Conveyor Gate Design

by

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Senior Design Report

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ABSTRACT

The current gates being used at Intelligrated need improvements in safety and ergonomics. A problem with the current gates is the gas shocks that are used. The main ideas for the design discussed in this paper address the problems that the operators of the current gates encounter. The goal of this research is to design a conveyor gate that will be easy and safe to operate and also put less stress on the body of the operator.

Three design concepts were taken into consideration to address the improvements that need to be made. Out of the three concepts, the most practical design involves a slider crank mechanism. The slider crank mechanism on the new design makes the gate easier for the operator to move the gate from the closed to open position, which improves the safety of the gate. This design also reduces the height of the gate in the open position which improves the ergonomics of the gate.

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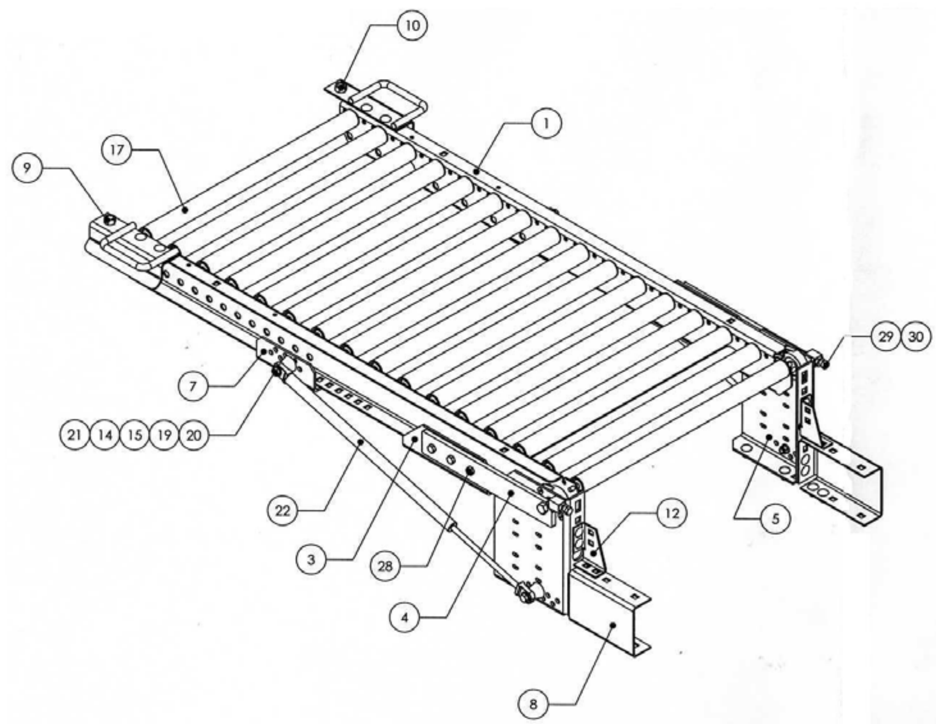
PROBLEM DEFINITION AND RESEARCH

Introduction

Intelligrated was founded in September 2001 and is headquartered in Mason, Ohio. Intelligrated is a company that offers material handling solutions for distribution centers and large warehouses. Their main focus is designing and installing conveyor systems. A few of Intelligrated's clients are Amazon, Big Lots, Dick's Sporting Goods, and Staples. Some of the conveyor lines designed by Intelligrated need gates because of their length. These gates allow personal entrances and exits through the conveyor line. These conveyor gates need to be improved for various reasons. Below is a picture of Intelligrated's current gate.

Figure 1 – Intelligrated's Current Gate



One problem with the current conveyor gate design is the gas shocks. The gas shocks are designed to provide assistance in lifting and closing the gate. However, the gas shocks are neither reliable nor consistent. When lifting or lowering the gate, the gas shocks offer too much or too little resistance. This inconsistency causes the operator difficulties when lifting or lowering the gate. When the gas shocks offer too little resistance, the gates can close too fast and slam into other sections of the conveyor causing damage.

