# Design Report 2

Ori Algave (Design 1)

Avalee Demidovich (Design 2)

Ashley Woodworth (Design 3)

Serene Yahia (Design 4)

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# Objective Definitions

**Total Cost:**

Total cost, in USD, measures the estimated price to manufacture and assemble each food mixer design. This includes stock material, purchased OTS parts, fasteners, and modified components of the original air engine if applicable. Overall cost is particularly important to quantify as we do not want to spend excess money on any design when cheaper alternatives are achievable. In addition, it is important to note that a cost constraint of $100 was enforced. The costs calculated in each Design Specification Table (DST) from DR1 will be compared to determine final assembly costs. A weighting factor of 15% is used as it is important to conserve money if savings are needed due to unexpected problems in the future. Therefore, the cheapest design will receive a score of 10 out of 10.

**Manufacturing Time:**

Manufacturing time measures the estimated labor and processing time required to fabricate and assemble all custom and purchased components into a functioning system. Concepts requiring fewer machining operations, reduced assembly complexity, and simpler fabrication methods decrease manufacturing time and lead to better mass production of the item. To quantify this objective, we will examine all the parts that make up each design while using the Times Estimation Workbook provided. This objective will be scored on a linear scale where a lower magnitude is better, thus the design with the lowest manufacturing time receives a higher score. A weighting factor of 8.3% has been chosen as the design selected must be feasible to fabricate within laboratory constraints. The design with the lowest overall manufacturing time will be given a score of 10 out of 10.

**Mixing Performance:**

Mixing performance measures the expected ability of each concept to disturb and circulate food content inside a mason jar. Since the proposed concepts use different mixing methods, including rotating paddles, blades, and reciprocating jar motion through a Scotch yoke mechanism, performance is quantified using the Disturbance Rate, defined as the total number of fluid disturbances generated per minute. For rotating concepts, the agitation rate is equal to the mixing element's output rotational speed. This is calculated by using the drive ratio between the air engine flywheel and the driven pulley or contact wheel. For all concepts, the air engine speed will be assumed to be 2000 RPM, which falls within the expected operating range of 600–2400 RPM. Each concept will be evaluated at its fastest available setting.

$$\text{Output RPM} = \text{Air Engine RPM} \times (\text{Driver Diameter} / \text{Driven Diameter})$$

For the Scotch yoke concept, the agitation rate is equal to the crank rotational speed because one complete crank revolution produces one complete back-and-forth motion of the jar. The crank speed is calculated using the same drive ratio equation. The final Disturbance Rate is calculated as shown below where each blade, paddle, fin, or mixing arm counts as one mixing feature. For concepts that mix with no internal mixing element, the jar is counted as one mixing feature.

Disturbance Rate = Agitation Rate × Number of Mixing Features

A thoroughly combined and quickly made mixture is important to the consumer, so a higher magnitude of disturbance rate is desired. The resulting disturbance rate will be converted to a linear objective score. A weighting factor of 31.7% is assigned as effective mixing is the primary function of the project, and concepts that disturb the contents more frequently are expected to have a better mixing performance. Higher disturbance rates receive proportionally higher scores, thus the design with the highest disturbance rate will receive a score of 10 out of 10.

**Exposed Pinch Points:**

Exposed pinch points refer to locations where a user's fingers, clothing, or other objects could become caught between moving components. Examples include the interface between belts and pulleys, springs, rotating shafts and stationary supports, or any other moving mechanical interfaces that could create an entrapment hazard. To quantifiably measure this objective, the total number of pinch points present in each design will be counted and added together, creating the total hazard score. Pinch points will be considered while each mixer is moving. A lower total pinch point count indicated a safer overall design as there are fewer opportunities for accidental contact with hazardous moving components. A weighting factor of 26.7% was chosen for this design as user safety is critical to consider in producing any consumer-operated device. The design with the lowest number of pinch points will receive an objective score of 10 out of 10.

**Number of Components:**

Number of components measures the total amount of individual parts required to build and assemble each mixer. This includes all custom manufactured parts, modified existing parts, and purchased OTS components needed for the final assembly. The numerical value for all materials needed for each design can be found in the DST for every concept. This objective is quantitatively measured by counting each separate component used in the complete system. A weighting factor of 11.7% was chosen for this objective as designs with fewer components are simpler to assemble, easier to maintain, less expensive, and have fewer potential failure points. The design with the fewest total components will score 10 out of 10.

**Footprint:**

The footprint of each design quantifies the amount of space each mixer will need on the user's counter. For this objective, only the length and width of each design base that lays on the user's counter is considered. Height is not considered as the mixer will be used in a kitchen where only the horizontally available counter space is important for preparing food. To quantify, we calculate only the interacting area of each design base. This objective is weighed at 6.7%, as a smaller design will be more desired by consumers for better storage and counter space. The concept that has the smallest base footprint will be given a score of 10 out of 10.

