Implementing A Visual Factory Check in Silver Line

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ABSTRACT— Silver Line, a window-production company, hires many people of different ethnicities within their factory, many of whom do not speak the same language. As a result, the company suffers from a large language disparity on the factory floor. In order to overcome this problem as well as aid Silver Line in the implementation of a new quality check, the factory was surveyed and it was decided that an "andon" light system would be the most cost effective and efficient solution. After consulting with an electrician and operations engineer, the colors of, locations for, and additions to the light were decided. The implementation of this light system will further develop the company's Lean Manufacturing System through implementing the practice of the 5S Methodology and avoiding the creation of Lean Manufacturing Wastes.

I. INTRODUCTION

The population of the United States is growing at a rapid pace, especially because of the number of immigrants that arrive from other countries. This influx of people has profound effects on American industry, one of which is the creation of a strictly divided language barrier. Language barriers arise from many different factors, including disparities in the languages spoken and regional accents and dialects. [1]

Silver Line is a window and door manufacturing company that employs many immigrants. Silver Line falls under the umbrella company Andersen Windows and specializes in the creation of vinyl windowpanes. There are four central languages spoken at Silver Linen North Brunswick: English, Spanish, Hindi, and Haitian Creole. The diversity in language use leads to various problems in communication, as this barrier inhibits the circulation of information along the factory lines. Communication, especially within factories, is essential to a safe and productive work environment. Currently, Silver Line is attempting to reduce glass defect escapes to assembly lines and customers.

A proposed solution is an enforced quality check every hour at the end of the glass lines. Ideally, this would allow the factory to stop the outflow of damaged glass. However, these quality checks take a significant amount of time and force the workers to stop the factory line entirely. The scheduled stops are foreseen to cause problems, worsened by the communication gap.

One solution to this difficulty is the implementation of a visual communication system. Light systems such as the andon light can be used to promote this visual system. Andon lights are signal lights of different colors stacked on top of each other with each color representing an idea. Switches are used to change the color of these lights to correspond to the state of the factory line.

The glass intercept lines at the factory were surveyed and the product flow was analyzed in order to determine the optimal positions for these lights. Working alongside a mechanical management team at Silver Line, feasible locations and designs for the switches were determined. In addition, a color analysis for the lights was performed in order to create a common and easily-interpreted system to help overcome the language barrier.

II. BACKGROUND

A. The Factory Line

The factory line can be split up into three major components: edge delete, space stackers, and out-feed. The glass begins at edge delete and leaves at out-feed. At edge delete, the worker grabs a glass pane with low-emissivity coating and removes the coating from the edges of the glass. They then send that through the washer. Afterwards, the worker sends a non-coated glass pane behind it. There are three tasks performed at the spacer stacking station. The first is the formation of the outline of the window. The second group then takes this outline and attaches the grid to it. Finally, glass panes are retrieved from the washing machine and are stacked with the glass-intercept lines in the middle. The stacked window is then sent through the oven. The out-feed then grabs and labels it. Then the glass is appropriately placed on the out-feed cart.

B. 5Ss of Lean Manufacturing

Silver Line, along with many other manufacturing companies, base their factories around Lean Manufacturing, which refers to maximizing resources, profits, and productivity, as well as minimizing waste within the factory. The principles of this methodology can be summed up with what is referred to as the 5S's: sort, set in order, shine, standardize, sustain.

1) Sort: Sort, the first 'S', aids in the organization within a distinct area of the factory. This principle states that items such as tools or machinery that are not required within the area should be moved to where they are needed. This allows workers to move around easier when they are searching for the materials they require.

2) Set in order: Set in order, the second 'S', is the creation of a system to organize specific objects such as tools or machines in a logical manner. This principle states that locations for each individual object should be clearly identified so that all items are easy to find and operate. This principle aims to reduce confusion among workers when attempting to locate particular materials, which promotes a more productive work environment.

3) Shine: Shine, the third 'S', is the cleaning of all materials within the factory. This principle states that all items should be cleaned regularly in order to maintain factory regulations. This allows for workers to easily utilize any of the tools or machines as well as identify any defects or damage.

4) Standardize: Standardize, the fourth 'S', is the enforcement of all of the prior principles. This states that rules and regulations should be added to and enforced within the factory in order to ensure and maintain proper factory conditions.

