Assembly Analysis of Clas Ohlson's Electric Hand Mixer

MG2040 - Assembly Technology

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Contents

List of Figures iv

List of Tables vi

1 Introduction **1**

2 Product Description **2**

2.1 About the Product 2

2.2 List of Components 3

2.3 Component Geometry and Symmetry 7

2.4 CAD - Exploded View 8

2.5 Bill of Materials (BOM) 9

2.6 Liaison Diagram 10

3 Assembly Analysis **12**

3.1 Assembly Operations 12

3.2 Assembly Time 13

3.3 Precedence Diagram 14

3.4 Liaison Sequence Diagram (LSD) 15

3.5 Design for Assembly (DFA) 15

3.5.1 Positive Aspects of the Existing Design 15

3.5.2 Suggested Improvements Based on DFA Principles 17

3.5.3 DFA for Manual Assembly (Boothroyd Method) 21

3.5.4 DFA for Automated Assembly 22

3.6 Feeder Suitability and Handling Challenge 24

4 Line Balancing **26**

4.1 Summary of Key Information 26

4.2 Largest Candidate Rule 26

4.3 Killbridge and Wester's Method 27

4.4 Ranked Positional Weight Method 28

4.5 Final Summary 29

5 Factory Layout **31**
5.1 Justification for Manual Assembly 31
5.2 Assembly Strategy and Task Allocation 31
5.3 Layout and Material Flow Considerations 32

6 Economic Analysis **34**
6.1 Basic Assumptions 34
6.1.1 Annual Demand Estimation 34
6.1.2 Takt Time Calculation 34
6.1.3 Theoretical Minimum Number of Workstations 35
6.1.4 Overall Efficiency 35
6.2 Financial Analysis for Manual Assembly 35
6.3 Financial Analysis for Automated Assembly 36
6.4 Comparing Manual and Automated Assembly 37
6.5 Break-even and ROI Analysis for Automation 38
6.5.1 Unit Cost Comparison 38
6.5.2 Break-even Volume Calculation 38
6.5.3 ROI Timeline 39
6.5.4 Conclusion 39

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List of Figures

2.1 Clas Ohlson's Electric Hand Mixer - HM9110-GS 2
2.2 Exploded View 9
2.3 Components assembled inside the product 9
2.4 Bill of Materials (BOM) 10
2.5 Liaison Diagram 11

3.1 Precedence Diagram 14
3.2 Liaison Sequence Diagram (LSD) 16
3.3 Design suggestion for Speed Control Frame 17
3.4 Design suggestion for Gear Mounting Frame 18
3.5 Design improvement for Gear Mounting Frame 19
3.6 Design improvement for ease of fastening 20

4.1 Largest Candidate Rule Method 27
4.2 Killbridge and Wester's Method 27
4.3 Ranked Positional Weight Method 28
4.4 Final Line Balancing Comparison 29

5.1 Division of Workstations 31
5.2 Isometric View of the Assembly Line 32
5.3 Assembly Workstation 33

List of Tables

2.1 Components and their description 4
2.2 Functional Decomposition and Component Analysis 7
2.3 Component Geometry and Symmetry 8

3.1 List of Operations with time taken and their predecessors 12
3.2 Trials for Assembly Time 13
3.3 Classification and Timing for the assembly operations 21
3.4 Assembly Index on Product level 22
3.5 Assembly Index on Part level 23
3.6 Part assessment for feeding and handling suitability 24

4.1 Largest Candidate Rule - Station Allocation 26
4.2 Killbridge and Wester's Method - Station Allocation 27
4.3 Ranked Positional Weight Method - Station Allocation 28

6.1 Equipments required for workstation 36
6.2 Cost breakdown for automated assembly equipment 36

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1
Introduction

Assembly technology is an essential part of modern manufacturing, bridging the gap between part production and complete, functional products. Unlike forming or subtractive manufacturing processes, which create individual parts, assembly focuses on joining components—mechanical, electrical, or structural—into systems that deliver the desired performance. As products become more complex and customized with the advancement of technology, efficient and well-structured assembly strategies become essential for ensuring quality, reducing costs, and maintaining competitiveness.

The field of assembly encompasses a wide range of concepts, from manual and automated operations to ergonomic workstation design, assembly sequencing, and line balancing. Moreover, methodologies such as Design for Manufacturing and Assembly (DFMA) highlight the strategic value of integrating assembly considerations early in the product design phase. These frameworks aim to minimize part count, simplify operations, and enable smooth transitions between design, manufacturing, and logistics.

As part of the "Assembly Technology" course, this project challenges us to apply theoretical concepts taught during the lectures to a real consumer product—a handheld electric mixer. The assignment involves analyzing its assembly process through various lenses, including component breakdown, bill of materials (BOM), liaison diagrams, assembly sequence planning, time and cost analysis, and design improvement proposals. Our work includes both qualitative and quantitative assessments, supported by engineering tools and structured methodologies taught in class.

Ultimately, the project serves as a method to understand the core learning outcomes of the course, equipping us with the knowledge and tools to assess, optimize, and innovate in industrial assembly settings.

2
Product Description

2.1 About the Product

The assigned product for this project is a handheld electric mixer by Clas Ohlson (Model HM9110-GS), a compact kitchen appliance designed for mixing and whipping food ingredients. It consumes standard household current (220–240 V AC, 50 Hz) with a power level of 250 watts, capable of performing such operations as whipping eggs, kneading dough, and mixing batter. Its main components are a motor unit housed in a plastic body, two removable accessories (whisks and dough hooks), and user interface controls that enable variable speed choice.

Figure 2.1: *Clas Ohlson's Electric Hand Mixer - HM9110-GS*

The user can operate the device through a six-level speed selector and a turbo button that temporarily increases the motor speed for heavy-duty mixing tasks. The mixer is ergonomically designed for handheld use, with a lightweight build and conveniently positioned buttons. There is an ejection button provided that allows safe detachment of the attachments after use, contributing to user protection and convenience in cleaning. The mixer has both electrical and mechanical subsystems on the inside. The electric motor drives a gear system that converts electrical energy into mechanical rotation, which is transmitted to the beaters. The housing also accommodates an internal fan for cooling, a power transmission system, and minimal safety features to protect users from accidental exposure to moving or live parts. The whisks and dough hooks are keyed to only fit in one orientation so that both user assembly and handling are minimized.

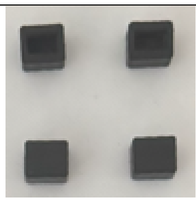
From an engineering perspective, the product is designed with modularity and ease of assembly in mind. Its construction involves various materials, including plastics for the outer casing and internal mounts, and metals for moving components and electrical conductors. The device showcases typical challenges and trade-offs seen in the assembly of small consumer electronics: balancing ease of use, safety, and manufacturing cost.

This project will explore the assembly of this mixer in detail, including disassembly and analysis of its components, and the creation of diagrams to represent assembly relationships and sequences. Through this analysis, we aim to assess not just how the product is built, but how it could potentially be improved from an assembly standpoint using concepts such as Design for Assembly (DFA) and ergonomic design principles.

2.2 List of Components

To understand the structure and assembly of the electric hand mixer, it is essential to first identify and document all the individual components that constitute the final product. This includes both externally visible parts, such as the plastic housing and user interface buttons, as well as internal mechanical and electrical components like gears, the motor, and wiring elements. In this subsection, a comprehensive table is presented listing each component by part number, name, quantity, and a corresponding image for visual reference. This systematic breakdown provides the foundation for subsequent analyses such as the bill of materials (BOM), liaison diagrams, and assembly sequencing. It also supports the evaluation of how each part contributes to the product's overall function and how they interact during the assembly process. Where necessary, some minor components such as standard screws or electrical connectors may be grouped or selectively included based on their relevance to assembly complexity and visibility in the disassembly process.

Table 2.1: *Components and their description*

No.	Name and Function	Image	Material	Qty.
1.	**Mixer Frame - 1:** Plastic housing for electronic components inside		Plastic	1
2.	**Mixer Frame - 2:** Plastic housing for electronic components inside		Plastic	1
3.	**Motor:** Several key components that work together to drive the lead screw which rotates the gears for mixing.		Plastic and Metal	1
4.	**Gears:** To translate motion from lead screw to attachments		Plastic	2
5.	**Gear Mount Frame:** To hold the gears axially and proper meshing of gears		Metal	2
6.	**Rubber Bushing:** Helps to reduce the vibrations, noise, and for structural support		Rubber	4
7.	**Turbo Button Extension:** Helps to activate and deactivate turbo mode by pushing mechanism		Plastic	1

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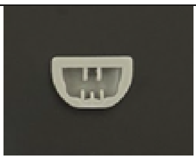
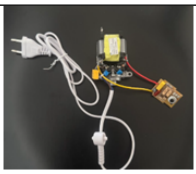
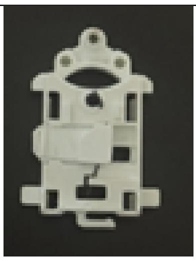
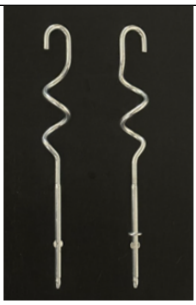
No.	Name and Function	Image	Material	Qty.
8.	**Turbo Button:** External button to operate turbo mode		Plastic	1
9.	**Transformer:** Converts electrical energy to mechanical motion by connection with motor		Metal and Plastic	1
10.	**Speed Control Wheel:** To control the speed of rotation of mixing attachments (whisks)		Plastic	1
11.	**Speed Control Gear:** Attached to control wheel to translate the rotation to attachments		Plastic	1
12.	**Speed Control Frame:** For holding the PCB, and speed control gear and wheel		Plastic	1
13.	**Speed Control Spring:** For clicking mechanism of speed control wheel		Metal and Plastic	1
14.	**Attachments:** Used for beating, whipping, and aerating ingredients		Metal	2
15.	**Attachments Button:** To change or release the attachments from the gears		Plastic	1

