REPORT

Executive Summary

The following report shows the results of the investigation performed on the technological feasibility and market viability of Zippy, a programmable bipedal robot that is intended to be released as a customizable bipedal STEM toy robot into the market. The study had two objectives: (1) to compare cost structures and manufacturing trade-offs between injection molding and 3D printing, and (2) to establish consumer preferences and market potential using conjoint analysis. The decision variables that led this study were **price, battery type, motor type, controller board, plastic type,** and **manufacturing process.** A comparison of the unit cost was estimated for injection molding and 3D printing across three production scenarios: worst-case, base-case, and best-case. Cost observations are:

- **3D Printing**: More practical for low volumes.
- **Injection Molding:** Becomes significantly cost-efficient in volumes above **31,000 units**.

In order to achieve greater profitability at higher volumes, it is recommended to switch to automated injection molding, which will further reduce cost and enhance the efficiency of production. The modeled market outcomes were based on three estimated yearly volumes: 200,000, 600,000, and 1,000,000 units, with an estimated total revenue potential of $580 million. Customer choice was modeled by testing such attributes as battery life, ability to be programmed, and the type of assembly delivered. The main findings indicate that the consumers are willing to pay:

- **+$14** per additional hour of battery life.
- **+$14** for basic programming vs. pre-programmed or advanced AI coding.
- **+$1** for DIY assembly.
- **-$25 to -$27** for pre-programmed and pre-assembled products, indicating lower perceived value.

Simulated market share among five realistic competitors (all in the $70–$110 price range) showed that Zippy would dominate the market with **~29% market share**, controlling the segment with its combination of semi-assembly, low programming, and mid-price point **($80)**. Cost estimates have an uncertainty range. The unit manufacturing costs under the injection molding estimate are **$26** [range: $20–$39]. Volume estimates are between **200K and 1M** units. Unknowns are:

- Tariffs and offshore component buying (specifically from China).
- Logistics and supply chain infrastructure (details not completely defined).
- Aesthetic appeal and shell design (not yet included in production costs).

The analysis indicates that Zippy is economically viable, especially if produced through injection molding in bulk. To gain a stronger market foothold and commercial success, the following recommendations should be considered:

- Shift to automated injection molding after 31,000 units.
- Enhance aesthetics with a physical shell design.
- Mitigation of sourcing risk through the evaluation of alternative suppliers or domestic manufacturing.
- Ongoing research on distribution and logistics planning to enable high-volume sales.

Zippy's unique customization, durable battery life, and learning value position it advantageously in the competitive landscape of customizable bipedal STEM toy robots.

Introduction

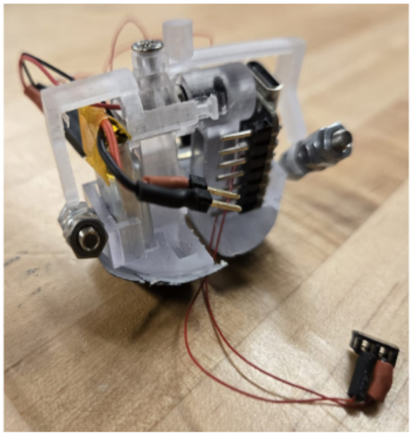


Figure 2.1: Zippy

Technology

Zippy is a 3 cm tall, fully customizable, bipedal STEM toy robot designed to introduce children to coding, robotics, and mechanical engineering through interactive, hands-on learning. It features a compact coreless DC motor, a rechargeable LiPo battery, and a microcontroller, allowing users to modify walking patterns by adjusting parameters like voltage, delay, and balance. The body of Zippy is made from modular, 3D-printed or injection-molded components, enabling children to creatively redesign, swap, and upgrade parts for both functional and aesthetic purposes.

Production Process

To support both early-stage prototyping and scalable commercialization of Zippy, two production methods for manufacturing its mechanical components were evaluated: **3D printing** and **injection molding**. The optimal method depends on production volume and cost efficiency. 3D Printing should be used for production volumes of up to 31,000, and injection molding above that.

Process Overview

The production flow shown in Figure 2.2 consists of several core steps: mechanical component manufacturing (3D printing or injection molding), electrical preparation, assembly, quality control, and final packaging. Inputs include raw materials (e.g., PLA or ABS plastic), purchased components (motors, batteries, microcontrollers), labor, and equipment. Outputs are final boxed Zippy units, with an expected rejection rate of 5–10% in early stages due to mechanical defects or soldering errors.

<ins>3D Printing – Small-Scale Production</ins>

In small-scale production, 3D printers such as the Bambu Lab PS1 are used to fabricate Zippy's arms and legs using PLA filament. While this method allows for flexible iteration and complex geometries, it involves longer print times and higher unit labor costs. Post-print, support structures are manually removed and inspected. Rejected parts are discarded. Parallel to component printing, firmware is uploaded to the microcontroller using a workstation, and wires are soldered manually to enable connection to motors and batteries. Following this, all components (electrical and mechanical) are assembled in four sub-steps. A quality control station checks Zippy's operability by testing for voltage balance and movement. Units that pass QC are fitted with their external shell and packaged along with printed manuals and accessories.

<ins>Injection Molding – Large-Scale Production</ins>

For volumes exceeding 31,000 units, injection molding becomes the cost-effective alternative. An Engel Victory 220 machine with custom aluminum molds, capable of producing 8 parts per batch, is selected for injection molding. ABS plastic is the preferred input material for its strength and compatibility with molding. Although this process requires a higher initial tooling investment, it significantly lowers per-unit costs and accelerates throughput, making it ideal for meeting large-scale demand. The remaining steps in the production flow are coding, soldering, assembly, QC, and packaging, which mirror those used in the 3D printing process.

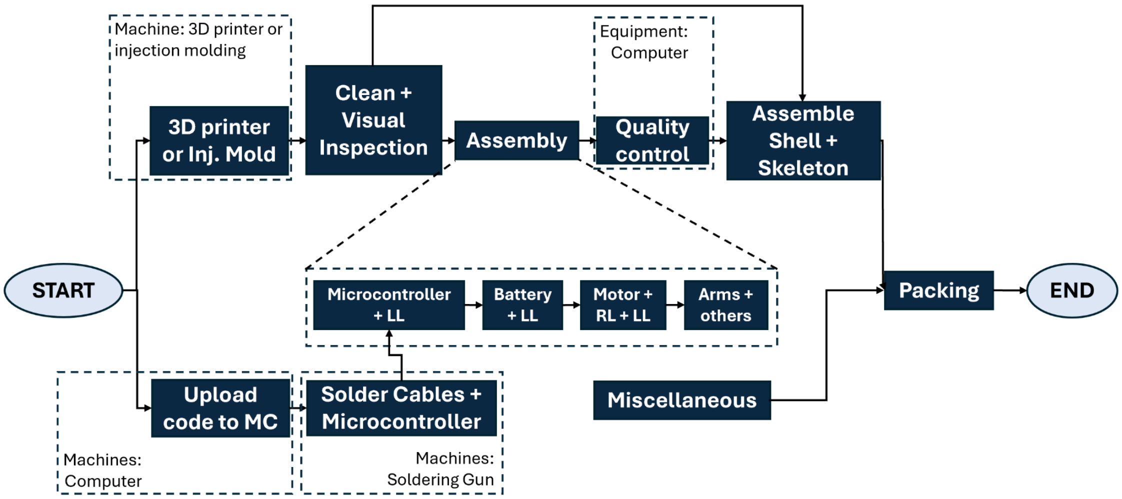


Figure 2.2: Process flow diagram to manufacture Zippy

Market Application

Zippy targets children aged 8–15 years, a group comprising approximately 24 million individuals in the U.S. Of these, about 25–30% (roughly 6 million) show interest in STEM toys. Around 50% of their parents are willing to spend approximately $100, narrowing the potential buyer pool to 3 million. An estimated 33% of these children express a preference for customizable bipedal robots, resulting in a best-case demand projection of around 1 million units. Production volume assumptions include a best case of ~1 million units, a base case of ~600,000 units, and a worst case of ~200,000 units. At an expected price point of $80, the Serviceable Obtainable Market (SOM) is estimated at approximately $580 million, though actual demand may vary based on broader market dynamics.

Zippy's primary competitors include the Freenove Bipedal Robot Kit, ACEBOTT QD021, and Tamiya Bipedal Robot. Compared to these alternatives, Zippy offers greater customizability, basic programming capabilities, longer battery life, a smaller, more portable design, and affordable mid-range pricing between $55–$80. These differentiated attributes position Zippy to address an emerging market demand for interactive and educational STEM toys.

