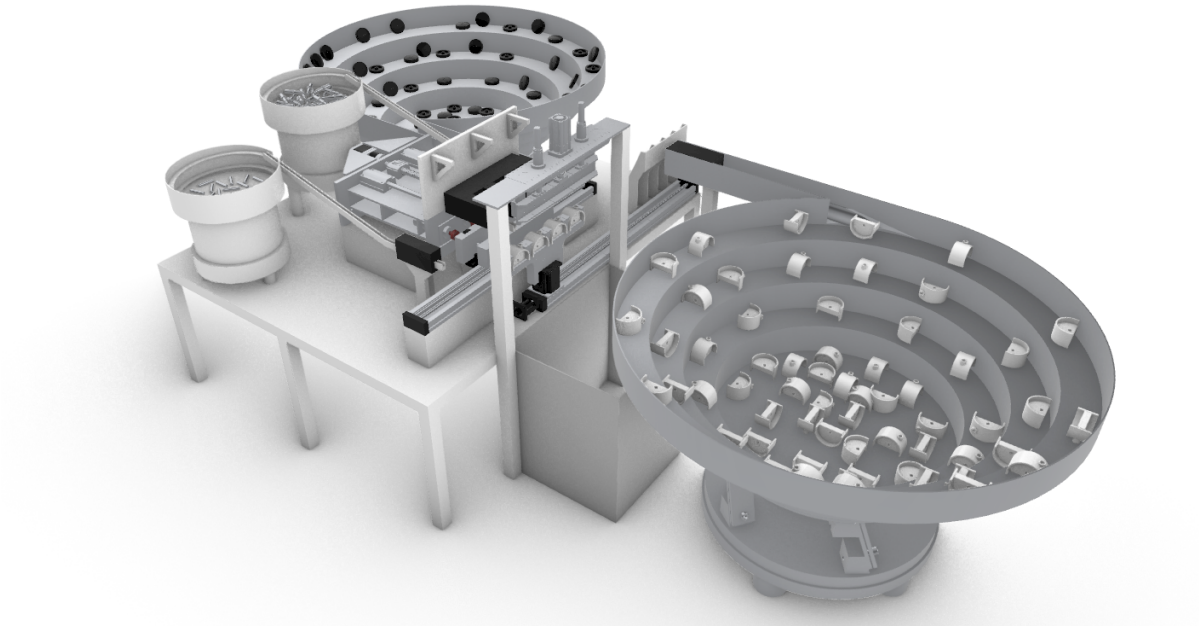
DEPARTMENT OF MECHANICAL AND INDUSTRIAL ENGINEERING
UNIVERSITY OF TORONTO

MIE 221 -Manufacturing Engineering

B. Benhabib

Call for Proposals for the Installation of

A Chair-Caster Assembly System



Group 29

Chengyao Yang, 1007018380

Lulu Zhang, 1006681299

Wenqi Shao, 1007066470

Maxwell Fang, 1006723379

Zewen Xu, 1006181551

1. Introduction & Executive Summary

Based on the task objectives our team received, we needed to design an assembly line that could assemble office chair pulleys. Through discussion and research, our team has presented the final plan in this proposal with the goal of high efficiency, low cost, good quality and small footprint. This copy covers the mechanical principle, structure selection, assembly process, quality and price evaluation. Hope it can help your company understand our products when deciding on the investment

2. Assembly Process

2.1 Sorting / Orientation / Transfering / Feeding of all parts

Vibratory feeding will be used in the feeding process to change all the parts into a proper orientation. Different parts will be discussed separately.

Housing

The housing is a part with the greatest number of stable orientations, which means more attachments will be used in the feeding process.