5) Sustain: Sustain, the fifth 'S', is the implementation of all of the prior principals in order to habituate them. This states that the principles should be practiced and improved upon daily to maximize efficiency within the factory.

C. Wastes of Lean Manufacturing

Many businesses strive to eliminate waste because it reduces their profitability. This waste can be defined as an "activity that consumes resources but adds no value." [2] These wastes are often split into 8 categories:

1) Downtime: Downtime is inaction on a factory line that adds cost to the product being produced for the customer. The longer it takes to produce a product, the less product a company will produce, which reduces the company's profit.

2) Defects: Defects are any products, information, or services that are incorrect, incomplete, or early. They are thought to be one of the most significant wastes because they lead to downtime, inventory, and motion.

3) Excess Processing: Excess processing occurs when products do not conform to a customer's requirements. The product then must be repaired or recreated to the customer's needs. Examples of excess processing include repairing and remanufacturing.

4) Overproduction: Overproduction is making too much of a product or finishing too soon. The goal of every company is to deliver what the client wants exactly when they want it, and overproduction inhibits this.

5) Inventory: Inventory is defined as a valuable product or material that is waiting to be sold or transformed into something of greater value. The longer an object sits in inventory, the more its value is reduced, which reduces profitability for a company.

6) Moving: Moving is transporting an object from one place to another. Resources, money, and time are consumed when moving material, while no value is added to the product.

7) Motion: Motion can be either people or machine, but it is most often a human resource whose effort and time are being wasted. This can be due to inefficient shop-floor layouts and improper equipment, both of which prevent free and organized movement of the employees.

8) Non-utilized talent: Non-utilized talent is when management in a manufacturing environment fails to ensure that the talent of their employees is being entirely utilized. [4]

D. Kaizen Event

Kaizen events are organized within an industry to improve upon existing processes. [3] In order to optimize the decision-making and facilitate intra-company communication, kaizen events often bring together the operators, managers, and owner into one place for a couple of days. These events often include the mapping of existing processes to visually portray the current state of the factory and make it easier to identify where improvement is required. Kaizen events usually last a week and end with the installation of an object or a change that makes a positive impact on the targeted process. These events fall under the fifth 'S', sustain. [5]

Silver Line is planning a kaizen event in which they will implement a quality check at the end of every glass intercept line to target the company's repair system. Repairs are split into two groups, internal and external. An internal repair is anything that was damaged along the glass process line and was repaired there, while an external repair is damage discovered and repaired by the employees at following window assembly lines. During this quality check, the worker at the end of the line is responsible for communicating this check utilizing the andon light, performing the check on a test piece of glass, and resuming the process once they are finished. An andon light is a visual communication system in which the colors of the light are used to convey the status of the factory line. This quality check will increase the number of internal repairs and reduce the number of external repairs, a goal of Silver Line's. The implementation of this quality check through the kaizen event must be taken into account when designing the andon lights because of the significant role the lights play in its implementation.

III. Implementing the Light and the Switch

A. Surveying the Glass Intercept Line

An entire tour of the factory was taken. A complete production of glass windows was presented, beginning with the extrusion lines. For the most part, the extrusion lines are unmanned. However, they were shown as an example of the implementation of andon lights. The light scheme used there is only slightly different, and provided a good base of understanding for andon lights. After that, the single-hung lines were observed. This process had multiple people working up and down the lines, and they used andon lights, providing a similar situation to the glass intercept lines. Later, the glass intercept lines were surveyed. Most of the surveying time was spent here, specifically on Line 5.

B. Color Scheme

Factory employees use the colors of the andon lights to communicate, without vocal cues, the state of the factory line. In order to create an effective visual system, the colors of the andon lights need to be easily-interpretable by the operators of the line.

To achieve this, the andon lights currently within the factory, as shown in Fig.1, were analyzed.