Key Decisions

- **Battery Type**: Li-Po selected for its lightweight properties and high discharge capability, aligning with Zippy's design priorities for balance and performance.
- **Motor Type**: Choose Brushed DC motors for a balance between durability, efficiency, and cost; Coreless DC reserved for potential upgrades.
- **Controller Board**: Adopted Seeed XIAO nRF52840 for compact design and Bluetooth functionality; Arduino Nano 33 BLE considered for future expansion.
- **Part Count**: Minimized to 4 parts to simplify assembly and improve durability.
- **Frame Material**: ABS used for injection molding (durability, lightweight); PLA for 3D-printed prototypes.
- **Pedal Material**: Rubberized anti-slip tape selected to enhance walking stability.
- **Manufacturing Process**:
  - 3D Printing for small-scale production (<31,000 units).
  - Injection Molding for large-scale production (>31,000 units) to reduce per-unit costs.

Each decision was made to optimize Zippy's cost structure, usability, and educational value.

Production Analysis

Production Model

Zippy is a small-sized bipedal robot that contains both mechanical and electronic components. To optimize its profitability as a STEM toy, its fabrication must be optimized. The process flow diagram shown in Figure 2.2 shows the optimal step-by-step procedure to manufacture a Zippy.

The current process used to manufacture a single unit of Zippy considers the use of a 3D printer to build the skeleton. However, another option that is viable to scale up the production is to replace the 3D printing stage with injection molding. This process tends to have a higher efficiency in large-scale production, maintaining the quality and replicability of the parts. The process flow diagram shown in Figure 2.2 is valid for both manufacturing processes.

Some of the steps must be sequential, but others can be done simultaneously. In the case of the code required to run Zippy, it can be uploaded while the skeleton is being printed. Consequently, the Upload code to MC shown in Figure 2.2 is a parallel activity to 3D printing or Injection Molding. After uploading the code to the microcontroller, cables must be soldered to it for them to be later connected to the battery and motor. Parallelly, after the parts of the skeleton have been manufactured, a visual inspection step is performed to ensure that the parts were correctly produced and that they can be used. The following step, called Assembly, contains all the sub-steps in which the mechanical and electronic components are assembled, such as the legs, arms, motor, battery, and microcontroller.

The following step is called Quality Control, and it consists of evaluating whether the assembly of Zippy can move. Since the code has already been uploaded and the components have been assembled, only failed Zippys will fail to pass this step and be considered rejected. Next, the shells produced to customize the exterior of Zippy using either 3D printing or injection molding are assembled with the skeleton. Finally, the Packing step culminates the production of Zippy as a STEM toy that is ready to be placed on a shelf to be sold.

Unit Cost Curve

The process flow diagram shown in Figure 3.1 allows a detailed definition of the costs incurred at each step. This model is called a Product-Based Cost Model. Through this model, the material, equipment, labor, and additional costs are defined. The results of this model are presented in the unit cost curves shown in Figures 3.1 and 3.2.

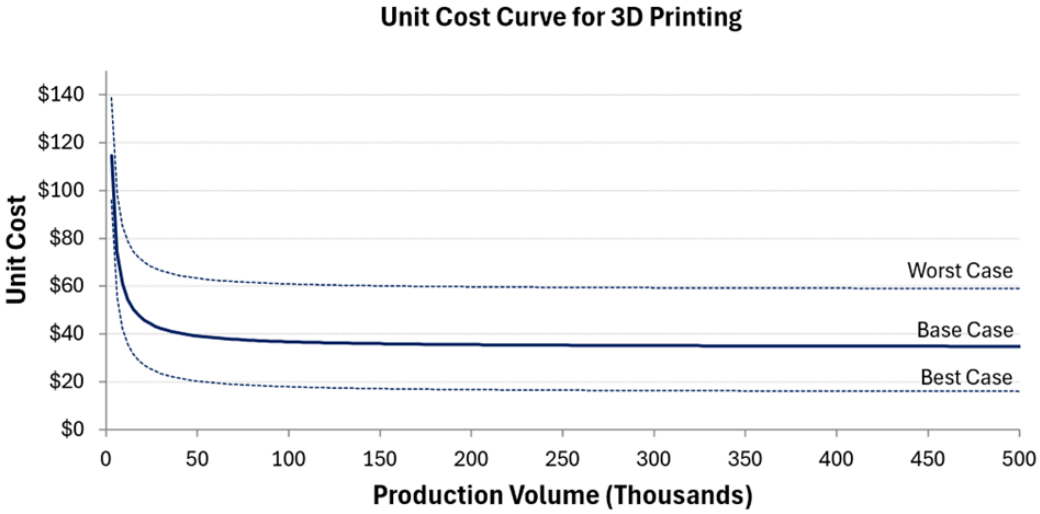


Figure 3.1: Unit cost curve considering 3D printing as the manufacturing process

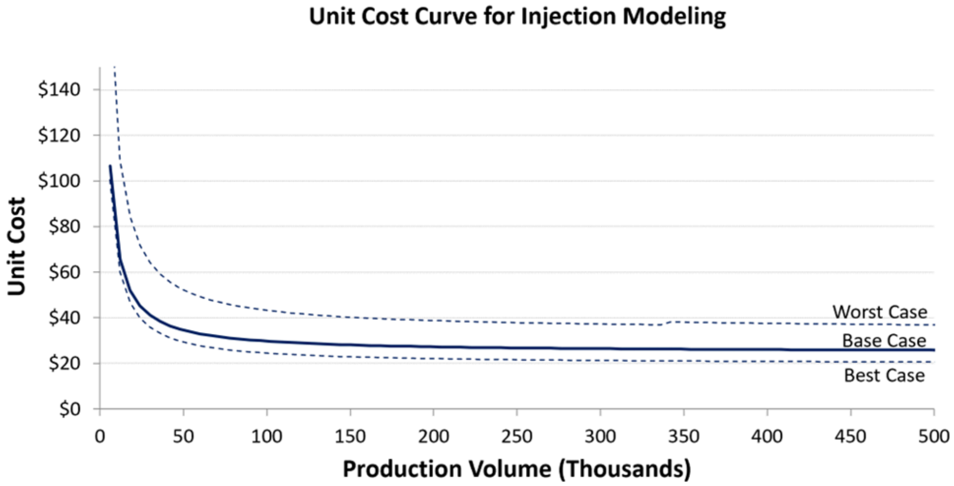


Figure 3.2: Unit cost curve considering injection molding as the manufacturing process

The unit cost curve shown in Figure 3.1 shows a base case scenario for the unit cost of producing Zippy with respect to the annual production volume if 3D printing is selected as the process to print the legs and arms. The uncertainty of this base unit cost curve is limited by a best- and worst-case scenario, considering that the prices of some raw materials or processes involved in the fabrication of Zippy may be lower or higher, respectively. Similarly, Figure 3.2 shows a base case scenario for the unit cost of producing Zippy with respect to the annual production volume if injection molding is selected as the process to produce the legs and arms.

In the case of 3D printing, the base unit cost tends to stabilize approximately at $35. In the case of injection molding, the base unit cost tends to stabilize approximately at $26. The difference in price is mainly because of the raw materials used. First, the plastic considered for the injection molding process is considerably cheaper per kilogram than the base price of the plastic filament considered for the 3D printing process. Also, the speed and scalability of injection molding compared to a 3D printer are noticeably higher. Hence, more units can be produced in the same period. Finally, since injection molding allows for large production, the prices of the electronic components tend to drop since a higher demand for them lowers the unit price at which these components can be bought from suppliers.

Cost Breakdown

The Product-Based Cost Model also details the distribution of cost through the steps described in Figure 2.2 and the type of material or operation. Figure 3.3 shows the cost breakdown for 3D printing.

