Lean Wastes Caused by Using Hard Copy Paper Forms on Manufacturing Processes

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Abstract *— The waste caused by using paper in manufacturing is a project to identify waste costs and possible solutions. In many publications, the objective is to demonstrate how using an electronic tool instead of printed reports has good effects. On the other hand, the researcher concentrated on locating the lean wastes connected to paper operations in the industrial sector. The project can be used as a proof of concept for companies exploring a digital transformation, by moving from a legacy paper system to electronic paperless systems. The main objective is to identify and quantify all the waste caused by using hard paper copies instead of a proper system. With the results, the project provided options and guidance on using cost savings to implement a manufacturing system.*

Key Terms *— ERP (Enterprise resource planning), Lean Manufacturing, (NC) Non-Conformance, QMS (Quality management system).*

INTRODUCTION

Any company's quality will always be impacted by waste processing. Every organization should be concerned about the cost of poor quality due to internal and external failures. This study aims to identify the wastes and how an appropriately integrated system could prevent them. Businesses should refrain from utilizing this inefficient processing method prospectively.

Manufacturing companies, especially small to medium companies, spend most of the continuous improvement budget on manufacturing processes. Money is the biggest barrier preventing businesses from implementing a better paperless system. But businesses frequently fail to research the true cost of paper.

A Non-Conformance (NC) process was used for this project, precisely a hold release form currently used in paper form. A current state benchmark process was created with several six sigma tools like a value stream map and spaghetti diagram to compare with the system's future state.

While this research was performed for a local medical device manufacturing industry, the contributions of this paper can be used in all types of manufacturing that utilize paper forms for processing. Over time, businesses may lose more money due to production line interruptions, underutilization of staff or equipment, and, most importantly, subpar quality. Customers may become dissatisfied with a product because of rushed approvals, insufficient visibility of paperwork, or product flaws.

LITERATURE REVIEW

Most of the work done about paperless systems focused on implementing strategies because of all the benefits. The positive benefits of a paperless system are unquestionable and well-documented. Many presented all the benefits of reducing cycle times from 30% to 50%. But there are more benefits than the obvious ones [1]. The cost of the waste caused by paper could be greater than companies usually think [2].

The paper “Implementation of Software Tools for Paperless Processes Oriented in Lean Manufacturing Applied Specifically in the Biotechnology Industry” [3], stated the theory of the waste associated with having paper in processes; this paper focuses on the Biotechnology industry, but the waste will be the same for any manufacturing industry. “Paper and paper-related expenses, storage, labor, capital expenses,

employee productivity, and business processes." In this paper, the objective is to identify the positive impact of having an electronic tool to replace printed reports. In contrast, the researcher focuses on identifying the lean wastes associated with paper processes in the manufacturing industry.

Some businesses used a temporary approach after COVID-19, having some papers on paper and the same digital choice. Confusion, double work, and process delays result from this.

METHODOLOGY

According to the research hypothesis, switching from paper to digital documents will improve cycle times, lower waste costs, and decrease the need for motion and transportation.

The hold-release paper form is the most prevalent and important one used in production. This form is a component of the nonconformance record discrepancy disposition process. A few six sigma tools were used to measure the waste in this process. The most important tool was the value stream map.

With the tool value stream map, a current state process was created to identify the most critical steps.

In addition to the VSM, a spaghetti diagram was used for the current process benchmark.

RESULTS & DISCUSSIONS

The VSM and Spaghetti diagram found an exaggerated amount of time needed to collect the signatures for the hard copy form. Sometimes the QA handling the event had to walk different buildings to get a signature; in the worst-case scenario, a call must be made for a person not in the facilities to get to the plant and do the signature. All these distances are time which adds downtime to the hold release process.

With the data collected from the VSM and Spaghetti diagram, the researcher started to identify all the seven wastes from lean. In a normal process without errors or with them, the investigator identified: unnecessary motion, waiting, and transformation wastes and defects, motion, over-processing, waiting, and transportation wastes. For this exercise, the researcher considered waste activities that a system will avoid or drastically reduce.

Finally, to jump into the results, the researcher gathered data from the finance department of a production line downtime cost and an estimate of an ERP system implementation. There was an average downtime cost of $20,000 per hour, but depends on the product, production line, and orders. Also, to start contrasting the actual state with the future state, an SAP system implementation costs $350,000 for a 100-user license.

Here are the current state benchmark times without errors in the process:

Step No.	Step Title	Duration mins
1	Detect the nonconformance event	10
2	Confirm the NC with quality (triage)	20
3	Create Hold (PAPER/SAP)	20
4	Initiate documentation (PAPER)	10
5	Add affected items to NC (segregation) (PAPER)	30
6	Generate a quality notification (SAP)	10
7	Add Reference documents (SAP)	20
8	Disposition tasks (SAP)	30
9	Close Hold (PAPER / SAP)	10
10	Generate corrective action	10
	Total	170

Figure 1
Current State

In Figure 1, the red steps are the most critical due to the presence of hard paper copies. Also, they are the most downtime they can cost by waste caused by paper. The downtimes started to ramp up when:

- An error was made after step 3; if the error is made in step 9, probably the paper will have to be re-done or re-signed from previous steps adding downtime.
- If new requirements or items are added to the NC event, the paper copy will have to be redone or resigned again.
- A combination of errors or discrepancies between the system and paper.

