# OBJECT ORGANIZING CONVEYOR SYSTEM DESIGN PROJECT


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# Introduction

The conveyor system is going to be used in Sanjeev's factory, to sort various containers measured in centimeters (cm). These objects are goat figurines which come in boxes with dimensions 20cm x 20cm x 20cm, and giant plastic replicas of cheerios that come in boxes with dimensions 10cm x 10cm x 30cm. This report will cover a description of the various constraints of the design, a brief background section of the relevant components of the design and specific product choices of non-mechanical components. Additionally, this report will discuss the overall system architecture, an outline of the software, a cost estimate for implementation, and recommended improvements.

The mechanical portion of our conveyor belt will consist of fasteners, shafts, bearings, aluminum extrusions, corner brackets, flat belting, and tensioner bearings. Each of these components will be explained in detail in upcoming sections.

Our conveyor belt will also incorporate various electronics. Included in these electronics are motors, motor controllers, safety sensors and vision sensors.

# Technical Constraints

## Dimensions

One constraint in our design is that the conveyor must operate with packages of sizes 20cm x 20cm x 20cm and 10cm x 10cm x 30cm. This means that the conveyor needs to be at least 20cm wide and must have at least 30cm of open space above it. The starting point of this 30cm measurement is the highest point of each roller, to ensure that there is an adequate 30cm of open space above the conveyor at all points. This is a purely vertical measurement which must be at least 30cm. All information from this paragraph was taken from [1].

Additionally, a tolerance of 2cm on each side of the box is implemented so that if the boxes are not perfectly aligned with the conveyer, they will not get stuck on the side and hold up the rest of the boxes. The final dimension constraint is the length of the conveyor. As described in the online document, there are 2 sections to the conveyor, which must both be at least 1.5m long. All information from this paragraph was taken from [1].

## Component Interaction

It's important that the bearings cannot move freely. If they could, then the rollers of the conveyor would be able to move up and down the conveyor. This would make the conveyor function either not as well as intended, or not at all, which is why the bearings' movement must be restricted. All information from this paragraph was taken from [1].

To ensure that the bearings could be positioned properly, we found an extrusion that could be drilled into, so the bearings have somewhere to sit. The dimension requirements are a width greater than 5/32", so that the hole drilled into the extrusion is not a through hole. This is important because if the hole was a through hole, the bearing would be able to slide out of the other side of the hole, and completely off the rest of the conveyor. All information from this paragraph was taken from [1].

The bearings also must have an inner diameter which is equal to the diameter of the shaft. We decided to machine the shaft so that the diameter at either end of the shaft is equal to the inner diameter of the bearing. All information from this paragraph was taken from [1].

### Environment

Since it's possible that foreign objects would find their way into the system, we decided to have sealed bearings as opposed to unsealed bearings. This meant that the bearing balls and lubricant inside the bearing were protected from foreign contaminants, which would cause the bearing to seize, and the conveyor to either not work as well as expected, or not at all. Our choice to use sealed bearings will help prevent this, making the conveyor system more reliable and longer lasting. All information from this paragraph was taken from [1].

## Other Constraints

### Intuitive Design

One important constraint of our design was an intuitive design. Although our conveyor system is completely automated, there are times where the conveyor requires human intervention to function as intended. For example, if barcodes of boxes are not scanned properly, they will continue down the conveyor belt into a separate section, where they will wait to be manually sorted (sorted by a human).

If human intervention like this is required, an intuitive conveyor design will make it easier for a worker to problem solve and ensure that the system works as intended. If the conveyor system was complicated, it would make it more difficult to operate, so a simple and intuitive design is important.

### Safety

Another constraint is the safety of the system. Again, the conveyor system will be operating on the factory floor. This means that people will likely be supervising, interacting with, and in close proximity to the conveyor. In this case, safe design practices will ensure that in the event of an emergency or an accident, the conveyor system and surrounding area is safe for the people around.

Our system incorporates various sensors to take precautions in the event of an accident or emergency, so that it is always a safe environment.

## Relevant Components

*Figure 1: Aluminum Extrusion with Fastener*

### Fastener

For this design, the chosen fastener is a T-Slotted Framing End-Feed Single Nut with a Button Head from McMaster – Carr, with a Hex Head and a ¼ - 20 thread, Part Number: 47065T139 [2]. This fastener is made from zinc-plated steel, making it corrosion resistant and abrasion resistant, therefore making it more durable. For the purposes of this design, this will greatly increase the strength of the mechanism and ensure a greater fatigue life of the fasteners, as they will last longer and be more resistant to wear and tear. All information in this paragraph was taken from [1] [3].

### Shafts

The shaft chosen is from McMaster – Carr, Part Number: 5936K26 [4]. The smaller the diameter, the lower the mass and the less power required from the motor to rotate the shaft. This size was chosen because the cost directly correlates to the diameter of the shaft, meaning the smaller the diameter of the shaft, the cheaper the cost of the shaft will be. All information from this paragraph was taken from [1].

The chosen shaft also has a nitride coating, which is one of the most corrosion resistant steel shafts on the market. This corrosion resistance is very important as it increases the fatigue life and durability of the shaft. The fatigue life relates to how long an object can last before it completely fails and is unusable [5]. Increasing the fatigue life means our shaft will ultimately last longer which leads to cost savings as we do not need to be concerned about corrosion of the shaft. All information from this paragraph was taken from [1].

This shaft has a small tolerance of only +/- 0.0625” for the diameter and a straightness tolerance of +/- 0.01875” per foot. Having a low tolerance is very important to our design as it will maintain a low variation in its physical dimensions therefore leading to minimizing the axial load and preventing over-heating, since the parts will assemble with less error and experience less stress. Therefore, tighter tolerancing decreases wear and increases the efficiency of the shaft. All information from this paragraph was taken from [1].

The nitride-coated carbon steel shaft has a yield strength of 45000 psi (pound per square inch). It's important to have a high yield strength so our shaft can withstand greater stress and ultimately increase its fatigue life. All information from this paragraph was taken from [1].

The nitride-coated carbon steel shaft has a hardness rating of very hard. The hardness of the material is important to our design because the harder the material is, the more resistant it will be to material deformation. All information from this paragraph was taken from [1].