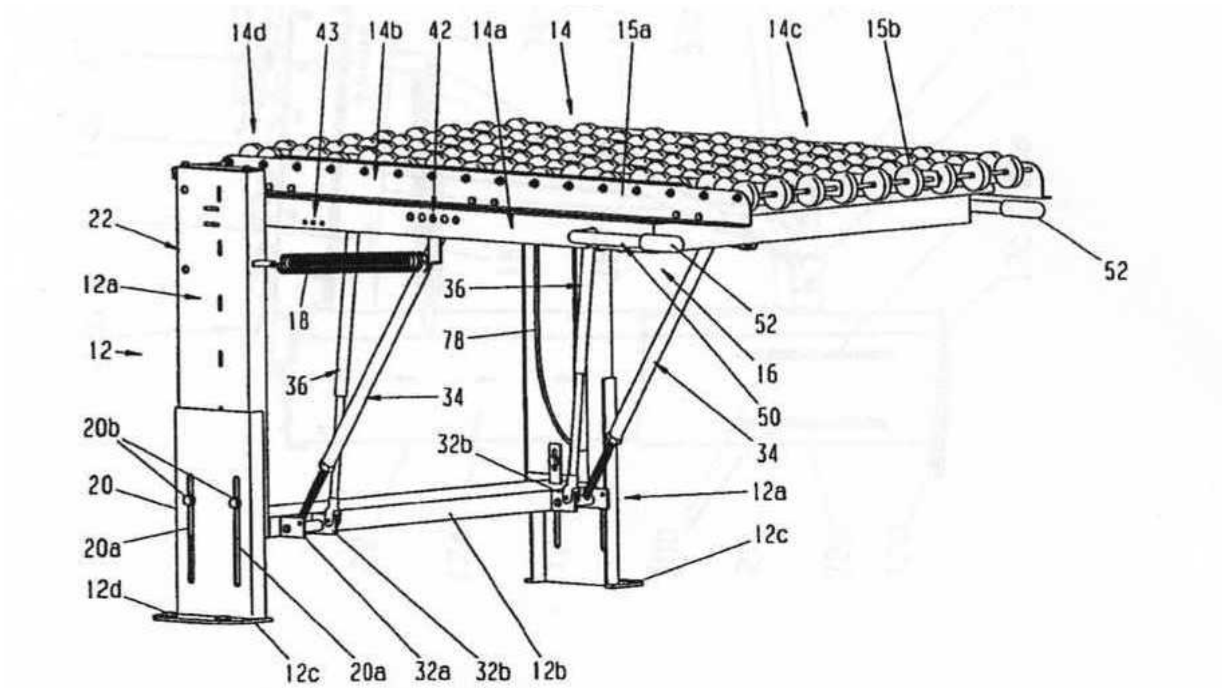
Another problem with the current conveyor gate design is ergonomics and safety. The gate can fall down when in the open position because there is no locking mechanism to hold the gate up. The gate also needs to be lifted above the attached section of conveyor, and this could cause injury to the operator.

Research

Existing Products

Patent number US 6,484,869 is an example of a conveyor gate that can open and slide down at the same time. This patent shows the use of springs, gas shocks, a locking mechanism, and other links. The date of the patent is November 26, 2002. The inventors of the patent are Gerald A. Brouwer and James L. Frank. The assignee is Rapistan Systems Advertising Corporation, located in Grand Rapids, Michigan. (Brouwer) This patent design will be used as a foundation for a new conveyor gate design. Below is a picture of the patented gate.

Figure 2 – Patented Gate



Interviews

There are three engineers at Intelligrated that gave insight on the previously mentioned problems. All three of these men have multiple years of experience in the company. Each offered different ideas and insights.

