Improvement of Work Inspection Process in a Construction Project using Lean Based Sustainability

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Abstract

Lean-based sustainability targets reduction in different types of waste such as material, time, and labor. Lean thinking and sustainability share similar goals of using processes efficiently using different tools and technology. This paper analyzes lean and sustainability under a system thinking lean using the perspectives concept that improves the current process for Work Inspection Requests in a Construction Project in Qatar. The current process mainly utilizes manual steps and physical paperwork. The suggested improvements were implementing an electronic workflow system, purchasing iPads for inspection, and removing redundant steps. As a result, the suggestions were found to reduce total process time and lead time and significantly reduce the material used. Cost comparison and sustainability indicators also supported the findings, showing that the improved process is better than the current one in the respective criteria.

Keywords
Lean Thinking, Sustainability, Construction, Value Stream Mapping and Inspection

1. Introduction

The twenty-first century has witnessed a prosperous, competitive environment that impacts different sectors, such as technological development and globalization. Therefore, there is a need for significant approaches and concepts to affect the new management positively. Therefore, the lean thinking approach plays a core role in business management and industry sectors by understanding the current process and improving processes by which products and services are created and delivered to customers. In addition, it has the essential concepts in the direction of production activities and processes, which were introduced in Japan during the fourth quarter of the last century. Most organizations across the globe now adopt this principle because it supports the concept of continuous improvement and does not just apply to the products or services; it involves processes and people.

This paper aims to explore the current work inspection request process and show how the implementation of lean concepts and principles is applied in a consultant company, as it is known that the lean approach is not limited to the manufacturing process. In the past 25 years, organizations have increasingly acknowledged that lean methods are applicable in other aspects outside car factories (Graban 2018). Industries see lean in their perspective as a way of improving their quality, safety, and cost and understand that it plays a crucial role in developing and optimizing various aspects.

According to Womack and Jones, there are five key lean principles . First, determine the value by the customer requirements. The second is value stream mapping, eliminating unnecessary activities that do not give value to the final product and ensuring a continuous and easy flow in the production and service process. During this process, it is necessary to ensure that the final product is acceptable to the customer at the right time and that the product or service is perfect. This requires continuous improvements.

In general, processes and services operations contain value-added and non-value-added activities. The first includes something the customer wants to acquire and pay for, anything that satisfies the customer's requirements, and everything that achieves customer satisfaction. While nonvalue-added activities include any activity that does not add value to the process, as well as any error, rework, unfinished work, or overproduction. Moreover, these activities are usually overlapping. To obtain distinct and profitable processes, the lean thinking principle, especially in mapping, separates these activities and eliminates them to reduce the waste from all these non-required processes. These activities and processes can include administration, customer service, or delivery. This paper will discuss other principles in more detail (Graban 2018).

This paper presents that lean thinking and sustainability are real global and transversal approaches to improve consultant company performance by implementing techniques and methods. These will maximize customer value by focusing on achieving a waste-free environment towards improving the current system's efficiency and, thus, will lead to receiving the right things at the right place, in the exact quantity. All of these concepts must be understood and appreciated by the real employees in the consultant company. As mentioned in this paper, value-added and non-value-added steps in every process shall be identified toward the principles successfully applied to the customers to achieve customer satisfaction with high efficiency.

1.1 Objectives
This paper also aims to identify the connection and the contribution between lean thinking and sustainability, specifically in construction consultancy, and how the first one plays a core role in achieving the second, as will be mentioned in this study. Both lean and sustainability share some similarities regarding their principles and values. For example, minimizing the resources, time, energy, and effort. In other words, the contribution will help to achieve productivity in terms of creating the most valued demands for the customer requirement efficiently. Furthermore, they work systematically to minimize and reduce waste, including material, labor, and time.

2. Methods

2.1. Process Mapping
A process map is a key analytical tool in lean manufacturing techniques that visualizes work processes by showing the link between the inputs, outputs, and tasks (Anjard 1996)(Barbrow and Hartline 2015). It emphasizes the main steps involved in producing output, who execute them, and where these key problems may arise. Process mapping aims to minimize human, financial, and physical resources in manufacturing and administrative process. Process mapping relies heavily on flowcharts in which different shapes represent different elements of a workflow in flowcharts (Barbrow and Hartline 2015). For example, diamonds correspond to decision points, upside-down triangles represent storage, and action is represented as a rectangle, as shown in Figure 1. In this study, a process map was created to understand the current practice of the work inspection stages and the parties involved.