## Bearings

*Figure 2: The Chosen Bearing from Bearings Canada*

The bearing that was chosen is the R1212-2RS Ball Bearing from Bearings Canada [2]. For the conveyor, we are using a shaft with a diameter of ¾". The inner bearing diameter is ½", so the shaft and bearing will fit together as needed with a seat. It is important that the chosen bearing can fit into a hole drilled into the aluminum extrusion, so that the bearing can sit in it. This bearing has an outer diameter of ¾", so it will sit in a hole of the same size. All information from this paragraph was taken from [1].

This bearing uses grease as a lubricant, and it comes pre-lubricated. This bearing also has two rubber closures which protect the ball bearings and lubricant from contaminants, which could cause the bearing to seize. These closures will also help with the heat distribution to avoid softening of the metal. All information from this paragraph was taken from [1].

The chosen bearing is made from Chrome Steel. This specific material is general-purpose and is known for its good fatigue life. We have chosen a general-purpose bearing material because the surrounding environment will not demand anything that requires a special material, and because it fits the desired shaft size. All information from this paragraph was taken from [1].

## Aluminum Extrusions

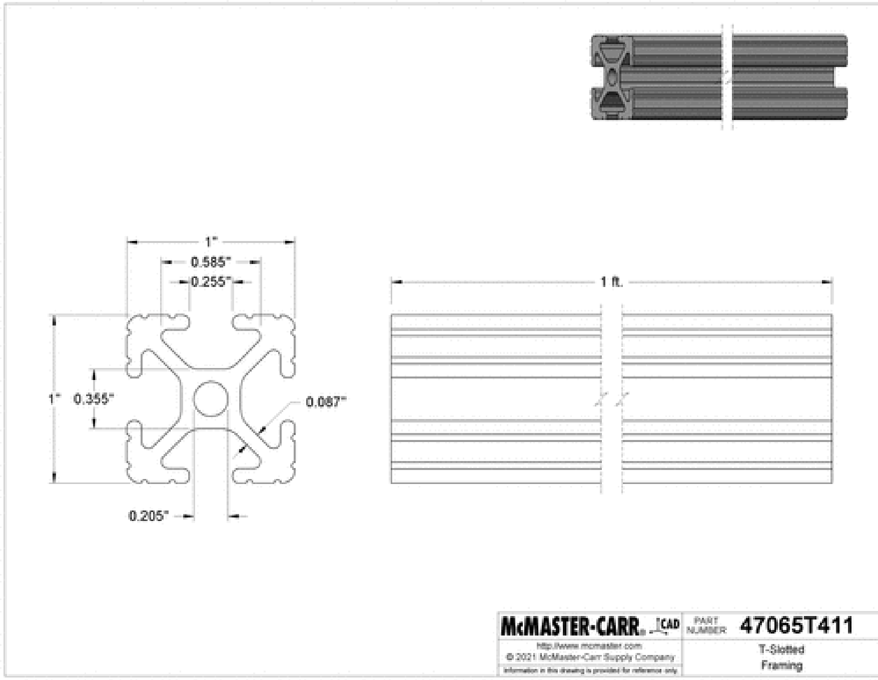


*Figure 3: Extrusion Technical Specifications*

For the aluminum extrusions we decided to go with a T-Slotted Framing Extrusion from McMaster – Carr, which has a rail height of 1”. Part Number: 47065T101 [3]. This part has many excellent features which will aid in designing a structurally sound conveyor system. All information from this paragraph was taken from [1].

The chosen aluminum extrusion has a black anodized coating which is extremely functional in preventing corrosion and adheres very well to the metal. This is important as these extrusions will be the main structural component in the design and must hold the weight of multiple boxes at once. All information from this paragraph was taken from [1].

The aluminum extrusions are made of 6105 aluminum which is comparatively strong as it has a higher sheer strength and fatigue strength [4]. This is important to the overall design of the conveyor system as it will be loaded with numerous boxes at a time requiring the aluminum extrusions to withstand a moderate sheer strength. With the loading and unloading of the conveyor system, some bending in the midsection of the system is inevitable, and a higher fatigue strength and sheer strength improves the service life of the conveyor system. All information from this paragraph was taken from [1].

We chose this specific aluminum extrusion as it is strong, durable and has excellent corrosion resistance. It also has the correct dimensions to accommodate the bearings and fasteners. All information from this paragraph was taken from [1].

### Corner Brackets

To provide extra support for the T-Slotted aluminum extrusions we will be using the following three parts from McMaster-Carr. A Silver Corner Surface Bracket, Part Number: 47065T267 [5], a Silver Gusset Bracket, Part Number: 4705T736 [6], and a Silver Tee Surface Bracket, Part Number: 47065T278 [7], and a Diagonal Brace, Part Number: 47065T331 [8]. These brackets are made from anodized aluminum which makes them corrosion resistant and strong. We chose these specific brackets as they accommodate the chosen T-Slotted Extrusions, as well as for their corrosion resistance. All information from this paragraph was taken from [1].

### Flat Belting

To drive the conveyor system, we decided to use three belts from McMaster – Carr (Part Number: 6075K17 [9]), spaced evenly along the drive shaft of the conveyor. We chose to use three belts to minimize slipping of the belt as it relies on friction to drive the system. These belts have a width of 1 and ½", a thickness of 0.09" and a minimum pulley size of ¾ ". The belt is made from Polyurethane Rubber, which is abrasion resistant and relatively inexpensive [10]. We chose this belt specifically as it works with small pulleys (in this case the shafts) and is cost effective for the design. All information from this paragraph was taken from [1].

### Tensioner Bearing

Alongside the previously mentioned bearing, we have chosen to use a Mounted Steel Ball Bearing with Cast Iron Housing (part number: 7728T51 from McMaster – Carr). This bearing is going to be primarily used a means to tighten the belt as needed. The bearing is flanged and has a base mount, so that it can be attached to the extrusion using fasteners. We chose this bearing because it has features such as the base mount which allow us to utilize the bearing effectively. Additionally, it fits into the shaft as needed, which makes it fit into the design well. All information in this paragraph was taken from [1] [11].

## Product Choices

### Safety Sensor

The safety sensor we decided to use is the Infrared Light Beam Photoelectric Switch Receiver from McMaster-Carr, Part Number: 65845K56. We decided to use this sensor because of its light beam switch operation, sensor classification, light beam frequency, sensing distance and temperature range.