Continued on next page

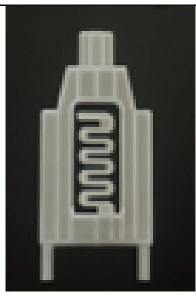
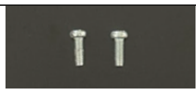
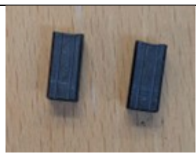
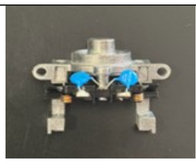
No.	Name and Function	Image	Material	Qty.
16.	**Attachments Button Extension:** Pushes the attachments from gears connecting to remove button		Plastic	1
17.	**Screw 1:** For fastening components		Metal	3
18.	**Screw 2:** For fastening components		Metal	2
19.	**Screw 3:** For fastening components		Metal	2
20.	**Screw 4:** For fastening components		Metal	1
21.	**Graphite Contacts:** Conducting electricity		Graphite	2
22.	**Motor Bearing:** Supporting the motor shaft		Metal	1

Table 2.2: *Functional Decomposition and Component Analysis*

Function	Primary Components / Subassemblies	Assembly Location	Notes
Convert electrical to mechanical energy	Motor, Transformer, Graphite Contacts	Central Motor Housing	Drives the entire rotation of attachments
Transmit rotational motion	Gear Mount Frame, Gears, Motor Shaft	Gear Subassembly	Ensures speed-torque optimization
Speed control	Speed Control Frame, Wheel, Gear, Spring, PCB	Top of Motor Housing	Allows user-defined control of motor speed
Turbo operation	Turbo Button, Turbo Button Extension	Handle Region	Temporary motor speed boost
User interface (ON/OFF, Speed)	Speed Control Wheel, Turbo Button	Handle	Provides input to electronics
Safety/Noise Control	Rubber Bushings, Ventilation slots, Mounting Plate	Frame-Motor Interface	Damps vibration; enables airflow and structural stability
Attachment Mounting/Release	Attachment Button & Extension, Beaters/Dough Hooks	Output Shaft	Facilitates easy insertion/removal
Power Transmission	Wiring, Graphite Contacts, Transformer	Electrical Subassembly	Links external power to the motor
Structural Integrity	Mixer Frame 1 & 2, Screws, Motor Bearing	Enclosure	Holds all internal systems

2.3 Component Geometry and Symmetry

Understanding the symmetry and dimensional attributes of individual components is essential for evaluating the complexity and efficiency of an assembly process. Symmetry directly influences the number of possible orientations a part can have during assembly. Components with high symmetry—such as those with 360° rotational symmetry—are easier to orient correctly, reducing the likelihood of errors and the time required for alignment. Conversely, asymmetric parts may require precise handling and visual verification, increasing cognitive and physical effort during manual assembly or requiring more sophisticated guidance systems in automated setups. Dimensional data, including size and thickness, impacts ergonomic considerations, fixture design, and the feasibility of automated part handling. Larger or irregularly shaped parts may require specialized tooling or pose challenges in maintaining assembly line balance. By systematically analyzing these characteristics, manufacturers can identify opportunities to simplify part geometry, improve assembly ergonomics, and support design decisions that align with principles of Design for Assembly (DFA).

Table 2.3: *Component Geometry and Symmetry*

No.	Name	Angle of Symmetry ($\alpha + \beta$)	Size(mm)	Thickness(mm)
1.	Mixer Frame - 1	$\alpha = 360°, \beta = 360°$	165	40
2.	Mixer Frame - 2	$\alpha = 360°, \beta = 360°$	165	40
3.	Motor	$\alpha = 360°, \beta = 360°$	140	25
4.	Gears: To translate motion from lead screw to attachments	$\alpha = 360°, \beta = 0°$	48	30
5.	Gear Mount Frame	$\alpha = 360°, \beta = 360°$	55	8
6.	Rubber Bushing	$\alpha = 360°, \beta = 180°$	12	10
7.	Turbo Button Extension	$\alpha = 360°, \beta = 360°$	50	13
8.	Turbo Button	$\alpha = 360°, \beta = 360°$	18	10
9.	Transformer	$\alpha = 360°, \beta = 360°$	45	23
10.	Speed Control Wheel	$\alpha = 360°, \beta = 360°$	40	15
11.	Speed Control Gear	$\alpha = 360°, \beta = 0°$	23	8
12.	Speed Control Frame	$\alpha = 360°, \beta = 360°$	60	18
13.	Speed Control Spring	$\alpha = 360°, \beta = 0°$	12	2
14.	Attachments	$\alpha = 360°, \beta = 0°$	180	20
15.	Attachments Button	$\alpha = 360°, \beta = 360°$	20	10
16.	Attachments Button Extension	$\alpha = 360°, \beta = 360°$	90	15
17.	Screw 1	$\alpha = 360°, \beta = 0°$	10	2
18.	Screw 2	$\alpha = 360°, \beta = 0°$	12	5
19.	Screw 3	$\alpha = 360°, \beta = 0°$	38	5
20.	Screw 4	$\alpha = 360°, \beta = 0°$	10	8
21.	Graphite Contacts	$\alpha = 360°, \beta = 180°$	10	4
22.	Motor Bearing	$\alpha = 360°, \beta = 360°$	60	36

2.4 CAD - Exploded View

The exploded view is a graphical representation that illustrates how all components of a product fit together while visually separating them to show their relative positions and relationships. It provides a clear understanding of the product's internal structure, part hierarchy, and the order of assembly. In the case of the electric hand mixer, the exploded view helps visualize the arrangement of key components such as the motor unit, gear assemblies, plastic housing, user interface elements, and attachments like the whisks and dough hooks. This visual aid is especially valuable for identifying sub-assemblies, understanding how parts interact, and verifying the completeness of the Bill of Materials (BOM). The exploded view also supports downstream analyses such as the liaison diagram and assembly sequence planning, serving as a foundational reference throughout the project. By creating this 3D representation, we gained deeper insights into the spatial constraints and potential design improvements related to assembly and maintenance.

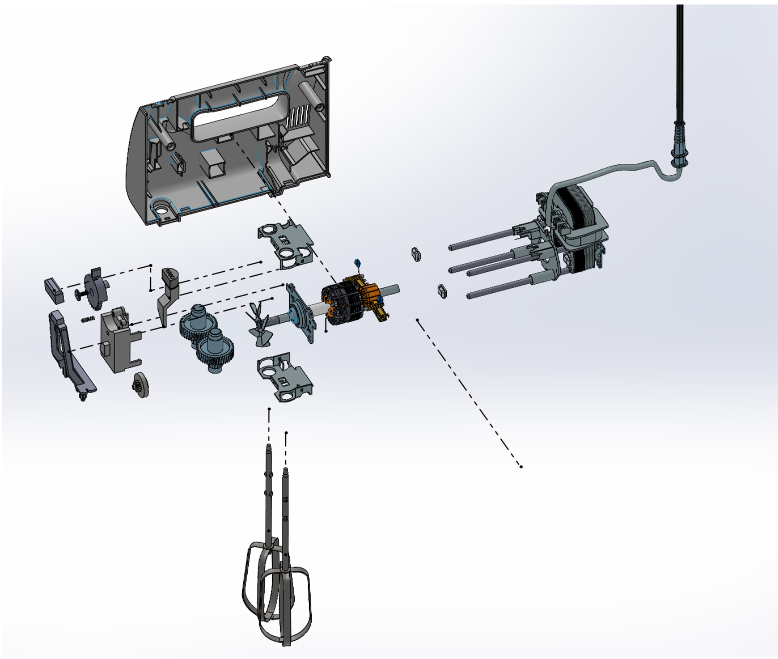


Figure 2.2: *Exploded View*

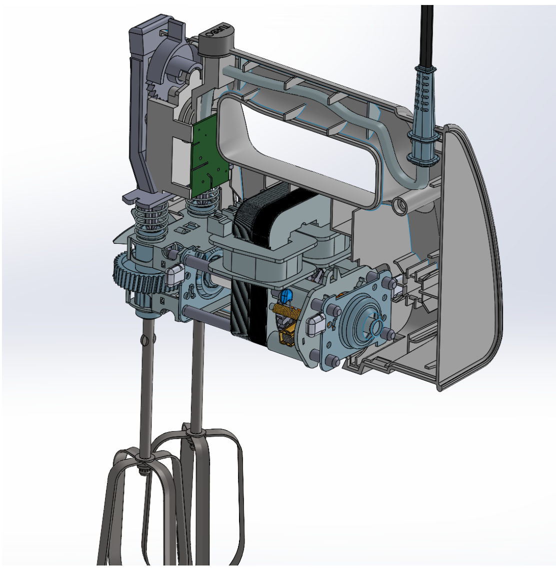


Figure 2.3: *Components assembled inside the product*

2.5 Bill of Materials (BOM)

The Bill of Materials (BOM) is a structured list that includes all the components required to assemble the electric hand mixer. It serves as a crucial reference point for procurement, inventory management, and cost estimation. The BOM not only identifies each part by name and quantity but also categorizes them based on their function—such as mechanical components, electrical elements, housing parts, and user interface components. In this project, a BOM flowchart is included to visually represent the hierarchical structure of the product, showing how individual parts and subassemblies integrate into the complete system. This flow-based view helps clarify assembly relationships and supports downstream tasks like liaison diagram creation and subassembly planning. The BOM also plays a vital role in evaluating the manufacturability of the design and identifying opportunities for simplification or standardization.

