Cost-Benefit Assessment of Additive Manufacturing for Injection Molds

Sertaç Akar and Parthiv Kurup

National Laboratory of the Rockies

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List of Acronyms

AM	additive manufacturing
CNC	computer numerical control
COR	cyclic olefin resin
NLR	National Laboratory of the Rockies
ORNL	Oak Ridge National Laboratory

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Executive Summary

Oak Ridge National Laboratory, National Laboratory of the Rockies, polySpectra, and other partners were awarded a project by Advanced Materials & Manufacturing Technologies Office to advance additive manufacturing (AM) technology, in which AM cyclic olefin resin (COR) molds would be used for injection molding. Oak Ridge National Laboratory and polySpectra are collaborating to develop advanced AM tooling that achieves 10 times faster lead times, 10 times lower costs, and more durability than traditional computer numerical control (CNC) tooling, while matching CNC production speeds. Meanwhile, the National Laboratory of the Rockies team is focusing on the costs and economics of this developing technology. This report presents a cost-benefit analysis of using the polySpectra AM COR molds at the start of the project (Present) and the potential lifetime, cost-effectiveness, and performance by the end of the project period (Period 3). The analysis of the AM COR molds is compared to that of traditional CNC machined aluminum molds across the time periods.

An AM facility model is used within the cost-benefit model framework to evaluate AM COR molds. This model accounts for mold delivery to customers, current and future levels of technology readiness, the type of material injected, and various business cases. The customer-facing version of the model outlines the associated costs, benefits, and expected performance improvements, based on the assumption that all planned technological advancements are successfully implemented. The analysis focuses on AM COR molds used to produce parts from nylon, glass-filled nylon, and polycarbonate, across four timeframes: Present, Period 1, Period 2, and Period 3. Each period corresponded to one project performance year. At the start of the project, the lifespan of an AM COR mold for glass-filled nylon is 200 parts, which is projected to increase to 2,000 parts per mold by Period 3.

The baseline scenarios for traditional CNC techniques to compare with the AM COR molds were collaboratively developed by ORNL, polySpectra and NLR, and focused on an injection molding manufacturer producing 5,000 or 10,000 parts using a CNC aluminum mold (10,000-part life).

A new CNC mold requires 28 days for fabrication, delivery, and integration; thus, production starts on day 28. It then produces 5,000 parts in 32 days for glass-filled nylon and 31 days for polycarbonate. In contrast, AM COR molds, using a 2-day, 2-mold, delivery setup, can produce 5,000 glass-filled nylon parts in 26 days and polycarbonate parts in 22 days. By Period 3, AM COR molds could potentially reduce this production time to 11 days for glass-filled nylon and to 8 days for polycarbonate. Depending on the AM COR mold delivery schedule and the number of parts to be injection molded, the use of the AM COR molds can lead to direct cost savings for the injection mold facility. The 2-day, 2-mold delivery model is the most cost-effective across both order volumes (5,000 and 10,000 units). Sensitivity analyses on the AM cost and life have also been performed. The first sensitivity analysis examined changes in CNC mold pricing over time, while keeping the AM COR mold cost constant at $250 per mold. To produce 5,000 glass-filled nylon parts, the breakeven cost is $6,250. For 10,000 parts, the CNC mold must cost no more than $12,500 to remain economically competitive with AM COR molds.

Key markets for AM COR molds are automotive, aerospace, medical and health care, defense and military, consumer electronics, packaging, sports and recreation. AM COR molds offer a significant advantage in lead time, reducing production setup from weeks or months (with CNC

machining) to as little as 2 to 5 days. This enables faster prototyping, quicker design cycles, and accelerated time-to-market, which are critical in these industries.

One of the key challenges to widespread adoption of AM COR molds is their durability. However, this analysis demonstrates even modest improvements in mold longevity can unlock substantial market opportunities. These calculations show that AM COR molds have the potential to complement traditional methods, especially in applications where shorter lead times and lower production volumes are critical. With continued development, AM COR mold technology could provide significant time and cost savings while supporting the growth of domestic manufacturing capacity.

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1 Introduction

The development of stereolithography 3D printing in the 1980s gave rise to a new process called "rapid tooling," in which industrial-scale molds could be quickly and cost-effectively created using additive manufacturing (AM) techniques (Hilton and Jacobs 2000).Since 2015, AM tooling was limited to prototyping and was cost-competitive with computer numerical control (CNC) tooling only when molding dozens to hundreds of parts (Pelin, Sonmez, and Pelin 2024). Although the cost and lead time for polymer AM tooling are significantly lower than those of CNC, the molding process would still require hundreds of these fragile AM tools to produce the tens of thousands of parts needed for large-scale production.

While the U.S. has faced growing global competition over the past decade, advancements in injection molding and injection machine technologies present valuable opportunities to enhance domestic industrial competitiveness. When the top 10 global plastic injection molding machine manufacturers are considered, Milacron, the only U.S. company was at 3rd. Japan had 4 in the top 10, Germany and China both with 2, with Engel, an Austrian company in first position for 2024 (Log-Machine 2024). With regards to the major injection molding brands by Country, again Japan came top with 10 injection molding machine manufacturers, China with 5, Germany with 3, and Milacron as the only major U.S. injection molding machine brand (Li 2023). Without a significant number of injection molding machine manufacturers in the U.S., few mold manufacturers can meet the demands in the U.S. CNC mold costs will be more expensive and difficult to source locally.

China, for example, has more than 7,000 injection molding facilities and tens of thousands of mold manufacturers, far exceeding any other country. The province of Guangdong alone has over 3,000 companies specializing in mold making (TPM 2024). This enormous capacity allows mass production of molds at a huge scale to meet high-volume demand. Abundant skilled labor and manufacturing capacity enables very rapid production of mold compared to other major economies. Lead times in China can be 50% or more faster than the U.S. (TPM 2024). To increase U.S. capacity in mold making, both increased CNC and advanced mold manufacturing techniques such as AM are needed. U.S. based mold and die companies such as Nypro and Proto Labs have demonstrated strengths in innovation and advancements in mold making, reflecting the sector's overall potential for growth and technological development (Acomold 2025). Nypro now known as Jabil, a U.S. company, ranked 7th in global competitiveness for mold and die companies (Acomold 2025).

CNC machining is ideal for large-scale (100,000 and above) production runs but is often inefficient for small-scale (between 1,000 and 10,000 parts) or low-volume productions because of the need for expensive tooling and extended setup times (Korpela et al. 2020). Small-scale injection molding is typically used for prototyping, pilot production, short-run manufacturing, or custom parts. The market for CNC machined molds in small-scale injection molding faces a significant gap because of the high costs and long lead times associated with traditional manufacturing processes and transportation (Thompson et al. 2016). This creates a challenge for businesses needing fast and cost-effective mold solutions for smaller batches.AM polymer molds offer a promising solution to fill this gap (Isania, Fanti, and Casalino 2024). With AM, molds can be quickly designed and produced with minimal setup and material costs, making it ideal for

small-scale production runs (Gibson, Rosen, and Stucker 2015). The speed and flexibility of 3D printing allows for rapid iteration and prototyping, enabling manufacturers to produce high-quality molds without the hefty investment in CNC machinery (Korpela et al. 2020). Additionally, AM can reduce material waste and provide greater design freedom, allowing for more complex and optimized mold geometries (Thompson et al. 2016). This approach provides a more affordable and efficient alternative to CNC machining for small-scale injection molding applications.

Injection mold tooling requires sufficient strength, stiffness, and heat deflection temperature to endure the injection molding process, ensuring the production of high-quality, high-resolution parts. For industrial prototypes and low-volume production, aluminum tooling is commonly used. These tools must be precision-machined, and costs range between $5,000 and $10,000 per tool, depending on complexity, with lead times ranging from weeks to months (Formlabs 2025a). In contrast, cyclic olefin resin (COR) high-strength polymer, commercialized by polySpectra, is distinct from tools created with extrusion-based 3D printing technologies, which do not fuse like thermoplastics. COR offers superior thermomechanical properties, low surface roughness, and a high-gloss finish, eliminating the need for any secondary machining processes (Weitekamp, Atwater, and Grubbs 2013).

However, there are barriers to entry into the tooling industry because of the maturity of existing solutions. Traditional methods have been optimized over the past 60+ years, which makes AM COR high risk for most adopters, especially contract manufacturers who are beholden to tight timelines and paying customers. Reducing the risk of mold failure and increasing part tolerances will be critical to adoption at scale and by contract manufacturers.

1.1 Objectives

The National Laboratory of the Rockies (NLR) has teamed up with polySpectra, Oak Ridge National Laboratory (ORNL), Fortify Inc., MPI Systems, and RePliForm Inc. to develop a direct AM tooling solution with a shorter lead time and lower cost than traditional CNC-based tooling by improving tool durability and cycle times short enough to compete with CNC-based tooling (DOE 2021). Previously, NLR developed a techno-economic analysis methodology for the extrusion of high-strength aluminum alloys (Akar, Kinchin, and Kurup 2022). This methodology has been adapted to assess the cost-effectiveness and performance of AM COR molds in comparison to conventional CNC tooling methods. Within the scope of this study is a cost-benefit analysis, which involves understanding the specific parameters (i.e., mold life, part complexity, production cycle time, and cost per part), technologies, and scenarios associated with delivery schedules of injection molds.

In this cost-benefit assessment, the potential advantages and challenges of AM are first highlighted. The broader adoption of AM COR mold technology is constrained by a combination of technical, workflow, and business challenges. Technically, current printable materials often lack thermal resistance, mechanical strength, and surface finish needed for high-volume production, while limited thermal conductivity and shorter cycle life restrict their use beyond prototyping. Workflow barriers include a shortage of additive-specific mold design expertise, variability in print quality, postprocessing bottlenecks, and the absence of standardized testing or certification protocols. On the business side, uncertainty about cost-benefit outcomes, low awareness of production-grade capabilities, and high upfront investment costs slow decision-

making. This report will suggest ways to overcome barriers in material performance and standardized processes, and the potential advantages of AM COR molds over traditional tooling, particularly regarding speed, cost, and flexibility.