The light beam switch operation is very important because the sensor follows a process when an object is either present or absent in the sensor's field of view. For our sensor whenever there is a change of light received when compared to light emitted, the sensor turns on the light beam, therefore signifying that there is an object which is present within the sensor's field of view. This change of light received would initiate signals to the motor controller, which would immediately change the motor's speed. This specific sensor is a photoelectric sensor as they are used to determine the distance, absence, or presence of an object by using a light transmitter (infrared) and a photoelectric receiver. This is an important feature because our sensor will output an electrical reading when someone is within the sensor's field of view. All information in this paragraph was taken from [12].

Our sensor has an infrared light beam frequency (300 Ghz - 400 Thz). We have chosen the infrared sensor because it has low power requirements, isn't affected by corrosion nor oxidation, does not require contact with an object for detection and has a high light beam frequency making it the perfect light beam for sensors as they're capable of detecting motion and responding quickly. The sensor has a sensing distance of 20m which is very important because our conveyor system is exactly 20m long, therefore our safety sensor covers the entire length of the conveyor. The temperature range for this sensor is -23.33$^{o}$ to 54.44$^{o}$C. This means that our sensor can fully function within that temperature range. This is very important to our conveyor system because the sensor can operate safely and provide accurate measurements within a greater specified temperature range. All information in this paragraph was taken from [12].

### Vision Sensor

The vision sensor we selected for our conveyor system is the FQ2 Smart Camera from OMRON Industrial Automation. The sensor can read both QR codes and barcodes but requires an Operation Interface which can also be purchased from OMRON Industrial Automation.

The vision sensor has an adjustable lens ranging from as close as 220mm to as far as 1000mm. This is very important to our design as it allows the sensor to focus on the two different boxes moving through the conveyor system. The sensor also has a wide view sensor, which allows the sensor to view the entire top of the box instead of one fixed section. This sensor also has 360-degree rotational compensation as it allows the barcodes or boxes to be orientated in any way (only if the barcode is facing the sensor) and it can still be read with minimal error. This is important as it allows for imperfections in the systems which minimizes error and problems that may arise in the scanning and sorting of the boxes. All information in this paragraph was taken from [12].

The sensor also includes a boundary correction feature which allows the sensor to accurately read labels in poor or over lighting conditions as the lighting in a factory setting isn't always optimal. The FQ2 sensor also has a calendar function meaning it keeps track of the date which allows for inventory management through the Operation Interface and tracking of other data. The chosen sensor features a large, built-in dictionary, meaning that it can identify letters and symbols from barcodes or other texts. The dictionary contains 80 different fonts that are most used. This is important to the design of the conveyor system as it allows for redundancy in the system and minimizes error in the scanning of the boxes. It also allows for a variety of labels to be used. All information in this paragraph was taken from [12].

## Motor

The motor we selected for the conveyor system is the MTPM-P25-1JK44 from AutomationDirect.

Our conveyor does not require a large amount power to be outputted from the motor for the packages to move down the line. DC motors, as opposed to AC motors, prioritize their speed control and output range, rather than increased power output and efficiency which one would get from the use of an AC motor, meaning a DC motor is ideal for our system. Since precise power output is something that a DC motor does better than an AC motor, we chose a DC motor. All information in this paragraph was taken from [12].

Another important aspect of our motor is the voltage rating. Our motor controller operates with the assumption that the motor has a voltage range of 12-24V, which is the voltage range of our motor. The voltage rating of our motor is important because we want to ensure that our motor controller operates as intended when incorporated into our system with our motor. Also, our motor is electronically reversible. This means that if desired, our motor can be programmed to operate in the opposite direction. Along with that, our conveyor system will require the motor to be mounted onto the aluminum extrusions which our conveyor skeleton is made from, so a flanged mounting will allow us to position the motor as needed. The motor has the capability to be orientated both horizontally and vertically, which is important to our design because of the desired orientation of our motor. The motor will be attached to an aluminum extrusion of the skeleton which is perpendicular to the conveyor belt allowing our motor to operate in a vertical position. All information in this paragraph was taken from [12].

## Motor Controller

The motor controller we selected was a GSD1-24-15N4X-R DC motor driver from Automation Direct which is designed for low voltage motors.

The chosen motor controller has a NEMA 4X casing. The rating NEMA 4X means the casing has protection against rain, sleet, dust and directed water. This ensures that any cleaning or liquids used around the product will not damage the electronics inside the casing. This is important to consider, because the product or personnel could be injured if the electronics fail. All information in this paragraph was taken from [12].

The chosen motor controller has an intended input voltage of 12/24 volts direct current, and the output voltage is a range from 0 volts to 24 VDC. This is very important because our motor controller voltage should have the same range as the motor itself, otherwise the motor or motor controller can become damaged. The power supply system is important to the system because it ensures that all systems are supplied with the right voltages to prevent damage or underperformance. Without a good power supply system, all electronic systems would be effectively useless, as they would not have the required power to function. All information in this paragraph was taken from [12].

The motor controller has the ability to invert the output and put the motor in reverse which allows the system to gain greater control over the acceleration and movement of the mechanisms driven by the motor. Motor controllers have a variety of output formats. In this case, that format is pulse width modulation, or PWM. This is a way of having a digital signal mimic an analog, or continuous signal by having a pattern going on and off over a specific time frame. This further allows a full range of control of the output device by using the digital signal. All information in this paragraph was taken from [12].

# System Architecture

## System Modularity

The system is designed to be modular. Various parts of the system have been isolated as much as possible to create an easy installation process and to make usage and maintenance of the system as simple as possible. The first example of this is the drive conveyor. This unit contains the motor and controller on the segment so that is its mechanically isolated from the other sections. This way, motion can be applied in a controlled manner, and should the end consumer wish to extend this section, longer belts could be used to drive a buffer unit as well.

In addition to the driven section, undriven buffer units are used to store object that have reached the end of the system. It is mechanically like the drive conveyor, but lacks drive components, allowing the loads to gently coast to a stop and pile up.

The storing unit contains all the needed programming and controllers to sort incoming packages. The mechanisms to sort and software needed to make decisions are all contained, so a failure of one unit to sort will not impact another unit down the line with proper implementation. Additionally, each one can be programmed separately, which allowed for smaller and more efficient programs for each unit. This way, all sorting units run effectively and will have minimal impacts on other portions of the system in case of failure.