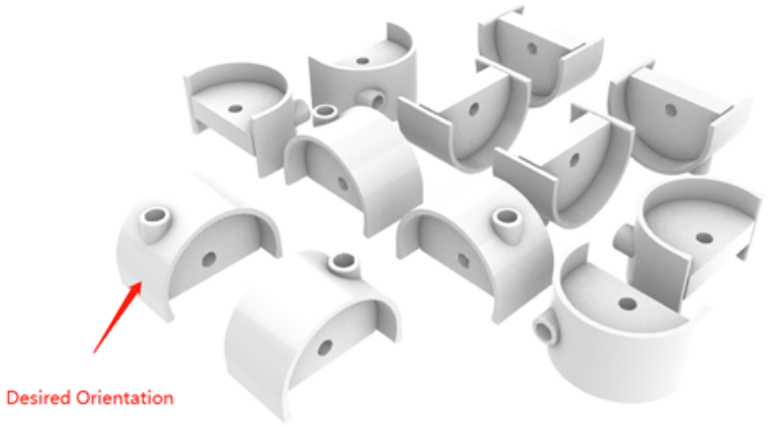


Figure 1: Orientation of the housings

At the same time, the housing part has the largest volume, so the vibratory feeder for the housing will have a greater diameter.

Wheel

The wheels may have a smaller number of possible orientations; the geometry of the wheel is a cylinder that only has the difference of up, down and bristling state.

Figure 2. Orientation of the wheels

To help the assembly process, we want the hole of the wheel facing toward the moving direction. The thickness of each wheel is small, so in the feed tracks the parts should stick with each to prevent the change of orientation during the process.

Axel

The axle is in the geometry of a cylinder, and it has three kinds of orientation: vertical, lay down with proper direction and lay down in the wrong direction.

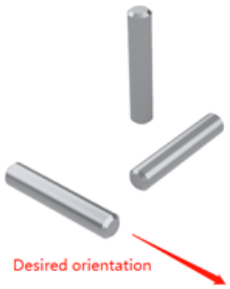


Figure 3. orientation of the axles

The reason why we want the axle to lay down is that the cylinder shape makes it not able to hang in a gap between two metal sticks. Also, the horizontal axle can get into a holder directly.

Bolt/Washer/Nut

Firstly, this part is loaded at the top of a wheel. And they may get into the system in an assembled way, which means they have already become one part. The geometry of this part can let it hang vertically in the feed track. Therefore, the desired orientation of this part should be a vertical way.

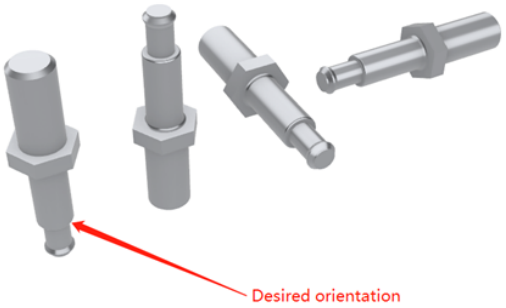


Figure 4. orientation of bolt/washer/nut

The problem will be the gravitational centre of this part will get to the upper part which makes it unstable.

2.2 Robots / Positioners (justifying choices)

In order to assemble housing, axle, and wheels together. We decided to use the positioner of one degree of freedom. Following is our graphed and detailed composition of our positioner,

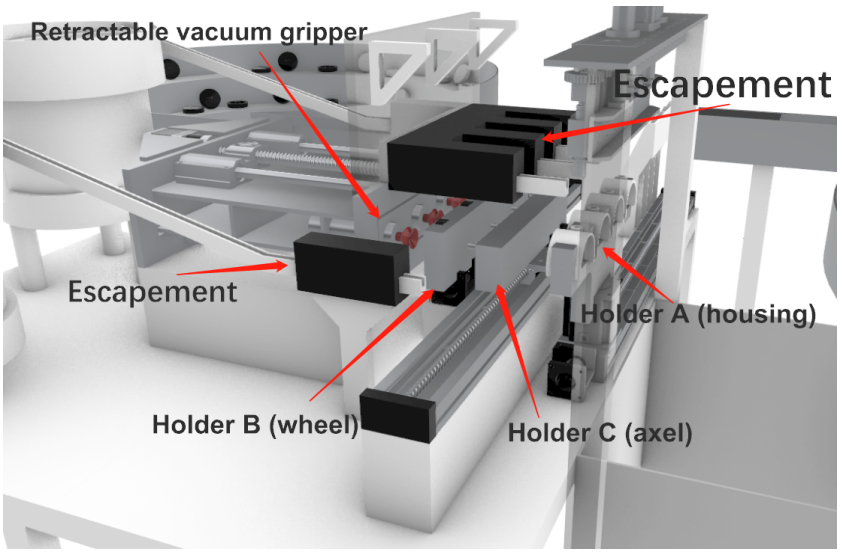


Figure 5: Positioner of transporting each parts.