1.2 Market Overview

The adoption of AM COR molds, particularly those using high-strength polymers, is rapidly gaining traction across various industries as a result of their ability to provide cost-effective, rapid, and efficient tooling solutions (Weitekamp, Atwater, and Grubbs 2013). These innovative materials have the potential to transform how injection molds are designed, fabricated, and used particularly by offering advantages over traditional metal molds in lead time, flexibility, and customization though broader market adoption and quantifiable impact remain to be fully realized. Although the automotive sector remains one of the largest adopters, other industries, such as aerospace, medical, and consumer electronics, are also using AM COR molds.

1.2.1 Automotive Market

The automotive industry is one of the largest and most influential markets for AM COR molds, particularly as manufacturers seek to reduce production costs, accelerate time-to-market, and maintain high-quality standards (Knauf Industries Automotive 2023). Traditionally, injection molds for automotive parts, especially for low-volume production or prototyping, have relied on costly and time-consuming CNC machining or aluminum tooling (Formlabs 2025b). These methods are often inefficient for producing the small-batch, customized, or prototype parts the automotive industry requires in the development phase.

The target market, automotive injection molding, is a multi-billion-dollar part of the tooling industry, which is also a major opportunity for the multi-billion-dollar additive manufacturing (AM) market. .The U.S. injection molding market generated a revenue of $42.8 billion in 2022 and is expected to reach $58.7 billion by 2030 with a compound annual growth rate of 4% (GVR 2023). The automotive tooling market is one of the fastest-growing segments of the overall tooling market with a compound annual growth rate of 7.5% and is expected to grow to a size of ~$440 million by 2030 (Allied Market Research 2021). This growth is driven largely by the increasing demand for electric vehicles, which in turn boosts the need for injection-molded plastic components. The adoption of electric vehicles and the consequent rise in the use of injection-molded plastic parts are anticipated to accelerate significantly over the next decade and beyond (Allied Market Research 2021).

Additionally, as the automotive industry continues to produce electric vehicles and other emerging technologies, the demand for small-batch, specialized parts increases. AM COR molds have the potential to help automotive manufacturers more rapidly produce lightweight, high-performance parts for evolving market segments, provided that current barriers to adoption, such as material performance and cost considerations, can be addressed (Knauf Industries Automotive 2023).

1.2.2 Aerospace Market

The aerospace industry, known for its stringent safety and performance standards, is also beginning to adopt AM COR molds for low-volume production and prototyping. AM COR

molds allow rapid prototyping of complex parts, reducing development time and costs associated with traditional molding techniques (Grefen et al. 2021).

Moreover, the ability to produce customized parts quickly without large upfront investments in tooling makes AM COR molds appropriate for the aerospace industry's highly specialized and low-volume production runs. Lightweight, high-strength components, particularly those used in interior or enclosures, can be produced with precision and high efficiency using COR-based molds.

1.2.3 Medical and Health Care Markets

The medical industry is another key sector that could benefit from AM COR molds using high-strength polymers. The demand for highly specialized medical devices, custom implants, and disposable medical components continues to grow (Chung et al. 2014). These products often require low-volume production runs or frequent prototyping, areas where AM COR molds can reduce cost and quicken turnaround times.

Since AM COR is biocompatible, durable, and precise, it can be effectively used in medical device applications. For example, it supports the production of custom surgical guides, dental implants, and prosthetic components, parts that must be safe for the body, strong enough to withstand regular use, and manufactured with high accuracy. Additionally, AM COR molds enable rapid testing and modification of new product designs, helping speed up development and improve design flexibility (Chung et al. 2014). This may help medical manufacturers meet regulatory standards and patient needs without the long delays associated with traditional molding processes. Additionally, the use of AM COR molds would eliminate the need for extensive secondary machining, streamlining production processes and reducing costs.

1.2.4 Other Potential Markets

Beyond the automotive, aerospace, medical, and consumer electronics industries, a range of other sectors are beginning to adopt AM COR molds made from high-strength polymers and resins. These emerging markets include defense and military, consumer goods and electronics, packaging, and sports and recreation:

- **Defense and military:** Custom parts, low-volume production of specialized components, and rapid prototyping for defense applications
- **Consumer goods and electronics:** Rapid prototyping and small-batch production for mobile phone cases, wearable devices, and custom accessories
- **Packaging:** Particularly for low-volume or customized packaging solutions, specialized molds for containers, closures, and dispensers
- **Sports and recreation:** Custom-fit or low-volume parts for sporting equipment and recreational products.

2 Brief Technology and Innovation Background

2.1 Traditional Computer Numerical Control Machined Injection Molds

Injection molding is a widely used manufacturing process for producing large volumes of plastic parts with high precision and repeatability. It involves injecting molten plastic into a precisely machined mold cavity, where it cools and solidifies into the desired shape. Central to this process is the mold itself, which must withstand high pressure, repeated thermal cycling, and the wear-and-tear of mass production. Significant challenges exist for injected parts of which less than 10,000 are needed, requiring the ability to amend the molds. Injection molds are typically made from either high-strength steel or aluminum, with the choice of material significantly influencing the mold's performance, cost, and application.

Steel molds, especially those made from hardened tool steels such as H13 or P20, are highly resistant to wear, abrasion, and thermal stress. They can produce hundreds of thousands to millions of parts with minimal degradation (Formlabs 2025a). Steel molds can be precision-machined to tight tolerances, making them ideal for complex geometries and fine surface finishes. However, they are expensive and often take several weeks or even months to manufacture. Once a steel mold is built, making design changes is costly (almost equivalent to the cost of a brand-new mold) and difficult, limiting its adaptability during product development.

Aluminum molds are cheaper and faster to produce than steel molds (Table 1), making them suitable for prototyping and low- to mid-volume production. Aluminum's malleability and machinability allow for rapid fabrication and easier iteration of mold designs. Aluminum dissipates heat more efficiently than steel, leading to shorter cycle times and improved production throughput. Aluminum molds are more prone to wear, deformation, and thermal fatigue, especially under high-pressure or abrasive applications. They are suited for thousands to tens of thousands of cycles (Formlabs 2025a).

Choosing between steel and aluminum molds depends largely on production volume, budget, and design complexity (Table 1). Tooling steel offers unmatched durability and precision for high-volume manufacturing but at a high initial cost and reduced flexibility. Aluminum, on the other hand, provides a more cost-effective and agile option for lower volumes or prototyping but sacrifices lifespan and toughness.

Advancements in hybrid tooling and AM are beginning to challenge this traditional dichotomy, offering new possibilities for faster, more affordable, and customizable mold solutions. Fiber-reinforced resin molds are made using high-performance polymer matrices, such as epoxy or COR, reinforced with fibers. These molds can be quickly manufactured via AM, making them a compelling option for rapid tooling, prototyping, and bridge manufacturing. However, they are not suitable for very high-volume production or abrasive materials like glass-filled nylon, may not withstand the high temperatures or pressures required for certain plastics or metals, and may need postprocessing for high-end surface finishes. The relative advantages and limitations of steel, aluminum, and fiber-reinforced resin polymer molds are summarized in Table 1.

Table 1. Comparative Analysis of High-Strength Steel, Aluminum, and Fiber-Reinforced Resin Polymer Injection Molds with Respect to Various Manufacturing Criteria

Criteria	High-Strength Steel Molds	Aluminum Molds	Fiber-Reinforced Resin Polymer Molds	Citation
Durability	Very high—Ideal for millions of cycles	Moderate—Best for low to mid volumes	Moderate—Depends on resin/fiber composition	(Kuo and Pan 2023)
Initial cost	High—Expensive to produce	Lower—Cost-effective	Low—Affordable for prototyping and bridge tools	(Lucyshyn, Des Enffans d'Avernas, and Holzer 2021)
Lead time	Long— Weeks to months	Short—Days to a few weeks	Very short—Can be produced in hours or days	(Kuo and Pan 2023)
Ease of modification	Difficult— Costly and slow	Easy—Good for iterative design	Very easy—Highly adaptable with 3D printing	(Kuo and Pan 2023)
Thermal conductivity	Low—Slower cooling cycles	High—Faster cooling and shorter cycles	Moderate—Can be enhanced with additives	(Lucyshyn, Des Enffans d'Avernas, and Holzer 2021)
Details and tolerance	Excellent— High precision possible	Good—Sufficient for many applications	Good—Adequate for functional parts and protos	(Lucyshyn, Des Enffans d'Avernas, and Holzer 2021)
Recommended volume	High—100,000+ parts	Medium—Up to ~10,000 parts	Low to medium—Ideal for hundreds to a few thousand	(Kuo and Pan 2023)
Weight	Heavy—Requires machinery to handle	Light—Easier to transport and set up	Very light—Easily portable and user-friendly	(Kuo and Pan 2023)
Thermal limits	High—Withstands high processing temps	Moderate—Better cooling, lower maximum temperature	Moderate—Tunable with resin type, may need cooling strategies	(Lucyshyn, Des Enffans d'Avernas, and Holzer 2021)
Surface finish	Excellent—Polished, detailed finishes possible	Good—Smooth but may degrade over time	Good—Postprocessing may be required	(Kuo and Pan 2023)

2.2 AM COR Photopolymer Injection Molds

AM COR was developed to meet a need for a unified, high-performance additive tooling solution capable of forming thermoplastic, thermoset, composite, and metal components. This approach involves the integration of polySpectra's COR photopolymers with the precision-driven, magnetically aligned Digital Light Processing 3D printing technology called FluxPrint,

developed by Fortify (Fortify 2025). This combination can offer the potential for new versatility, durability, and functional performance in AM. As shown in Figure 1, the digital composite manufacturing process uses the Fortify FluxPrint 3D printer and polySpectra COR photopolymer material to produce injection mold tooling with a ceramic-reinforced microstructure, enhancing its thermomechanical performance.

Figure 1. Digital composite manufacturing for injection mold tooling printed from Fortify FluxPrint 3D printer and polySpectra COR photopolymer material exhibits a ceramic reinforcing microstructure that enables superior thermomechanical performance. ***Images from (Fortify 2025; polySpectra 2024)***

PolySpectra and ORNL have been awarded a project to advance technology. The goal is to deliver a 10 times reduction in lead time, measured in days instead of weeks and a 10 times cost savings, targeting under $1,000 compared to traditional CNC tooling costs exceeding $10,000 (Weitekamp 2022). Additionally, the objective includes achieving 10 times greater durability than current AM tooling, with more than 1,000 cycles to failure, and cycle times fast enough to rival CNC tooling, aiming for more than one part per minute (Weitekamp 2022).