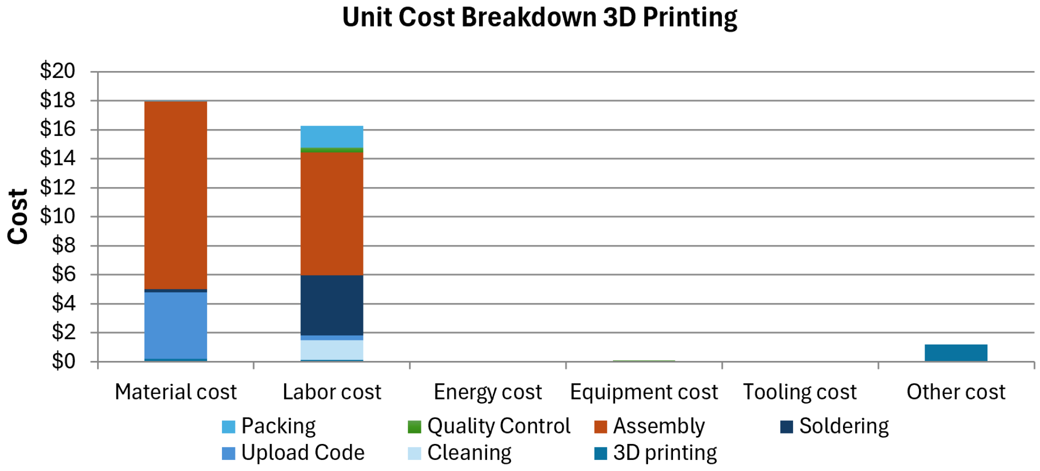


Figure 3.3: Unit cost breakdown considering 3D printing

It shows how most of the cost of Zippy is concentrated in the assembly step. Additionally, most of the cost is being used by the materials used (plastic filament, electronic components, etc.). The second category that concentrates a high share of the costs is labor, which is consistent with the manual labor required for this process.

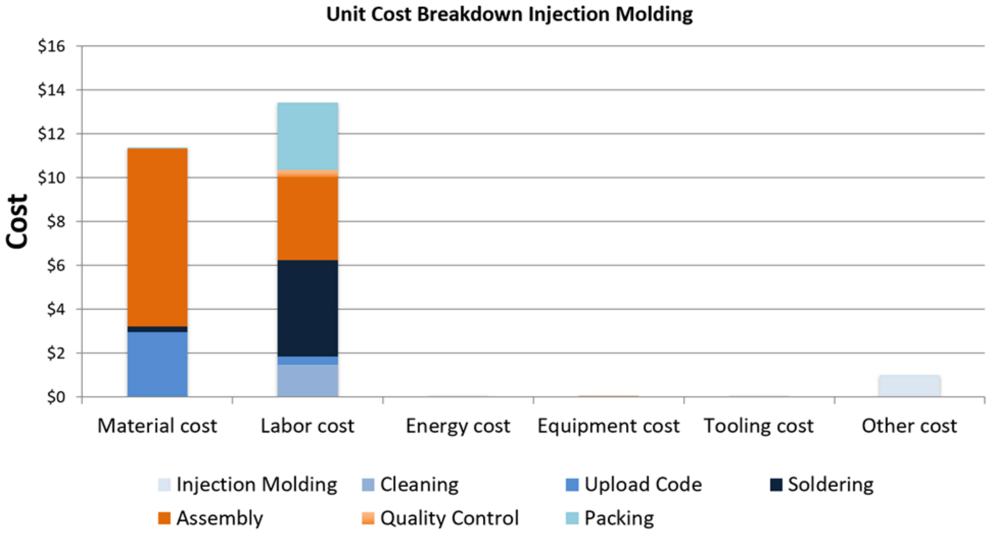


Figure 3.4: Unit cost breakdown considering injection molding

Figure 3.4 shows the cost breakdown if injection molding is used. In this figure, the assembly step also has the majority of the share of the cost, but there is a shift regarding the category that leads to costs. For injection molding, labor cost has the highest share, followed by material cost. This finding goes along with the large-scale production that injection molding allows, which in turn lowers the unit cost of materials bought from other suppliers, such as electronic components.

Cost Drivers and Cost Levers

The main cost drivers for both manufacturing alternatives are material and labor. The material consists of the plastic used for the 3D printers of the molds used with the injection molding machines. Also, the price of the motor, battery, and microcontrollers has a high impact on the overall unit cost. A potential alternative to reducing these costs is to work on a contract with a foreign supplier that can commit to lower-than-market prices if the whole demand is solely given to them.

Another alternative is to design a customized battery, microcontroller, and motor that have sufficient attributes to correctly operate the functions of Zippy. Since the electronic components chosen for Zippy were picked from the available market, some of them have attributes that exceed the requirements of this project. A custom design combined with a foreign manufacturer could significantly reduce the costs of these parts and consequently reduce the unit cost of Zippy (Refer to appendix[14,15]).

Production Analysis Conclusions

The main cost drivers are the materials required to manufacture Zippy. These materials represent around 45-55% of the total cost, and even though there might be some alternatives to keep reducing them, these possible solutions could also put the project in a vulnerable condition. If most of the materials were to be acquired from international sources, the current variability of the tariffs would make this project highly volatile. Since the tariffs are also dependent on the country of origin, centralizing the demand on solely one supplier could lead to a highly variable total unit cost if tariffs were to be increased by the government. Consequently, in the current scenario, the best alternative is to diversify the suppliers with respect to their country of origin.

Demand Analysis

Demand Model

Survey

The survey for Zippy, a customizable bipedal STEM robot for children aged 8–15, aimed to assess customer preferences, estimate willingness to pay (WTP), and simulate market share based on product attributes. It included 16 questions: 9 discrete choice-based conjoint (CBC) questions, 2 demographic questions, and 5 warm-up or context-setting questions. Each CBC question presented three product alternatives and an opt-out option to improve realism and response validity. The products varied across four key attributes—price ($70, $100, $130), battery life (1, 2, or 3 hours), programming (pre-programmed, basic coding, advanced coding), and assembly type (DIY, semi-assembled, pre-assembled).

A total of 140 screened respondents, all parents, guardians, or relatives of children aged 8–15, participated. Most were aged 25–50, with one under 18, one over 61, and none between 18–24, and participants came from urban, suburban, and rural areas. Additional questions captured STEM toy purchase frequency, preferred purchase channels (e.g., Amazon, retail stores), and preferred control methods (manual, remote, app-based). An attention-check question featuring a clearly superior product was included to flag inattentive responses; no participants were disqualified, but flagged responses were reviewed during data cleaning.

Demand Model

Our demand model is based on survey responses from 140 participants, used to estimate consumer preferences and simulate market shares. Feedback data were analyzed through a Hierarchical Bayes (HB) logit model to estimate mean utility coefficients (β). In this hybrid model, price and battery life were treated as continuous variables, while programming and assembly methods remained categorical. This approach enabled precise estimation of willingness to pay (WTP) by capturing sensitivity to incremental changes. The findings from the model highlight strong consumer preferences for hands-on engagement and extended usability, both integrated into Zippy's design.

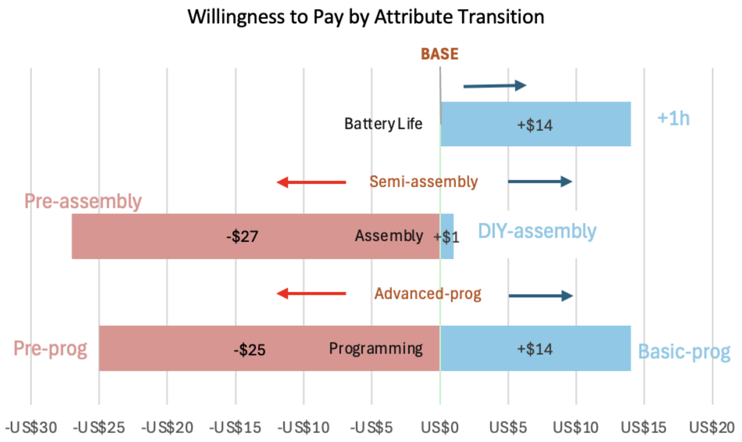
Key assumptions in the model include the idea that consumers make rational decisions based solely on the four defined attributes—price, battery life, programming method, and assembly type—and that each attribute contributes independently to overall utility (i.e., no interactions were modeled). The model assumes a linear relationship between utility and price/battery life in the hybrid model and uses the middle level of each attribute (e.g., $100 for price, 2 hours for battery life) as the base for comparisons. It also assumes that the survey sample (140 screened respondents who are parents, guardians, or relatives of children aged 8–15) is representative of the actual target market. Additionally, the inclusion of an "opt-out" option in each CBC question accounts for real-world consumer behavior, allowing for the possibility that none of the presented products are chosen. Market simulations assume rational choice based on utilities, stable preferences across respondents, and a fixed market size of one million customers per year, projecting Zippy's 29% share based on its default configuration.