With servomotor-mount positioning slides set on the track, holder A, holder B, and holder C are made slidable separately for the use of housing, wheels, and axles. An additional stepper motor which is rational for at least 180 degrees is added under holder A, particularly for future use. With several escapements set to put each part into feedtracks, we also make the retractable vacuum gripper available along both sides to take each part as we want when the parts are transported.

In order to turn the already-composed screw into the prepared housing. Our choice of the positioner is two degrees of freedom. Following is our graphed detailed composition of the positioner.

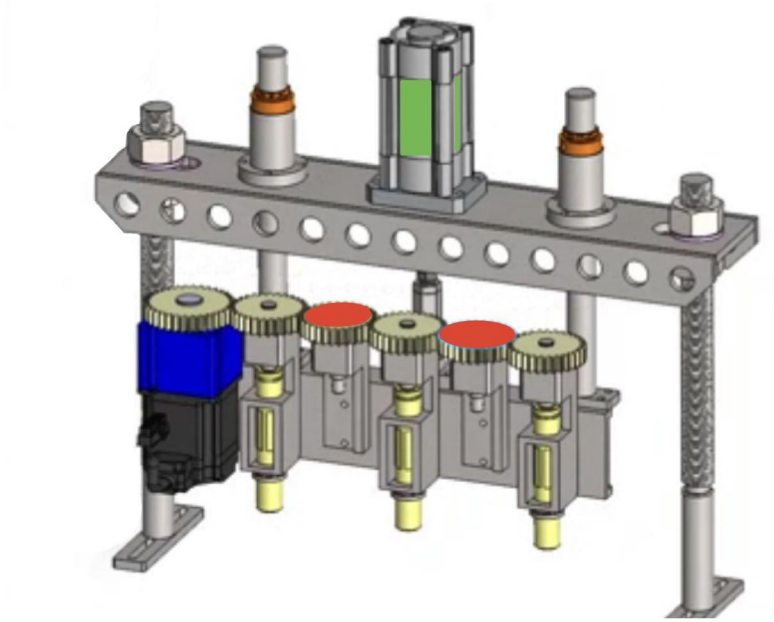


Figure 6: Positioner of Screw Driver

Two servo motors named Motor 1 and Motor 2 are set in the blue part and green part separately.

For Motor 1, it's attached with the drive gear. The drive gear is connected with other gears which can rotate to turn the bolts into the housing in the further process. The transition gears in the middle marked as red are used to make sure that the gears with hex screwdriver, which are shown in the figure as the yellow parts, turn in the same direction. For example, if the drive gear rotates clockwise, the transition gears will all rotate clockwise to make sure that the function gears will rotate counterclockwise.

For Motor 2, it functions as a linear actuator. It is capable of the positioner to have the ability to move up and down when turning the bolts. It's necessary for the reason that the hex screwdriver is fixed, so when the bolts are rotated down to the housing, there has to be a free space for the height difference.

2.3 Fixtures / Grippers (figures in the main body)

There are three fixtures needed in the assembly process, one fixture is used for the housing, one for the wheels, and the last one for the bolt.

The wheels are held in place by a fixture as shown in figure 7. To achieve stability in the vertical direction, one supporting point is located on the top and bottom of the fixture, with clamps directing force towards the supporting points. A suction cup gripper is used to hold the wheels in place, and when the wheels are pushed horizontally into the housing, the gripper is then released to its original position ready to stick onto the next batch.