The first interview was conducted with James Seiwert on September 24, 2007. James Seiwert is a Mechanical Product Engineer at Intelligrated. The information gained from the interview is that the gas shocks are not very reliable, the mounting plates for the shocks have too many variations, each gate needs to have its own supports, and he would like a universal bracket to eliminate the two different brackets currently used. (Seiwert)

The second interview was with Ron Wagner on September 24, 2007. Ron Wagner is the Manager of Product Engineering at Intelligrated. The information from the interview is that he does not like the current gas shocks because they offer too much or too little resistance. The current gas shocks used at Intelligrated are rated for 50, 75, 100, 125, 150, and 175 pounds. Ron also would like a gate that opened and slid down the support at the same time. (Wagner)

The third interview was with Ron Wagner and James Halsey on October 1, 2007. James Halsey is a Senior Development Engineer at Intelligrated. In the interview they, again, suggest replacing the gas shocks, by using springs counterweights, or other options. Other information discussed was to have the gate open and slide down the support at the same time. They also suggested looking at patents that already exist. (Halsey)

Survey Results

A number of professionals at Intelligrated were surveyed to determine what features would be most important in the conveyor gate design. The features surveyed were derived from existing products and the current functions of the conveyor gate. The individuals surveyed at Intelligrated included mechanical engineers, industrial engineers, and installation managers. A blank copy of the survey can be found in Appendix A.

The product features that were surveyed were safety, reliability, durability, ease of assembly, ease of manufacturing, compatibility with existing components, locks in open and closed positions, cost, ease of repair, force required to lift gate, and ergonomic design.

QFD

The survey results were placed into a quality functional diagram or QFD (Refer to Appendix B). This table shows the most important aspects of the design will be the weight of the gate, the geometry and setup of the links, and springs/gas shock assistance. The less important aspects of the design will be the material, cost of manufacture, height of gate, and interchangeable parts.

Product Objectives

The new gate conveyor design will improve the safety and ergonomics of Intelligrated's conveyors. The improvements in safety and ergonomics will help prevent injuries to the operator of the gate. The improvements will also help prevent damage to the attached conveyor lines. Below is a list of product objectives that will help improve the safety and ergonomics.

Table 1 – List of Product Objectives

#	Product Objective
1	A gate with an opening of at least 36 inches
2	A gate that has a floor length of 42 inches
3	A gate that weighs less than 100 pounds
4	A gate that can support 25 pounds per foot
5	A gate that uses Intelligrated's standard rollers, frame, and height

The first product objective is to have a gate with an opening of at least 36 inches, which is required by the Occupational Safety and Health Administration (OSHA). This allows for more than one person to exit in case of an emergency. The second product objective is to use a floor length of 42 inches. This will allow the new conveyor gate to be the same length as the old conveyor gates. The third product objective is to have a gate that weighs less than 100 pounds for ease of lifting. The fourth product objective states the gate must be able to support 25 pounds per foot. 25 pounds per foot is an Intelligrated guideline when designing sections of conveyors. The fifth product objective requires the design to use 1.9 inch diameter rollers, a 3.5 inch C-channel frame, and a height of about 32 inches from the ground when closed.

DESIGN

Design Alternatives and Selection

Design Concept #1

The first design concept for the conveyor gate is to have the gate open and slide down the support at the same time. This concept uses a slider crank mechanism that positions the gate perpendicular to the ground when open. The slider crank mechanism guides the gate into the upright position with more ease than the current gate. The old conveyor gate had a height of 64 inches when open. Using a slider crank mechanism will reduce the height of the open gate which will improve the ergonomics and safety.

Design Concept #2

The second design concept is to have the gate slide under the attached section of conveyor. This is done by mounting tracks under the attached section to have the gate slide on. This design positions the gate parallel to the ground and conveyor. One advantage of this concept is that it reduces the lift of the gate.

Design Concept #3

The third design concept is to have the gate swing down. This concept makes it easier for the operator to open the gate. This design concept is also compatible with the current conveyors. One problem with this concept is that the operator will have to bend down and lift the gate to put it into the closed position. Bending down to lift the gate can cause injury to the operator.

Selection

A weighted decision matrix was setup to select the best design concept (Refer to Appendix C). The first step of the weighted decision matrix was to fill in the design criterion, weight factors, and units. The weight factors were calculated be taking the relative weight, from the QFD Table (located in Appendix B), and multiplying by two. The next step was to decide the magnitude and score for each design concept. The third step was to calculate the ratings and then total the ratings. These scores take into account the magnitude and the weight factor for each design concept.