Willingness To Pay

The Willingness to Pay (WTP) values were calculated using a continuous specification for price, applying the following formula:

$$WTP=-\Delta\beta_{\text{attribute}}/\ \beta_{\text{price}}$$

For the categorical attributes, one level was set as the base case and computed WTP values by comparing the utility of the other levels relative to this base. The resulting WTP estimates and the diagram are as shown below:



The analysis of willingness to pay (WTP) shows that programming is a major driver. Programming options include pre-programmed actions (no coding needed), basic coding via app/software (drag-and-drop programming), and advanced AI learning and coding (for tech-savvy users). Consumers are willing to pay $14 more to move from advanced to basic programming, favoring ease of use, while shifting to pre-programmed actions results in a $25 decrease in perceived value.

Assembly preference also strongly impacts decisions. Options include fully DIY (built from scratch), semi-assembled (partial assembly), and pre-assembled (ready out of the box). Moving from semi-assembled to pre-assembled causes a $27 drop in WTP, highlighting the value of hands-on engagement. Transitioning from semi-assembled to fully DIY increases WTP by $1, showing a slight additional preference for full assembly involvement. Battery life, the duration before needing a recharge, is a moderately valued feature, with 1 hour (short play), 2 hours (balanced session), and 3 hours (extended play) as options. Each additional hour boosts WTP by $14. Although less critical than programming and assembly, longer battery life remains a desirable enhancement. Overall, consumers prefer products that balance customization and interaction without being overly complex.

Simulated Market Scenario

Attributes and placement of Zippy and Competitors

To define and understand our simulated market scenario, five products were analyzed (four competitors and one potential product – Zippy) across key attributes influencing consumer choice: price, battery life, assembly method, and programming level. For each product, the total utility v_j was calculated by adding the corresponding β values. The choice probability for each product was then computed using the multinomial logit formula. [Please refer to Appendix 7]

These attributes were chosen based on their impact on willingness-to-pay (WTP) from prior analysis, and they play a critical role in shaping product appeal. The simulation assumes a static market where consumers choose one of the five product options (including our product "Zippy"), based on how well each aligns with their preferences.

The outside goods represent consumers who choose not to buy any product in the market. These individuals may opt for alternative educational activities or simply defer purchase due to price or lack of interest.

Simulated Market Share with Uncertainty

The product Zippy performs best with a 29% market share, thanks to its balance of semi-assembly, basic programming, and a mid-tier price point ($80). While Freenove offers a lower price, its advanced programming may deter less tech-savvy buyers. Products like Ruko 1088, with pre-assembly and pre-programming, align poorly with consumer preferences and are likely to lose market relevance. The Zippy, which is positioned as the entrant product, is priced at $80 and features a semi-assembly format and basic coding capabilities. Its battery life of 120 minutes is competitive, offering more runtime than several competitors at a mid-range price. Zippy appears designed to strike a balance between hands-on engagement and ease of use, closely matching the strongest consumer preferences indicated in WTP data. This balance positions Zippy as an accessible yet satisfying option for both casual users and education-focused buyers.

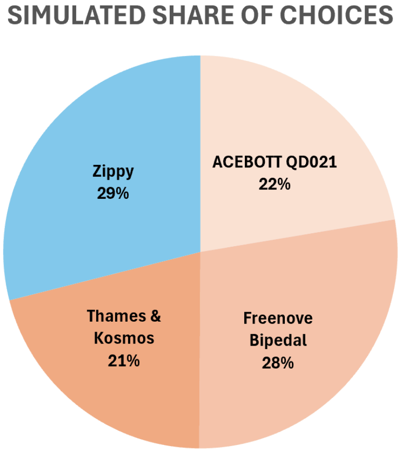
The confidence intervals were derived by propagating the uncertainty in the mean utility coefficients (please refer to Appendix [13] for mean utility coefficients) shown in the table. For example, attributes such as battery life ($\beta = 0.843 \pm 0.565$) and basic programming ($\beta = 1.032 \pm 0.805$) exhibit relatively wide confidence intervals, suggesting meaningful variation in individual-level preferences. Despite this variability, Zippy consistently emerges as the preferred choice due to its well-balanced features. Its projected market share ranges between 26% and 32%, reflecting stable appeal across different consumer segments. Freenove remains a strong competitor; however, its more advanced programming could slightly limit its appeal to the broader market. Meanwhile, ACEBOTT and Thames & Kosmos perform moderately but trail behind, primarily due to either shorter battery life or higher pricing.

Product	Price ($)	Battery Life (min)	Assembly	Programming
Zippy	80	120	Semi-assembly	Basic coding
Thames & Kosmos	100	180	Semi-assembly	Basic coding
Freenove Kit	60	90	DIY-assembly	Advanced coding
ACEBOTT QD021	70	60	Semi-assembly	Basic coding
Ruko 1088	130	90	Pre-assembly	Pre-programmed
Outside Good	–	–	–	–

Table 4.3.1 Analysis of Zippy vs Competitors

Product	Market Share (%)	95% Confidence Interval (±)
Zippy	29%	±3%
Freenove Bipedal	28%	±3%
ACEBOTT QD021	22%	±2%
Thames & Kosmos	21%	±2%

Table 4.3.2 Market share with uncertainty



Market Volume Estimates

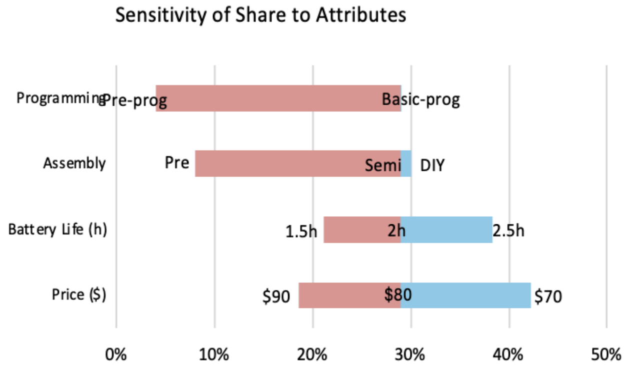
To estimate potential demand for the Zippy bipedal STEM robot kit, three tiers of market volume projections were defined based on industry-standard segmentation: **Total Addressable Market (TAM), Serviceable Available Market (SAM),** and **Serviceable Obtainable Market (SOM)**.

Market Tier	Description	Size (Units)
TAM	All kids aged 8–15 in the target region	24 million
SAM	Kids within the TAM who are interested in STEM toy robots	6 million
SOM	Parents willing to purchase + kids specifically interested in customizable bipedal STEM robots	3 million

Table 4.3.3 Market analysis

Scenario	Zippy Units (30% Share)	Justification
Conservative	200,000 units	Early market stage, limited brand awareness, minimal distribution reach
Base Case	600,000 units	Moderate brand exposure, decent retail, and school adoption
Optimistic	1 Million units	Strong STEM education momentum, partnerships with schools, and campaigns

Table 4.3.4 Zippy Production



Opportunities to Increase Demand
The tornado plot reveals how changes in Zippy's product attributes and price influence consumer demand, with programming level emerging as the most impactful factor. Shifting from pre-programmed to basic programming increases market share by over 20 percentage points, highlighting consumers' strong preference for interactivity that remains accessible. Offering basic coding provides an ideal balance between customization and ease of use. Similarly, the assembly method has a major effect: switching from pre-assembled to semi-assembled boosts the share by about 15 percentage points. This confirms prior findings that users value hands-on engagement, especially in educational contexts. Semi-assembly and DIY formats contribute significantly to the product's appeal by supporting learning and personalization.

While battery life has a more moderate influence, increasing it from 1.5 to 2.5 hours still raises market share by roughly 10%, suggesting that longer usage enhances value in both home and classroom settings. Price sensitivity also plays a meaningful role—reducing the price from $90 to $70 increases share by over 15%. However, price changes have a slightly less impact than adjustments to programming and assembly, indicating that functional features drive more sustained demand. Overall, the analysis supports that Zippy's current configuration—basic programming, semi-assembly, good battery life, and a mid-range price—is well aligned with consumer preferences. Refining these core features offers the most effective path to maintaining and growing market share.