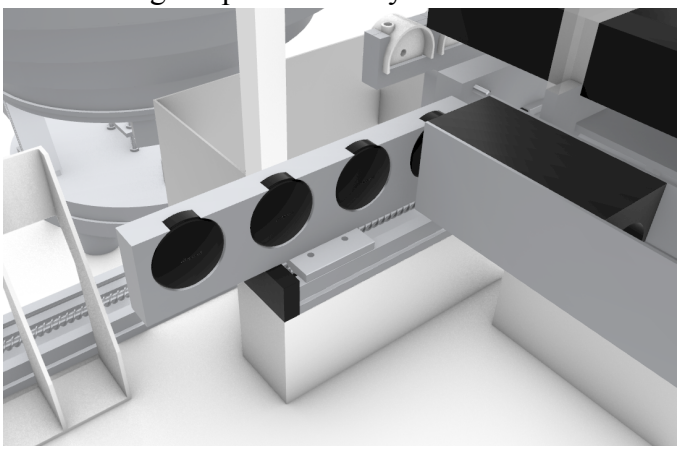


Figure 7. The fixture of the wheel

In order to hold the housing in place, a fixture is used. As shown in figure 8, using the 3-2-1 rule, three of the support points would be located at the bottom of the workpiece, two would be located on the one side, while another one is on another side of the workpiece. The workpiece lays against the supporting points, and immobility is achieved through two camps located on the opposite sides of the support points on the sidewalls of the workpiece, creating clamping forces towards the two supporting points, while the weight of the workpiece is pushing against the supporting point located at the bottom. The top of the fixture is shaped into 4 hollow circles that are able to hold 4 separate housings. The fixture lays on top of turntable systems, attached to a motor. After the wheels have been attached to the housing on one side, the turntable system rotates 180 degrees for the wheels to be filled on the other side.

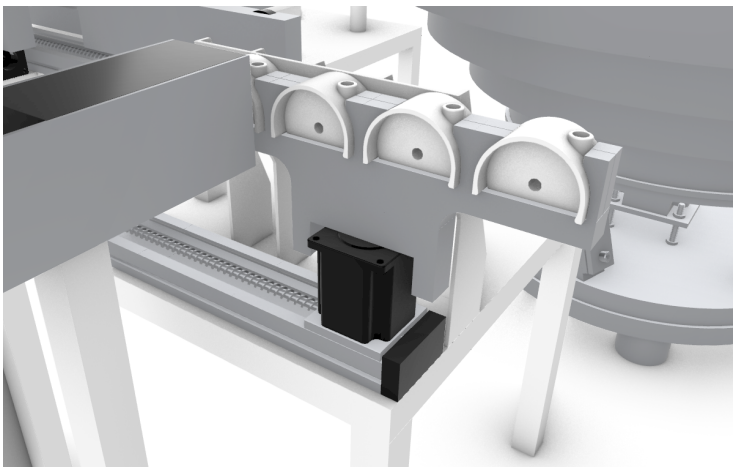


Figure 8. The fixture of the housing

The bolt is held in place by another fixture. Similar to the fixture of the housing, the 3-2-1 rule is also applied where three support points are placed at the bottom, with the other three supporting points acting on three sides of the bolt. A clamp acts on the opposite side of the supporting points on the sides of the nut, The washer is allowed to then fall onto and to be connected to the nut. After the washer falls to the bolt, a customized gripper would grip the six sides of the nut, with a rotational degree of freedom that is able to rotate and screw the bolt into the nut.

2.4 Workcell layout / Process plan

First, in order to help understand the steps when mentioning the parts of the system, several pictures with name labels are shown below.