3 Methodology

3.1 Cost-Benefit Model Framework

The modeling process for both traditional CNC and AM COR molds, detailing key parameters (i.e., mold life, part complexity, production cycle time, and cost per part), is explained in this section. The cost-benefit model framework is presented in Figure 2.

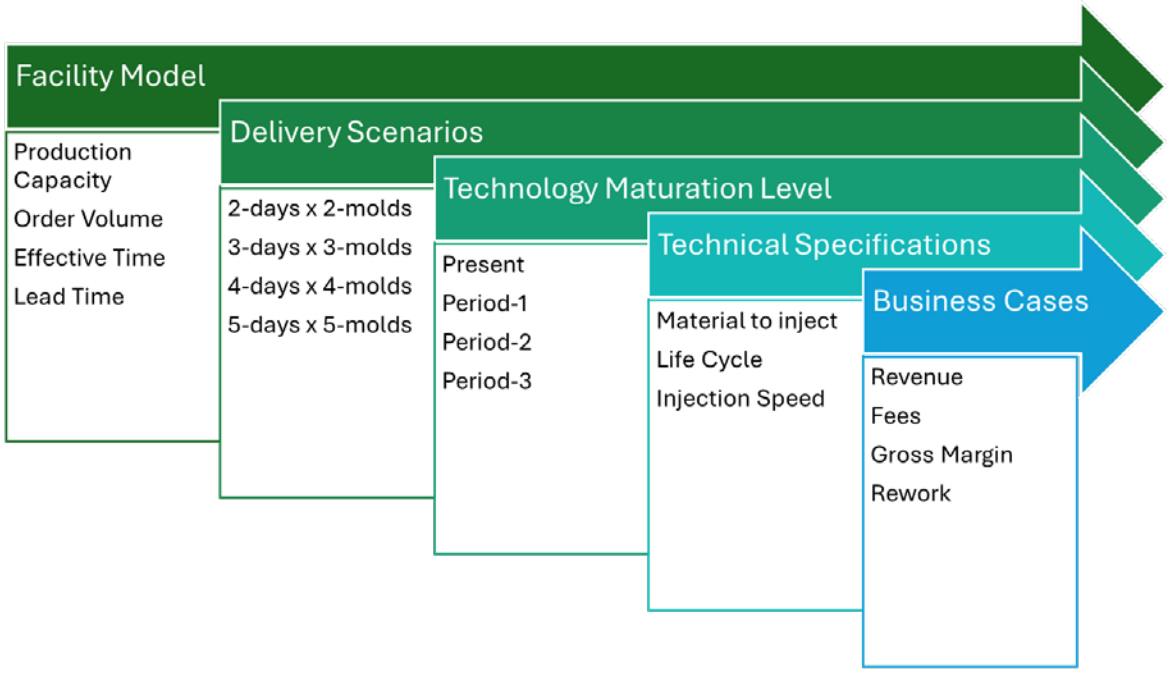

Figure 2. Cost-benefit model framework

The manufacturing cost model of the AM COR mold itself is outside the scope of this analysis. ORNL and polySpectra are developing the process steps, and NLR is conducting an analysis to understand the impact of the AM COR mold on a customer-facing cost-benefit model, assuming all innovation advances are completed as planned. Business cases were centered on factors such as, cost, life cycle, and rework, to reveal opportunities for savings through the initial cost, reduced lead times. Interruptions caused by extended mold fabrication timelines or CNC rework resulting from design modifications can also result in substantial hidden costs. These include lost revenue from delayed product launches and increased labor expenses, emphasizing the monetized value of time in manufacturing operations.

3.1.1 Facility Model Assumptions

The manufacturing facility model outlines the operational framework for a manufacturing plant, based on a set of key assumptions. These parameters were chosen to provide a realistic and representative model of a manufacturing facility representing a medium-scale manufacturing operation. Annual production capacity is designed to meet custom or small-batch production needs. The facility is designed to operate at an annual production capacity aligned with projected manufacturing volumes, functioning over a defined number of operating days and hours per year. A single-shift operation that is typical for medium-scale facilities spans 208–260 days/year, 8

hours/day. It accounts for downtime resulting from maintenance or unexpected disruptions, with effective operating time calculated accordingly. CNC downtime of 20% and 3D printing downtime of 10% reflect realistic expectations in medium-scale operations. The model incorporates a standard equipment depreciation period, influencing capital expenditure planning. Both direct and indirect labor requirements are included, along with their respective labor rates for manufacturing and design roles. Capital investment considerations cover machine costs (CNC machine: $400,000, and 3D printer: $160,000), which are mid-range prices for industrial-grade machines, and the number of machines needed to meet production targets. Energy consumption is an important factor, with assumptions for electric power requirements specific to CNC machines and 3D printers, along with the prevailing electricity price. Electricity price of $0.850/kWh assumes a location with high industrial rates. Together, these variables form the basis for estimating the facility's performance, cost structure, and capacity planning (Table 2).

Table 2. Assumptions for Facility Operations

Facility Operations	Unit	CNC Machining	3D Printing
Annual production capacity	Molds/year	7–10	200–250
Manufacturing volume	Mold/order	1	1–50
Days per year	Days/year	208	260
Operating hours	Hours/day	8	8
Downtime	%	20	10
Effective time	Days/year	232	234
Equipment depreciation period	Year	20	20
Direct worker	Count	1	1
Indirect workers/line	Count	1	0
Labor rate (manufacturing)	$/hr	25	25
Labor rate (design)	$/hr	54	54
Machine cost	$	$400,000	$160,000
# Machines	#	1	1
Electric power	kW	40.00	4.0
Electricity price	$/kWh	0.850	0.850

Table 3 outlines key assumptions for mold tooling parameters used in a manufacturing context. It includes dimensions of the mold, 100 mm × 95 mm × 150 mm (3.94 in. × 3.74 in. × 5.9 in.), which were determined based on polySpectra's initial estimate for the part to be 3D printed, as well as details on the selected mold material, its corresponding density, and associated cost. These parameters serve as a foundational reference for estimating tooling requirements, material selection, and budgeting in mold design and production planning.

Table 3. Assumptions for Mold Tooling Parameters

Mold Tooling Parameters	Unit	CNC Machining	3D Printing
Length	mm	100	100
Width	mm	95	95
Thickness	mm	150	150
Mold volume factor	%	1	0.15
Total volume	m^3	0.001425	0.00021375
Volume of part to injection mold	m^3	0.00043	0.00043
Mold material	n/a	Aluminum	COR Alpha
Material density	kg/m^3	2,710	1,200
Material price*	$/kg	$5.46	$549.00

*Values in 2024$.

3.1.2 Delivery and Production Assumptions

These assumptions are grounded in realistic industrial benchmarks, reflecting typical differences in workflow, process characteristics, and production behavior between CNC machining and AM. They are particularly relevant for medium-scale production environments. CNC molds typically involve low-volume, single-piece orders because of higher costs and longer production times. However, AM (3D printing) supports batch production, allowing more flexible delivery in smaller lots or staggered shipments. Table 4 highlights various delivery assumptions that impact the cost and timeline of implementing the CNC and AM COR molds.

Table 4. Assumptions for Production Speed, Lead Time, and Shipment

Durability and Cycle Time	Unit	CNC Machining	3D Printing
Lead time	Days	28	2–5
Lead time (weeks)	Weeks	4.00	0.29–0.71
Shipment size	#mold	1	2–5
# Shipments	#	1	1–10
Design time	hr	6.50	6.50
Set up time	hr	4.00	2.00
Manufacturing speed	Mold/day	0.04	1.00
Typical manufactured part yield	%	70	95

3.1.3 Financial Assumptions

To support the cost-benefit assessment, several key financial assumptions have been established to provide a consistent basis for comparison (Table 5). These include the value of 1 week of business, which represents the revenue impact of potential production delays, and the average annual revenue per customer, reflecting the typical revenue generated by each client. The average gross margin per customer is used to estimate profitability on a per-customer basis. Operational costs are also considered, such as the fee for 100 parts ($), which accounts for batch

manufacturing expenses. Additionally, tool maintenance and replacement are factored in through the CNC mold rework frequency and the AM COR mold replacement frequency, which highlights expected intervals for tooling updates or replacements. These assumptions form the foundation for evaluating both the financial risks and the advantages associated with the proposed solution.

Table 5. Summary of Financial Assumptions Used in Building Business Cases for CNC Machining and Additive Manufacturing

Variable	CNC Machining	3D Printing
Value of 1-week business ($)	$2,000	$2,000
Average annual revenue per customer ($)	$5,000	$5,000
Average gross margin per customer (%)	20%	20%
Fee for 100 parts ($)	$3,000	$3,000
CNC mold rework frequency (%)	10%	0%
AM COR mold replacement frequency (%)	0%	10%

- The value of 1 week of business ($2,000) is estimated based on polySpectra's assumption for a typical customer at manufacturing volume of 5,000–10,000 parts per order. It is included in quantifying the potential financial impact of production delays, which is an important consideration in manufacturing environments where downtime can lead to lost orders or missed delivery deadlines. This metric serves as a proxy for lost revenue because of delays in tooling or part production.
- The average annual revenue per customer ($5,000) represents the expected income generated from a typical customer over the course of a year. This figure is particularly relevant in evaluating how process inefficiencies or improvements (e.g., faster lead times or more reliable tooling) can influence customer retention and overall revenue generation.
- The average gross margin per customer (20%) provides insight into profitability, helping to assess how changes in production strategy may affect net financial performance. For instance, improvements in efficiency or reductions in rework could translate directly into higher margins.
- The fee for 100 parts ($3,000) is used to represent batch manufacturing costs for a standardized volume, allowing for direct comparison between the unit economics of CNC and AM technologies. This helps highlight differences in per-part cost, especially for low-to-mid-volume production runs in which cost structures diverge significantly.
- Tooling maintenance and life cycle assumptions are also key to understanding long-term operational costs. The CNC mold rework frequency (10%) reflects the expected rate at which CNC molds require repair or re-machining as a result of wear, alignment issues, or damage—factors that introduce additional downtime and maintenance expenses. In contrast, the AM COR mold replacement frequency (10%) assumes periodic full replacement as a result of material fatigue or evolving part design requirements in the additive processes. Notably, AM molds are assumed not to require rework but are instead replaced entirely at defined intervals.