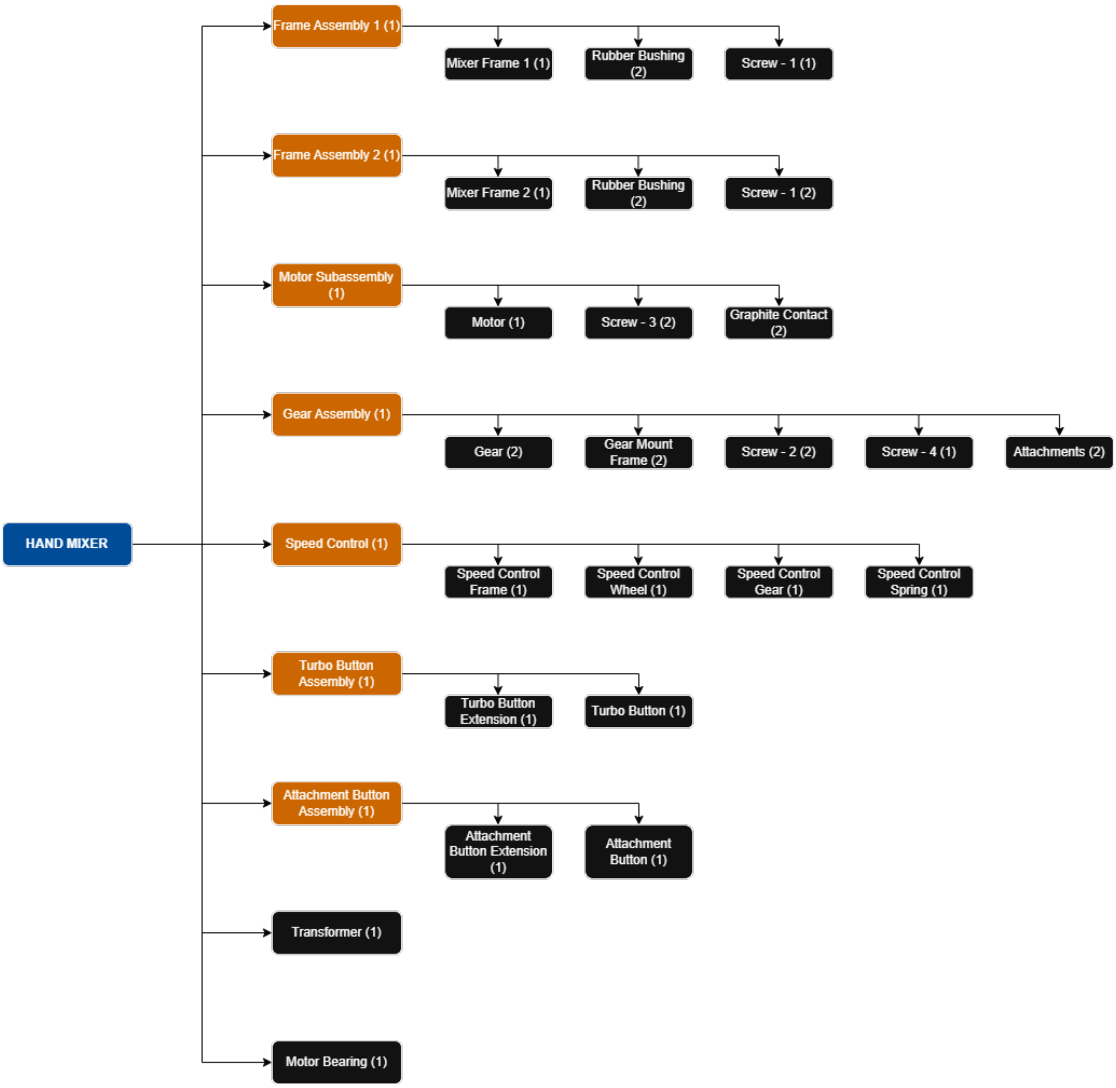


Figure 2.4: *Bill of Materials* (*BOM*)

2.6 Liaison Diagram

The liaison diagram is a graphical tool used to illustrate the physical and functional connections between components in an assembly. Each node in the diagram represents a component, while the lines (or links) between them indicate points of contact or interfaces where assembly operations occur. This diagram is particularly useful for visualizing the product's structure and understanding the dependencies between parts, which in turn informs the development of assembly sequences and identification of subassemblies. For the electric hand mixer, the liaison diagram highlights the central role of the main housing in supporting and connecting various internal components such as the motor, gears, and wiring. By mapping these interactions, the diagram helps to pinpoint complex interfaces that may require precise alignment, specific fastening techniques, or present potential challenges during assembly. Ultimately, the liaison diagram serves as a foundational reference for improving assembly efficiency, identifying simplification opportunities, and guiding design-for-assembly considerations.

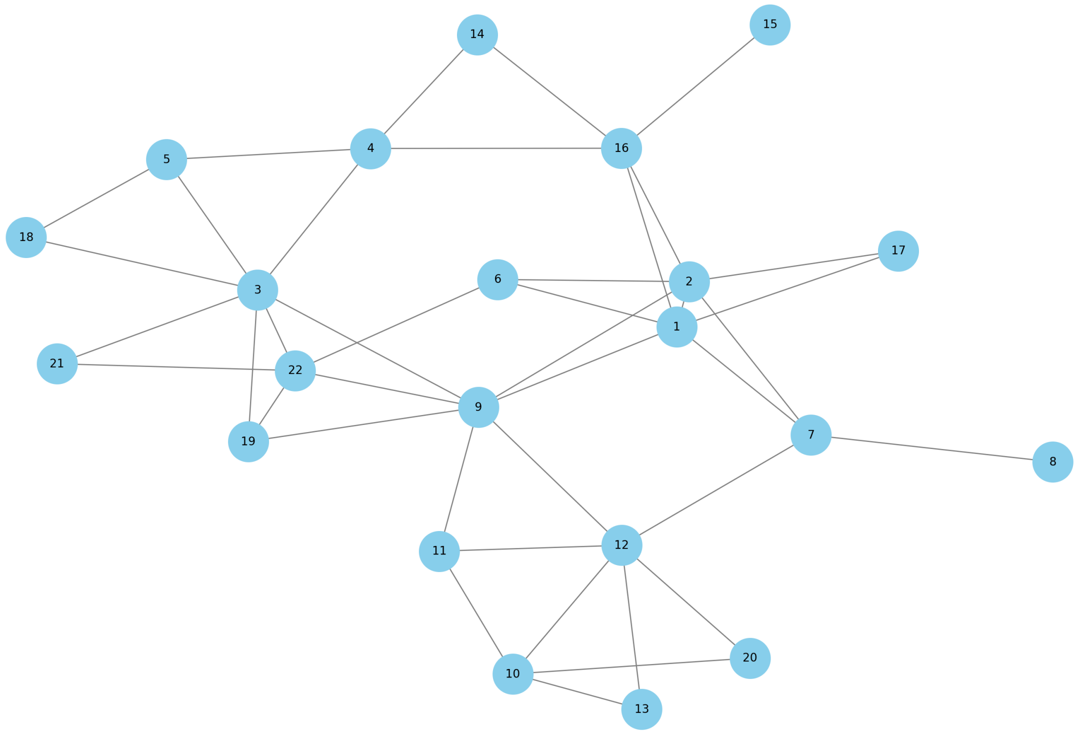


Figure 2.5: *Liaison Diagram*

3
Assembly Analysis

3.1 Assembly Operations

This subsection presents a comprehensive breakdown of all the assembly operations involved in assembling the electric hand mixer. Each operation is listed alongside the specific components involved, the estimated time required to complete the task, and its immediate predecessor(s) in the assembly sequence. Including the time duration for each operation allows for a quantitative evaluation of the total assembly time, helping to identify time-intensive tasks that may benefit from simplification or automation. Meanwhile, the predecessor information highlights dependencies between operations, forming the basis for constructing accurate precedence diagrams and optimizing the assembly sequence. This data is critical for tasks such as line balancing, where workloads must be evenly distributed across workstations, and for assessing the feasibility of parallel or modular subassemblies. By analyzing this table, we gain valuable insights into the efficiency and structure of the current assembly process, which supports later stages of process optimization and design improvement.

Table 3.1: *List of Operations with time taken and their predecessors*

Op. Code	Op. Description	Time (s)	Predecessors
A	Inserting both Screw 3 into the motor	5	-
B	Inserting transformer into the screws	5	A
C	Aligning the bearing with the screws	5	B
D	Fastening both Screw 3	39	C
E	Inserting the graphite contacts	23	D
F	Placing one of the mounting plates	3	E
G	Fastening one of Screw 2	17	F
H	Placing the gears	7	G

Continued on next page

Op. Code	Op. Description	Time (s)	Predecessors
I	Placing one of the mounting plates	3	H
J	Fastening one of Screw 2	17	I
K	Placing the spring in speed control frame	3	-
L	Aligning the speed control wheel with the frame	2	K
M	Placing the gear in the frame	2	-
N	Fastening Screw 4	12	L
O	Joining the motor subassembly with speed control assembly	5	M, N
P	Assembling the attachment's button and frame	2	-
Q	Assembling the turbo's button and frame	2	-
R	Placing the rubber bushing in Mixer Frame 1	5	-
S	Placing the rubber bushing in Mixer Frame 2	5	-
T	Final assembly placing motor subassembly, attachment, speed control, and turbo	80	J, O, P, Q, R, S
U	Fastening the final assembly with the Screw 1	54	T

3.2 Assembly Time

We carried out the entire assembly of the electric hand mixer in a controlled place and wrote down the time required for every step. To ensure the results were correct and similar, each task was repeated five times, and the average was taken as the final time. All the tasks were measured separately, and no operations were grouped during the process. Even when we did the same step twice in a row, such as putting in the rubber bushings (R and S) or joining the button and its extension (P and Q), the stopwatch was reset and treated each step as a different operation. Even though the physical assembly worked well, using this approach made it possible to measure each action accurately. It takes into account that people's performance can vary depending on familiarity, dexterity, and minor distractions. Using the data, we study the assembly process, identify areas that take a lot of time, and find chances to improve it. The table below shows the recorded times for each operation, along with their five trial durations and the average.

Table 3.2: *Trials for Assembly Time*

Op. Code	Trial 1 (s)	Trial 2 (s)	Trial 3 (s)	Trial 4 (s)	Trial 5 (s)	Average (s)
A	5	6	4	4	4	5
B	4	4	6	4	5	5
C	4	4	5	6	4	5
D	39	37	38	41	39	39

Continued on next page

Op. Code	Trial 1 (s)	Trial 2 (s)	Trial 3 (s)	Trial 4 (s)	Trial 5 (s)	Average (s)
E	23	24	22	23	21	23
F	3	4	2	3	3	3
G	17	16	18	17	17	17
H	7	6	7	8	7	7
I	3	3	4	3	3	3
J	18	16	17	19	17	17
K	3	3	4	3	3	3
L	2	3	2	2	2	2
M	2	2	3	2		2
N	12	11	12	13	12	12
O	5	6	5	4	5	5
P	3	2	2	2	3	2
Q	2	3	2	2	3	2
R	4	6	5	4	5	5
S	6	5	4	5	5	5
T	80	77	82	80	79	80
U	54	50	58	53	56	54

3.3 Precedence Diagram

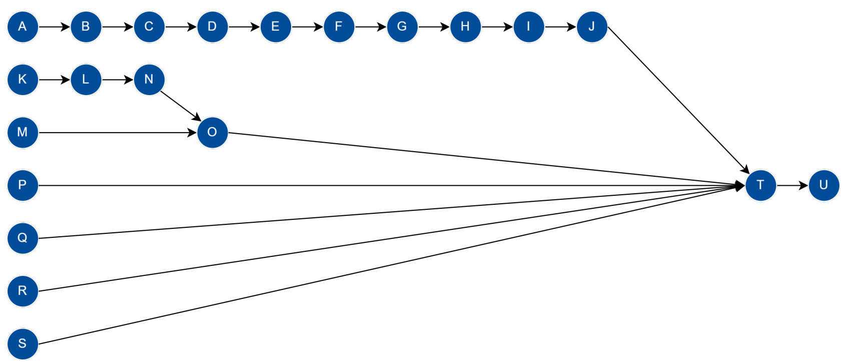


Figure 3.1: *Precedence Diagram*

A precedence diagram is a visual representation that outlines the logical sequence in which components must be assembled. It shows the dependencies between operations, indicating which tasks must be completed before others can begin. This tool is essential in complex assemblies involving multiple subcomponents, as it helps ensure that the process flows smoothly and efficiently without backtracking or rework. By identifying parallel and dependent tasks, the diagram aids in optimizing assembly line planning, reducing bottlenecks, and balancing workloads across stations. In this project, the precedence diagram was developed based on our detailed analysis of the hand mixer's components and their functional relationships. It serves as a foundation for developing optimal assembly sequences, line balancing calculate,ons, and evaluating potential for automation or process improvements.