The concept with the lowest rating was determined to be the most practical. Design concept number two had a total score of 3.60. Design concept number two scored higher ratings with compatibility with existing components and cost. Design concept number three had a total score of 3.68. Design concept number three had higher ratings with safety and ergonomics. Design concept number one had the lowest score, 2.64, and was the design concept developed.

Loading Conditions

Calculations were performed to ensure the link supporting the gate had a sufficient diameter to withhold the force. First the force exerted from the gate needed to be taken into consideration. The force was calculated by adding the weight of each component of the gate together to get a total weight. The total weight of the gates is composed of the frames, cross-members, rollers, and product weight. The standard product weight used at Intelligrated is 25 pounds per foot. The total weight of the gate is 154 pounds or 3.8 pounds per inch.

After finding the force from the gate, the direct compression design stress with a shock load was calculated for 1040 Cold-Drawn Steel. The design stress was calculated to be 8083.33 pounds per square inch (psi).

Next, the area of the link was found. It was found by taking the force from the gate divided by the design stress. This was calculated to be 0.019 inches squared. Finally, the diameter of the link was calculated. The formula yielded a result of 0.155 inches.

All of the above calculations can be found in Appendix D.

Design Analysis

There are many components that needed to be taken into consideration when designing the desired gate. The first component taken into consideration was the section of conveyor to be used for the gate. This section of the conveyor is 22 inches wide by 40.5 inches long. This will allow for an opening of 36 inches. Next, the lengths of the slider crank mechanism needed to be considered. The links need to fixate on the conveyor gate in the center to counter balance the weight. The links also need to be short enough to allow the gate to be less than 55 inches tall when in the upright position. The diameter of the links needed to be greater than 0.155 inches (Refer to Appendix D). This ensured that the links did not buckle from the compressing forces.

The gate is held up by two supports mounted to the ground and the attached section of the conveyor. The cross member, which is attached to the two supports, running parallel to the ground, is where the link and shock brackets are mounted. The shocks are used to provide assistance when opening and closing the gate. They allow a smooth transition from the closed position to the open position. The supports also have brackets that serve as a track for the slider crank mechanism.

Using this design will address all of the previously mentioned concerns of the current gates. This design also addresses all of the product objectives. When this design is in place, access through the conveyor system will be safer and more ergonomic.

Factors of Safety

When performing the direct compression design stress calculations (located in Appendix D), a shock load factor was considered, which made the diameter of the link larger. This factor of safety compensates for a circumstance in which an operator may drop the gate. If the gate is dropped, the extra support will ensure that the links will not buckle from the shock of the drop.

The load from the boxes traveling across the gate was taken into consideration when factoring the support of the links. This load corresponds with Intelligrated's policy of 25 pounds per foot.

Bill of Material

The following table is a list of the sub-assemblies and components used in the new gate conveyor design. The first column includes the descriptions and part numbers of the sub-assemblies. The second column contains the components used in the sub-assemblies. The third column is the material of the components.

Table 2 – Bill of Material

Sub Assemblies	Components	Materials
SRD GT SUPPORT W/ RUNNER (7019110_)		
	SRD GT SUPPORT _H (7019120_)	7 GA
	SRD GT SUPPORT RUNNER (70191300)	10 GA
	HARDWARE	PURCHASED
SRD GT SUPPORT CROSS MEMBER ASSEMBLY (70191400)		
	SRD GT CROSS MEMBER (70191500)	10 GA
	SRD GT CM LINK BRACKET (70191600)	10 GA
	SRD GT CM SHOCK BRACKET (70191700)	PURCHASED
	HARDWARE	PURCHASED
SRD GT CONVEYOR ASSEMBLY (70191800)		
	SRD GT CONVEYOR FRAME RAIL (7019190_)	10 GA
	SRD GT CONVEYOR CROSS MEMBER (70192000)	10 GA
	SRD GT CM SHOCK BRACKET (70191700)	PURCHASED
	ROLLERS	PURCHASED
	HARDWARE	PURCHASED
SRD GT LINKAGE ASSEMBLY (70192200)		
	SRD GT LINKAGE ROD (70192300)	0.375-24 THREADED ROD
	SRD GT LINKAGE TUBE (70192400)	0.375 DIA SCH 80 PIPE
	HARDWARE	PURCHASED
SRD GT HANDLE (7019250_)		
	ANGLE-REST MOUNTING PLATE (4503080_)	10 GA
	HANDLE (3-11257-001)	0.5 DIA 1018
	HARDWARE	PURCHASED