# Weighting Factor Determination

# Decision Matrices

# Appendix A: Scoring Justifications and Calculations

## Total Cost

In Design 1,

In Design 2,

In Design 3, the costliest components are the adjustable speed step pulley and 3D printed base, costing $26.86 and $12.65 respectively. All other components, including OTS parts, cost under $10. In addition, all stock material and screw components were purchased in bulk to help reduce expenses. Design 3's final assembly costs $87.15, which is most expensive out of all designs. As a result, this design received a score of 9.3 out of 10.0 using linear score calculations.

In Design 4,

**Example Score Assignment Calculation**

*Design 1 Cost: $81.03*

*Design 4 Cost: $86.56*

*Design 1 Cost Score: 10.0 (highest score)*

*Design 4 Cost Score:* $\frac{81.03\times10}{86.56}$ *= 9.4*

# Manufacturing Time

Design 1

Design 2

Design 3 has by far the highest total manufacturing time, where over 96% of this time comes from the 3D printed mounting base. The infill percentage was not taken into account when calculating this amount of time. A total of 88.69 hours, or almost 4 days, are spent printing this part. This is due to the large amount of volume that needs to be printed compared to the other parts that are being manufactured. In fact, all other elements take less than 1.5 hours to manufacture. These components only utilize simple machining techniques such as milling, turning, drilling, and bandsaw cutting, and while the mixing paddle and flywheel require CNC machining, those components take virtually no time to manufacture compared to the mounting base. As design 3 takes the longest amount of time to manufacture, it receives a score of x out of 10.0 using linear score calculations.

Design 4

**Example Score Assignment Calculation**

*Design x Time:*

*Design x Time:*

*Design x Time Score: 10.0 (highest score)*

*Design x Time Score:*

# Mixing Performance

Design 1

Design 2

Design 3 achieved an effective disturbance rate of 5,000 disturbances per minute. This value was calculated using an estimated air engine input speed of 2,000 RPM, a 2.5:2.0 drive-to-driven pulley ratio, and two mixing features corresponding to the two paddle surfaces. The smaller driven pulley, associated with the smallest step pulley diameter, increased the output shaft speed above the input speed, resulting in a higher agitation rate than Designs 2 and 4. Design 2 utilized a lower drive-to-driven pulley ratio, producing a slower agitation rate, while Design 4 employed a Scotch yoke mechanism and did not incorporate a pulley-driven mixing element. Although Design 3 produced the second-highest disturbance rate among the four concepts, its performance remained significantly lower than that of Design 1, which utilized a four-blade spinner and generated the highest effective disturbance rate. As a result, Design 3 received a score of 3.9 out of 10.0 for mixing performance based on linear calculations.

Design 4

**<u>Example Score Assignment Calculation</u>**

*Design 1 Disturbances/Min: 12706*

*Design 3 Disturbances/Min: 5000*

*Design 1 Mix Performance Score: 10.0 (highest score)*

*Design 3 Mix Performance Score:* $\frac{5000 \times 10}{12706} = 3.9$

# Exposed Pinch Points

Design 1

Design 2

Design 3

Design 4

**<u>Example Score Assignment Calculation</u>**

*Design x Number of Hazards:*

*Design x Number of Hazards:*

*Design x Hazard Score: 10.0 (highest score)*

*Design x Hazard Score: =*

# Number of Components

Design 1

Design 2

Design 3

Design 4

**Example Score Assignment Calculation**

*Design 3 Number of Components: 18*

*Design 2 Number of Components: 21*

*Design 3 Number of Components Score: 10.0 (highest score)*

*Design 2 Number of Components Score:* $\frac{18\times 10}{21}$ *= 8.6*

# Footprint

Design 1

Design 2

Design 3 had a total footprint of 51.75 in$^2$, calculated using the mounting base dimensions of 11.5 in × 4.5 in. Although the larger mounting base contributed to the highest estimated manufacturing time among the four concepts, it resulted in the smallest overall footprint due to the compact arrangement of the remaining components. This reduced footprint makes the design easier to position on a countertop, requires less storage space, and improves overall practicality for consumer use. Because Design 3 had the smallest overall footprint of all concepts, it received the maximum linear objective score of 10.0 out of 10.0.

Design 4

**Example Score Assignment Calculation**

*Design 3 Footprint: 51.75*

*Design 4 Footprint: 144*

*Design 3 Footprint Score: 10.0 (highest score)*

*Design 4 Footprint Score:* $\frac{51.57\times 10}{144}$ *= 3.6*

# Appendix B: Testing Data