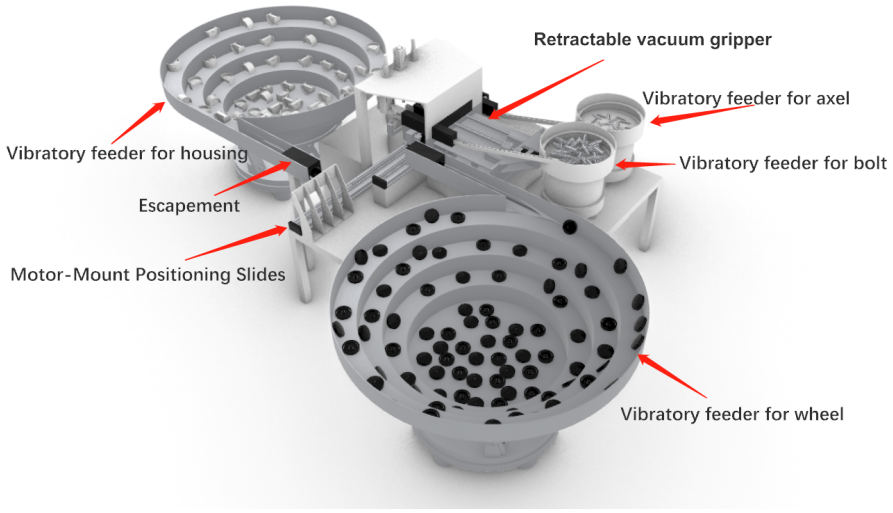


Figure 9: A overview of the assemble system

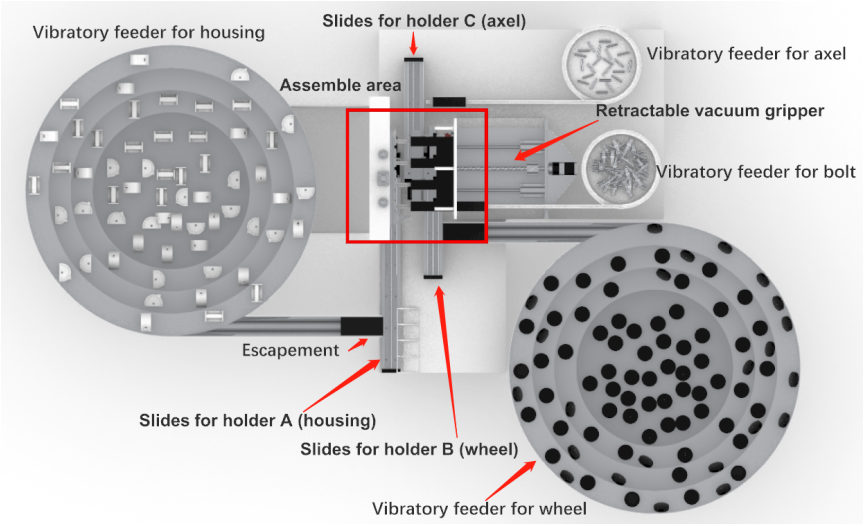


Figure 10. A top view of the assemble system

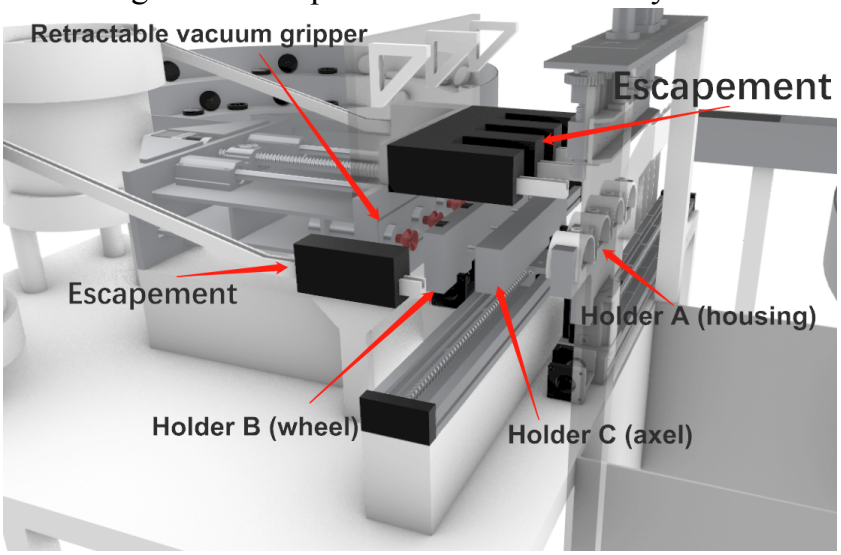


Figure 11: A detailed view of assembly area

Table 1 below shows all the assembly steps and their estimated time.