3.4 Liaison Sequence Diagram (LSD)

The liaison sequence diagram is a visual tool used to represent the order in which components are assembled based on their physical and functional relationships. Building on the information provided in the liaison diagram and the precedence chart, this diagram helps identify feasible assembly paths and highlights dependencies between components. Each row in the diagram typically represents a component, and shaded or marked sections indicate the sequence in which that component becomes relevant during assembly. By comparing different starting points and pathways, the diagram assists in identifying the most efficient and logical assembly sequence. It is especially useful for recognizing subassemblies, minimizing assembly delays, and ensuring that all interactions between components are respected. In our hand mixer analysis, the liaison sequence diagram helped validate our proposed assembly plan and supported the identification of parallel operations and potential process optimizations.
The above figure shows the Liaison Sequence Diagram for our product with three different alternatives for the assembly sequence. The sequence marked in blue was deemed to be the most optimal because the motor subassembly is the most crucial subassembly in the product and several subassemblies are directly dependent on it. Assembling it first simplifies further assembly of parts and subassemblies leading to an optimum assembly time and also makes it convenient for the operators.

3.5 Design for Assembly (DFA)

Design for Assembly (DFA) is a methodology aimed at improving product design with a focus on simplifying the assembly process. By considering how a product will be assembled during the design phase, DFA helps reduce the number of parts, minimize assembly steps, and improve manufacturing efficiency. This leads to reduced production time and cost, fewer assembly errors, and improved overall product quality. DFA encourages intuitive part orientation, standardized components, and thoughtful integration of features that make both assembly and disassembly easier.
During our analysis of the electric hand mixer, several aspects of the design were identified as either supporting good assembly practices or offering opportunities for improvement. These observations are listed below:

3.5.1 Positive Aspects of the Existing Design

- The speed control frame includes a plastic projection to hold the wire securely in position, protecting the soldered connections and preventing potential damage.

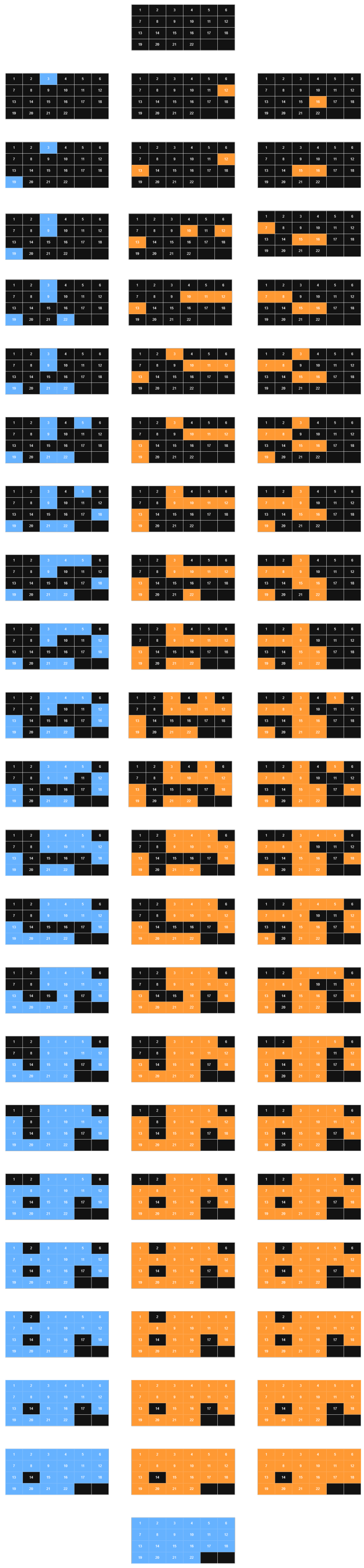


Figure 3.2: *Liaison Sequence Diagram (LSD)*

- Adequate ventilation holes are provided in the speed control frame, facilitating effective heat dissipation from the PCB.

3.5.2 Suggested Improvements Based on DFA Principles

Eliminating the hole in the Speed Control Frame

In the current design of the speed control frame, two holes are provided, one on each side of the frame. However, the spring is intended to be inserted exclusively into the right-side hole. The presence of the left-side hole can lead to assembly errors, as operators might mistakenly insert the spring into the wrong hole, potentially resulting in improper functioning of the assembly and increased rework time.

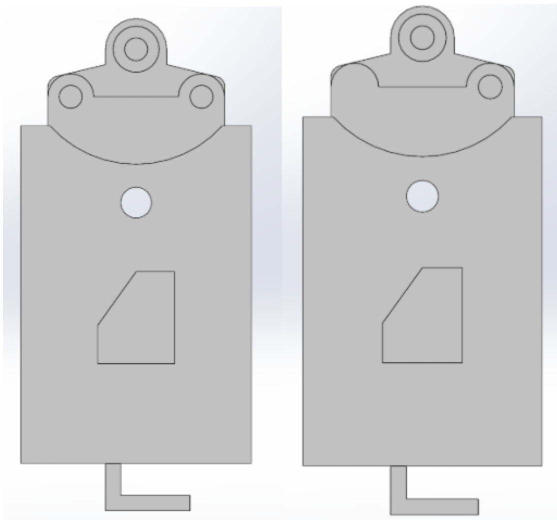


Figure 3.3: *Design suggestion for Speed Control Frame*

Eliminating the unnecessary left-side hole simplifies the assembly process by removing the possibility of confusion. From a quantitative perspective, removing the hole would marginally reduce the machining or manufacturing time for each part, as one less feature needs to be drilled or cut. This slight reduction in manufacturing time contributes to overall production efficiency, especially in high-volume manufacturing environments. Furthermore, by reducing potential assembly errors, the change minimizes the likelihood of rework or quality inspection failures, thereby improving overall yield and reducing indirect costs associated with quality control.
Trade-offs associated with this modification include a negligible reduction in the flexibility of the frame if future design revisions were to require the left-side hole for a different purpose. However, given the current design intent, the elimination of the left-side hole directly enhances assembly reliability, improves manufacturing efficiency, and supports lean manufacturing principles.
Additionally, it is important to note that in certain cases, the left-side hole might be essential for accommodating a different variant of the product. If the speed control frame serves as a common component across multiple variants, removing the left-side

hole could limit its versatility and lead to additional redesign efforts for other configurations. However, for the specific product addressed in this report, the left-side hole is not required for the current assembly and can be eliminated without compromising the functionality of the speed control frame.

Welding of the Gear Mount Frame

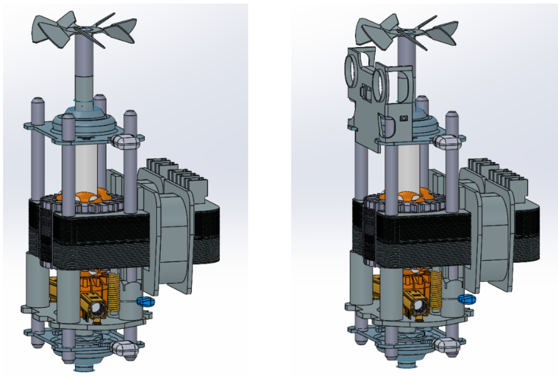


Figure 3.4: *Design suggestion for Gear Mounting Frame*

If the motor is procured with one of the gear mount frames already welded to it, the assembly process would become significantly easier and more efficient. This modification would eliminate the need for additional fastening operations, such as aligning and securing the frame to the motor during assembly, thus reducing the number of assembly steps. From a quantitative perspective, this streamlining translates into a reduction in assembly cycle time and minimizes the possibility of alignment errors that could compromise performance or require rework. Consequently, overall productivity and product quality would improve, resulting in a more reliable assembly process that aligns with lean manufacturing objectives.
Quantitatively, welding the gear mount frame directly to the motor would involve a small increase in initial production costs, as welding is typically more resource-intensive than using fasteners or other joining methods. The upfront cost for welding equipment, jigs, and skilled labor would need to be considered. However, this change would significantly reduce the assembly time, eliminating the need for manual alignment and bolting operations during assembly. This reduction in labour can lead to decrease in overall assembly cycle time, depending on production volume and complexity. Additionally, eliminating the fasteners not only simplifies inventory management and reduces associated costs but also minimizes potential quality issues related to loose fasteners in operation. Over the lifecycle of high-volume production, these incremental cost increases in the welding process would be offset by substantial time savings, lower labor costs, and improved product reliability and performance.