Step No.	Step Title	Duration mins	Error
1	Detect the nonconformance event	10	
2	Confirm the NC with quality (triage)	20	
3	Create Hold (PAPER/SAP)	20	20
4	Initiate documentation (PAPER)	10	10
5	Add affected items to NC (segregation) (PAPER)	30	30
6	Generate a quality notification (SAP)	10	
7	Add Reference documents (SAP)	20	
8	Disposition tasks (SAP)	30	
9	Close Hold (PAPER / SAP)	10	
10	Generate corrective action	10	
	Total	170	
	Total with errors		230

Figure 2
Current State with Errors

The second example in Figure 2 is an error when adding more items to the NC (non-conformance). The error step was step 5, because it's a paper process, it must be modified and likely re-done. This common scenario added 60 minutes to the process, resulting in more downtime on the production line.

Step No.	Step Title	Duration mins	Error
1	Detect the nonconformance event	10	
2	Confirm the NC with quality (triage)	20	
3	Create Hold (PAPER/SAP)	20	20
4	Initiate documentation (PAPER)	10	10
5	Add affected items to NC (segregation) (PAPER)	30	30
6	Generate a quality notification (SAP)	10	10
7	Add Reference documents (SAP)	20	10
8	Disposition tasks (SAP)	30	30
9	Close Hold (PAPER / SAP)	10	
10	Generate corrective action	10	
	Total	170	
	Total with errors		280

Figure 3
Current State with Errors

In Figure 3, the most critical step, number 8, is the disposition of the event, which involves multiple signatures and the review of many documents. If an error occurs in this step will add a minimum of 110 minutes. This is a common issue; the most extreme cases are the disposition completed at 5:00 PM, someone finds an error, and everything needs to be re-done, and there is no quality, manufacturing, or engineer representative in the area. This event can add hours to the downtime.

Figure 5

Step No.	Step Title	Duration mins	Error	Error with System
1	Detect the nonconformance event	10		
2	Confirm the NC with quality (triage)	20		
3	Create Hold (PAPER/SAP)	20	20	5
4	Initiate documentation (PAPER)	10	10	2.5
5	Add affected items to NC (segregation) (PAPER)	30	30	7.5
6	Generate a quality notification (SAP)	10	10	2.5
7	Add Reference documents (SAP)	20	10	2.5
8	Disposition tasks (SAP)	30	30	7.5
9	Close Hold (PAPER / SAP)	10		
10	Generate corrective action	10		
	Total	170		
	Total with errors		280	197.5

Figure 4
Future State, Errors with System

In this example from Figure 4, the researcher was able to improve 34.5% of the downtimes in the process. This will vary from event to event. The waste reduction is evident, mainly by reducing transportation, unnecessary motion, and defects by reworking the paper.

To be able to obtain results on a major scale, a simulation of 30 events was created minute by minute.

	Mean	Min	Max
Paper	286.5	270	300
System	196.4	177	214

Figure 5
Simulation Results

Based on the simulation from Figure 5 of the 30-non-conformance event, a 37.31% improvement in downtimes was achieved. In the next ANOVA we did a simulation to measure the entire process duration with errors on paper and with errors in system.

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Factor	1	121770	121770	1071.94	0.000
Error	58	6589	114		
Total	59	128359			

Figure 6
ANOVA Results from Simulation

In the Figure 6, with a p-value of 0.0, the researcher concluded that there is statistical significance in the overall process with a correct sample size. When dealing with errors in the process with paper, the mean was 286.5 minutes versus 196.40 handling with the system.

According to the medical device manufacturer, an hour of production line downtime costs $22,000. The average cost of the NC disposition event in paper with errors is $102,850 instead of $72,013.33 with a capable system.

The savings per event at this company average $30,836.67.

The SAP implementation that cost $350,000 for a 100 license [4] was selected for this research. Larger companies that need a widespread solution cross companies will be much higher.

For example, the saving cost of this medical device company is an average of $30,836.67 per event. The cost of the implementation of this solution may be around $350,000 [5]. For this company, 11.35 events with a system will save for implementation. Most companies will have more than 11 NC events in a year.

CONCLUSION

The main contribution to this research is that companies need to identify wastes and do a proof of concept before investing in a solution.

Is it worth the cost of the implementation? Yes, but every company must decide based on its financial status. The cost of the waste caused by paper copies is higher than companies usually think. Using a couple of six sigma methodologies like value stream map and spaghetti diagram, the researcher planned to identify and quantify the costs associated with paper. There is more transportation by moving the paper from person to person, building to building, or process to process. A digital system should be accessible from everywhere in real-time within the company networks or remotely, reducing transportation by 100%.