Together, these assumptions provide a practical financial framework to evaluate the relative risks and benefits of each manufacturing method. They mirror real-world operational considerations such as customer revenue impact, tooling reliability, and recurring production costs, making the analysis relevant to decision makers evaluating capital investment or process transitions.

3.1.4 Mold Price Assumptions

The cost of materials plays a significant role in the overall economics of injection mold production. This section focuses on material pricing for molds with dimensions of 100 mm × 95 mm × 150 mm, providing a baseline for cost estimation and comparison. For traditional aluminum molds of this size, the cost is approximately $10,000, based on recent pricing from WP Manufacturing ($2024). In contrast, advanced AM COR molds are priced at $549 per kilogram (polySpectra 2024), reflecting the premium associated with high-performance resin materials. The total cost of the same size COR mold is expected to be approximately $250. Assuming only 15% material usage factor (resulting from internal structures, infill patterns, or optimized material use in 3D printing), the estimated cost of the COR Alfa resin material would be approximately $140, which is approximately 56% of the total mold cost.

3.2 Technical Specifications for Technology Maturation Levels

This section outlines the technical specifications of AM for injection molds across four technology maturation levels each corresponds to one performance year: Present, Period 1, Period 2, and Period 3, each corresponding to a specific performance year within the project timeline. These levels represent progressive stages of technological development, process refinement, and integration into production environments. The Present level reflects the baseline capabilities at the project's outset, whereas Periods 1 through 3 illustrate subsequent yearly improvements in performance, reliability, and scalability.

Key performance indicators analyzed include life cycle per mold, defined as the number of parts that can be produced before mold degradation or replacement, and injection speed, which accounts for the total cycle time per shot, including cooling. These metrics are benchmarked against conventional CNC-manufactured molds for reference. In addition, two critical factors influencing production efficiency, days to finish the order (from mold creation to batch completion), and part complexity (geometric and structural intricacy) are considered to assess the practical applicability of AM COR molds in diverse manufacturing scenarios.

Table 6 summarizes the life cycle per mold for different materials across the four maturity periods relative to CNC molds, whereas Table 7 details the injection speed per mold (in seconds) for each technology level and material type. Together, these data points provide a comprehensive view of the evolving performance and feasibility of AM technologies in the context of injection mold production.

Table 6. Life Cycle per Mold (Parts to Inject) for Different Materials at Each Technology Maturation Level with Respect to CNC Mold as a Reference

Cycles	Present	Period 1	Period 2	Period 3	CNC Reference
Nylon	300	600	1,500	3,000	10,000
Glass-filled nylon	200	400	1,000	2,000	10,000
Polycarbonate	150	300	750	1,500	10,000

Table 7. Injection Speed (Including Cooling Time) per Mold (in Seconds) of Each Technology Maturation Level for Different Materials with Respect to CNC Mold as a Reference

Times (s)	Present	Period 1	Period 2	Period 3	CNC Reference
Nylon	145	111	72	48	20
Glass-filled nylon	145	111	72	48	20
Polycarbonate	120	92	60	40	20

3.3 Field Visit to an Injection Molding Facility

On July 12, 2024, a site visit was conducted at WP Manufacturing's injection molding facility located in Longmont, Colorado. The purpose of the visit was to gain firsthand insight into the operational workflow, equipment setup, and manufacturing processes involved in high-volume plastic part production. During the tour, special attention was given to mold design and tooling practices, as well as the integration of automated systems within the production line. This visit provided valuable context for evaluating material selection, process efficiency, and the practical implementation of aluminum molds in industrial-scale injection molding. Aluminum mold components used in the injection molding process at WP Manufacturing are displayed Figure 3. These images illustrate the tooling's structural design, surface finish, and setup within the mold press environment.

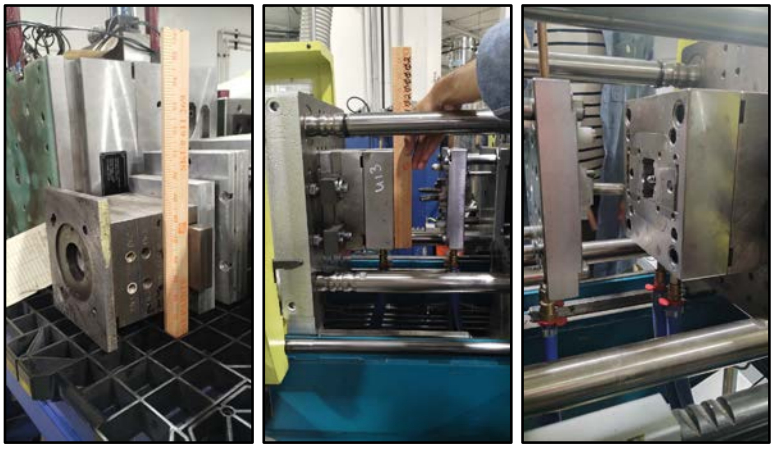

Figure 3. Aluminum mold photos from WP Manufacturing injection molding facility in Longmont, Colorado

4 Model Results

4.1 Cost Comparison

The following figures present a comparative cost analysis of traditional CNC machined molds versus AM COR molds, highlighting both one-time and recurring expenses under varying delivery conditions. Figure 4 illustrates cost breakdown for producing 5,000 parts using glass-filled nylon and polycarbonate materials in a rapid 2-day delivery scenario with 2 molds. The key aspect of this analysis is that the manufacturing facility producing the parts can only produce parts with new molds, and there are no spare molds available immediately. For the CNC or AM COR mold, injection-molded part production can start only once the mold is received and integrated into the operation. In the 2-day delivery scenario, a set of 2 AM COR molds are produced and delivered to the site every 2 days. The AM COR molds are continuously delivered to ensure 5,000 parts can be produced. Because the CNC mold takes 28 days to be made, received, and integrated, the parts production over time remain at zero until day 28.

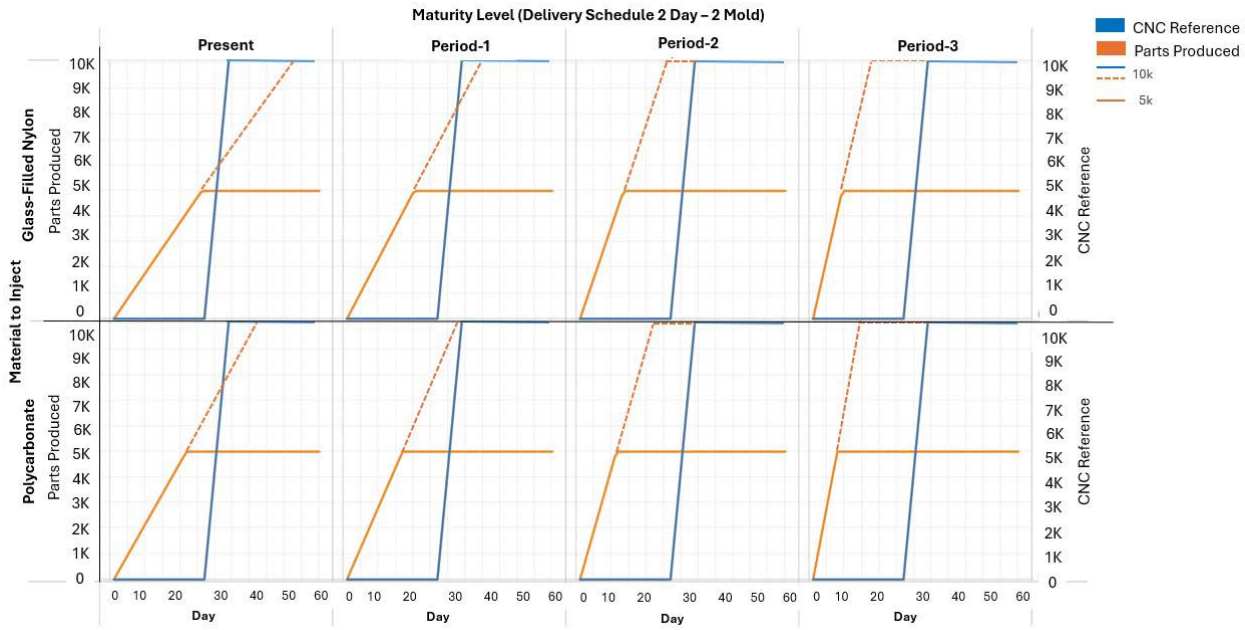

Figure 4. Comparative summary of parts produced from AM COR molds* with respect to CNC machined molds in 2-day, 2-mold delivery scenario for injection of 5,000 parts with glass-filled nylon and polycarbonate materials.

*The orange line highlights the parts produced using the AM COR molds and the blue line, reference production for one aluminum CNC mold up to a life cycle of 10,000 parts.

The CNC mold, because of the speed of the injection process, use of a singular mold, and cooling of the parts, can produce 5,000 parts in 32 days for glass-filled nylon parts and 31 days for polycarbonate parts. The CNC mold is assumed to remain constant in technology and production capability over the time periods. Because the AM COR molds are delivered and integrated into the facility in 2 days, production is zero for the first 2 days.