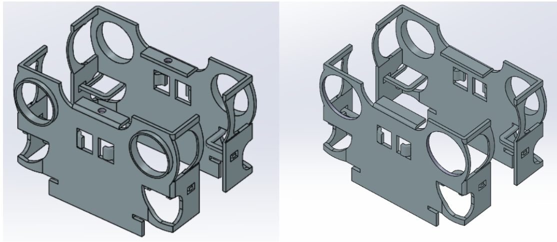


Figure 3.5: *Design improvement for Gear Mounting Frame*

Varying the diameter of Gear Mounting Frame

Currently, the ends of the gears and the holes in the gear mounting frame have identical diameters, which may lead to confusion during assembly. This similarity can result in incorrect gear positioning or misalignment, potentially compromising the performance and reliability of the final product. To address this issue, one end of the gear could be modified to have a different diameter, with the corresponding hole in the gear mounting frame adjusted accordingly. This differentiation would serve as a visual and physical guide, effectively eliminating assembly errors by ensuring that the gear can only be inserted in the correct orientation. As a result, assembly efficiency and accuracy would improve, while the risk of misalignment and associated rework would be significantly reduced.
Quantitatively, introducing a different diameter for one end of the gear and the corresponding hole in the gear mount frame would involve slight modifications to the machining or manufacturing processes. This adjustment may increase the initial tooling or setup costs marginally, as two different hole sizes would need to be accurately produced and inspected. However, the long-term benefits such as reducing assembly errors, minimizing rework, and improving first-pass yield would outweigh these minor upfront investments. Specifically, avoiding rework and ensuring proper assembly can lead to a measurable reduction in total assembly cycle time and associated labor costs. Additionally, by eliminating potential misalignments, the product's operational reliability and lifespan would improve, contributing to lower warranty claims and increased customer satisfaction. Overall, this design improvement enhances assembly quality and throughput with minimal impact on the manufacturing cost per unit.

Changing the Orientation of the Screw

Fastening screws on the gear mount frame is challenging because the fan, press- fitted to the motor subassembly, obstructs access. Changing the screw orientation to a direction perpendicular to the fan would simplify assembly. Quantitatively, altering the screw orientation to a direction perpendicular to the fan would require modifications to the gear mount frame design and the associated tooling or fixture setup. This design change may introduce a minor increase in manufacturing costs due to additional design, machining, or retooling efforts to accommodate the new screw orientation. However, the significant benefit lies in the substantial reduction of assembly time and effort.

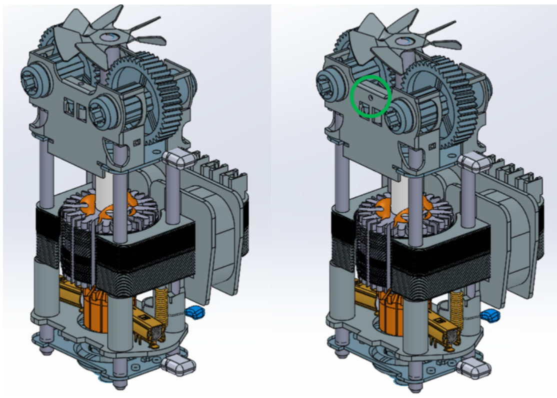


Figure 3.6: *Design improvement for ease of fastening*

With improved accessibility to the screws, operators would be able to fasten the gear mount frame more efficiently, reducing the risk of tool slippage, potential damage to adjacent components, and associated rework costs. Preliminary assessments suggest that this design change could reduce the time required to fasten each screw, leading to overall cycle time savings and a corresponding decrease in labor costs.
Additionally, simplifying the assembly process reduces operator fatigue and the potential for quality defects, thus improving first-pass yield and ensuring consistent product quality. Therefore, while minor upfront investments may be necessary, the long-term productivity gains and quality improvements make this trade-off a favorable one in high-volume production environments.

Providing a Cavity in the Frame

During disassembly, separating the frames requires a sharp tool due to the absence of dedicated separation features. Introducing a small cavity at the frame intersections would make disassembly easier and safer.
Quantitatively, introducing a small cavity at the frame intersections would slightly increase the machining or tooling complexity during manufacturing, adding minor costs in terms of processing time or equipment adjustments. However, this addition would significantly ease the disassembly process, reducing the time required and the risk of damaging the components or the surrounding structure during maintenance, repair, or rework operations. By enabling safer and quicker separation of the frames, operator injuries due to the use of sharp tools could be minimized, potentially improving safety and reducing costs associated with workplace injuries or ergonomic issues. Early estimates suggest that disassembly time could be reduced, leading to cumulative labour savings in maintenance or repair operations. Overall, the trade-off involves a negligible increase in manufacturing costs, balanced by improved product maintainability, reduced damage risk, and enhanced safety, making it a beneficial modification in most industrial applications.

3.5.3 DFA for Manual Assembly (Boothroyd Method)

Design for Manual Assembly (DFMA) calculations are used to quantitatively assess how efficiently a product can be assembled by hand. The method, developed by Boothroyd and Dewhurst, involves assigning standard time values to basic manual assembly tasks such as part handling, orientation, and insertion. By evaluating each component in the product, we can estimate the total manual assembly time and subsequently determine the assembly efficiency of the design.

In our analysis of the hand mixer, we assigned appropriate handling and insertion times to each part using standard DFMA tables. Factors like part symmetry, orientation difficulty, and fastening method were considered. The final efficiency value provides a measure of how well the product design supports manual assembly. A low efficiency suggests opportunities to simplify the design, combine parts, or reduce reorientation and fastening effort.

In the context of Design for Assembly (DFA), N_{min} represents the theoretical minimum number of parts required to achieve the product's intended functionality. It serves as a benchmark to assess how efficiently a product has been designed from an assembly perspective. The idea is to determine which components are truly essential—those that must remain as separate parts because they either move relative to other parts, must be made from different materials, or are required for assembly/disassembly.

$$N_{\text{min}} = 18$$

Table 3.3: *Classification and Timing for the assembly operations*

Op. Code	Op. Description	Code	Time (s)
A	Inserting both Screw 3 into the motor	09	7.5
B	Inserting transformer into the screws	35	2.73
C	Aligning the bearing with the screws	35	2.73
D	Fastening both Screw 3	92	5
E	Inserting the graphite contacts	62	5.55
F	Placing one of the mounting plates	30	1.95
G	Fastening one of Screw 2	38	6
H	Placing the gears	00	1.13
I	Placing one of the mounting plates	30	1.95
J	Fastening one of Screw 2	38	6
K	Placing the spring in speed control frame	08	2.45
L	Aligning the speed control wheel with the frame	30	1.95
M	Placing the gear in the frame	00	1.13
N	Fastening Screw 4	38	6

Continued on next page

Op. Code	Op. Description	Code	Time (s)
O	Joining the motor subassembly with speed control assembly	35	2.73
P	Assembling the attachment's button and frame	30	1.95
Q	Assembling the turbo's button and frame	30	1.95
R	Placing the rubber bushing in Mixer Frame 1	11	1.8
S	Placing the rubber bushing in Mixer Frame 2	11	1.8
T	Final assembly placing motor subassembly, attachment, speed control, and turbo	35	2.73
U	Fastening the final assembly with the Screw 1	38	6
			$t_{\mathbf{ma}}$ **= 71.03**

The assembly efficiency can be calculated using the following formula:

$$E_{\text{ma}} = \left(\frac{3 \times N_{\text{min}}}{t_{ma}}\right) \times 100 = 76\%$$

where:

$$\begin{aligned} E_{\text{ma}} &= \text{Assembly Efficiency (\%)} \\ N_{\text{min}} &= \text{Theoretical minimum number of parts} \\ t_{ma} &= \text{Total manual assembly time (in seconds)} \end{aligned}$$

3.5.4 DFA for Automated Assembly

Table 3.4: *Assembly Index on Product level*

	No. of parts	Unique Parts	Base Object	Design base object	Assembly direction	Parallel Operations	Chains of tolerances	Sum
Product	3	1	1	1	1	3	1	11

Table 3.5: *Assembly Index on Part level*

	Need to assemble part	Level of defects	Orientation	Non Fragile parts	hooking	Centre of gravity	Chains of tolerances	Shape	Weight	Length	Gripping	Assembly motion	Reachability	Insertion	Hole assembled parts	Fastening method	Joining	Check/Adjust	Sum
1	9	1	3	3	1	1	1	3	3	3	1	3	3	1	1	1	3	1	42
2	9	1	3	3	1	1	1	3	3	3	1	3	3	1	1	1	3	1	42
3	9	3	1	3	1	1	1	3	3	3	1	1	3	1	1	1	1	1	38
4	9	1	3	3	9	3	3	9	9	9	3	3	3	9	1	3	3	3	86
5	9	1	3	3	9	3	3	3	9	3	3	3	3	3	3	3	3	3	70
6	9	9	3	9	9	9	3	3	3	1	9	3	3	3	9	9	9	3	106
7	9	9	3	1	9	1	1	3	1	3	3	1	1	1	9	3	9	9	76
8	9	9	3	1	9	1	1	3	1	3	3	1	1	1	9	3	9	9	76
9	9	1	1	1	1	1	1	9	9	1	1	1	1	1	1	1	1	1	41
10	9	3	3	3	9	3	3	9	3	1	1	3	3	3	3	3	3	3	68
11	9	1	3	3	1	1	1	3	3	3	1	3	3	1	1	1	3	1	42
12	9	1	3	3	1	1	1	3	3	3	1	3	3	1	1	1	3	1	42
13	9	1	3	3	9	3	9	1	1	1	9	3	9	1	3	9	9	3	86
14	9	3	3	3	1	1	3	9	9	3	9	3	3	3	9	9	9	3	92
15	9	9	3	1	9	1	1	3	1	3	3	1	1	1	9	3	9	9	76
16	9	9	3	1	9	1	1	3	1	3	3	1	1	1	9	3	9	9	76
17	9	9	9	3	9	1	9	9	3	3	3	3	9	3	3	3	3	3	94
18	9	9	9	3	9	1	9	9	3	3	3	3	9	3	3	3	3	3	94
19	9	9	9	3	9	1	9	9	3	3	3	3	9	3	3	3	3	3	94
20	9	9	9	3	9	1	9	9	3	3	3	3	9	3	3	3	3	3	94
21	9	9	3	9	9	9	3	3	3	1	9	3	3	3	9	9	9	3	106
22	9	1	1	1	1	1	1	9	9	1	1	1	1	1	1	1	1	1	42

Parts 6 and 21 (The rubber bushing and graphite contacts respectively) score highly in almost all the criteria, since square shape provides high rotational symmetry, allowing a robot to insert it without needing precise angular alignment, which saves time and simplifies programming. The clear asymmetry between the hollow top and flat bottom is easily detectable by sensors to prevent upside-down assembly. Finally, its compact, block-like form prevents tangling in automated feeders, and the compliant rubber material forgives minor misalignment during the simple, straight-line insertion process. To evaluate the suitability of automatic assembly, the Eskilander method was

employed. This assessment enables a comparison of the efficiency between automatic and manual assembly processes for the components in question. Table 3.4 presents the assembly index at the product level, indicating that the feasibility of automatic assembly is relatively low. Subsequently in table 3.5, the Eskilander method was applied at the part level, yielding an automatic assembly efficiency of 44.4%, in contrast to a manual assembly efficiency of 76%.

$$\text{Assembly index on part level} = \frac{\text{Total sum}}{\text{Max no. of points} \times \text{Number of parts}} = \frac{1583}{162 \times 22} = 44.4\%$$

3.6 Feeder Suitability and Handling Challenge

Even though our final assembly line was entirely manual, we analysed each part separately to check if it would work well in an automated assembly line. This analysis is necessary to see if automation or hybrid strategies are possible and to find out which parts would be easy to automate and which would be more difficult.