Table 1. Steps to the assembly process and estimated time

Step #	Description	Estimated time
1	• Sorting all parts into a single line with a proper orientation by using a vibratory feeder	/
2	• Transport parts with feedtracks	/
3	• Put 4 housings into the holder A through escapements • Put 4 wheels into the holder B through escapements • Put 4 axles into the holder C through escapements	2s
4	• Move the holder A forward to assemble area using servomotor-mount positioning slides	1s

	• Move the holder B forward to assemble area using servomotor-mount positioning slides	
5	• The vacuum grippers move forward and grip up 4 wheels • 4 retractable screwdrivers with bolts loaded move down and insert the bolts to the holes of the housing	0. 5s
6	• The vacuum grippers move backward • Move the holder B backward out of assembling area using servomotor-mount positioning slides	0.5s
7	• Move the holder C forward to assemble area using servomotor-mount positioning slides • Put 4 wheels into the holder B through escapements	0.5s
8	• The vacuum grippers move forward and put the 4 axles into the hole of each wheel	0.25s
9	• The vacuum grippers move backward • Move the holder C backward out of the assembly area using servomotor-mount positioning slides.	0.5s
10	• The vacuum grippers move backward to insert the 4 axles with wheels into the housings.	0.25s
11	• Vacuum grippers release the wheels and retreat. • 4 retractable screwdrivers move upward.	0.25s
12	• Stepper motor under holder A rotates 180 degrees.	0.75s
13	• Move the holder B forward to the assembly area using servomotor-mount positioning slides.	0.5s
14	• The vacuum grippers move forward and grip up 4 wheels.	0.25s
15	• The vacuum grippers move backward. • Move holder B backward out of the assembly area using servomotor-mount positioning slides.	0.5s
16	• The vacuum grippers move forward and load the 4 wheels to the axles from another side of the housing.	0.25s
17	• The vacuum grippers continue to move forward and release the products into the container.	0.25s
18	• The vacuum grippers move backward.	0.25s
19	• Move the holder A backward out of assembling area using servomotor-mount positioning slides	0.25s

3. Process control

With a rotary encoder, the PLC is supplied with signals that can be used for analysis and calculations. In the context of this project, it is necessary to first determine that the encoder rotates exactly one cycle for each process of the assembly line (including the pauses in each cell and the running times in between) and that each cycle can be further divided into 10,000 equal parts. Also, other options, such as 100,000 equal parts, are available for PLC control so that it can be made much more precise. However, this number should still be determined according to the resolution speed of the encoder. A signal (0-10000) from the encoder is used as a control signal for the PLC, and the 10,000 equivalent values are used to control every single process, not all processes at once. Consider the resolution speed and model when choosing an encoder. A programmable logic controller (PLC) is an industrial computer that is suitable for the control of manufacturing processes and is also commonly installed on assembly lines. It is a fact that PLCs are capable of precisely controlling the halting, moving, and even turning of an assembly line at any given moment using a program that is specially designed for that particular purpose. In this project, PLC controls servo drives (control servo motors) and electromagnetic valve or valve terminal (control drive cylinders and electric cylinders). It is noteworthy that the main driving force behind this assembly line is not only the robot system but also the servo motor and electric cylinder. Due to their precise control by PLC, the servo motor and electric cylinder are able to achieve precise speed control, RPM control, speed control, and position control.