Conclusions
This analysis shows that programming simplicity, assembly format, and battery life are the key drivers of consumer choice in the STEM toy robot market. Zippy's design—basic programming, semi-assembly, 120-minute battery life, and a competitive $80 price—is well aligned with these preferences, earning it a leading 29% simulated market share. Sensitivity analysis confirms that programming and assembly changes have the greatest impact on demand, while battery life and price play supporting roles. Based on Zippy capturing ~30% of a 3 million-unit SOM, estimated sales range from 200,000 to 1 million units across conservative to optimistic adoption scenarios.

That said, several limitations and uncertainties remain. The discrete choice experiment relies on stated preferences, which may differ from actual behavior. Market simulations assume static competitor offerings, and price sensitivity may vary by demographic. The biggest unknowns include conversion from interest to purchase, the effect of marketing and distribution, future changes in consumer preferences, and the potential impact of tariffs or trade policies on pricing and margins. These factors will be critical in determining Zippy's real-world success.

Integrated Analysis

Unit price and unit cost analysis
The plot unit cost and unit selling price changes with annual production in the same graph, showing the trends for the baseline, optimal, and worst-case scenarios. These scenarios reflect our key uncertainties with respect to material prices, labor costs, consumer preferences, and other factors. Flowing two charts correspond to the 3D printing and injection molding processes

respectively, and are used to compare the relationship between the cost and price of the two processes at different production volumes, helping us to assess the economic viability of each. (Please refer to appendix [9,10])

This analysis focuses on the selling price range from $40 to $110, which is derived from market analysis and reflects the basic rule that "the higher the price, the lower the share, and the lower the price, the higher the share". Our modeled market assumes a total annual demand of 1 million units for STEM bipedal robots. The results show that injection molding has advantages in stability, reliability, and economy of scale, since the unit cost is always lower than the selling price from the best case to the worst case.

3D printing can be profitable in the base case and the best case, but there is a greater risk in the worst case: when the selling price is above $61, there is some profit margin; around $60, the break-even point is approached; and below $57, losses occur. Overall, injection molding is more robust, while the viability of 3D printing is more dependent on market price positioning.

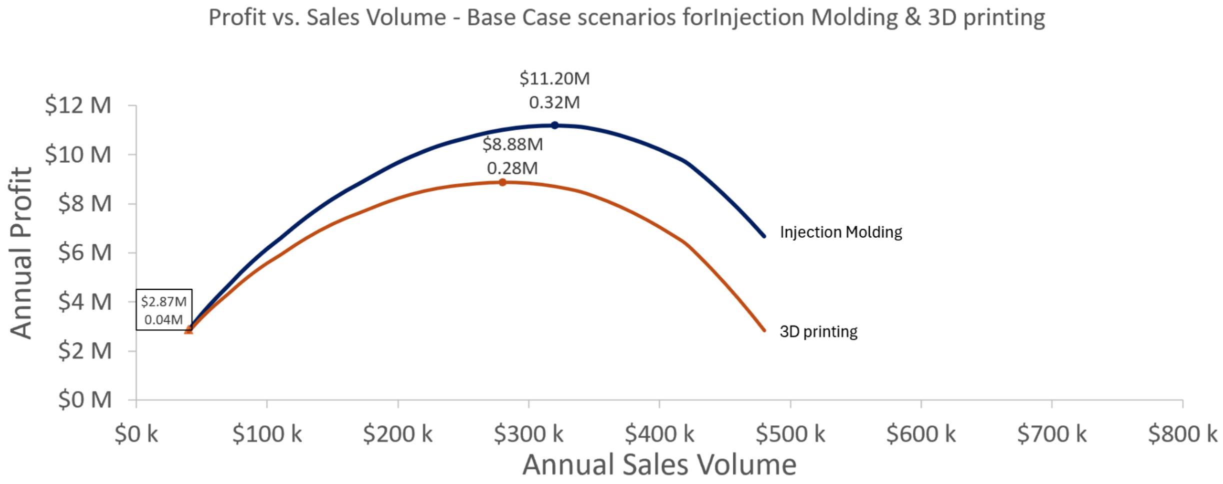
Profitability

In order to assess profitability under different market volume and manufacturing methods, a graph was plotted showing profit against sales volume for both processes, 3D printing and injection molding. The graphs show base case, best case, and worst case scenarios, which reflect our key uncertainties in unit cost, product pricing, and market acceptance. (Please refer to appendix [11,12])

In the base scenario, the profits of both modes of production rise as production increases and peak at a certain level of production, before falling back slightly. However, overall profits have always been positive, and no losses have been incurred. This indicates that the project has basic economic viability within the assumed cost, sales volume, and pricing range.

Profits from 3D printing peaked at about 280,000 units produced (about $8.8 million) and then fell back slightly. The reason for the pullback is that even though price reductions have resulted in more market share, the growth has not been sufficient to offset the impact of lower unit prices due to narrower profit margins.

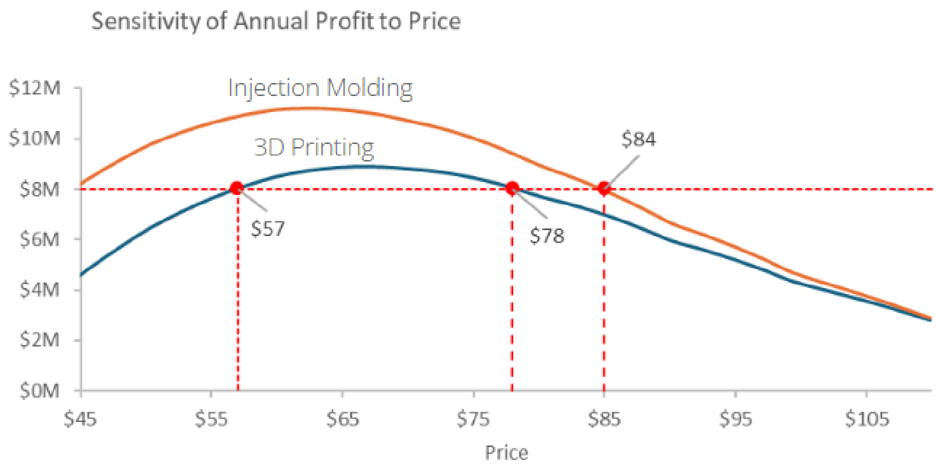
Injection molding showed a stronger profit performance, peaking at 320,000 units (approximately $11.2 million). Although profit does decrease beyond the peak, injection molding maintains a higher level of profitability across a wider range of sales volumes. Here is the zoomed-in comparison graph for base case profitability between 3D printing and injection molding.



In assessing the overall economic viability, attention was also paid to the performance in the worst-case scenario. As can be seen in the zoomed comparison chart below, injection molding remains positively profitable over the range of production volumes, peaking at $2.87M on annual sales of approximately 90,000 units, and remaining in the overall profitability range, even after a decline thereafter. In contrast, 3D printing performed significantly badly in the worst case, posting a loss of $3.08M with 160,000 units annual sales, and barely making a profit for the entire range. It is important to note that areas with unit prices below $40 or above $110 and annual production below 0.04 million or above 0.80 million are part of our model extrapolation.

Key Decisions

Price Decision:



To assess the impact of different pricing on profits, a graph was plotted of annual profits against price. The figure shows the annual profit of 3D printing and injection molding in the base scenario as the selling price changes. A profitability target of $8 million per year was set, analyzing the pricing ranges for each method to meet this target and make price recommendations.

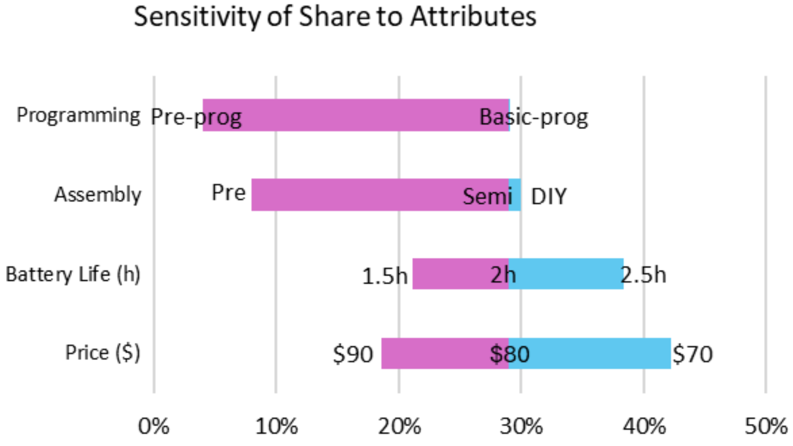
As shown in the chart, injection molding (orange line) has a much wider pricing range, maintaining an annual profit of over $8 million when priced between $45 and $84. In contrast, 3D printing (blue line) has a narrower earnings range, achieving the same profit target only when priced between $57 and $78.