- Where the orange and blue lines cross (in any period of technological capability) highlights the number of days the AM COR molds and the CNC molds produce the same number of parts.
- For the glass-filled nylon or polycarbonate parts produced in the Present (i.e., the level of the AM COR mold technology at the start of the project), the AM COR molds can produce 5,000 parts in 26 days and 22 days, respectively.
- If the AM COR molds improve over the time periods based on the projected improvements from the research that polySpectra and ORNL are undertaking, the production capability of the AM COR molds increases.
- By Period 3, potentially the AM COR molds could produce the 5,000 glass-filled nylon parts in 11 days, and the 5,000 polycarbonate parts in 8 days, respectively.
- Once the CNC mold is integrated, because of the speed of the injection process and cooling, it can produce 10,000 parts in 35 days for glass-filled nylon, and 34 days for polycarbonate parts.
- With the 2-day, 2-mold delivery schedule, for the glass-filled nylon or polycarbonate parts produced in the Present, the AM COR molds can produce 10,000 parts in 45 days and 40 days, respectively.
- By Period 3, potentially the AM COR molds could produce the 10,000 glass-filled nylon parts in 21 days, and 10,000 polycarbonate parts in 15 days, respectively.
- A similar trend is seen in the extended 5-day, 5-mold delivery scenario (Figure 5), where production with AM COR molds begins on day 5.
- These results show how delivery timing and volume affects cost.
- At the Present, AM COR molds produce 5,000 glass-filled nylon parts in 29 days and polycarbonate parts in 25 days, compared to 32 and 31 days with CNC molds.
- With 5 AM COR molds delivered every 5 days, production time drops to 13 days for nylon and 11 days for polycarbonate by the end of Period 3.

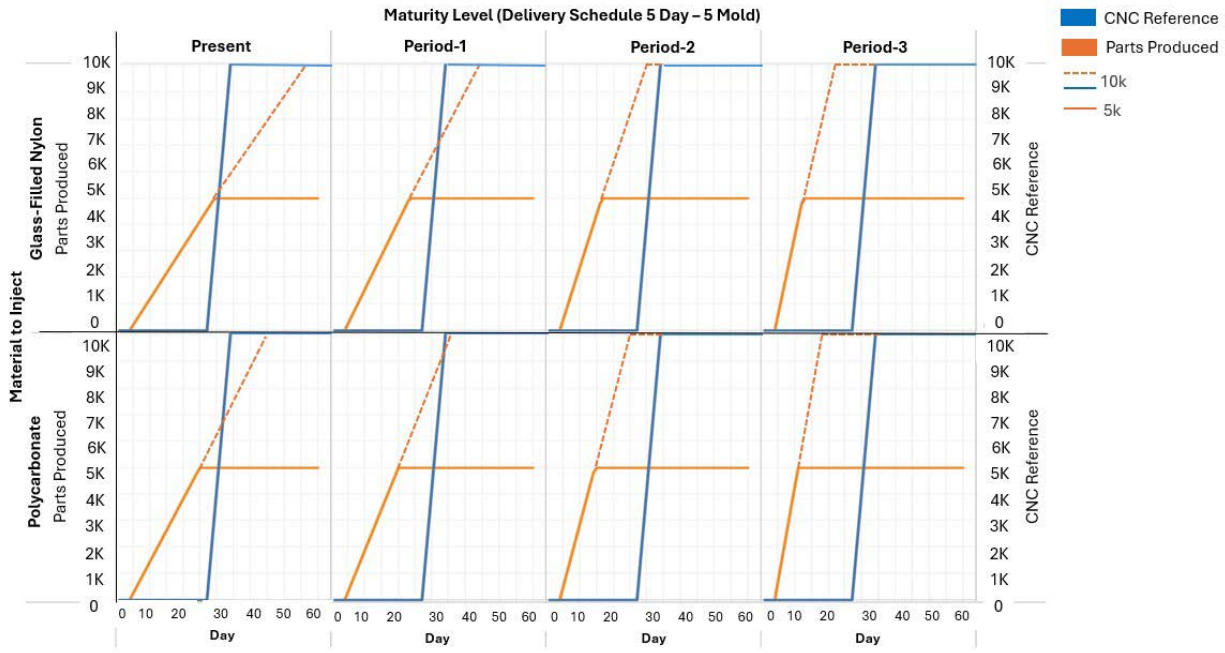

Figure 5. Comparative summary of parts produced from AM COR molds* with respect to CNC machined molds in a 5-day, 5-mold delivery scenario for the injection of 5,000 parts with glass-filled nylon and polycarbonate materials.

*The orange line highlights the parts produced using the AM COR molds, and the blue line indicates reference production for one aluminum CNC mold up to a life cycle of 10,000 parts.

Before a CNC mold arrives, a facility relying solely on this mold faces a 28-day delay with no production, leading to lost revenue. AM COR molds, delivered on a faster schedule, can start production much earlier, helping reduce downtime and improve savings.

- CNC-only production causes a 28-day (4-week) delay before parts can be manufactured.
- During this time, no revenue is generated to fulfill customer orders.
- Each week of downtime equals lost revenue of $8,000 over 4 weeks.
- AM COR molds can be delivered in 2 ways: 2 molds every 2 days, or 5 molds every 5 days.
- With AM COR molds, production can start as early as day 2, instead of waiting until day 28; this significantly reduces wait time and revenue loss.
- Savings depend on the delivery schedule and how many parts must be produced.

As seen in Figure 6, for an order of 5,000 glass-filled nylon parts, using the 2-day, 2-mold delivery schedule, at the present day, there is nearly $5,000 in savings compared to the CNC reference.

- This is calculated considering the 2 days of nonproduction to get the first delivered molds, the number of days to hit 5,000 produced parts (day 26), and the remaining days the CNC reference would hit 5,000 parts (day 32).
- When 10,000 glass-filled nylon parts are considered, as seen in Figure 6, with the 2-molds-in-2-days schedule, with the AM COR molds in the present, there is nearly a $10,000 loss of savings compared to the CNC reference.

- The 2-day, 2-mold delivery model is the most cost-effective across both order volumes (5,000 and 10,000 units).
- The model consistently delivers the highest savings at every maturity level, yielding the highest savings at Period 3.

Figure 6. Customer-facing business model savings for injection molding using glass-filled nylon as a function of delivery schedule, technology maturity level, and order volume

4.2 Breakeven Analysis

The breakeven analysis aimed at identifying the production volume at which AM COR molds become cost-competitive with traditional CNC machined molds. By an examination of mold costs in relation to the number of parts produced, the analysis highlights the thresholds where AM transitions from a high-cost prototyping method to a viable option for low- to mid-volume production. Key variables include material type, tooling costs, and production batch sizes. Figure 7 shows the mold cost as a function of the number of parts injected, comparing AM COR molds and traditional molds across different material types.

A single CNC mold, costing $10,000, can produce up to 10,000 glass-filled nylon parts. This cost remains the same whether you produce 1,000 or the full 10,000 parts. Once the mold reaches its production limit, a new mold is required to continue manufacturing.

The total mold cost for AM COR Alfa molds increases proportionally with the production volume of nylon-glass-filled parts (Figure 7). This is primarily due to the limited lifespan of AM COR molds, which necessitates the procurement of multiple units to meet higher production demands. In contrast, CNC molds exhibit significantly greater durability and can sustain larger production runs without replacement.

As illustrated in Figure 7, the cost curves for AM COR and CNC molds intersect at production volumes of approximately 8,000 and 16,000 parts. At 8,000 parts, the cumulative cost of AM

COR molds equals that of a single CNC mold priced at $10,000. At 16,000 parts, the AM COR mold cost aligns with that of two CNC molds ($20,000).

This cost relationship indicates, for production volumes below 8,000 units, AM COR molds offer a lower total mold cost. Overall, the data highlights that, although AM COR molds are cost-effective for low to moderate production volumes, CNC molds become more economically viable as production scales because of their longer operational life and lower replacement frequency.

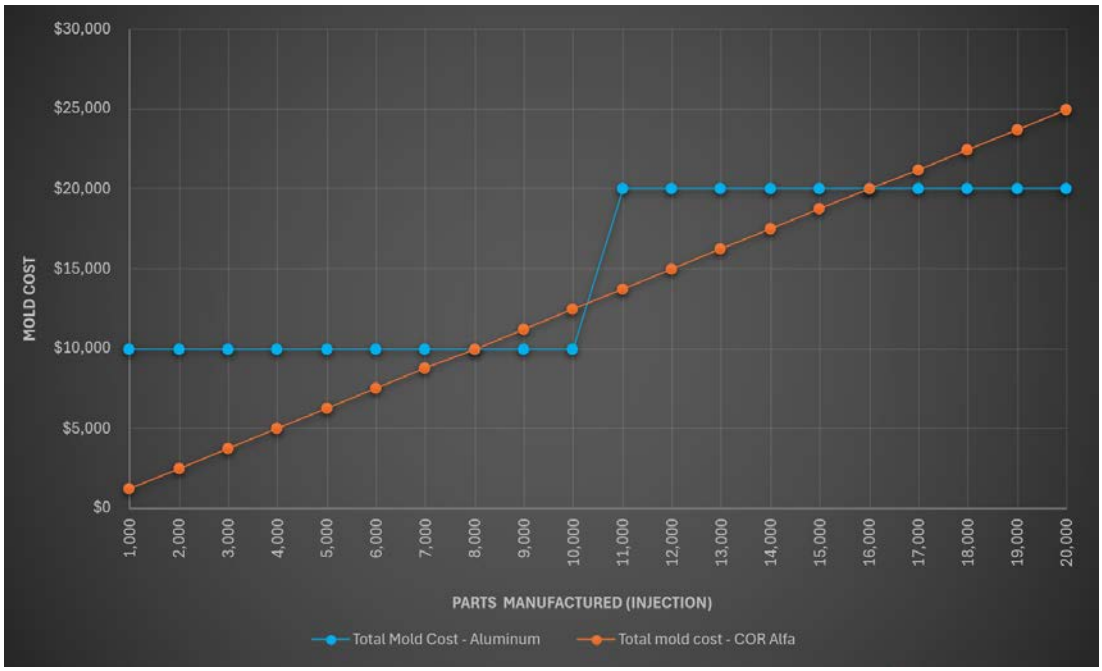

Figure 7. Breakeven analysis for mold cost* with respect to parts injected.

*Glass-filled nylon at Present case—the blue line highlights the CNC aluminum mold cost, and the orange highlights the COR alfa mold costs.

4.3 Sensitivity Analysis

This section presents a sensitivity analysis aimed at evaluating how key variables influence the economic outcomes of adopting AM COR molds. The sensitivity analysis focuses on three critical aspects: mold cost, life cycle, and the impact of CNC mold rework on cost as primary economic drivers affect the overall feasibility and performance of AM COR molds relative to traditional alternatives. Understanding the sensitivity of these variables helps identify conditions under which the AM COR solution delivers the greatest economic value and where its performance may be challenged.