This research found that processing in paper hard copy was causing almost all lean wastes [5]:

- Defects: The effort of reworks, incorrect information, or typos. This may trigger delays like waiting, motion, and extra processing.
- Overproduction: Processes in a paper may not have instructions, and employees can fill more or less than needed causing overproduction.
- Waiting: Usually, manufacturing processes need more than one approval; in some cases, multiple (more than 3). Motion waste is created when two or more people are waiting on the same paper in the possession of another employee.
- Unused talent: In the same way of waiting, other employees are waiting on the paper to be moved along, causing un utilization.
- Transportation: Because the paper is physical, not digital, it must move from employee to employee and sometimes from building to building, causing unnecessary movements.
- Inventory: Because the paper is physical, if it's not stored correctly, it may get lost if miss placed, causing all other waste over again.
- Extra-Processing: This waste is often caused by any other defect in the process. If there is a typo, missed information, or any other error, the is a high chance that the paper needs to be done again.

When comparing the previous state with the new current state of the system, the results are promising. A 37.31% improvement in the downtimes handling non-conformities was achieved only by changing to a system instead of using paper. The research project demonstrated the real cost of the waste from paper.

Every finance department in any manufacturing has a downtime cost per minute or hour [1]. From the example of the methodology, we see that the automotive industry has an average of $22,000 per minute. The company in work on this research project is in the medical device industry with several production lines. A hold in a product rarely will shut down the entire production but likely will stop one line or two. The average downtime cost for this company is $22,000 per hour.

Downtime Cost per hour	Hours
22,000.00	1.00
44,000.00	2.00
66,000.00	3.00
88,000.00	4.00
110,000.00	5.00
132,000.00	6.00
154,000.00	7.00
176,000.00	8.00
198,000.00	9.00
220,000.00	10.00
242,000.00	11.00
264,000.00	12.00

Figure 7
Downtime Costs per Hour

When a process is being worked on paper, many different scenarios can occur. Downtimes can escalate quickly; as shown in Figure 7, a 12-hour downtime can cause more than a quarter of a million-dollar waste.

Utilizing the data from the simulation, the downtime of a hold release with paper had a mean of 280.5 versus 196.40 minutes working with a system.

With a $22,000 per hour cost, we got a $366.66 a minute downtime cost. An average downtime with paper will cost $102,850 versus $72,013.33 with the system.

As a result of a paperless implementation, the manufacturing company got a saving of $30,836.67 per event.

If the manufacturing company has more than 11 NC events a year, the savings can start reflecting in the same year.

Poor transportation by the need to move the paper from person to person, building to building, or process to process. A digital system should be accessible from everywhere within the company networks or remotely, reducing transportation by 100%. The archiving process will be easier, more accurate, accessible, and quick, reducing the inventory completely. As same as transportation motion will be removed by a paperless system. There will be less waiting because the system should be accessible to users without any delay. Correcting errors should be easier and quicker in systems than having to do the paper all over again and get the signatures a second time.

In addition to the conclusion of this research document, reducing downtime will improve the overall quality of the product, prevent further defects, and improve worker labor conditions. Interviewing a QE in the manufacturing plant, a few non-quantifiable problems associated with the downtimes were found. After a hold is released, the production will likely have to ramp up to catch up with the demand. This will have a domino effect on the cost of the production (having to pay overtime), and the sense of urgency might stress up and affect the quality of the production and cause more defects. Also, this may create dissatisfaction among the employees; if the production doesn't meet the demand, it will cause customer dissatisfaction.

The most significant contribution of this research project is that companies can use this as a kickstart for digital transformation. Most of the time, companies are skeptical of investing in expensive software solutions, but they don't know that not having the solution may cost more.

Almost all companies have current systems that can be used to include this project as an add-on. For example, all companies have an ERP system like SAP. This means the implementation can be less expensive, and the current software team has experience with familiar implementations. This might be a frictionless implementation for most companies.

Compliance is one of the most important requirements when deciding what software solution to use. That is one of the reasons companies often use SAP as their ERP system because it provides validation & compliance modules for easier validation.

The archiving process will be easier, more accurate, accessible, and quick, reducing the inventory completely; a paperless system will remove the transportation motion. There will be less waiting because the system should be accessible to users without delay. Correcting errors should be easier and quicker in systems than doing the paper all over again and getting the signatures a second time. In theory, these are all benefits, but money is the only holdback for companies.

Future researchers can study the cost of inventory waste. The researcher studied the production aspect of the process, but manufacturing companies have many government compliances that require a certain type of inventory for the records. For example, depending on the documents, forms must be stored for x number of years in a cage with document control and record tracking. If all the documents over a few years of all NC events are collected, it will reach thousands of records to archive. This will require more real state, a tracking

system, and a special room temperature, and the document should be available for any further audit.

Handling this type of inventory is hard, complex, not secure, and expensive. With a digital system, documents will be available in real-time and easy to access, and the digital record should keep track of all logs too. In the event of an audit, the documents should be easier to find, avoiding audit findings.

In conclusion, systems will achieve less waste cost during manufacturing, fewer downtimes, better quality, and better visibility. This implementation should not be seen as a cost but as an investment.

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