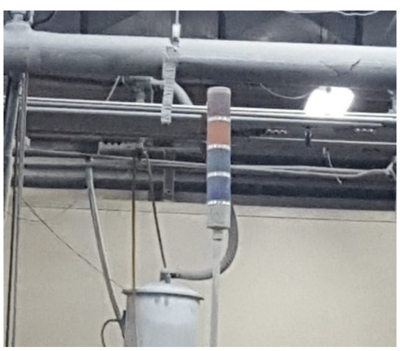

Fig. 1 Andon light on the extrusion line

The lights on the extrusion process line are comprised of four different stacked colors: red, yellow, green, blue. The red light signals a problem and that the automated line needs to stop and be reviewed by a mechanic. The yellow light is used to communicate the possibility of slight deviations in the extrusion process and that the products should be reviewed and the machine checked. The green light remains on throughout the entire extrusion process unless there is a problem with a machine or a deviation in the material. Finally, since extrusion is run solely by machines, the equipment requires time to start up and cannot begin to run until after it does so. The blue light signals that the machine is not yet ready to operate, but is starting up. This andon light system is the inspiration for the first model of the andon light for the intercept line.

The first model of the andon light system for the intercept line was comprised of four stacked colors, similar to the extrusion lights. Red, often representing stop, would tell the workers that there is a problem with a piece of glass and that they needed to halt their tasks. Yellow, representing caution, would warn the workers that there could be problems with the glass. An example would be if one of the glass panes did not pass the quality checks but the others preceding and following it did. Next, green, the universal signal for go, would assure the operators that everything is running smoothly on the line and that they can continue to work. Blue would be the color with the most significant change. It was determined that blue would be used to signal the new quality check that Silver Line was seeking to implement. It would turn on when the quality check was scheduled and signal the workers to stop the line as there would be a quality check being performed at the end of the line. This method would reduce confusion between the workers.

However, when the andon light's objective was re-analyzed, it was determined that the yellow light would not serve a purpose. With a quality check, the glass either passes because it lacks any flaws and deformations or it does not pass because it is dirty, cracked or chipped. Along with that, if there is any pane of glass that does not pass the quality check, the entire batch needs to be re-analyzed, which would be signaled through the red light. Due to this, the yellow light would be useless on the factory line and would simply cost Silver Line more money. Similarly, as shown in Fig. 2, at the end of the glass intercept line there was already an existing andon light that utilized only the colors red, yellow and green. In an effort to utilize this light, it was then determined that the blue light would be voided and the yellow andon light would represent the new quality check being implemented.

Fig. 2 Andon light at the end of the intercept line

Through this decision, the price of the andon light and its installation would be reduced and the factory would be able to reuse the light already implemented at the end of the line.

C. Determining the Locations of the Lights

In order to determine the optimal location of the lights, many conditions needed to be taken into consideration. The visibility of the light from the workstations surrounding it, its position in relation to where the mechanics and electricians had to access the machine, and the electronics required to install the light were all factors in deciding its final location. To make this process easier, the process map in Fig. 3 was used.

Fig. 4 Column in front of edge delete station was a possible location for the andon light

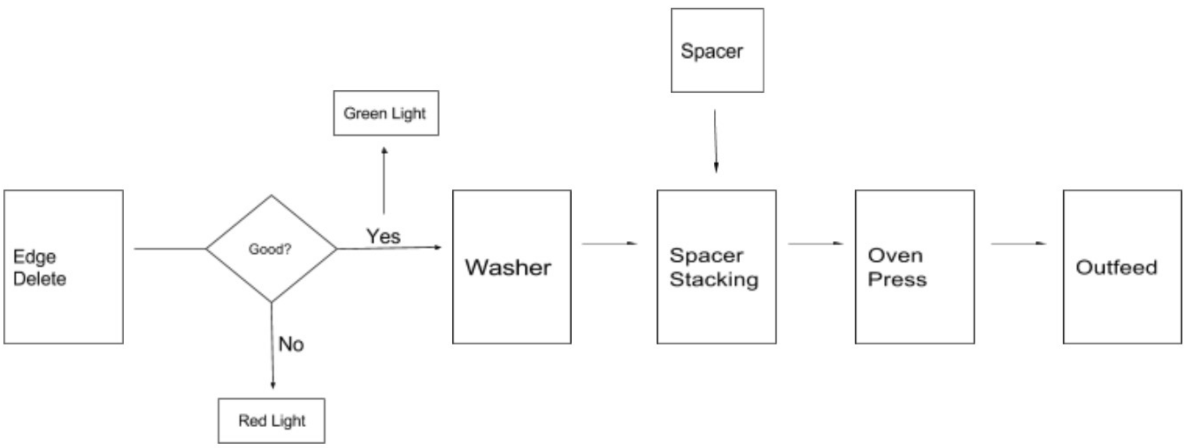

Fig. 3 Process map of glass intercept line detailing current quality check system

Using this map, general feasible locations for the lights were determined. It was decided that there would be one light located at the beginning of the line and one at the end in order to maximize visibility.