FABRIACTION AND ASSEMBLY

Intelligrated's manufacturing facility, located in London, Ohio, is where the majority of the parts were made. Part of the fabrication was to have the supports, cross-members, and the frame rails punched, formed, and powder coated specific to the design. The rollers, hardware, and shocks were purchased from Intelligrated's normal supplying companies. The gate was assembled at Intelligrated, in Mason, Ohio. This is the also the location where the gate was tested.

TESTING AND PROOF OF DESIGN

The first testing method was to apply 25 pounds per foot. This is the typical testing load used at Intelligrated. To test this standard, three twenty-five pound boxes, each with a length of one foot, were stacked next to each other and placed on the gate. The gate was able to withstand the force load.

The second test performed on the gate was performed to test how effective the gate was as it was being opened and closed numerous times. One area assessed was the binding of the bearings and runners (the track the bearings run down while the gate changes position). Another area assessed during this testing was the effectiveness of the shocks. Both of these areas satisfied the testing and proved to be efficient.

The third test was to open the gate and drop it down to simulate a case where an operator loses control and the gate falls. During this test damage was assessed on the gate and the conveyor line. The gate was able to withstand these drops without significant damage done to either the gate or the conveyor line.

PROJECT MANAGEMENT

Schedule

The Gantt Chart was established to keep the project on track. The orange squares are the proposed schedule. The green squares are the actual and updated schedule. The design of the gate and support took longer than the proposed time. This caused the drawings and the ordering to be delayed.

Table 3 – Updated Schedule

Quarter	Winter															Spring													
Week	1	2		3	4	5	6	7	8		9	10	11			1	2	3	4	5	6	7		8	9		10	11	
Date	1/2-1/5	1/6-1/12	Target Date	1/13-1/19	1/20-1/26	1/27-2/2	2/3-2/9	2/10-2/16	2/17-2/23	Target Date	2/24-3/1	3/2-3/8	3/9-3/15	Traget Date	Spring Break	3/23-3/29	3/30-4/5	4/6-4/12	4/13-4/19	4/20-4/26	4/27-5/3	5/4-5/10	Target Date	5/11-5/17	5/18-5/24	Target Date	5/25-5/31	6/1-6/7	Target Date
Proof Of Design Statement			9																										
Proof Of Design Agreement			9																										
Design of Gate																													
Design of Supports																													
Drawing of Components																													
Drawing of Assembly																													
Design Freeze										20																			
Order Material for Gate																													
Order Material for Supports																													
Order Hardware																													
Oral Design Presentation														12															
Design Report Due														19															
Construct Gate																													
Construct Supports																													
Final Assembly																													
Testing/Trouble Shooting																													
Demonstration for Advisor																							9						
Tech Expo Display																													
Tech Expo																										22			
Final Oral Presentation																										28			
Final Report																													9

Budget

The preliminary budget includes forecasted amounts for the frame, rollers, springs and mounts, supports, bearings, mounting brackets, hardware, and miscellaneous expenses. The total forecasted amount for the preliminary budget was \$580.00. The actual budget was \$376.62. Below are the cost and totals for each piece of equipment needed for the project.