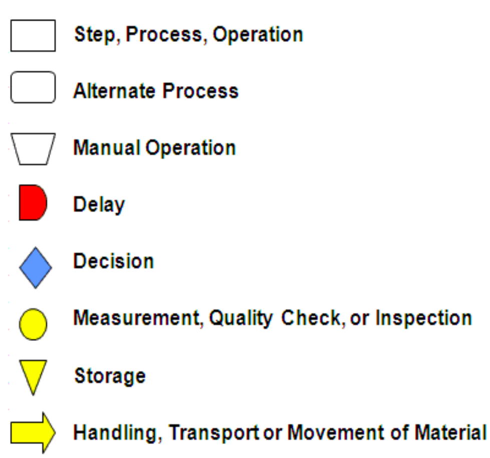

Figure 1 Process Mapping Flowchart Symbols

2.2. Value Stream Mapping

Value stream mapping (VSM) is a technique that allows businesses and organizations to visualize the whole process of delivering a product or service to analyze and optimize it. A value stream map captures all the necessary information, including all the relevant individuals, processes, and inventory, categorizes them, and displays them in a flow chart (Lucidchart). VSM is considered a customer-centered metric in which steps are mapped according to whether they add value or not from a customer perspective. By visualizing all aspects of the process using VSM, lean principles can be applied in specific areas of the organization to reduce waste and see the source or cause of the waste. In addition, continuous improvements are possible with VSM, bringing better processes online over time [9]. In this study, waste was identified, changes were proposed to improve the process by eliminating waste, and an improved VSM was created, representing the current state.

2.3. Identifying Waste & Seven Waste of Lean Management

Getting rid of industrial Muda is one of the greatest challenges facing production experts daily. Anything that is not valuable or does not add value is considered waste or Muda [10]. In a lean management system, industrial waste is mainly found in seven types, including defects, overproduction of items that customers do not need, inventories that are awaiting further processing or consumption, overprocessing, the motion of employees, and transport of unnecessary goods, waiting for material or equipment to deliver or for un idle equipment, unnecessary process, and variation[11]. Figure 2 represents the seven wastes of lean and their explanation [12]. This paper identified the major waste through oral interviews with the consultant, document controller, and discipline engineer on a project site.

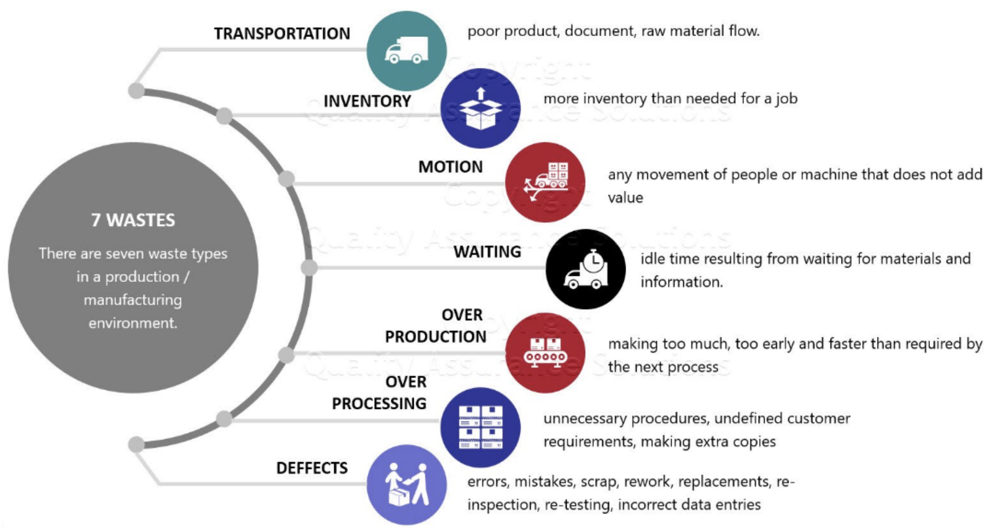

Figure 2. Seven Waste of Lean Management [12]

2.4. Implementation & Measurement of Improvement

The first step is to capture all the necessary information, including all the relevant individuals, processes, and inventory, categorize them and display them in a visualized form. Afterward, identifying parties involved (contractors, consultants, and stakeholders) define the three stages preparation, inspection, and closing. Next, waste of Lean Management and Value Stream Mapping of the Current Process during the inspection stage will be determined. Finally, the improvement process will be measured according to Process Time, Lead Time, and Material Used and compared with the current process to determine the improvement percentage.

The collected data will go through filtering, cleaning, and standardizing. It is important for data analysis for high-dimensional data processing. The suggested workflow software can store data with timestamps and dates that help understand which step in the process is the bottleneck. Further improvements can be suggested using this information to make the process more efficient. Integrated Sustainability Performance presents a three-level: structure, process, and construction. Construction organizations use Building Information Modeling (BIM) to improve their project's quality, optimize efficiency in collaboration, and reduce construction time.

3. Data Collection

3.1. Current Process description

In a construction project, there are many parties involved. The shareholders can be divided into the client, consultant, and contractor. A client is an individual, group, or organization with needs to be fulfilled. Consultants in the construction industry in Qatar are the hands and eyes of the client. They provide advice based on their expertise. In addition, they help supervise and manage the project. Finally, the contractor is the main entity conducting the construction site work.