## Sensor Implementation

Sensing equipment is added in last to make the use of the modular base of the system. Without inefficient rigging, may sensors would be difficult to place with the segmental design of the conveyor. Due to this fact, sensors are added on last, to provide easy and effective mounting of the sensors.

More specifically, light beam switch sensors are placed on frames along the edges of the conveyors to act as shutdowns if something crossed the rail of the conveyor, either person or package. The sensors are linked to a relay in series with the power for the system, so in case of emergency power is cut without the chance for logic failure in a computer-based safety system. This helps to guarantee both he heath of the system and its operators.

Additionally, the vison system is mounted on a frame away from the sorting unit so that the camera may be placed in an optimal position to read data off the packages running through the system. This provides more flexibility in the end use of the system and makes positioning the camera easier.

## Installation and Usage

The system is designed to be installed in blocks. Workers will have sections of conveyors where each has brackets extending off the end to link together with another. This way, once a worker is given a section, only a few bolts are needed to fasten the section to the rest of the system. Additionally, should a section need to be added or changed, it is easy to remove or disconnect sections to give replacements or to add in a new section.

## Technical Drawings

This section will show drawing of each unit and major subassembly of the system, with drawings for the overall system, driven and buffer conveyor sections, key part modifications such as shafts or side rails, and sensor mount subassemblies. Each drawing will have a small bill of materials to show the kinds of parts required for each separate module.

