation, and longer product lifespans translate into customer

advantages. By demonstrating the link between sustainability and cost savings, improved quality, and a reduced environmental footprint, companies can strengthen their appeal to a growing segment of eco-conscious consumers.

## 5.2 Enriching product portfolio

Opportunities for innovation are in sustainable products. These opportunity goes beyond simply reducing emissions, focusing on a complete transformation with two key areas:

1. **Redesigning existing products:** This involves developing a new generation of energy-efficient and eco-friendly machines, empowering customers to operate more sustainably.
2. **Brownfield automation:** This leverages brownfield automation, strategically upgrading existing equipment and pre-owned machined with cutting-edge technologies like robotics and sensors. This optimizes efficiency, minimizes waste, and extends the life of current infrastructure.

### **Beyond environmental responsibility: a win-win for all**

This initiative is not just about environmental protection, but creating benefits for all stakeholders:

- **Cost reduction:** Increased energy efficiency translates to lower operational costs for both Manufacturing company and its customers.
- **New job opportunities:** The project will drive innovation, fostering new jobs across the industry.
- **Competitive advantage:** By embracing sustainability, metal manufacturers, its suppliers, and its customers will position themselves as leaders in the global market.

### **Brownfield automation: a strategic fit**

Brownfield automation aligns well with the project's goals:

- **Maximizes existing investments:** Upgrading existing machinery is often more cost-effective than a complete overhaul.
- **Phased implementation:** The project can be rolled out gradually, minimizing disruption.
- **Reduced environmental impact:** Upgrading is more eco-friendly than scrapping old equipment.

### A sustainable future for company customers

Metal sheet companies with global network ensures its after-sales services seamlessly support the transition to these greener solutions. These services include:

- **Component and spare parts:** Access to the latest energy-efficient parts for existing machines.
- **Machine retrofitting:** Upgrading existing machinery with brownfield automation technologies.
- **Preventative maintenance:** Proactive maintenance plans ensure optimal performance and longevity of upgraded equipment.

### 5.3 Project implications and impacts

The proposed project to reduce its carbon footprint has the potential for significant positive impacts across various aspects, both in the short and long term. Here's a breakdown of the potential impacts:

**Short-term impact:** The project promises a cascade of benefits beyond just environmental impact. By developing more energy-efficient machines, company can expect not only to reduce its own environmental footprint but also to bring down energy consumption for its

customers, potentially leading to lower electricity bills for all involved. These newer, more efficient machines can also translate to enhanced efficiency through reduced maintenance needs and less downtime, further boosting productivity and potentially lowering overall costs. The research and development efforts required to achieve this energy efficiency also hold the potential to unlock new product features and technologies, creating exciting commercialization opportunities in the short term. Finally, taking a proactive stance on sustainability through this project can significantly improve public perception of company products, burnishing its reputation as an environmentally responsible corporation.

**Medium-term impact:** Looking beyond immediate environmental benefits, the project offers a range of medium-term advantages. Company's commitment to eco-friendly products positions them for market differentiation, attracting customers who prioritize sustainability and potentially increasing market share. This proactive approach also ensures compliance with upcoming, more stringent carbon pricing and emission regulations, avoiding potential future costs. Additionally, a focus on sustainability can boost employee morale and attract new talent who value environmentally responsible companies. These factors combined can have a significant positive impact on company's product medium-term success.

**Long-term impact:** The project's long-term benefits extend far beyond immediate gains. By driving decarbonization efforts throughout the metal industry, company product portfolio and its customers can expect significant cost savings through reduced energy consumption and potentially lower material costs. This leadership role in sustainable sheet metal fabrication can have a ripple effect, influencing the entire industry to adopt more environmentally friendly practices. Ultimately, the project's potential to significantly reduce CO<sub>2</sub> emissions across the value chain plays a crucial role in mitigating the long-term effects of climate change, making a positive impact on the planet for generations to come.

**Impact on research:** Beyond its operational and market advantages, the project presents a significant opportunity for research and development. The focus on energy efficiency and sustainable materials can attract crucial funding to accelerate advancements in these areas within the sheet metal fabrication industry. Collaboration with leading research institutions will be key, fostering a powerful synergy between cutting-edge research and real-world expertise. This collaborative approach should extend to include SMEs (Small and

Medium-Sized Enterprises) as well. Their agility and niche focus will ensure that developed solutions are not only sustainable but also readily adopted by a wider range of businesses. Finally, sharing the project's findings with the broader research community can accelerate advancements in sustainable manufacturing practices for the benefit of the entire industry.

**Impact on economy:** The project's impact extends beyond the company and the environment, offering a potential economic boost. Developing and implementing new sustainable technologies can create new job opportunities in green engineering and sustainable manufacturing. Furthermore, the project's focus on resource efficiency can potentially lower the overall cost of sheet metal fabrication, benefitting the broader economy. This increased efficiency, coupled with the growth of the sustainable sheet metal fabrication market, can create a wave of new business opportunities for various stakeholders across the industry.

**Social Impact:** The project's impact reaches beyond just the company and the environment, offering societal benefits as well. By reducing energy consumption and promoting sustainable practices, the project contributes to a cleaner environment and healthier communities for everyone. This translates to potential improvements in public health through reduced air and water pollution associated with traditional manufacturing processes. Ultimately, the project serves as a model for responsible manufacturing, prioritizing both environmental and social well-being throughout the production process.

#### **5.4 Research limitations**

Although acknowledging the limits imposed by resources, this research may have overlooked the exploration of all potential new customer segments. Furthermore, a more thorough financial viability analysis might be required that goes beyond the existing scope of this research. Additionally, a deeper understanding of the internal processes, customer requirements, and competitive landscape within the metal sheet fabrication industry—which is often limited by publicly available data—could provide a stronger foundation for applying the Blue Ocean Strategy. Lastly, while market data is important, it might not provide metal sheet fabrication companies with enough detail on specific customer segments or unmet demands.

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