Table 4 - Budget

Budget for Conveyor Gate				
Materials		Forcasted Amount		Actual Amount
Frame		$100.00		$38.30
Rollers		$80.00		$104.44
Springs with mounts		$100.00		$42.82
Supports		$75.00		$64.38
Bearings		$25.00		$5.00
Handles		$25.00		$21.26
Mounting brackets		$25.00		$37.04
Hardware		$50.00		$10.00
Miscellaneous		$100.00		$53.38
Total		**$580.00**		**$376.62**

CONCLUSION/RECOMMENDATIONS

The new gate proves to be safer, more ergonomically fit, and withholds the product objectives desired. The new gate is safer than the current gate for two reasons. It has a lower lift height (ten inches lower) than the current gates and it is less likely to fall and cause damage to the conveyor line. The new gate is also more ergonomically fit than the current gates. It provides less stress on the body.

All of the product objectives were satisfied on the new gate. The design of the new gate does not weigh more than 100 pounds, is compatible with Intelligrated's current standards, has an opening of 36 inches, a floor length of 42 inches, a height of about 32 inches when closed, a height of less than 55 inches when opened, and supports 25 pounds per foot. The new gate also satisfies all of the OSHA requirements.

One recommendation that could be made to improve this gate is to attach a locking mechanism. This locking mechanism would secure the gate when it is in the closed position. This ensures that the gate will not open when heavier boxes cross over the gate. Another recommendation that could be done to improve the gate would be to install a photo eye. The photo eye would be beneficial to the gate because it would detect when the gate starts to open. It would then send a signal to a conveyor upstream to shut down the conveyor line. Shutting down the conveyor line would prevent clogging. It would also prevent boxes from hitting the open gate and potentially causing damage.

REFERENCES

Brouwer, Gerald A. and James L. Frank, "Conveyor Personnel Gate," US Patent 6,484,869, November 26, 2002.

Halsey, James, Senior Development Engineer, Intelligrated, and Ron Wagner. Personal Interview. 1 October 2007.

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Seiwert, James. Mechanical Product Engineer. Intelligrated. Personal Interview. 24 September 2007.

Wagner, Ron. Manager of Product Engineering. Intelligrated. Personal Interview. 24 September 2007.

APPENDICES

Appendix A

SURVEY

Conveyor Gate Design

Product Improvement Survey

I am a senior at the University of Cincinnati studying Mechanical Engineering Technology. I am intending to improve the current conveyor gate design used at Intelligrated. Please take a few minutes to answer the following questions to help better the design.

Rate your satisfaction with the current conveyor gate? Please circle the appropriate answer.

1 = Lowest

5 = Highest

N/A = Not Applicable

Safety	1	2	3	4	5	N/A
Reliability	1	2	3	4	5	N/A
Durability	1	2	3	4	5	N/A
Ease of assembly	1	2	3	4	5	N/A
Ease of manufacturing	1	2	3	4	5	N/A
Compatibility with existing components	1	2	3	4	5	N/A
Locks in open and closed positions	1	2	3	4	5	N/A
Cost	1	2	3	4	5	N/A
Ease of repair	1	2	3	4	5	N/A
Force required to lift gate	1	2	3	4	5	N/A
Ergonomic design	1	2	3	4	5	N/A

What is important to you for the design of a new conveyor gate? Please circle the appropriate answer.

1 = Lowest	5 = Highest	N/A = Not Applicable

Safety	1	2	3	4	5	N/A
Reliability	1	2	3	4	5	N/A
Durability	1	2	3	4	5	N/A
Ease of assembly	1	2	3	4	5	N/A
Ease of manufacturing	1	2	3	4	5	N/A
Compatibility with existing components	1	2	3	4	5	N/A
Locks in open and closed positions	1	2	3	4	5	N/A
Cost	1	2	3	4	5	N/A
Ease of repair	1	2	3	4	5	N/A
Force required to lift gate	1	2	3	4	5	N/A
Ergonomic design	1	2	3	4	5	N/A

Please answer the following questions to the best of your knowledge

Please give other suggestions you may have, in improving the conveyor gate.

Thank you very much for participating in this important survey. Your input is important and greatly appreciated.