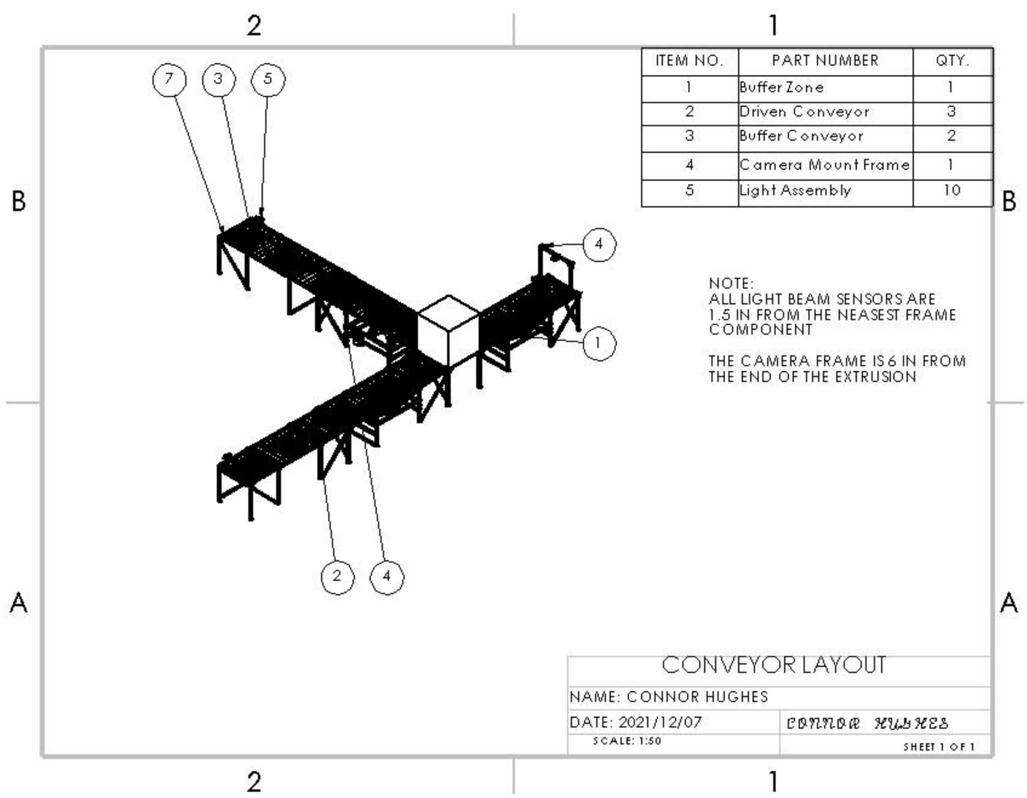


*Figure 4: Main Assembly*

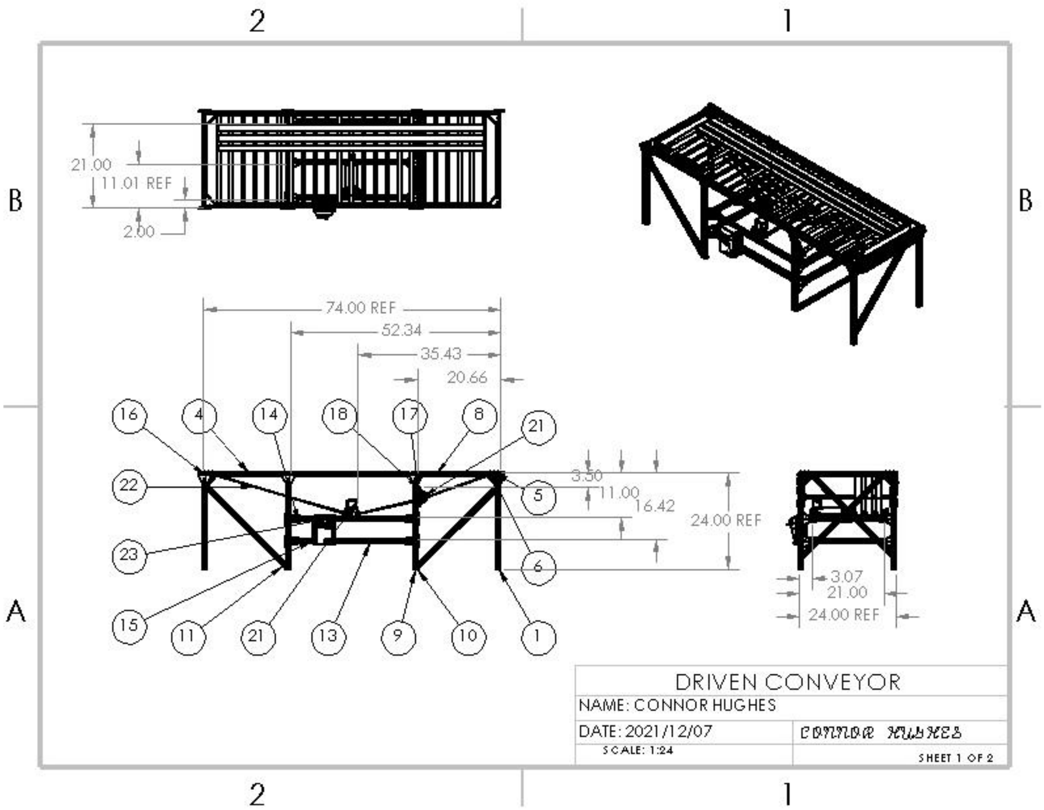


*Figure 5: Driven Conveyor Design*

| ITEM NO. | PART NUMBER | DESCRIPTION | QTY. |
|---|---|---|---|
| 1 | 47065T122 | T-Slotted Framing LG 24 in | 4 |
| 2 | 47065T122 | T-Slotted Framing LG 22 in | 6 |
| 3 | 47065T122 | T-Slotted Framing LG 72 in | 1 |
| 4 | 47065T122 | T-Slotted Framing LG 72 in | 1 |
| 5 | 47065T267 | Corner Bracket | 4 |
| 6 | 47065T736_Silver Gusset Bracket | Silver Gusset Bracket | 12 |
| 7 | KIT21057 | R1212-2RS Sealed Ball Bearing 1/2" x 3/4" x 5/32" inch One Ball Bearing | 47 |
| 8 | 5936K26 | Nitride-Coated 1045 Carbon Steel, 3/4" Diameter, 24" Long | 25 |
| 9 | 47065T122 | T-Slotted Framing LG 23 in | 4 |
| 10 | 47065T331 | Diagonal Brace Ends for 1" High Single Rail T-Slotted Framing | 12 |
| 11 | 47065T122 | T-Slotted Framing LG 26 3/8 in | 4 |
| 12 | 47065T122 | T-Slotted Framing LG 25 7/8 in | 2 |
| 13 | 47065T122 | T-Slotted Framing LG 30 2/3 in | 12 |
| 14 | 47065T278 | T-Bracket | 47 |
| 15 | 47065T139 | End-Feed Single Nut with Button Head 1/4"-20 Thread Size | 304 |
| 16 | 47065T122 | T-Slotted Framing LG 4 in | 1 |
| 17 | 7728T51 | Mounted Steel Ball Bearing with Cast Iron Housing | 2 |
| 18 | 91306A379 | Button Head Hex Drive Screws | 4 |
| 19 | 9845T204 | Vibrate-Damping Precision Flexible Shaft Coupling | 2 |
| 20 | 9845T14 | Durometer 98A Spider for 1" OD and 25 mm OD Vibrate-Damping Precision Flexible Shaft Coupling | 1 |
| 21 | MTPM-P25-1JK44 | Ironhorse DC Motor 12VDC-24VDC | 1 |
| 22 | 6075K17 | Flat Belting 1-1/2" W | 3 |
| 23 | GSD1-24-15N4X-R | IronHorse GSD1 series DC reversing drive | 1 |