4.3.1 Mold Cost Sensitivity

The cost sensitivity of using AM COR molds in comparison to traditional CNC machined aluminum molds for injection molding processes is analyzed by investigating the variations in mold costs, order-specific mold requirements, and key input parameters to understand how fluctuations in these factors influence the total cost of production. Particular attention is given to the elasticity of the cost structure, the responsiveness of overall costs to changes in mold pricing

and usage conditions, and the resulting implications for economic feasibility. The analysis includes a comparative overview of the cost and quantity of AM COR molds relative to shifts in CNC mold pricing, as illustrated in Figure 8, and highlights critical breakeven points for producing 5,000–10,000 parts using glass-filled nylon and polycarbonate (Figure 8).

The first sensitivity analysis (Figure 10) examines changes in CNC mold pricing over time, while keeping the AM COR mold cost constant at $250 per mold. To produce 5,000 glass-filled nylon parts, the breakeven cost of CNC mold should be $6,250. For 10,000 parts, the cost of CNC mold should not be no more than $12,500 to remain economically competitive with AM COR molds. CNC mold costs can fluctuate because of various factors such as changes in aluminum raw material prices, labor and manufacturing expenses, and potential tariffs, particularly if molds are imported from China to the United States for domestic injection molding.

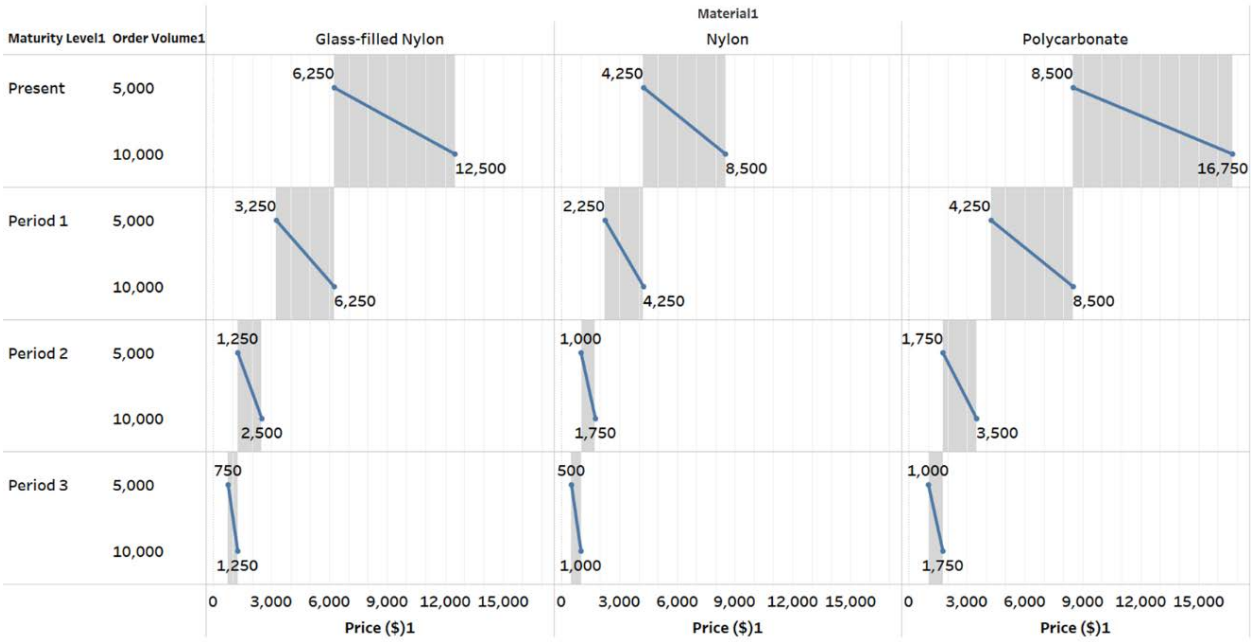

Figure 8. CNC machined aluminum mold price breakeven* points for AM COR injection molds for injection of 5,000–10,000 parts with glass-filled nylon and polycarbonate materials volume.

*AM COR injection molds cost $250.

As improvements extend the life of AM COR molds over time, they become more competitive to CNC molds. For example, by Period 3, if AM COR molds can still be produced for $250 each, then the CNC mold must cost as little as $750 for 5,000 parts, and no more than $1,250 for 10,000 parts to stay competitive. These represent significant reductions, potentially lowering CNC mold costs from $10,000 to under $1,000, which is a challenging target for established technology. This analysis highlights that, with advancements such as enhanced internal cooling and longer AM COR mold life, AM COR molds can become not only more competitive but also a complementary solution for injection moldering manufacturers.

In the second mold cost sensitivity analysis, the aluminum CNC mold cost is held constant at $10,000, while the AM COR mold cost is varied to identify the breakeven point (Figure 9). For

instance, at the current AM COR mold lifespan, the maximum competitive AM COR mold cost is $294 per mold for producing 5,000 polycarbonate injection-molded parts, and $149 per mold for 10,000 parts. As AM technology advances, particularly in terms of increasing the number of parts that can be produced per mold, the allowable AM COR mold cost can rise while still remaining cost-competitive with CNC molds. By Period 3, accounting for such improvements, the breakeven AM COR mold cost increases significantly: up to $2,500 per mold for 5,000 parts and $1,250 per mold for 10,000 parts. This rise in acceptable AM COR mold cost also reflects potential added complexity, such as the inclusion of internal cooling channels or other functional enhancements. Additionally, AM COR mold costs may increase because of factors such as higher polymer material prices, limited supply of AM materials, or more intricate and time-consuming manufacturing processes.

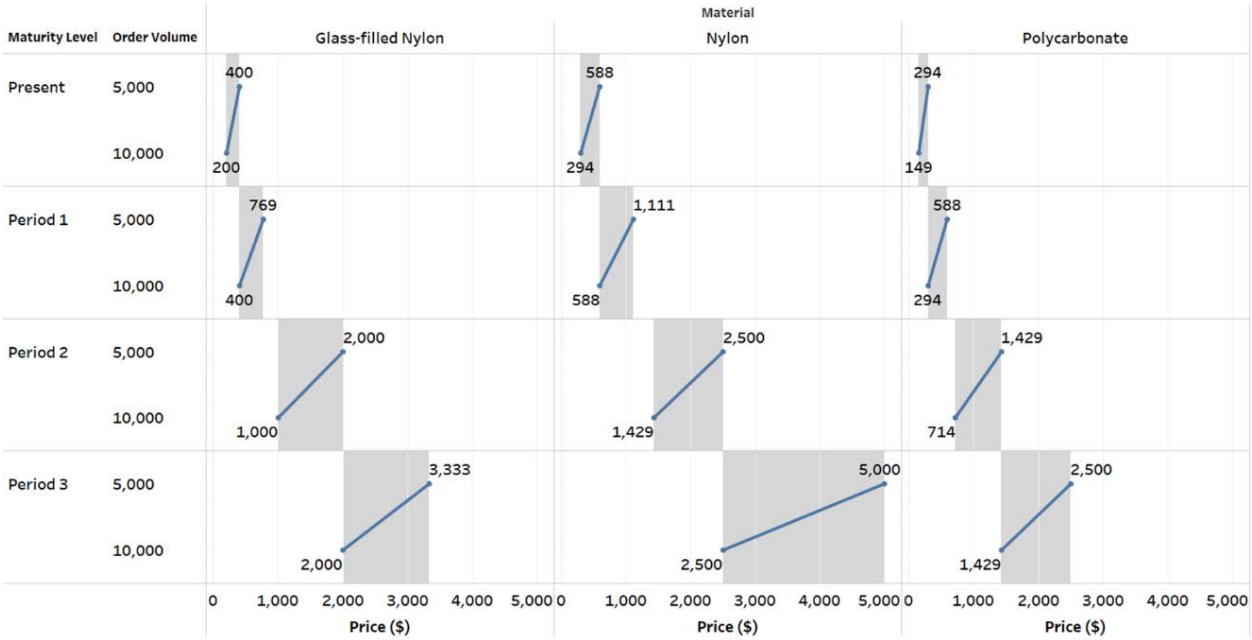

Figure 9. AM COR injection mold price breakeven* points for injection of 5,000–10,000 parts with glass-filled nylon and polycarbonate materials volume.

*Aluminum mold costs $10,000.

4.3.2 Life Cycle Sensitivity

The cost-effectiveness of AM COR molds is highly sensitive to the expected lifetime of each mold, making life cycle analysis is a critical consideration in production planning. Because the durability of the mold directly influences how many cycles it can withstand before failure, a shorter mold lifespan necessitates more frequent replacements, driving up both material and operational costs. Figure 10 and Figure 11 illustrate this relationship by showing the number of molds required to fulfill production orders of 10,000 and 5,000 parts, respectively, as mold lifetime varies. A lower mold lifetime results in a significant increase in the number of molds needed, thereby increasing manufacturing complexity and cost.