Since the washer is such a large structure, it segregates the worker performing edge delete from the rest of the line. A light at the front would allow edge delete to have a clear line of sight to one of the andon lights. Although, the light could not be placed directly onto the edge delete station as it was placed on wheels and could move freely. In the end, using pictures of edge delete, three, more specific, locations were determined for lights located at the front of the line. The first option was placing the light on the column depicted in Fig. 4.

The light would theoretically be in the operator's line of sight; however the operator would be required to look up from their work, something that does occur very often. The next option was placing the light on a power box located slightly to the side of the washer, as shown in Fig. 5.

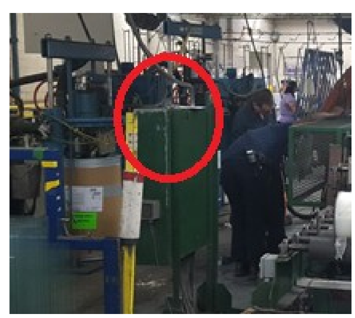

Fig. 5 Electronic box was a possible location for the andon light

While this option would allow the andon light to easily connect to the power supply, it would not be in the worker's line of view and they would have to be responsible for checking the light themselves. The final option was placing the andon light on the side of the washing machine depicted in Fig. 6.

Fig. 6 Washing machine was a possible location for the andon light

Although it would be in a generally more visible location, it was not in the direct line of sight of the operator of the edge delete. The final location of the andon light at the front of the line would not be decided until a meeting with the electrician was scheduled to ensure that these locations were feasible.

Next, the location of the andon light at the end of the line had to be determined. When observing the line, it was pointed out that there was a pre-existing light already at the end of it. In an attempt to save money and resources, it was determined that the light already in place at the end of the line would be utilized as long as it got the electrician's approval.

the ceiling. The suggested location for the light is shown in Fig. 7.

Fig. 7 Finalized location of the andon light on the ceiling

This solution would allow the light to be in the direct line of sight of the edge delete operator without interfering with the work of any of the mechanics. Similarly, the electrician also confirmed the possibility of the reuse of the andon light already placed at the end of the line.

Following the final decision of the lights, an andon light procedure, shown in Fig. 8, was made to help guide workers on how and when to use the light system. The map begins with the initiation of the quality check that will be implemented. When an hourly quality check is called, the out-feed operator must switch the andon lights to yellow in order to signal the rest of the line. The line will then promptly be halted to allow the worker to perform the quality check on a randomly chosen glass pane. The outcome of this survey determines what the next course of action is.

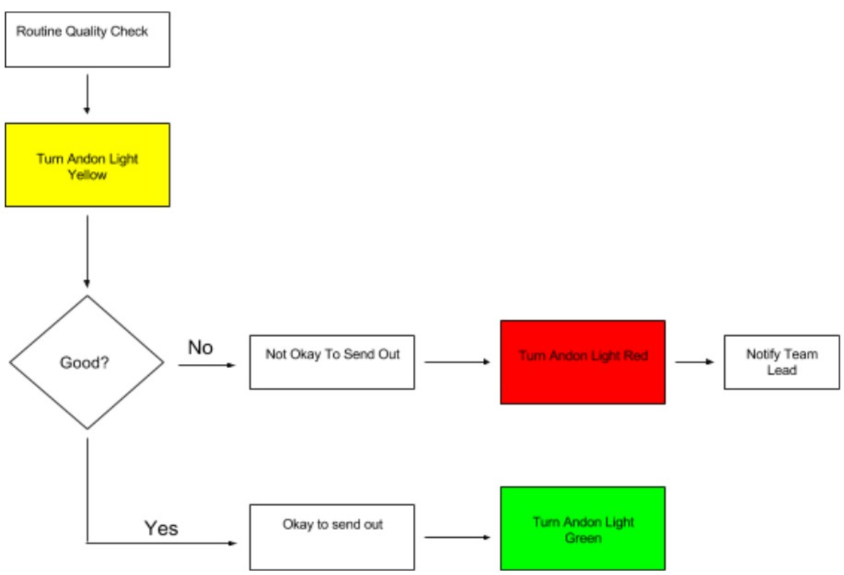

Fig. 8 Andon light procedure to guide employees when and how to use the andon light