Based on this analysis, we make the following pricing recommendations:

1. The recommended pricing for 3D printing is $65-$70, which is close to peak margins ($8 million) and allows for higher margins while maintaining reasonable volumes.
2. The recommended pricing for injection molding is $55-$70, which is in the high-margin band (over $10 million) and has good market flexibility for scale-up.

Design Decision:

The chart below illustrates the extent to which Zippy's product attributes (programming method, assembly method, battery life vs. price) influence market share, reflecting user preferences when shopping for bipedal stem robots. This data is derived from the Discrete Choice Survey, which was conducted to estimate the impact of each attribute on market share by simulating user choice behavior under different combinations. Further analysis shows:



1. Basic programming is significantly better than preset programmes
2. DIY self-assembly is the most popular method of assembly. Users prefer hands-on experience and engagement.
3. Users have a clear preference for longer range
4. Provided that the profit can be controlled, the lower the price, the more popular the product will be with the users.

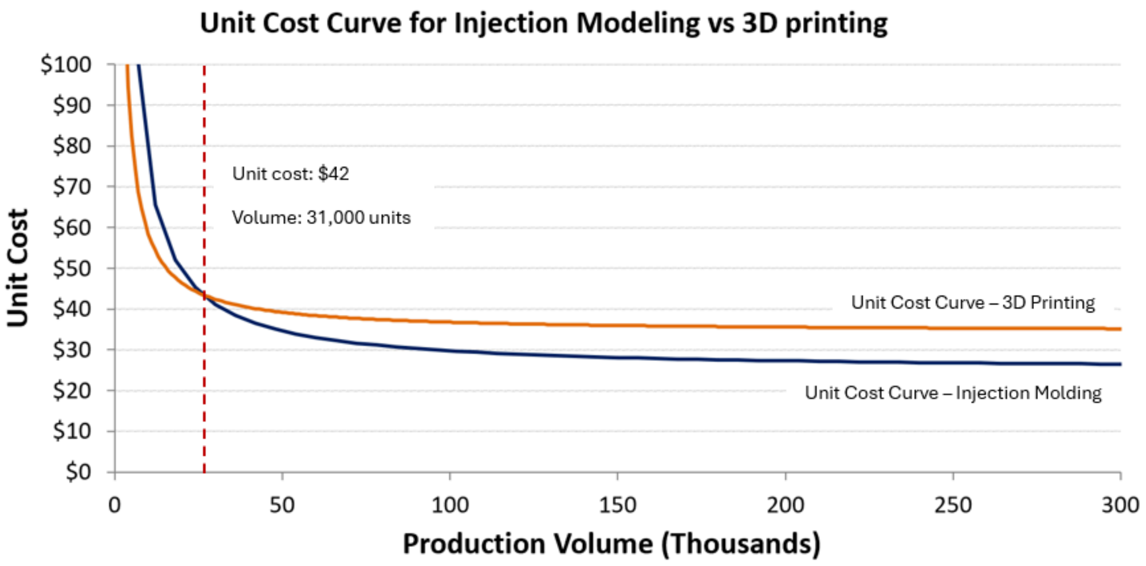
In summary, the recommended design combination is:
Basic programming + DIY assembly + 2.5 hours of battery life + $70 MSRP.

Our model estimates that the product's simulated market share would increase from 29% to 54% if the recommended design is adopted. In the base scenario, the total market is assumed to be 600,000 units sold annually:

- If the 3D printing process is used for production, it is expected that a profit of approximately $11 million can be realized.
- If the injection moulding process is used for production, it is expected to be even more profitable at approximately $13.7 million.

Process Decision

The graph below shows the trend in unit costs of the two production processes, as a function of volume growth in the base scenario. The unit cost of both processes drops as production volume increases; the cost of injection molding drops more quickly, falling below 3D printing after 31,000 units of production volume, and staying lower. This suggests that injection molding is more cost-effective when the goal is to control costs and maximize profit.



However, 3D printing is still a viable option when considering the finer details or the need for early iteration, especially when structural complexity or personalization is required.

Limitations and Out of Scope

Costs:

- Tariffs: The model does not include the possible cost impact of future trade policy changes.
- Logistics: Costs such as transport, warehousing, and distribution are not included in the overall cost estimation.
- Partial automation: The current model for injection molding only automates the assembly step; the rest of the steps are assumed to be done manually.
- Shell Omitted: No cost, materials, or design modeled for the aesthetic outer toy covering
- Component Costs:All component costs are based on preliminary estimates, and actual supplier quotes may vary.

Markets:

- Static assumption model: The model assumes that the lower the price, the higher the market share, but it does not take into account brand perceptions or quality doubts arising from low prices.
- Consumer preferences are modelled as averages: the model uses the overall average WTP and does not disaggregate for different user groups (e.g., students vs parents, different age groups).
- Competitor response: The model does not account for competitor reactions, such as price matching or launching similar products in response.
- Limited survey respondents: The market survey is based on a limited sample size of 140 respondents and may not fully represent the wider target user community.

Conclusion

A comprehensive analysis of cost and market preferences was conducted. The results show that the recommended product mix of basic programming, DIY assembly, 2.5 hours of battery life, and a $70 price point is well accepted among users. Injection molding is more cost-effective at medium to high volumes, while 3D printing is suitable for low volume (under 30,000 units/year) and high precision needs. The model is based on static assumptions, does not include logistics, tariffs, case design, and a limited market sample. The results help guide key decisions, but need to be confirmed with real-world testing in the future.

Final Recommendations and Conclusions

Economic Viability and Confidence

The analysis indicates that *Zippy* is a **viable and profitable product** within the customizable STEM toy market. The assessment is considered fairly reliable, based on robust findings from both production and market simulations. However, certain uncertainties could significantly influence profitability:

- Tariffs and Import Dependence: Zippy's critical components, motors, and controller boards are currently imported from China. Any shift in tariffs or foreign trade policy would boost the cost of material astronomically.
- Labor Costs:Labor is a cost-determinant. Dividing the activity into skilled and unskilled labor and paying wages accordingly could reduce the manufacturing cost to a large extent.
- Automation Limitations: As we have automated the assembly step of injection molding, automating the whole process of production would be even more economical and effective.
- Logistics and Distribution: Shipping, warehousing, or last-mile delivery could impact profitability and scalability, but our cost estimation has not included them yet.
- Product Design Enhancements: Aesthetic considerations, such as adding a protective or desirable casing, have not been factored into the cost of production but are essential for sellability.

Product, Price, and Process Recommendations

To yield maximum profitability and an optimum match with customer wants, we recommend the following choices for each of the key factors:

- **Manufacturing Process**:
  - Use **3D printing** for volumes below **280,000 units** (optimal profit: **$8.8M**)
  - Shift to **injection molding** at or above **320,000 units** (optimal profit: **$11.2M**).
- **Product Features**:
  - Maintain **basic programming** and **semi-assembled** configuration, as these maximize willingness to pay.
  - Extend battery life from **1.5 to 2.5 hours**, boosting share by nearly **10%**.
- **Pricing Strategy**:
  - Target a **mid-range price** ($80–$90). While a $20 reduction increases share by 15%, feature improvements yield greater long-term value.

These recommendations are considered **robust**, supported by simulated consumer preference data and profitability analysis.

Top Opportunities for Cost Reduction & Demand Growth

- **Cost Reduction**:
  - Automate additional production steps beyond assembly.
  - Divide and optimize labor based on skill level.
  - Explore domestic or diversified sourcing to mitigate tariff risk.
- **Demand Growth**:
  - Increase battery life, even moderately, to enhance value in home and educational environments.
  - Highlight feature-based value—specifically programming and assembly features, over-aggressive price.

Next Steps: Critical Information to Collect

To strengthen future decision-making, we recommend gathering the following data:

1. Supply Chain Feasibility: Assess domestic and other foreign sources of major components.
2. Logistics Cost Estimates: Include warehousing, shipping, and fulfillment information in total cost modeling.
3. Aesthetic Design Feasibility: Determine cost and process implications of adding a robot shell.
4. User Testing: Validate assumptions with direct feedback from target users (kids, parents, and educators).
5. Regulatory Factors: Investigate compliance requirements for toys in key markets (e.g., CE, ASTM, FCC).