4. Quality control

Photoelectric sensors may be installed on the assembly line as a means of quality control. In order to detect whether the parts are positioned in the correct position, diffuse photoelectric sensors may be considered. The purpose of this type of sensor is that it contains a transmitter and receiver in one unit, which uses photoelectric induction to generate a signal. The general flow of use is that the photoelectric sensor detects the part that should be in place, and once it senses that it is installed correctly, the conveyor continues to run, and if it senses a non-conforming part, it transmits a signal to an electric cylinder to remove the non-conforming part. For more accurate detection, at least three or more diffuse photoelectric sensors should be provided for the entire assembly line. If a part that was removed in the previous process is at or near the downstream process position on the conveyor, PLC control is used to keep the station inactive, thus ensuring that no excess processed parts are placed on the conveyor. In the event of a failure at a station, an alarm is sounded, and the entire line should be shut down. To obtain quality checks for the systems, three inspections and testing need to be done in order to ensure that the assembling process has guaranteed quality. First, each component is checked by measuring its weight, if the weight is within a reasonable range, the component can be accepted. Second, in order to check if the components are properly assembled, a rotating force is applied to the wheels in order to check if the wheels can rotate while the housing remains stable, in addition, a pulling force is applied to the nuts and bolts attached on the top of the housing, for which the test would fail is the wheels fail to rotate, or the nuts and bolts are detached when pulled. In addition, a rotational force can also be acted on the nuts and bolts to ensure that they have been properly screwed and assembled.

5. Cost Analysis

The cost estimation for each the component and the quantity needed for each are summarized in table 2.

Table 2 . The Price and the Quantity of Each Component Needed.

Name of the Component	Estimated Price Range (CAD)	Quantity Needed
Positioners	$ 2,403.32 ～ $3,566.07	1
Vibratory Feeder & Feed Track & Escapements	~ $ 3287.14	4
Pneumatic piston	~ $ 38.99	3
Metal Rail & Fixture	~$ 16.29/10.63in	3 + 3
Suction Cup	$ 3.20 ～ $8.65	4
Micro Air Pump	~ $ 119.00	1
Suction Grippers	~ $ 616.83	4
Screw Tighten Gripper	~$ 140.10 /100 g	1
Turntable Motor	~$ 140.42	1
Encoder	~$ 9.90	1
Servo Motor	~$ 5.77	4
Two-Axis Robot	~$159.00	1
PLC Industrial Control Board	~$ 61.11	1
Photoelastic Sensor	~$ 25	3
Total	$ 28500.27 ～ 32225.08	36

5.1. Line Evaluation

Each component is evaluated regarding rejection attachment, feedtrack, escarpment, and fixture, as shown in table 3.

Table 3. Component Evaluation

	Rejection Attachment	**Feedtrack**	**Escarpment**	**Fixture**
Housing	No prominent issue	No prominent issue	No prominent issue	The 3-2-1 rule is utilized to achieve immobility
Wheels	No prominent issue	No prominent issue	No prominent issue	It allows accurate vertical positioning of the wheels within the housing due to clamps on the top and bottom of the fixture.

Axel	No prominent issue	Cylindrically shaped, not easy to get stuck.	No prominent issue	No prominent issue
Bolt	Could be not enough screwed in the desired place	Cylindrically shaped, not easy to get stuck.	No prominent issue	No prominent issue
Washer	No prominent issue	The washer moves smoothly due to its round shape.	No prominent issue	No prominent issue
Nut	Could be not enough screwed in the desired place with bolt all together	Nuts can get stuck in the narrow part of the track.	No prominent issue	With the clamps pressing through the point supports, the bolt is immobilized in the x-axis, gravity acting on the nut to keep it from moving vertically.

5.2. Maintenance

Table 4. Maintenance Evaluation

Suction Cup	2-axis Screw Robot	Pneumatic piston
Because the suction part is made from rubber, it needs to be changed and requires more maintenance effort.	The robot has to attach a gripper to tight the screw, the gripper will be loose and easy to wear, it needs to be checked before wear happens.	Several pneumatic products still require internal oil lubrication. A light machine oil needs to be added periodically to pneumatic tools.

6. Conclusions

This document presents the proposal in the form of a business proposal for the installation of a mass-production automated assembly system for the assembly of 2-inch chair casters, where it is most important to make use of automation for profits. A typical 2-inch chair crate consists of six parts, including the housing, two wheels, one axel, a bolt, a washer, and a nut. Production plan, process, quality and financial ethics are analyzed and enforced. Thus, the chair wheel production line meets the standard.