Appendix B

QFD

	material	weight of gate	geometry and setup of links	cost of manufacture	spring/gas shock assistance	height of lift	interchangable parts	Customer importance	Current Conveyor Gate	New Conveyor Gate	Improvement ratio	Relative weight
1. safety		3	1		3	1		5	4	5	1.3	0.08
2. reliability		3			3			5	3	4	1.3	0.09
3. durability	3	3	1		3			4	3	4	1.3	0.09
4. ease of assebly	1		3				3	4	3	4	1.3	0.09
5. ease of manufacturing	3		3	3			3	4	3	4	1.3	0.09
6. compatibilty with existing components				9			9	4	3	4	1.3	0.09
7. locks in open and closed positions		3	9					5	2	4	2.0	0.13
8. cost	9		3	3	3		1	4	3	3	1.0	0.06
9. ease of repair			3		3		1	4	2	4	2.0	0.13
10. force required to lift gate		9	3		3	9		4	3	4	1.3	0.09
11. eronomic design		9	1		9	9		5	3	4	1.3	0.09
Absolute Importance	1.2	2.68	2.75	1.22	2.36	1.62	1.48	13.28			15.6	1.00
Relative importance	0.09	0.20	0.21	0.09	0.18	0.12	0.11					
Units		lbs.		$		inches						

Appendix C

Weight Decision Matrix

Design Criterion	Weight Factor	Units	Design #1 (Slide down support and open)			Design #2 (Slide under attached conveyor)			Design #3 (Swing down)		
			Magnitude	Score	Rating	Magnitude	Score	Rating	Magnitude	Score	Rating
Safety	0.16	L/M/H	MEDIUM	3	0.48	MEDIUM	3	0.48	LOW	5	0.8
Ergonomics	0.18	L/M/H	MEDIUM	3	0.54	MEDIUM	3	0.54	LOW	5	0.9
Weight of Gate	0.18	L/M/H	MEDIUM	3	0.54	MEDIUM	3	0.54	MEDIUM	3	0.54
Cost	0.12	L/M/H	MEDIUM	3	0.36	HIGH	5	0.6	MEDIUM	3	0.36
Reliability	0.18	L/M/H	MEDIUM	3	0.54	MEDIUM	3	0.54	MEDIUM	3	0.54
Compatiblity With Existeing Components	0.18	L/M/H	HIGH	1	0.18	LOW	5	0.9	MEDIUM	3	0.54
				Total	2.64		Total	3.6		Total	3.68

Appendix D

Calculations

1) Weight of Conveyor

- Frame = 10lbs.
- 1 roller = 4lbs. => 14 rollers = 56lbs.
- A load of 25lbs. per foot (Intelligrated guideline)
    i. Conveyor has 42 inch openings => 3.5 feet.
    ii. Load = 87.5lbs.
- Total weight of conveyor with load = (10) + (56) + (87.5) = 153.5lbs.
- Total weight of conveyor with no load = (10) + (56) = 66lbs.

2) Sum of moments about point A

$$\sum M_A = 38.5(10.25) - 38.5(10.25) + R_{By}$$
$$R_{By} = 0$$

3) Sum of forces in the y-axis

$$\sum F_y = R_{Ay} + R_{By} - 38.5 - 38.5$$
$$R_{Ay} = 77 lbs.$$

4) Design stress for compressing load based on ultimate strength (Applied Strength of Materials, pg.86)

- Manner of loading = impact or shock, material = ductile => N = 12 (pg.89)
- Su = 97 ksi for 1040 cold-drawn steel (pg.646)

$$\sigma_d = \frac{Su}{N} = \frac{97000 psi}{12} = 8083.33 psi$$

5) Required cross-sectional area of 1040 cold-drawn steel link(pg.91)

$$A = \frac{F}{\sigma_d} = \frac{154 lbs.}{8083.33 psi} = 0.019 in^2$$

6) Required minimum diameter fro 1040 cold-drawn steel(pg.97)

$$D = \sqrt{\frac{4 * A}{\pi}} = \sqrt{\frac{4 * 0.019}{3.14}} = 0.155 inch$$

Appendix E

Free Body Diagram