APPENDIX

1. Team Contributions:

Name	Contributions
Medhavi Goyal	Executive summary, Recommendations, and Conclusions
Sneha Hassan	Demand Analysis
Carlos Valverde	Production Analysis
Chenhao Tan	Integrated Analysis
Medha Boosam	Introduction, Formatting

2. Model Relationship Table: Refer to Excel File: Model Relationship Table
   Model Relationship Table.xlsx
3. Process-based cost model: Refer to Excel file: PBCM_Integrated_Analysis
4. A mathematical description of your utility function specification.

$$P_j = \frac{e^{v_j}}{\sum_k e^{v_k}}$$

The choice behavior of respondents is modeled using a **multinomial logit framework**. The probability that a respondent selects alternative j is given by:

$$P_j = e^{vj} / \sum_k e^{vk}$$

Where:

- P_j is the probability of choosing option j,
- v_j is the deterministic utility of option j,
- $\sum_k e^{vk}$ is the sum over all available alternatives in the choice set.

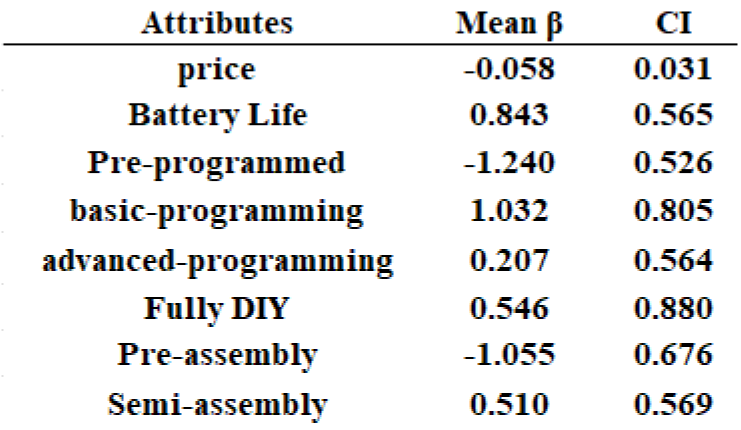
The deterministic utility v_j is specified as a linear combination of observed product attributes:

$$v_j = \beta_1 x_{1j} + \beta_2 x_{2j} + \cdots + \beta_n x_{nj}$$

Where:

- x_{nj} are the attribute levels of option j,
- β_n are the estimated part-worth utilities (preference weights) obtained from choice modeling,
- Attributes are dummy-coded where applicable.

5. Estimated Model Coefficients with standard errors: Refer to Excel File PBCM_Integrated_Analysis
6. Market Survey and Data: Market Survey
7. Beta Values and Confidence Intervals

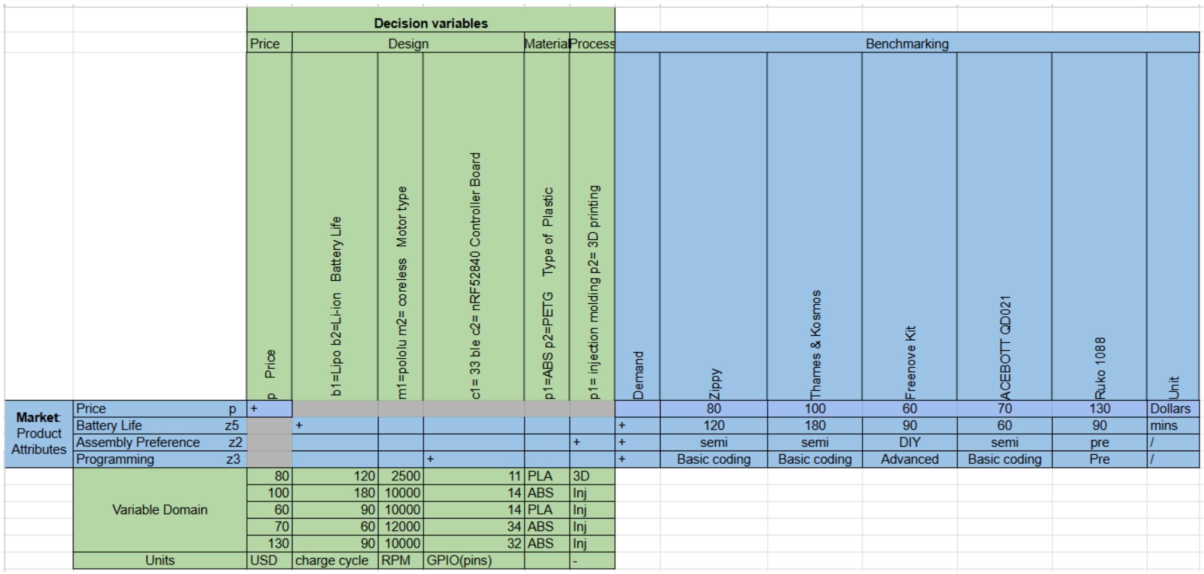


Attributes	Mean β	CI
price	-0.058	0.031
Battery Life	0.843	0.565
Pre-programmed	-1.240	0.526
basic-programming	1.032	0.805
advanced-programming	0.207	0.564
Fully DIY	0.546	0.880
Pre-assembly	-1.055	0.676
Semi-assembly	0.510	0.569

Figure X.1. Estimated β values (Preference Weights) and Confidence Intervals for Product Attributes

The β values and uncertainty obtained are shown in the figure. These β values reflect the relative strength of consumer preference for each attribute, but do not represent absolute utility levels. Due to the limited sample size and early-stage data collection, the uncertainty in the estimates remains relatively high.

8. Model Relationship Table



			Decision variables													
			Price	Design			Material	Process	Benchmarking							
			p Price	b1=Lipo b2=Li-ion Battery Life	m1=pololu m2= coreless Motor type	c1= 33 ble c2= nRF52840 Controller Board	p1=ABS p2=PETG Type of Plastic	p1= injection molding p2= 3D printing	Demand	Zippy	Thames & Kosmos	Freenove Kit	ACEBOTT QD021	Ruko 1088	Unit
Market: Product Attributes	Price	p	+							80	100	60	70	130	Dollars
	Battery Life	z5		+					+	120	180	90	60	90	mins
	Assembly Preference	z2						+	+	semi	semi	DIY	semi	pre	/
	Programming	z3				+			+	Basic coding	Basic coding	Advanced	Basic coding	Pre	/
	Variable Domain		80	120	2500	11	PLA	3D							
			100	180	10000	14	ABS	Inj							
			60	90	10000	14	PLA	Inj							
			70	60	12000	34	ABS	Inj							
			130	90	10000	32	ABS	Inj							
	Units		USD	charge cycle	RPM	GPIO(pins)		-							