Feeder suitability means that a part can be fed to a workstation in the correct way and orientation using typical feeding systems. The handling challenge reflects the complexity involved in the part's geometry, how delicate it is, its symmetry, and the level of precision needed. Tasks that are easy to automate are those that are easy to feed and not too complicated to handle.

The table below outlines this analysis for key components of the product:

Table 3.6: *Part assessment for feeding and handling suitability*

Part No.	Part Name	Feeder Suitability	Handling Challenge	Remarks
1	Mixer Frame	Low	High	Large, asymmetrical; difficult to orient or feed
4	Gears	High	Low	Small, symmetric; ideal for automatic insertion
6	Rubber Bushings (L/R)	Medium	Medium	Flexible; requires compliance and angular insertion
7	Turbo Button Extension	High	Low	Rigid, simple shape; easy to automate
9	Transformer	Low	High	Heavy and sensitive; alignment is critical
14	Attachments (Whisks)	Medium	High	Long and delicate; difficult to grip without damage
17–20	Screws	High	Medium	Easy to feed; tool engagement and torque control needed

It seems that a line that uses automation would encounter various design and integration difficulties. While the gears, screws, and turbo button extension can be automated, the mixer frame, transformer, and attachments are very hard to automate. Because of their shape, size, and sensitivity, these parts would need special grippers, controlled force during insertion, or vision-guided systems, which would add both cost and complexity.

Furthermore, when the work involves fine alignment, soft materials, or long components, it would be necessary to use either very specialized automation or a combination of automation and human help at certain points. For instance, placing the transformer would probably require a robot with advanced compliance and feedback to avoid any misalignment and damage.

In summary, some parts of this product could be made using automation, but to make the whole assembly process automated, several parts would have to be redesigned to reduce asymmetry, add alignment features, and simplify the way they are joined. Therefore, automation can be done in theory, but because of the product's design and the expected number of units, manual assembly is still the best and most affordable way. It helps find parts that can be automated and directs future DFA changes to support the growth of manufacturing.

4

Line Balancing

4.1 Summary of Key Information

- Total Demand = 127,000
- Adjusted Takt Time (for η = 90%) = 89 seconds
- Minimum Number of Workstations = 4

As a part of line balancing, we have considered all three methods:

1. Largest Candidate Rule
2. Killbridge and Wester's Method
3. Ranked Positional Weight Method

4.2 Largest Candidate Rule

The Largest Candidate Rule is based on arranging operations in descending order of cycle time and then assigning them to individual stations while maintaining precedence constraints.

Table 4.1: *Largest Candidate Rule - Station Allocation*

Station #	Operations	Total Assembly Time (s)
1	A, B, C, D, E, R, S, Q	89
2	F, G, H, I, J, K, M, P, L, N, O	71
3	T	80
4	U	54

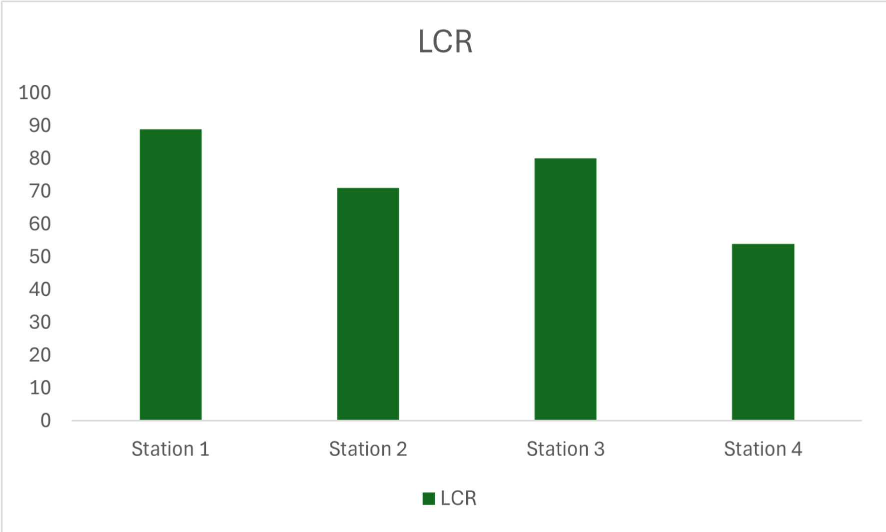


Figure 4.1: *Largest Candidate Rule Method*

4.3 Killbridge and Wester's Method

In this method, tasks are arranged in columns based on their position in the sequence diagram and then allocated to stations based on precedence constraints.

Table 4.2: *Killbridge and Wester's Method - Station Allocation*

Station #	Operations	Total Assembly Time (s)
1	A, K, M, P, Q, R, S, B, L, N, C, D	87
2	O, E, F, G, H, I, J	75
3	T	80
4	U	54

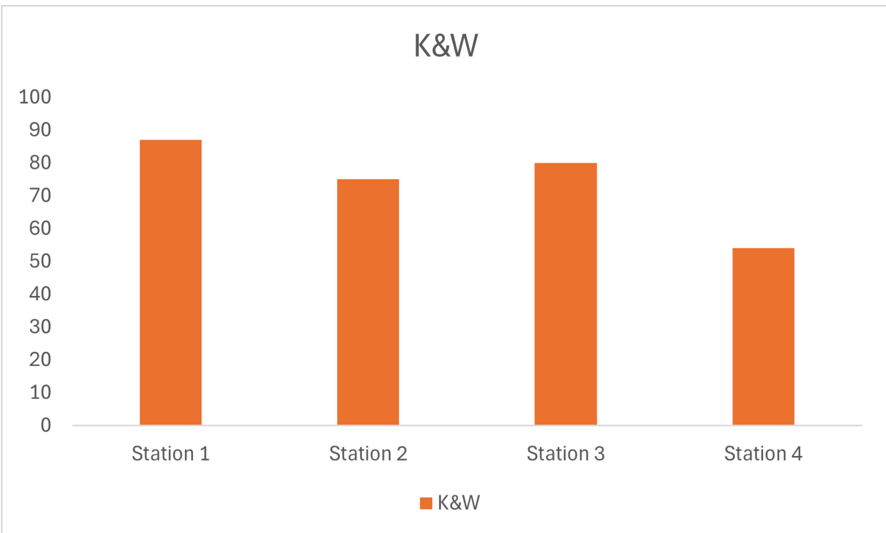


Figure 4.2: *Killbridge and Wester's Method*

4.4 Ranked Positional Weight Method

In this method, tasks are first assigned positional weights (sum of times of the task and all its successors). Tasks are then arranged in descending order of these weights and assigned to stations based on precedence constraints.

Table 4.3: *Ranked Positional Weight Method - Station Allocation*

Station #	Operations	Total Assembly Time (s)
1	A, B, C, D, E, F	80
2	G, H, K, I, L, J, N, O, R, S, P, Q	80
3	T	80
4	U	54

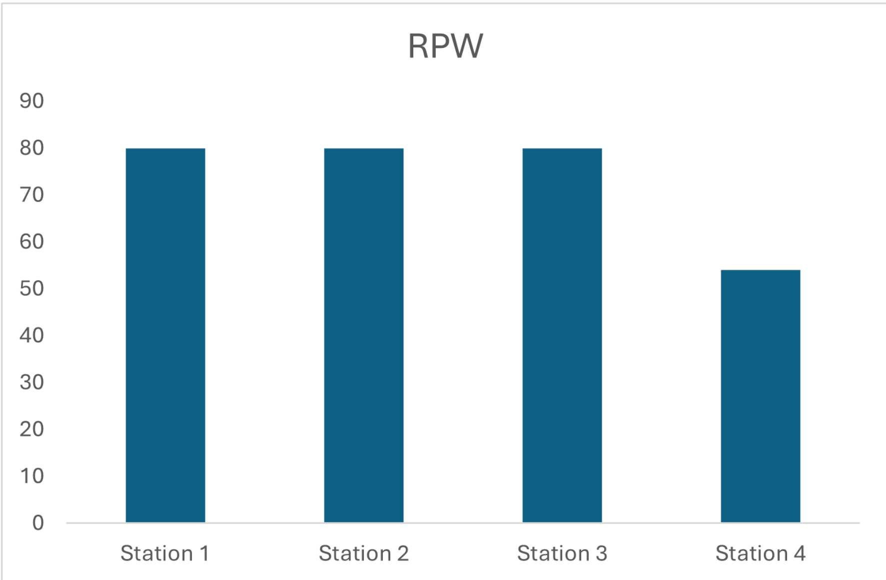


Figure 4.3: *Ranked Positional Weight Method*

4.5 Final Summary

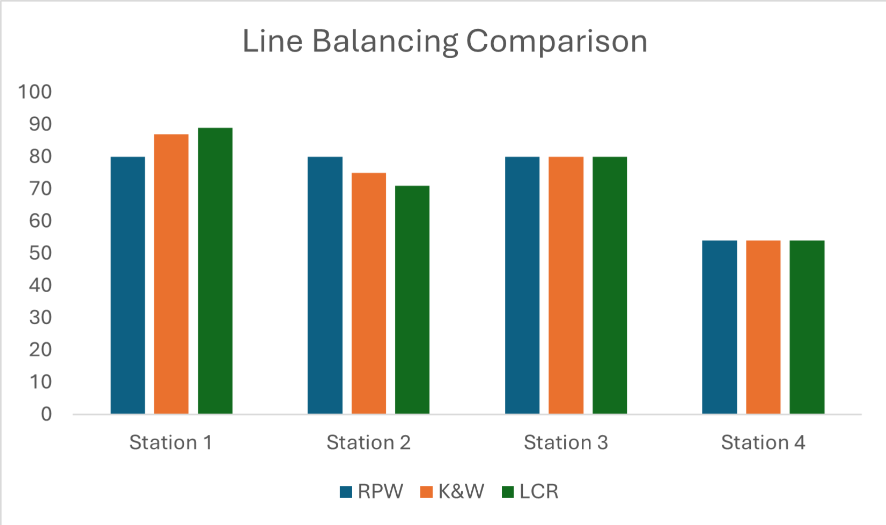


Figure 4.4: *Final Line Balancing Comparison*

Although the RPW method provided the best balance among tasks at the four stations, the line efficiency was only about 75%, which may not seem ideal. Still, this choice was planned and made after considering practical issues, the task's characteristics, and ergonomics.