In order to finalize locations, it was necessary to consult an electrician. For the light at the front of the line, the electrician proposed a more sound solution: hanging the andon light from

If the window does not pass the quality check, then the operator of the out-feed station must turn the andon lights to red to signal a problem and call the team lead for further guidance. On the other hand, if the window does pass the quality check, meaning it has no deviations, then the lights should be switched to green and the line should be restarted.

D. Adding Sound

Distinct sounds are often used to help signal the occurrence of a certain event to a wide range of people that may not be located in one specific area. One example of this would be a fire alarm. Although one may not be located in the same room as an active fire, they would be alerted of the danger through a piercing sound system in order to ensure their safety. This same principle can be applied in a factory setting. When there is a problem on a factory line, a sound system could go off to alert nearby mechanics or managers of the issue. The immediate response would help save resources and time, two of the wastes of lean manufacturing.

Initially, the common consensus was that there was no need for a sound system as it would be incredibly difficult to hear the noise over the inherently loud factory environment. Although, after surveying the andon light system on the vertical line which included speakers, as depicted in Fig. 9, it was decided, with the help of the operations manager, that it would be beneficial to include sounds to accompany the lights.

Fig. 9 Speaker on the andon light system of the vertical line plays a loud tone to alert mechanics when there is a problem

On the other hand, with the implementation of the sound system, each line would have to adopt its own unique sound pattern so that the alarms do not get confused with problems on other lines or the buzzer for shift changes. After discussing the possibilities with the electrician and the operations manager, the usage of a sound system in joint with the andon lights was finalized.

E. Determining Location for the Switch

When determining the location for the switch, it was imperative that the accessibility of the switch and workload of each possible operator was analyzed. Using the process map again, three locations were chosen for the switch: edge delete, stacking station, and out-feed. Following this decision, the benefits and disadvantages of each location were listed and discussed.

If the switch was placed at edge delete, it would be beneficial because the operator is at the beginning of the line. If they stop it, it would cause less confusion overall because they have the power to stop sending glass down the line. The drawback would be that the workers in the middle and end of the line will have to come to the front if they had issues and needed to stop the line.

If the switch was placed at the stacking station, it would be beneficial because the worker has the power to stop the washing line which comes before, so they would not be overloaded with materials if they decide to stop the line. Although, there is already a lot of work designated to those at the spacer stacking station, so giving them more may overwhelm them.

If the switch was placed at the out-feed, it would be beneficial because that is where the new factory checks are going to be implemented. In addition, there are two operators at this station which grants them more than enough time to turn the switch, stop the line, and continue with any remaining work. This station is largely separated from the front of the line, so if the edge delete operator needed to change the switch, they would have to travel all the way to the other end of the line.

Ultimately, it was decided that the best location for the switch would be at out-feed because of its significance in the upcoming quality check. A meeting with the electrician confirmed the switch's spot at the side of the table which guides the window to the hands of the operator. This way the switch would be easily accessible by the out-feed workers.

Similarly, the design of the switch had to be determined as well. The first design that was considered was a dial which would turn and change the color of the light, as shown in Fig. 10.

Fig. 10 Dial for the andon lights currently installed on the extrusion line

Designs similar to these were already in place at the factory and have proved to be dust and factory-life resistant. Although, after consulting with the electrician, it was proposed that color-coded button similar to the one in Fig. 11 should be used instead.

Fig. 11 Button style that will be implemented on the glass intercept line

Each button would turn on a light and multiple lights could be used simultaneously. Overall, it was decided that buttons would be the best switch for the andon light.

IV. Results and Discussion

A. Final Andon Light

It was decided that the final colors for the andon light would be the standard red, yellow, and green. Red would represent a problem and would require the line be shut down and the team lead be contacted. Yellow signifies the new quality check, and green would signal to continue working. This color combination matches the already installed andon light and, as a result, eases installation. It was decided there would be two andon lights: one would be the existing light at the end of the line and the other would hang from the ceiling in front of the edge delete station. This was all determined after consulting with the electrician, who also confirmed that it would be possible to synchronize the lights. The operations manager also asked for sound to be played when the lights turned red. This is so that the workers would be instantly notified of a problem.