9. Unit Cost and Price vs. Volume Graph

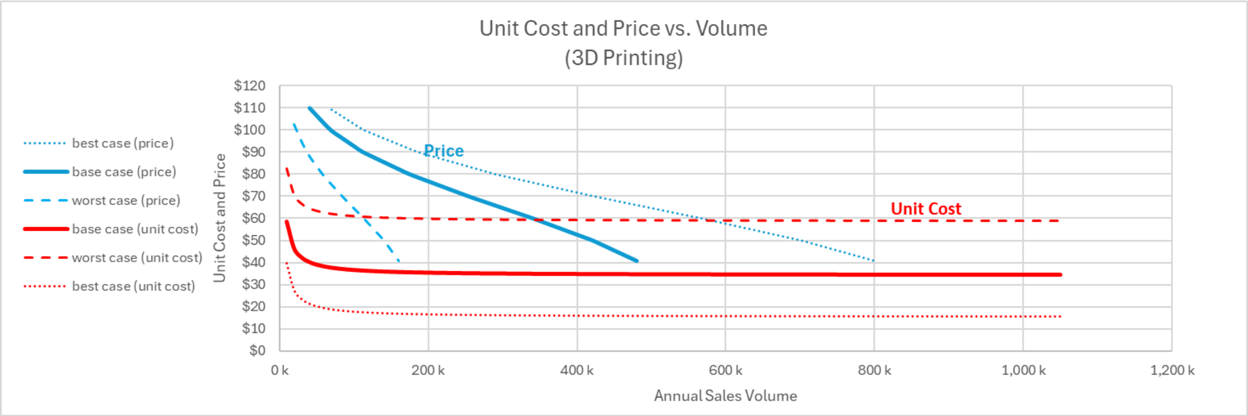


Figure X.2 Unit Cost and Price vs. Annual Sales Volume – 3D Printing Scenario

10. Unit Cost and Price vs. Volume

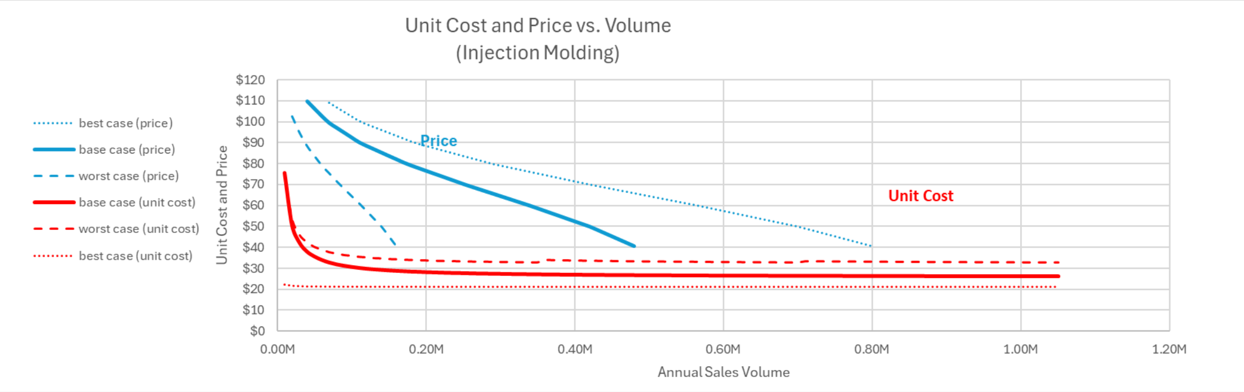


Figure X.3 Unit Cost and Price vs. Annual Sales Volume – Injection Molding Scenario

11. Annual Profit vs. Sales Volume - 3D Printing

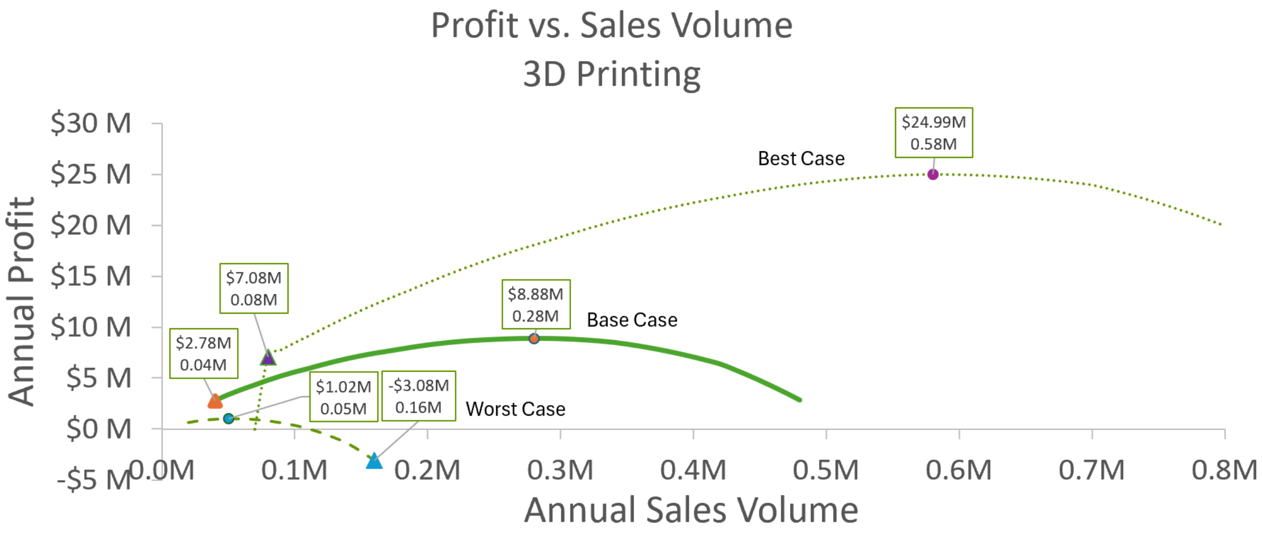


Figure X.4 Annual Profit vs. Sales Volume – 3D Printing Scenario

12. Annual Profit vs. Sales Volume – Injection Molding

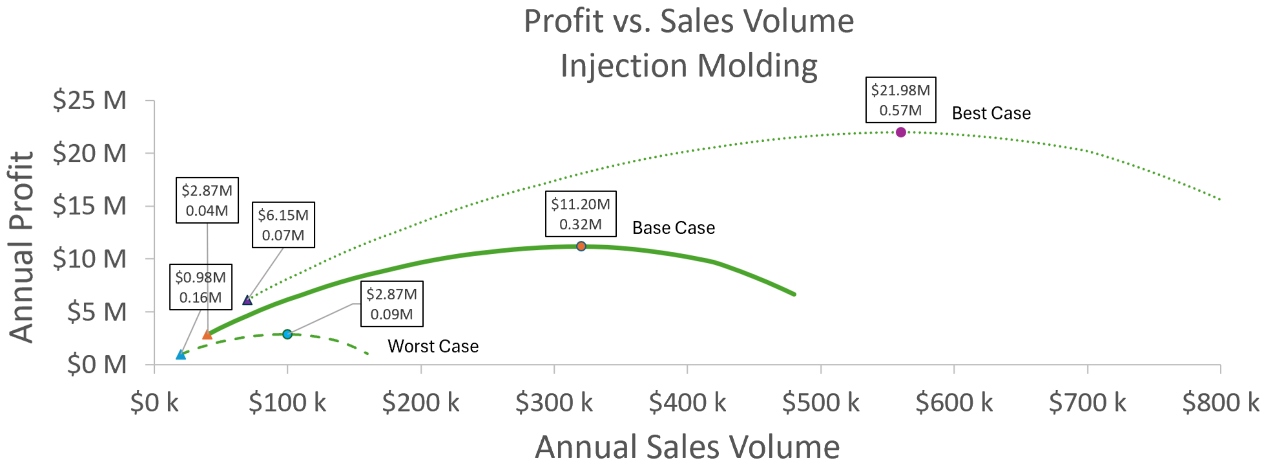


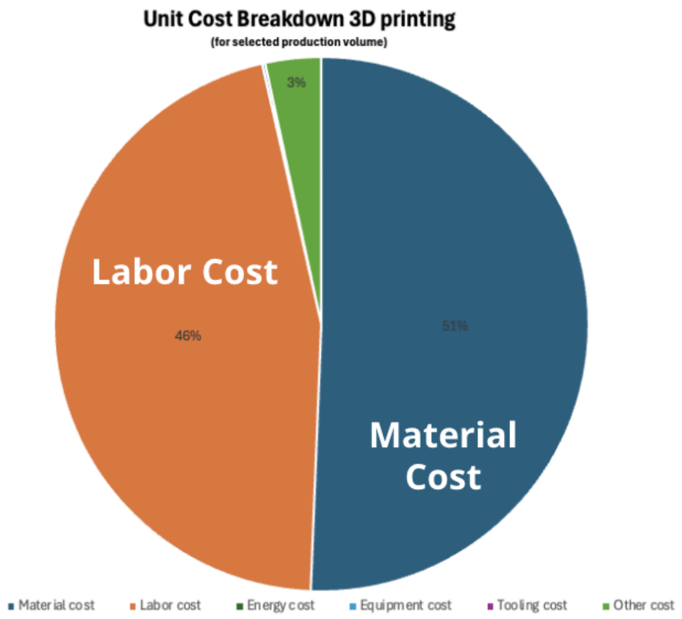
Figure X.5 Annual Profit vs. Sales Volume – Injection Molding Scenario

13. Mean β/ mean utility coefficients - The mean utility coefficients, also called beta (β) values, show how much people like or dislike different features of a product. They come from the survey we did, where people chose between different versions of the Zippy robot. A positive beta means people liked that feature—it made them more likely to choose the

product. A negative beta means people didn't like that feature—it made them less likely to choose it. If the beta is close to zero, it means people didn't care much about that feature.

These numbers help us understand which features are most important to customers and what changes we can make to the product to increase its popularity.

14. Unit cost breakdown for 3D printing



15. Unit cost breakdown for Injection Molding