Some of the first tasks in our process require us to use our hands, switch tools, or handle small parts such as rubber bushings (Tasks R & S), align the gears, and deal with the transformer unit. Although these steps are short, they still need care and repositioning, which adds more complexity to the situation than the time data shows. As for time data, we did it five times, but in the actual production line, the situation will be different. Instead of making the cycle time very short with the same balancing efficiency, we kept buffer time at each station to handle unexpected issues.

- Operators make brief pauses to check the situation or adjust their view
- Repositioning losses from handling asymmetrical parts
- Checking the tightness of the fasteners for torque-based operations
- The time it takes to change tools, mainly when many fastenings happen one after another at Station 1

Second, some tasks are very short, and it is tough to assign them without overloading a station. The tasks are connected and cannot be separated since they are close and must be handled together. Adding a fifth station would cut the workload for each station but would also create more idle time and an imbalance among operators, mainly in a semi-manual line.

Also, we see the time spent at each station as a planned way to be flexible. This time can be used for:

- Inline visual quality checks for alignment-sensitive parts

- Changing operators, managing their fatigue, and avoiding overly tight work schedules
- Keeping the line moving even when there are small tool or part-feeding issues

It follows lean principles by respecting operators' differences, preventing errors instead of fixing them, and having some extra capacity to avoid delays.
Finally, the low efficiency was compared to the throughput that was needed. As the target production volume (described in Section 6.1.1) is not high and allows for a little extra capacity, we made sure to focus on making the line comfortable for operators and stable, rather than maximizing efficiency.

5

Factory Layout

5.1 Justification for Manual Assembly

Manual handling was selected primarily due to the medium to high product demand anticipated for the hand mixer. In this context, the cost associated with establishing an assembly line is justified by the expected production volume, making manual handling an efficient and economical choice. Furthermore, the nature of the product lineup, consisting mainly of identical or very similar models, enables process standardization. With minimal variation between products, it becomes easier to optimize workflows, reduce errors, and maintain consistent quality across production batches.

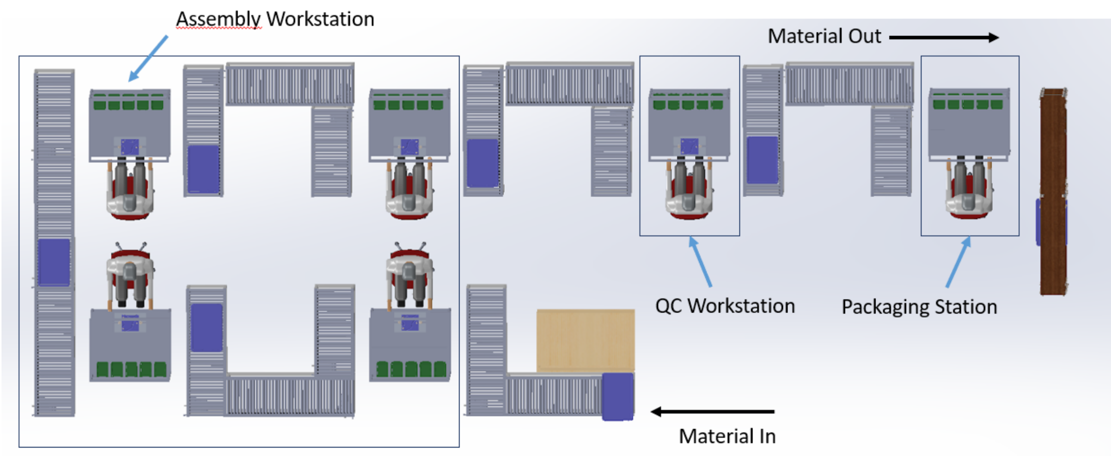


Figure 5.1: *Division of Workstations*

5.2 Assembly Strategy and Task Allocation

The assembly tasks associated with the hand mixer can be effectively divided into smaller, manageable work elements. This divisibility allows tasks to be assigned systematically across multiple operators, enhancing labor efficiency and ensuring that the workload is balanced throughout the line. Additionally, automation was assessed but ultimately deemed infeasible for this application. The complexity and costs involved in automating such a detailed assembly process would not offer sufficient return on investment, especially considering the flexibility and adaptability required in production. Thus, manual assembly was chosen as the most practical and responsive approach.

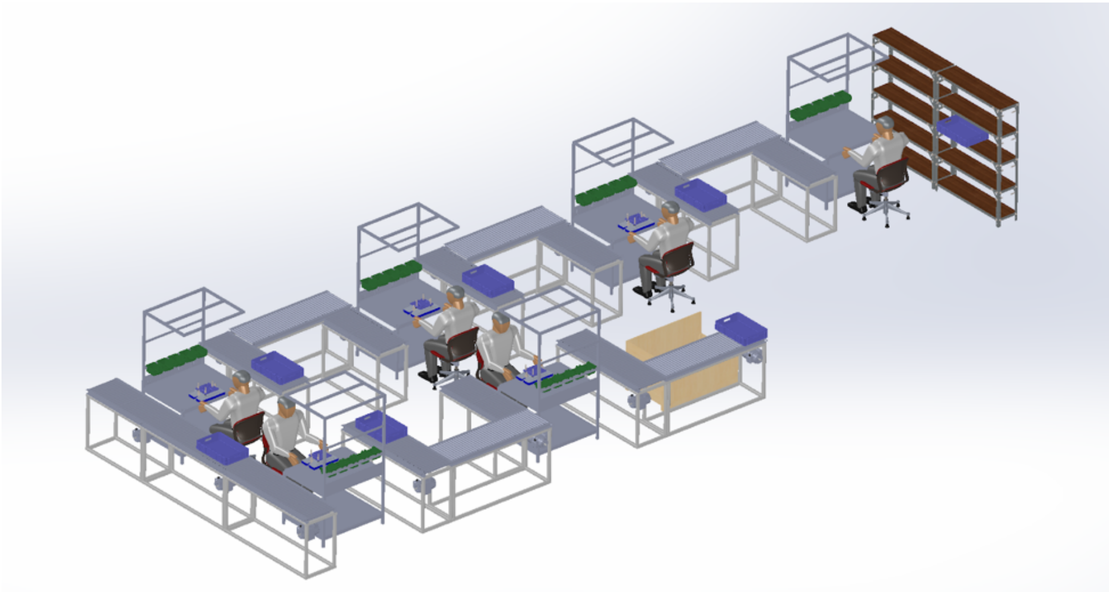


Figure 5.2: *Isometric View of the Assembly Line*

Manual assembly remains a common practice, particularly in the production of consumer goods where variability, frequent design updates, and moderate production volumes make complete automation less desirable. Following best practices, the assembly system for the hand mixer is organized to focus on producing a single product or a very limited range of variations. This strategy helps to maintain a smooth flow, minimize setup times, and enhance overall operational efficiency.

5.3 Layout and Material Flow Considerations

Each hand mixer is constructed from multiple individual components, and the assembly process involves joining these parts through distinct manual work elements. Careful attention is given to ensure that each step contributes to the structural and functional integrity of the final product. The total work content, therefore, represents the accumulation of all manual operations necessary to assemble one complete unit, factoring in both the complexity of the tasks and the handling of parts.

To align with the requirements for product size, production volume, and needed flexibility, a multi-station assembly layout was selected. In this system, the product moves progressively through a series of dedicated stations, with each station responsible for specific assembly tasks. Mechanized transport has been incorporated to support the efficient handling of the hand mixer units as they move between stations. Given the product size and the need to maintain a continuous and reliable assembly flow, mechanized movement ensures that components and partially assembled units are trans-

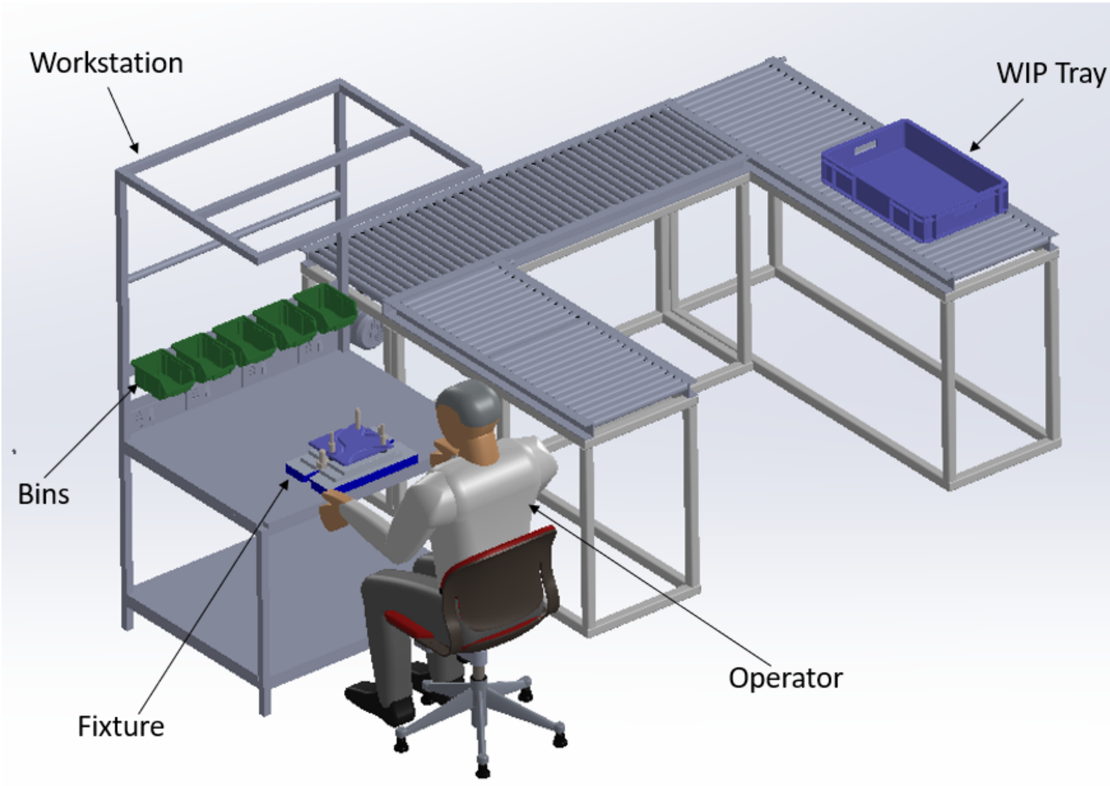


Figure 5.3: *Assembly Workstation*

ported smoothly without excessive manual lifting or delays. This approach improves productivity, reduces worker fatigue, and helps maintain a consistent production rhythm across the entire line.