DRIVEN CONVEYOR
NAME: CONNOR HUGHES
DATE: 2021/12/07 CONNOR HUGHES
SCALE: 1:24
SHEET 2 OF 2

*Figure 6: Driven Conveyor Bill of Materials*

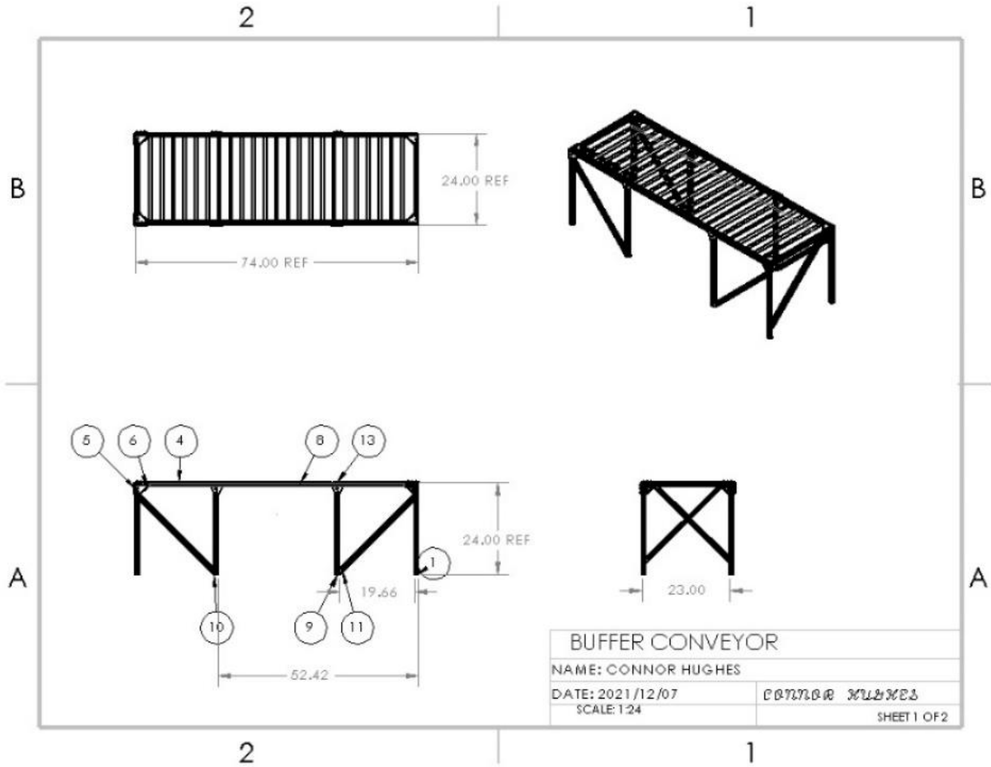


*Figure 7: Buffer Conveyor Design*

| ITEM NO. | PART NUMBER | DESCRIPTION | QTY. |
|---|---|---|---|
| 1 | 47065T122 | T-Slotted Framing LG 24 in | 4 |
| 2 | 47065T122 | T-Slotted Framing LG 22 in | 2 |
| 3 | 47065T122 | T-Slotted Framing LG 72 in | 1 |
| 4 | 47065T122 | T-Slotted Framing LG 72 in | 1 |
| 5 | 47065T267 | Corner Bracket | 8 |
| 6 | 47065T736_Silver Gusset Bracket | Silver Gusset Bracket | 12 |
| 7 | KIT21057 | R1212-2RS Sealed Ball Bearing 1/2" x 3/4" x 5/32" inch One Ball Bearing | 49 |
| 8 | 5936K26 | Nitride-Coated 1045 Carbon Steel, 3/4" Diameter, 24" Long | 25 |
| 9 | 47065T122 | T-Slotted Framing LG 23 in | 4 |
| 10 | 47065T331 | Diagonal Brace Ends for 1" High Single Rail T-Slotted Framing | 12 |
| 11 | 47065T122 | T-Slotted Framing LG 26 3/8 in | 4 |
| 12 | 47065T122 | T-Slotted Framing LG 25 7/8 in | 2 |
| 13 | 47065T278 | T-Bracket | 4 |
| 14 | 47065T139 | End-Feed Single Nut with Button Head 1/4"-20 Thread Size | 126 |