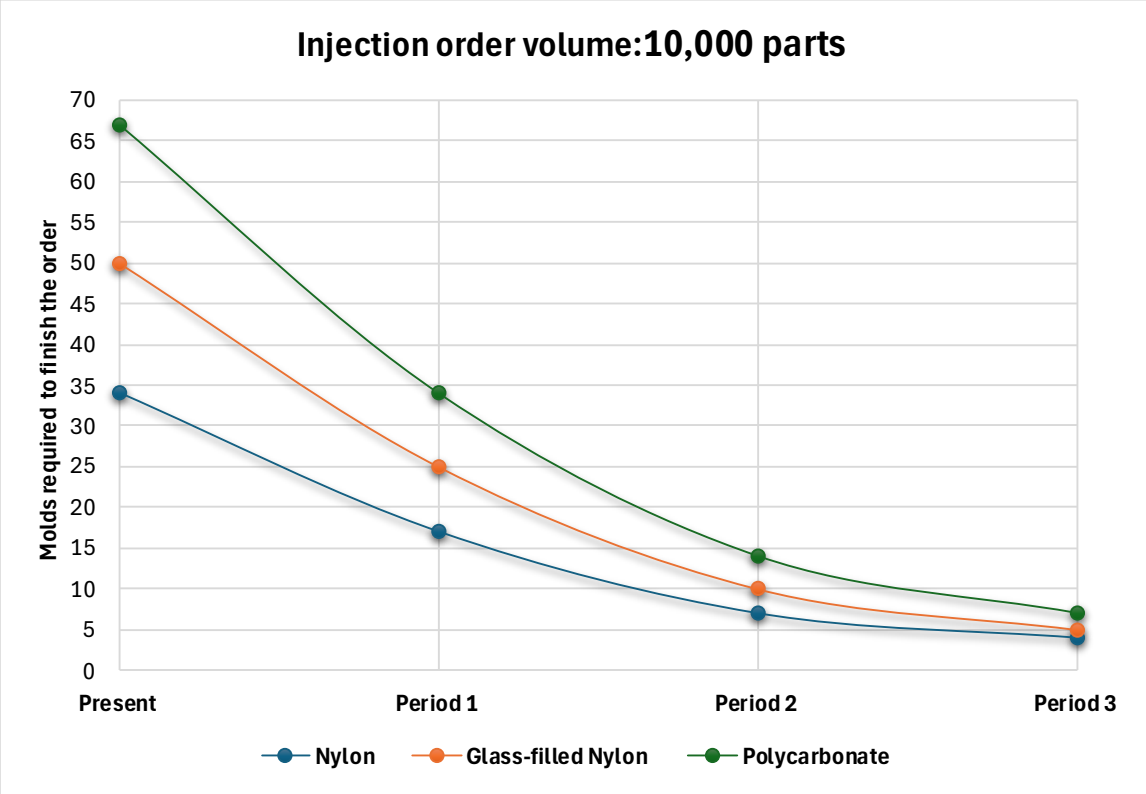

Figure 10. Lifetime sensitivity analysis with respect to molds required to finish the order for 10,000 parts to inject

As shown in Figure 10, to produce 10,000 injection-molded parts using AM COR molds at their current capability, without any redundancy or spares, the manufacturer requires 34 molds for nylon, 50 molds for glass-filled nylon, and 67 molds for polycarbonate. By Period 3, the number of AM COR molds needed to produce 10,000 parts lessens significantly. In this example, only four molds for nylon, five molds for glass-filled nylon, and seven molds for polycarbonate are needed.

A similar analysis was conducted for a production volume of 5,000 parts, and the trend remains consistent, as illustrated in Figure 11. At the current capability of AM COR molds, 17 molds are required for nylon and 34 molds for polycarbonate. With technological improvements by Period 3, only three to five molds are needed to meet the production requirements.

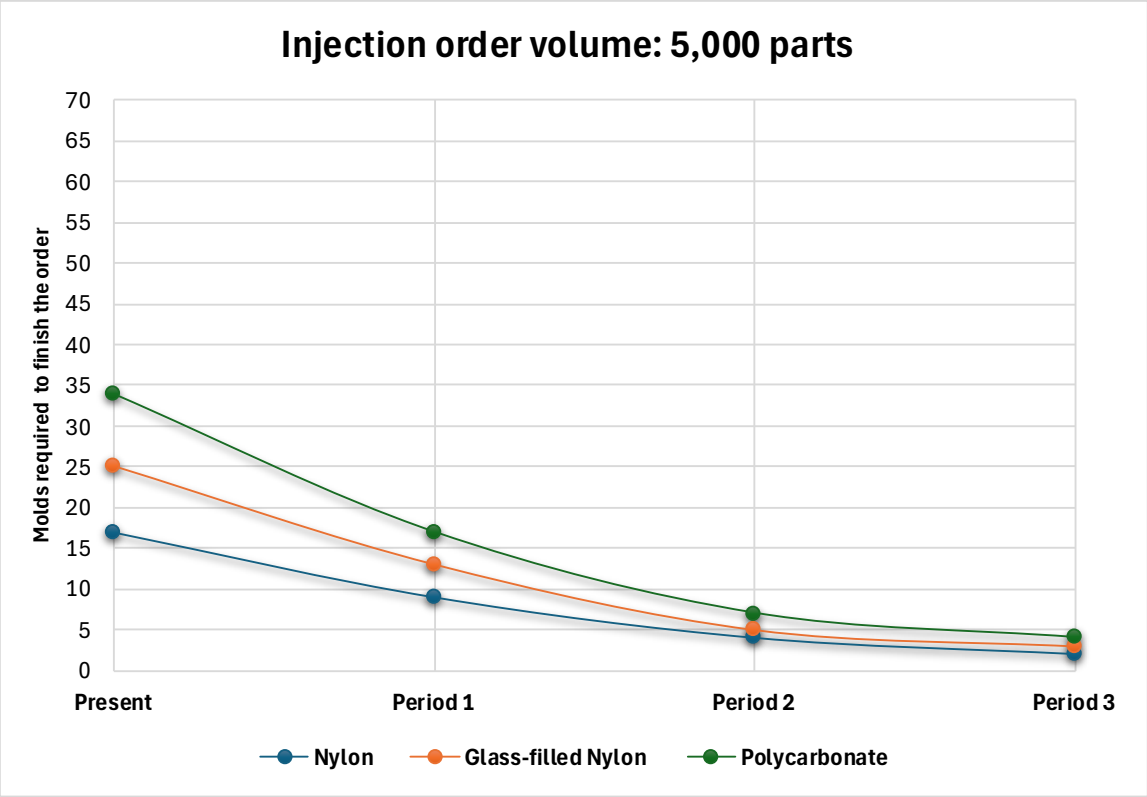

Figure 11. Lifetime sensitivity analysis with respect to molds required to finish the order for 5,000 parts

Similarly, Figure 12 and Figure 13 demonstrate how mold life impacts the total production timeline for the same part quantities, highlighting how frequent mold changes can prolong production schedules and reduce throughput efficiency. These findings emphasize that extending the functional life of AM COR molds is key to maximizing their economic and logistical viability in injection molding operations. As seen in Figure 12, at present the AM COR molds, and having a constant supply of the molds, could fulfill an order of 10,000 parts in 51 days for nylon and glass-filled nylon parts, and 42 days for polycarbonate parts. By Period 3, the number of days needed to fulfill the 10,000-part order has been reduced to 17 days (for nylon and glass-filled nylon parts), and 14 days for polycarbonate parts. Through the periods, this is approximately a 67% reduction in production time for nylon, glass-filled nylon, and polycarbonate parts.

Figure 13 shows the same reduction in production days to complete a 5,000-part order. With the present technology (or at the start of the project), 25 days are needed for injecting nylon and glass-filled nylon parts) and 21 for polycarbonate parts. As the AM COR mold technology improves to Period 3, the production time reduces to 8 days (for nylon and glass-filled nylon parts) and 7 days for polycarbonate parts.

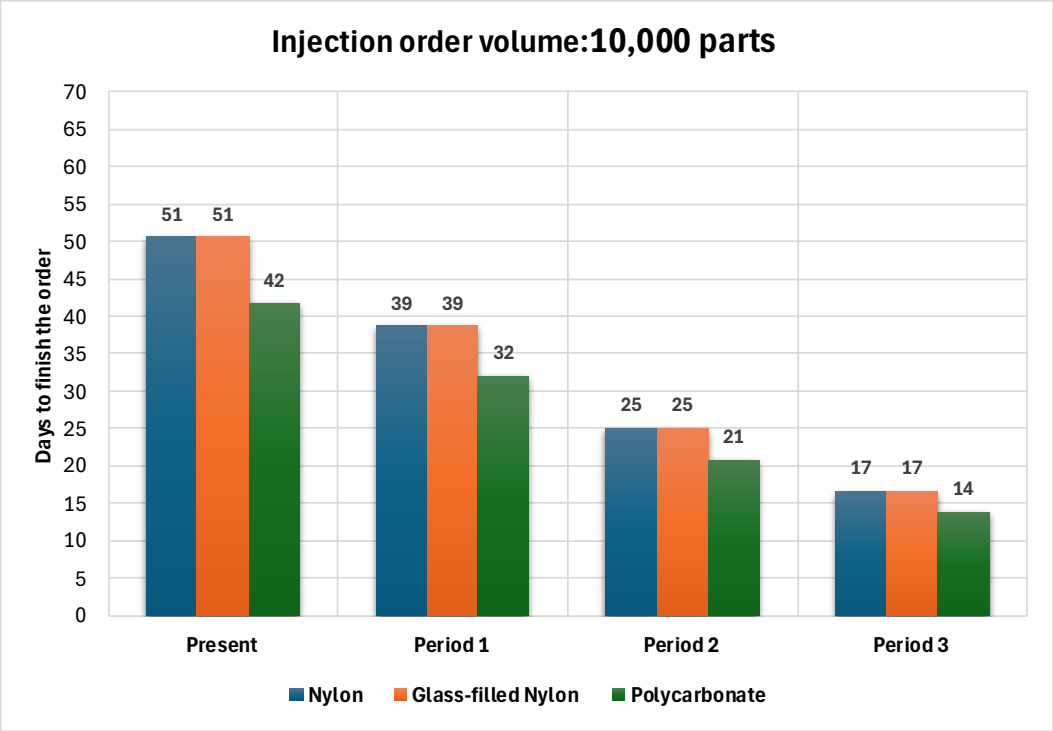

Figure 12. Lifetime sensitivity analysis with respect to days to finish the order for 10,000 parts to inject