6
Economic Analysis

In this chapter, a comprehensive economic analysis of the project will be presented, outlining the key financial assumptions, methodologies, and considerations that form the basis of all subsequent calculations. This includes identifying cost components, estimating revenues, evaluating operational parameters, and assessing financial feasibility using standard economic evaluation techniques.

6.1 Basic Assumptions

- **Working days in a year**: 250
- **No. of shifts per day**: 2
- **Shift Duration**: 7 hours
- **Annual Demand**: 127,500 units

6.1.1 Annual Demand Estimation

- **Annual Revenue of Clas Ohlson products**: SEK 10.2 billion
- **Estimated Share of Kitchen Appliances (approx.)**: 10% = SEK 1.02 billion
- **Estimated Share of our product (Electric Hand Mixer)**: 2.5% = SEK 25.5 million
- **Cost per unit**: SEK 200

$$\textbf{Annual Demand} = \frac{25{,}500{,}000}{200} = 127{,}500 \text{ units/year}$$

6.1.2 Takt Time Calculation

$$\text{Takt Time} = \frac{\text{Available production time per year}}{\text{Annual Demand}} = \frac{250 \times 2 \times 25200}{127{,}500}$$
$$\implies \text{Takt Time} = 98.8 \text{ seconds/unit}$$

Considering a line efficiency of 90%, we get:

$$\text{Actual Takt Time} = 89 \text{ seconds/unit}$$

6.1.3 Theoretical Minimum Number of Workstations

$$\text{Total Throughput Time} = 296 \text{ seconds}$$

Thus, the theoretical minimum number of workstations is calculated as:

$$\frac{\text{Throughput Time}}{\text{Adjusted Takt Time}} = \frac{296}{89} \approx 3.32 \approx 3 \text{ workstations}$$

6.1.4 Overall Efficiency

Consider the repositioning time:

$$\text{Repositioning Time} = 2 \text{ seconds}$$

Maximum time available per station:

$$T_{\max} = \text{Takt Time} - \text{Repositioning Time} = 89 - 2 = 87 \text{ seconds}$$

Repositioning efficiency:

$$\eta_r = \frac{T_{\max}}{\text{Takt Time}} = \frac{87}{89} \approx 0.9775 = 97\%$$

Balancing efficiency:

$$\eta_b = \frac{\text{Throughput Time}}{N_{\text{th}} \cdot T_{\max}} = \frac{296}{4 \times 87} = \frac{296}{348} \approx 0.8506 = 85\%$$

Overall efficiency:

$$\eta = \text{Line Efficiency} \times \eta_b \times \eta_r = 0.95 \times 0.85 \times 0.97 \approx 0.748 = 75\%$$

6.2 Financial Analysis for Manual Assembly

Based on the average wages in Sweden currently, we assumed the hourly pay of the operators to be 130 SEK per hour. From Line Balancing, we got the required number of assembly stations as four. Two more stations would be required for quality control and assembly. One operator would work on each station. Therefore, each shift would have a total of 6 operators. Considering two shifts in a day, a total of 12 operators would be hired. Cost for annual salary would be:

$$\text{Annual Wages} = 6 \times 2 \times 7 \times 250 \times 130 = 2,730,000 SEK$$

Table 6.1: *Equipments required for workstation*

Item	Cost p. unit (SEK)	Qty.	Total Cost (SEK)
Workbench	5000	4	20000
ESD Strap	300	4	1200
Torque Driver	900	4	3600
Vise	1000	4	4000
			Total = 28800

Each workstation would have certain tools and supplies for the workers to use for carrying out the assembly operations. The cost breakdown for setting up the stations is given in the above table.
The total cost is for manual assembly is as follows:

Annual Wages + Workstation Cost = 2730000 + 28800 = **2,758,800 SEK**

6.3 Financial Analysis for Automated Assembly

The proposed automated assembly system is divided into two operational groups, each equipped with specialized robotic and material handling solutions to streamline the hand mixer assembly process. The breakup of the equipment required for carrying out the assembly with automation is shown in the table below.

Table 6.2: *Cost breakdown for automated assembly equipment*

Operations	**Equipment**	**Qty**	**Price (SEK)**	**Total Cost (SEK)**	**Supplier**
A,B,C,E,F,H,I,K,L,M	Custom Automated Assembly Line with Hopper, Parts Feeder, Orientor and Feed Track	4	450,000	1,800,000	AVT Industrietechnik AB
	ABB YuMi IRB 14000	2	600,000	1,200,000	ABB
D,G,J,N	Custom parts feeding, orienting, and conveying solution	2	200,000	400,000	Hoosier Feeder Company
	ABB YuMi IRB 14000	1	600,000	600,000	ABB
				TOTAL	**4,000,000**

While much of the assembly process is automated, a certain level of human involvement remains necessary for monitoring robot performance and system status, refilling feeders and handling raw materials, performing quality control (QC), conducting final packaging operations, addressing minor faults or resets, etc. One operator per operation group and two operators would be required for supervising quality control and packaging. Therefore a total of 4 operators would be required per shift.
For operations P and Q, automated assembly could have been used, but it is not feasible to implement automation for just two operations, as they can be easily performed

manually. Operations O, R, S, T, and U are also carried out manually in this example case due to the asymmetry of the parts and the subsequent handling difficulty.
Operations P and Q seem the most feasible to automate since the components involved are the turbo button and the attachment buttons (and their frames). These parts score highly on DFA for Automation(part level). These components are light, wont tangle during feeding and are easy to perform the operation as it is just a simple insertion of the button into the respective frames. The insertion process is also guided adequately by chamfers present on the frame. For the other operations, especially operation U are very complicated to perform. Even though it is a simple placing of the parts on the main body frame, they need manual handling as they need very precise placement. Additionally, there are no standout guiding features to place the part.

Given:

- Hourly wage per worker = 130 SEK
- Working days per year = 250
- Hours per shift = 7
- Shifts per day = 2
- Total number of workers = 8

Step 1: Annual working hours per worker

$$\text{Annual Hours} = 250 \text{ days} \times 7 \text{ hours/day} = 1750 \text{ hours}$$

Step 2: Annual wage per worker

$$\text{Annual Wage (per worker)} = 1750 \text{ hours} \times 130 \text{ SEK/hour} = 227,500 \text{ SEK}$$

Step 3: Total wage for 8 workers

$$\text{Total Annual Wage} = 227,500 \text{ SEK} \times 8 = \textbf{1,820,000 SEK}$$

$$\therefore \text{Total Cost for Automated Assembly} = 1820000 + 4000000 = \textbf{5,820,000 SEK}$$

6.4 Comparing Manual and Automated Assembly

Based on our cost analysis, the estimated annual cost of manual assembly is approximately 3 million SEK, while the automated assembly setup—including equipment, labor, and support infrastructure—amounts to around 6 million SEK. This significant cost difference plays a crucial role in determining the most suitable approach for our production context.
Given the moderate production volume and the relatively simple nature of the product, manual assembly emerges as the more cost-effective and practical solution. The high

initial investment and maintenance costs associated with automation are not justified, especially when the return on investment would take multiple years to materialize.
In addition to economic factors, manual assembly offers several operational advantages:

- Flexibility: Manual processes are easier to adapt to minor design changes or product variations, which is particularly important for consumer electronics like hand mixers.
- Lower Setup Complexity: Establishing a manual assembly line requires significantly less time and infrastructure compared to programming and integrating robotic systems.
- Human Oversight: For tasks involving quality control, visual inspection, and precise manual adjustments, human workers remain more versatile and responsive.

While automation offers benefits in high-volume or highly standardized production environments, in our case, manual assembly provides an optimal balance of cost, flexibility, and quality assurance, making it the more suitable choice for current production needs.

6.5 Break-even and ROI Analysis for Automation

To assess the financial viability of adopting automation in the assembly of the electric hand mixer, a break-even analysis and a basic return on investment (ROI) calculation have been conducted.

6.5.1 Unit Cost Comparison

At the current annual production volume of 127,500 units:

$$\text{Unit Cost}_{\text{manual}} = \frac{2,758,800 \text{ SEK}}{127,500 \text{ units}} \approx 21.64 \text{ SEK/unit}$$

$$\text{Unit Cost}_{\text{automated}} = \frac{5,820,000 \text{ SEK}}{127,500 \text{ units}} \approx 45.65 \text{ SEK/unit}$$

As shown, the unit cost with automation is more than double that of manual assembly at the current production level.

6.5.2 Break-even Volume Calculation

Let Q be the production quantity where both manual and automated assembly incur the same total cost.

$$\text{Total Cost}_{\text{manual}} = 21.64 \times Q$$

$$\text{Total Cost}_{\text{automated}} = 5,820,000$$

Solving for Q:

$$21.64 \times Q = 5,820,000 \Rightarrow Q = \frac{5,820,000}{21.64} \approx 268,934 \text{ units}$$

Therefore, automation becomes cost-effective only if the annual production exceeds approximately 269,000 units.

6.5.3 ROI Timeline

Assuming the fixed investment in automation is approximately 4,000,000 SEK, and the annual savings from reduced labor costs are:

$$\text{Annual Savings} = 2,758,800 - 1,820,000 = 938,800 \text{ SEK}$$

$$\text{Payback Period} = \frac{4,000,000 \text{ SEK}}{938,800 \text{ SEK/year}} \approx 4.26 \text{ years}$$

6.5.4 Conclusion

While automation reduces operating costs over time, the significantly higher unit cost and break-even threshold indicate that it is not currently viable at the existing production level. Manual assembly remains the more economical and flexible solution unless production is scaled up significantly or sustained long-term demand is projected.

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