BUFFER CONVEYOR
NAME: CONNOR HUGHES
DATE: 2021/11/08 CONNOR HUGHES
SCALE: 1:24 SHEET 2 OF 2

*Figure 8: Buffer Conveyor Bill of Materials*

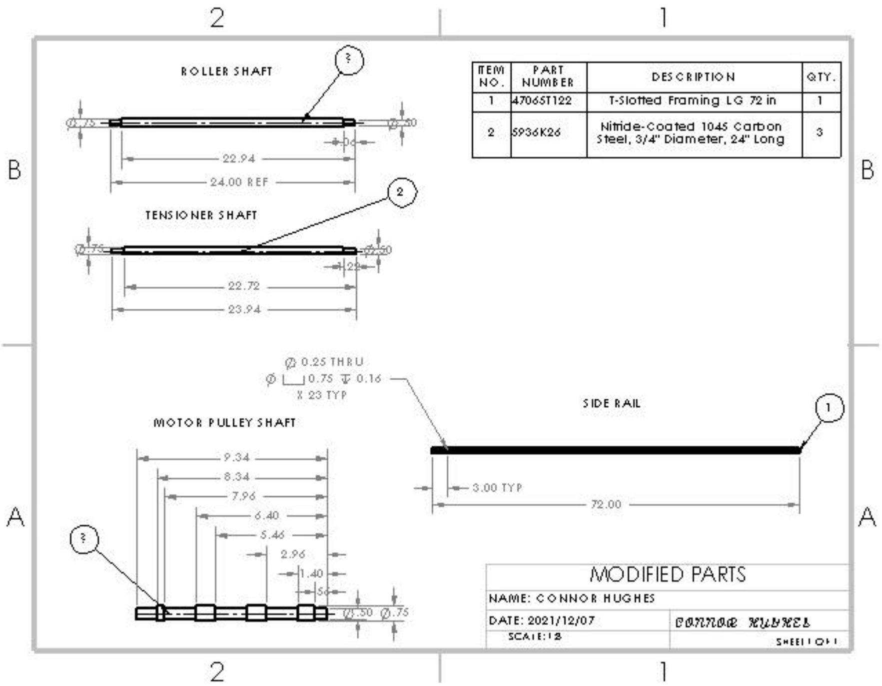


*Figure 9: Notable Part Modifications*

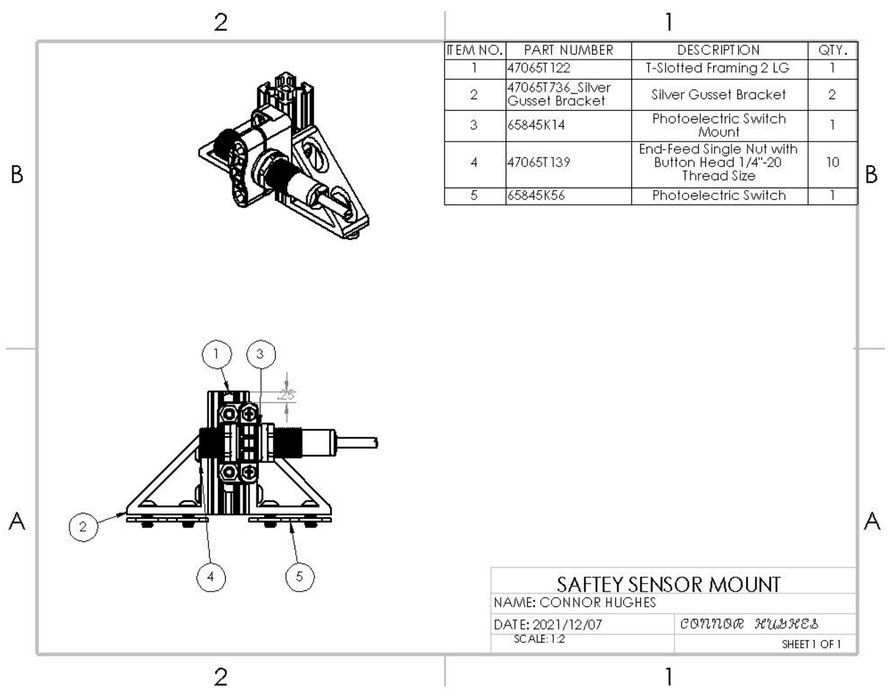


*Figure 10: Light Beam Mount*

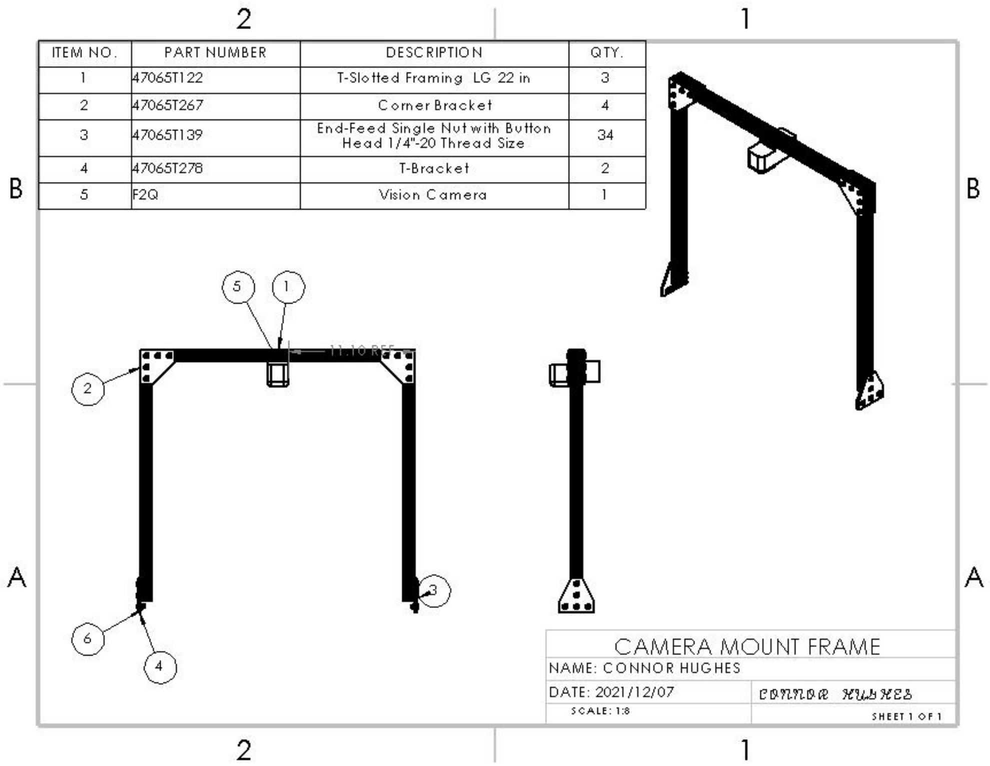


*Figure 11: Vision Camera Mount*

# Software Design

## Control Algorithm

The convey system is controlled by a series logic checks at each sensor node. At the first node, the camera reads material and orientation. If the material is porcelain, the computer then checks orientation to determine which of the first two buffers to put the packages in. If the material is not porcelain, the packages carry down the line to a second sorting unit where the material is checked. If the material is rubber, the package is diverted to a buffer conveyor. If the material is unidentified it continues along the path to a buffer for unknown packages. Each unit performs independent checks to reduce complexity at each sorting node. At all sorting nodes, conveyors were reset before any logical checks occurred. This way, if no action was taken the yet unidentified objects would simply continue along the system to their end destination.

## Testing Procedure

The first key step in testing the algorithms was to introduce console outputs. With this, it was possible to see the data the computer was receiving and understand the inputs into the logic. This way, when the program was running the result could be compared against the input to check for logical errors. The following table outlines the inputs and expected actions at each sorting node.

*Table 1: Simulator Test Procedures*

| Node | Inputs | | Expected Action |
|---|---|---|---|
| Pink | Material | Orientation | |
| | Porcelain | 0 / Side | Divert to the right with the first container |
| | Porcelain | 1 / Upright | Divert to the right with the second container |
| | Not Porcelain | N/A | Do not divert, continue straight |
| Blue | Material | | |
| | Rubber | | Divert to the right with the third container |
| | Not Rubber/ Unknown | | Do not divert, continue straight |

At this point the simulator was left to run for several minutes under observation to see if any deviations in logic occur.  This was done because there is no other quantifiable metric to see if the logic is wrong, then that by witnessing it go wrong. As such, it was required that the code be ran for a period of time to see what kind of errors occurred. After an issue was discovered, the console output was compared with the result to see where in the code the failure occurred so that the issue could be addressed. This was done multiple times and after every change to the code to see if a new bug cropped up. By doing this, it allowed for debugging issues that came up after a period of running as well. Debugging procedures were ran until no more observable issues were occurring. At this point, the program was left to run for longer than normal under observation to ensure that the code was functioning, and once the code passed this test it was considered completed.

### Results

The simulator can be considered a success, after over 5 minutes of run time with every case occurring, no issues were recorded. All boxes went to the correct locations while traversing the correct paths. Considering the code did what it was intended to do consistently and without exception, the code can therefore be considered a success.

## Cost Estimate

Shown below is a bill of materials for everything required for the conveyor system.

*Table 2: Bill of Materials*

| ITEM NO. | PART NUMBER | DESCRIPTION | QTY | PRICE PER UNIT | TOTAL COST | MANUFACTURER |
|---|---|---|---|---|---|---|

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 47065T122 | T-Slotted Framing Extrusion 24" | 24 | $9.48 | $227.52 | McMaster-Carr |
| 2 | 47065T122 | T-Slotted Framing Extrusion 22" (Ordered as 24" and cut to size) | 20 | $9.48 | $189.60 | McMaster-Carr |
| 3 | 47065T122 | T-Slotted Framing Extrusion 72" | 10 | $26.50 | $265.00 | McMaster-Carr |
| 4 | 47065T267 | Silver Corner Surface Bracket | 28 | $9.07 | $253.96 | McMaster-Carr |
| 5 | 47065T736 | Silver Gusset Bracket | 72 | $11.89 | $856.08 | McMaster-Carr |
| 6 | R1212-2RS | Ball Bearing | 239 | $15.65 | $3,740.35 | McMaster-Carr |
| 7 | 5936K73 | Rotary Shaft | 118 | $15.08 | $1,779.44 | McMaster-Carr |
| 8 | 47065T122 | T-Slotted Framing Extrusion 23" (Ordered as 24" and cut to size) | 20 | $9.48 | $189.60 | McMaster-Carr |
| 9 | 47065T331 | Diagonal Brace Ends | 60 | $10.04 | $602.10 | McMaster-Carr |
| 10 | 47065T122 | T-Slotted Framing Extrusion 26 3/8" (Ordered as 36" and cut to size) | 20 | $12.86 | $257.20 | McMaster-Carr |
| 11 | 47065T122 | T-Slotted Framing Extrusion 25 7/8" (Ordered as 36" and cut to size) | 10 | $12.86 | $128.60 | McMaster-Carr |
| 12 | 47065T122 | T-Slotted Framing Extrusion 30 2/3" (Ordered as 36" and cut to size) | 27 | $12.86 | $347.22 | McMaster-Carr |
| 13 | 47065T278 | Silver Tee Surface Bracket | 100 | $9.46 | $946.00 | McMaster-Carr |
| 14 | 47065T139 | T-Slotted Framing Fasteners | 956 | $0.54 | $513.85 | McMaster-Carr |
| 15 | 47065T122 | T-Slotted Framing Extrusion 4" (From cut-off of other Extrusions) | 3 | $20.23 | $60.69 | McMaster-Carr |
| 16 | 7728T51 | Mounted Steel Ball Bearing with Cast Iron Housing | 6 | $79.07 | $474.42 | McMaster-Carr |
| 17 | 6075K17 | Flat Belting (cost and quantity per foot) | 140 | $6.92 | $968.80 | McMaster-Carr |
| 18 | MTPM-P25-1JK44 | Ironhorse DC motor 12VDC-24VDC | 1 | $145.00 | $145.00 | AutomationDirect |
| 19 | ZP-MC06B-2-SCP16M | Shaft Coupler | 1 | $15.00 | $15.00 | AutomationDirect |
| 20 | GSD1-24-15N4X-R | Motor Controller 12VDC – 24VDC | 1 | $519.00 | $519.00 | AutomationDirect |
| 21 | 65845K56 | Safety Sensor – Photoelectric Switch | 2 | $147.26 | $294.52 | McMaster-Carr |
| 22 | 65845K14 | Safety Sensor Mounting Bracket | 2 | $16.20 | $32.40 | McMaster-Carr |
| 23 | FQ2-S25050F Omron | Vision Sensor - FQ2 Photoelectric Sensor (Including Interface) | 1 | $1918.09 | $1918.09 | World Industrial Automation |