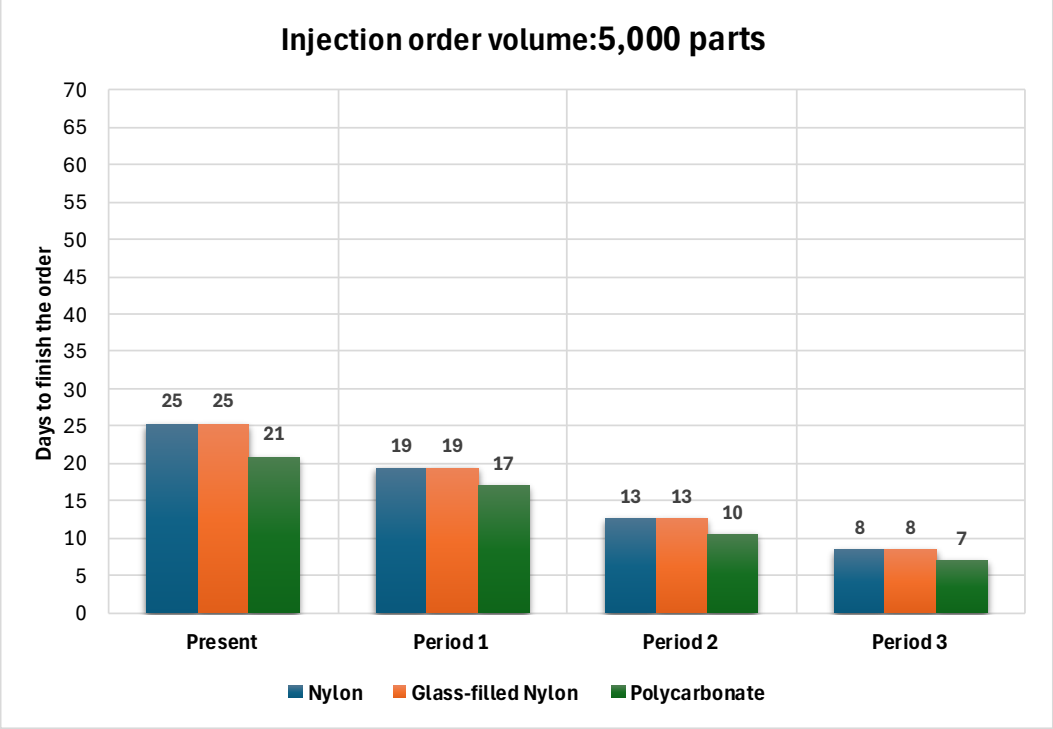

Figure 13. Lifetime sensitivity analysis with respect to days to finish the order for 5,000 parts to inject

4.3.3 Impact of CNC Mold Rework on Cost

This analysis examines a case scenario to evaluate the impact of CNC mold rework on overall production costs by comparing it with the use of AM COR molds at present technology level and a manufacturing volume of 5,000 parts. The scenario assumes a weekly business value of $2,000 and includes 1 CNC mold and 25 AM COR molds in production. It considers downtime of 2 weeks per CNC rework and 0.29 weeks per AM COR mold replacement, with mold replacement frequencies of 10% for CNC and 5% for AM COR molds. Three CNC mold cost levels ($5,000, $10,000, and $15,000), with each mold incurring an additional $650 in design and tooling costs, are compared against three AM COR mold cost levels (ranging from $250 to $650, with $100 increments). The analysis calculates total cost savings by factoring in replacement costs and production time lost because of rework. The results show total savings ranging from $3,150 to $4,400, depending on the combination of mold type and cost (Figure 14). These findings highlight the economic impact of CNC rework and demonstrate the potential benefits of adopting AM COR molds in reducing operational costs.

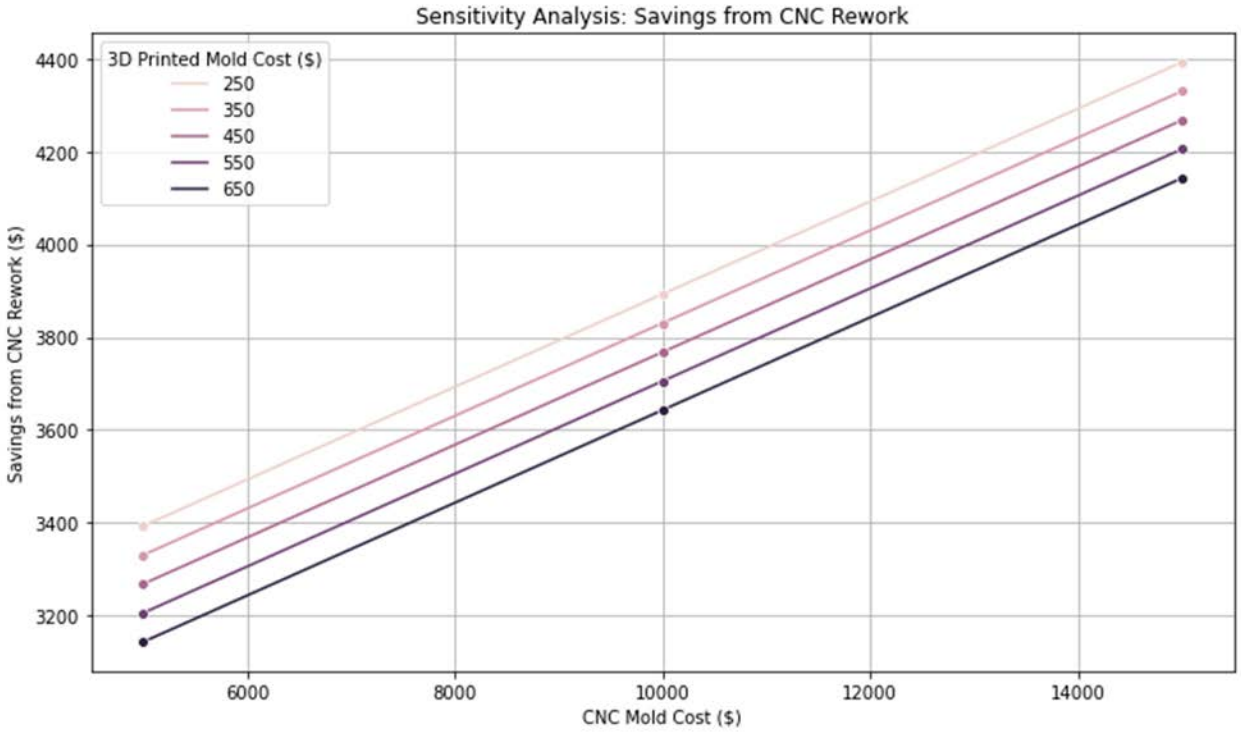

Figure 14. Projected cost savings from CNC rework vs. AM COR mold replacement across varying mold costs

5 Summary of Key Findings

The analysis found that AM COR molds offer several advantages over traditional CNC aluminum molds, particularly for low- to mid-volume production. Key benefits include significantly faster lead times (2 days vs. 28 days), reduced production times (up to 3× faster by Period 3), and much lower initial tooling costs (as low as $250 per mold). As technology advances, the durability of AM COR molds is expected to improve from 200 to 2,000 parts per mold, further enhancing their cost-effectiveness. However, early limitations include shorter mold lifespans compared to CNC molds (10,000 parts) and reliance on successful implementation of planned performance improvements. The breakeven analysis shows that to remain competitive with AM COR molds; CNC molds must cost no more than $6,250 for 5,000-part manufacturing volume and $12,500 for 10,000-part manufacturing volume. Overall, the AM COR approach is most economical under a 2-day, 2-mold delivery model and becomes increasingly attractive as performance improvements are realized.

The findings of this cost-benefit analysis are grouped under time savings, material savings, and operational flexibility, which enables faster prototyping, quicker design iteration, and accelerated time-to-market. This is especially important in fast-paced industries such as consumer electronics, aerospace, medical devices, and automotive.

5.1 Time Savings

AM COR molds significantly reduce lead times, from several weeks or even months, with traditional manufacturing methods to just days or hours. As highlighted, even at the present printing speed, such as 1 AM COR mold printed in 1 day and 2 molds being delivered in 2 days, an injection molding facility can begin producing parts almost immediately. Compared to the AM COR mold, the CNC mold takes approximately 4 weeks to arrive before parts can start production again. As a result of the massive capital investment of the specific metal molds, the industry practice is not to have backup or spare molds for low volumes of production. For large volumes of production (i.e., 100,000 parts or more), it would be more reasonable to have spares.

This accelerated turnaround is especially valuable in industries where speed-to-market is a crucial competitive advantage, such as car parts, consumer products, aerospace, and medical devices. Faster prototyping leads to quicker iteration cycles and shorter R&D timelines, enabling companies to bring products to market faster and begin generating revenue sooner.

The monetary value of the time savings can be substantial, particularly in time-sensitive production runs or products with short life cycles. Based on an interview with WP Manufacturing, in Longmont, Colorado, lead times for traditional CNC aluminum tooling typically range from 2 to 8 weeks, depending on complexity and shop load, whereas AM COR molds can be completed in just 1 to 5 days, resulting in time savings of 70% to 95%. The analysis only considered $2,000 in business value per week. If each week of downtime not producing certain parts was higher (i.e., $10,000 per week), the time saving and the ability to generate revenue in 1 week versus 4 to 8 weeks become significantly valuable.

5.2 Material Savings

3D printing for mold production often uses only the material required to form the mold structure, generating significantly less waste than subtractive methods such as CNC machining.

Additionally, AM COR molds are generally less expensive than the hardened steel or aluminum that is required for traditional molds. For example, the cost of AM COR molds ($250–$500/mold) compared to a CNC machined aluminum mold cost ($5,000–$10,000/mold).

This efficiency leads to lower raw material costs, particularly for prototypes and low-volume production runs. Because 3D printing eliminates the need for large stock blocks, manufacturers also avoid over-purchasing and reduce scrap. Strategic use of high-strength polymers allows for selective reinforcement instead of overengineering entire molds. Although AM materials may be more expensive per kilogram than raw metals, the overall material use is typically much lower. However, for high-volume applications, material wear and thermal degradation may diminish the cost benefits.

5.3 Operational Flexibility

AM COR molds offer operational flexibility, supporting on-demand manufacturing, rapid design changes, and quick iteration—all essential features of an agile development environment. This flexibility enables manufacturers to adapt quickly to design updates, customer requirements, or regulatory changes without incurring substantial delays or costs.

Economic advantages include avoiding expensive CNC rework, which can cost between $2,000 and $5,000 and take 1 to 2 weeks. In contrast, a revised AM COR mold can be produced overnight for less than $100. 3D printing supports rapid design modifications and on-demand mold production. This agility allows manufacturers to quickly respond to changes in customer needs or regulations. It also opens the door to mass customization, particularly valuable in sectors such as automotive, aerospace, and medical technologies, in which tailored components are often required. Long-term savings on tooling, labor, and rework further enhance the economic appeal.

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