In order to implement this system into the factory a set of andon light systems instructions was created, as depicted in Fig. 12.

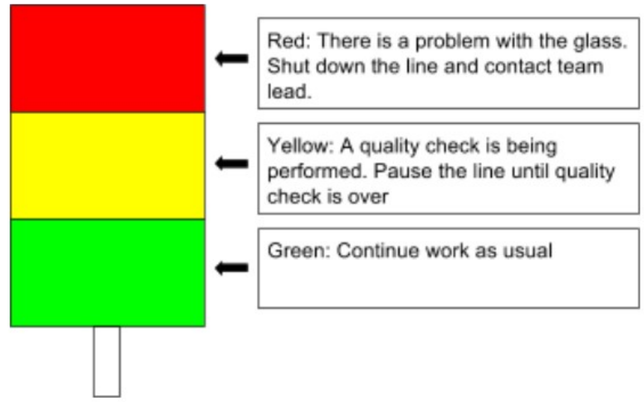

Fig. 12 Andon light system instructions created to guide worker once the quality check is implemented

The set of instructions will provide workers with guidance when it comes to utilizing the new lights. The colors of the map each represent the corresponding light and the instructions to the side detail the cases in which the lights should be used and the immediate action following the diagnosis of the problem.

B. Communication Analysis

Implementing this andon light system will facilitate communication within the factory, especially when it comes to calling the quality checks.

Without the andon light system, operators will have to travel up and down the line by foot in order to alert the others to pause the line. This would severely increase the cycle time, as production time would be wasted. If the andon light was in place, the operator would just have to press the button to turn the light yellow. At this point, both the light in the front and back would switch to yellow, alerting the others of the quality check. This would save a significant amount of time and help maintain a lower cycle time.

Along with that, if there was a problem with the window pane, the operator performing the quality check would need to track down the team lead. If the team leader was not in the immediate vicinity it could take up to 5 minutes to locate them, greatly reducing production time considering a window is produced approximately every 22 seconds. If the andon light was in place, the operator would switch the light to red, causing the alarm to blare throughout the factory. This would quickly signal the team lead and alert them to the trouble on the line, saving the time of the operator who would be required to find them.

On the other hand, the andon light would be able to play a significant role outside of the quality checks as well. If there was an issue with a machine or if someone was injured during production, then one of the operators could flip the switch to red in order to attract attention and help. The sound and light would alert the mechanics and the team lead to any possible issues on the line.

Overall, the implementation of the andon light would significantly improve communication within the factory setting. It was estimated that the light system would provide an approximate 67% improvement on the time required to perform the quality check. This would prevent the wastage of unnecessary time and promote a Lean Manufacturing setting within Silver Line.

C. Cost of Installation

The cost of installation was also important for the project, as a high initial cost would potentially make it not worthwhile to continue with the project. The cost of an andon light is around $250. Although there are two andon lights, one is already installed on the line, so its cost need not be considered. It would take the electrician about 3 hours to install and connect the two andon lights, as well as include sound. An electrician's time is worth about $50 an hour, bringing the total cost of installation to around $400. However, not running the line will also cost Silver Line money. If one pane is made every 20 seconds, not running the line will cost Silver Line the profit of 720 panes. [6][7]

V. Conclusion

It was found that the amount of time spent on the quality check was reduced by 67% after the andon light system was implemented. With such a significant amount of improvement, it would only take about 2 days for the project to turn a profit.

However, this project does have some drawbacks. The lights would have to be on all the time, which would increase the utility bill of the company. This evaluates to about $0.94 a day, which is almost negligible. [8]

It is expected that the goals of this project will be met, resulting in an improvement in communication along the factory line and a reduction in waste from overproduction.

This project can easily branch out into other projects that can help improve the lean manufacturing system within the factory. Even while looking solely at communication, many other problems can be found. The factory is very loud, and the workers are required to wear noise-cancelling earplugs. This makes verbal communication near impossible, even without considering the effects of the language barrier. The success of a visual communication system for quality checks means that other visual communication systems can be implemented.

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