Total Cost: $14,724.44

Therefore, our total cost for all materials needed for the conveyor system is $14,724.44. The first 17 items on the bill of materials consist of everything that is required to make the skeleton and overall mechanical layout of the conveyor system. As we can see item 19 is essential because a shaft coupler must be used for our shaft selected in item 18. Item 20 is the motor controller and items 21 and 23 are the sensor required for the conveyor system. A mounting bracket for the safety sensor is included in item 22. We decided to purchase 2 safety sensors so they can cover both sides of our conveyor system. For items 1-17, all the quantities were referenced from the SolidWorks model created for the conveyor system.

After doing some research, we were able to determine that setting up the motor and motor controller can take up to ½ day for someone with no experience, but a car dealership mechanic can do the job in 2 hours [13]. Dealership mechanics charge an average of $130/hour, so we can estimate that we'd have to pay 1 person $780 to fully setup the 3 motors and motor controllers [14].

Since it takes 30 minutes to an hour to setup a DIY alarm sensor, we can approximate that it can take us roughly 45 minutes per sensor to ensure that everything is aligned and functioning to perfection [15]. Since we have 2 safety sensors and 1 vision sensor, it can take us roughly 2 hours and 15 minutes. On average a machinist in Canada is paid, $24.65/hour, so we'd have to pay $55.46 to get our sensors aligned and properly functioning [16].

For the overall skeleton of the mechanical system, it can take approximately 2 hours to fully setup one side of the railing for each section of the conveyor system. These 2 hours include the time to put the extrusions together with fasteners and brackets. Since it takes 2 hours for 1 side, it'll take 4 hours for 1 whole section and with 5 total sections, it would take us 20 hours to fully assemble all the railings.

It can take about 30 minutes to an hour to cut each shaft from the manufacturer to our desired length for the conveyor system. Therefore, we can take an average of 45 minutes per shaft, and with 118 total shafts, that gives us a total of 88.5 hours. Assembling each buffer section will take approximately 4 hours including time for the 100 braces, extrusions, brackets and fasteners and 6 hours for the driven section (extra 2 hours for the motor). Since we have 3 driven sections and 2 buffer sections, that totals to 24 hours to assemble the buffers together.

Lastly, when fully assembling the whole system including the conveyor belt will take approximately 3 hours which also includes the time it takes to incorporate all the sensor and ensure that the whole conveyor system is working to perfection. All the approximations regarding the hours required to assemble the overall mechanical system were based off personal experience when working in machine shops and building similar parts.

Totaling all the hours required to construct the skeleton of the system, it would take 135.5 hours. To speed up the process, we are hiring 4 machinists which are paid $24.65/hour, therefore totalling our cost to $3340.075 [16].

Now totalling all the costs for the labor and materials, it would cost $18,900.65.

## Recommended Improvements

After analysing both the mechanical and software component of the system it was decided that, in order to increase the effectiveness of the system, some improvements should be made.

For the mechanical system, changing the drive belts into a geared system along the edge of the rollers to drive the system, would be beneficial as it would decrease the possibility for mechanical slipping. The belt drive system relies on friction between the belt and the rollers; overtime the belt will wear out and need to be replaced, meaning downtime for the system which can cost the company money due to lost time. The belt drive system also needs to be tightened as the belt stretches, meaning maintenance costs for the company. If an enclosed gearing system was used, unless anything breaks in the gearbox, it will last for a very long time with little maintenance required. The gearing system would cost more to implement; however, it reduces maintenance costs and system downtime, therefore saving the customer money in the long run.

Another modification to improve the mechanical system would be to use software-controlled motor controllers. This would allow the system to be completely controlled by the software system and make it easier to run the conveyor. Currently, manual motor controllers are being used, meaning that the speed of the system has to be manually set by a worker every time the system is turned on and off. With there being multiple drive sections, this is not time efficient for the company. Using software-controlled motor controllers would allow us to use a software system to control motor speed making the system consistent and easier to run as the employee will only have to turn on the operation interface. This would also reduce the possibility for the employee to make the conveyor run too fast.

Lastly, for improvement to the mechanical system, a buzzer should be added for when the system is starting and stopping as well as if the safety sensor is tripped causing a power shutoff to the conveyor system. This will increase safety with respect to human interaction, with the conveyor system as it will warn people before any change happens in the system. The buzzer when the safety sensor is tripped is extremely important as it warns others that someone could potentially be injured from the conveyor system (ideally the safety sensor reduces the chance for injury however it cannot be completely eliminated, and this is a good redundancy to make sure no one is left un attend if they are injured). If the system stops for an unknown reason this will also alert the workers, reducing downtime of the conveyor system as the employees will know it has stopped working instantly.

The software that drives the conveyor system is included with the purchase of the vision sensor. To improve the efficiency of the user control interface we will use '.NET' controls to customize the user interface and to integrate the mechanical changes into the software.

In conclusion, the original design is effective and very useful however with a few improvements the control of the system can be increased, and maintenance costs can be decreased.

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