The process analyzed in this paper involves the consultant and contractor. When Contractor conducts work on-site, it must be inspected & approved by the Consultant based on standards & specifications before the Contractor can continue work. This process is named the Work Inspection Request (WIR) and is shown in the process flow diagram in **Figure 3**. The process is divided into three stages: preparation, inspection, and closing.

The preparation stage initiated by the Contractor when the work is ready on site goes through multiple checks and approval internally before it is transferred to the Consultant's focal point, the Document Controller (DC). The Consultants carry out their checks & approval before the inspection stage starts, where the discipline engineers inspect the site. The discipline engineers do the inspections based on approved drawings, Qatar Construction Standards, international standards, project specifications & quality standards. Then, the discipline engineer either approves or rejects the work done and provides comments. Finally, the closing stage involves the WIR going through internal approvals in the Consultant's team before it is transferred to the Contractor to take any necessary action. The information is archived if the WIR is approved, ending the process. However, if the WIR is rejected, then the Contractor is informed, and the cycle restarts with a new revision.

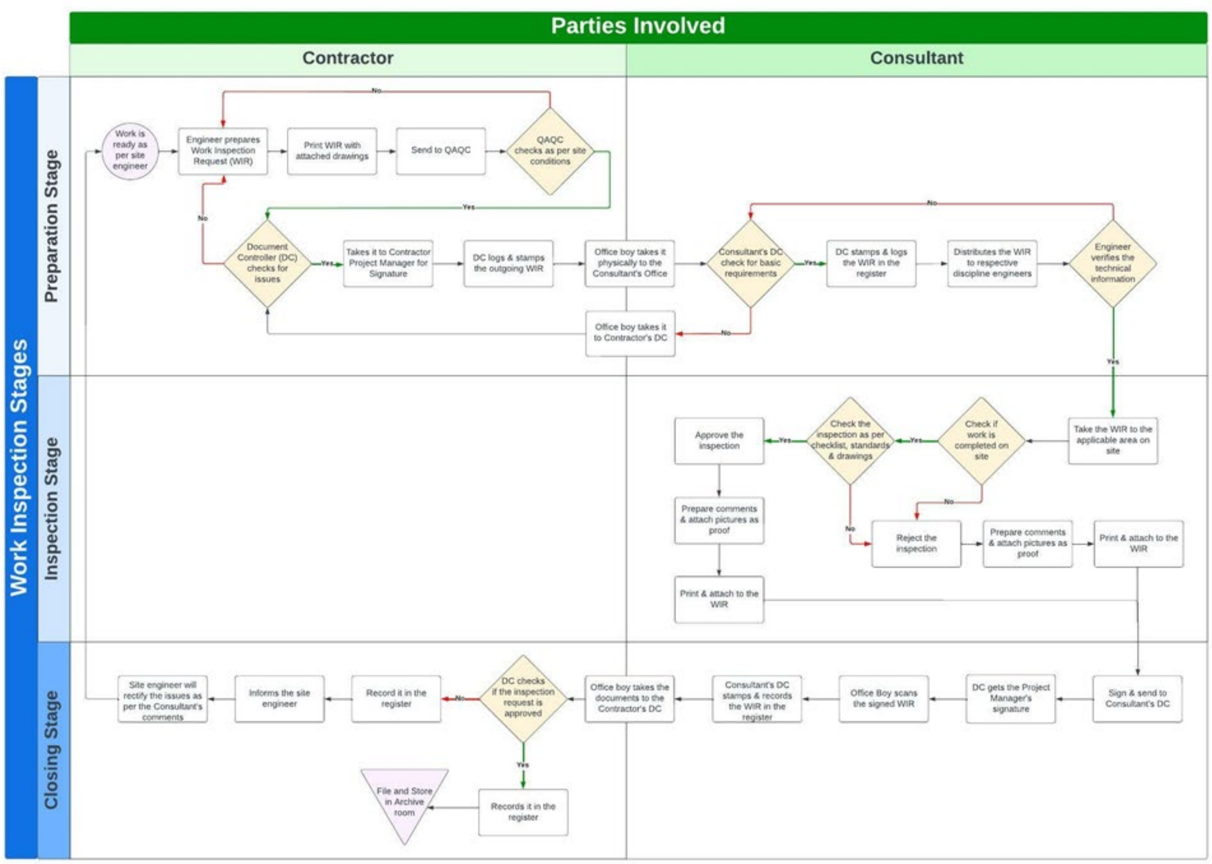

Figure 3. Current Process Flow Diagram

To better understand the issues with the process, interviews were conducted with the Consultant Document Controller and a discipline engineer on a project site. They were asked to describe the process and provide the information required for Value Steam Mapping. This information was incorporated in preparing the Process Flow Diagram and the Value Stream Mapping, as shown in **Figure 4**.

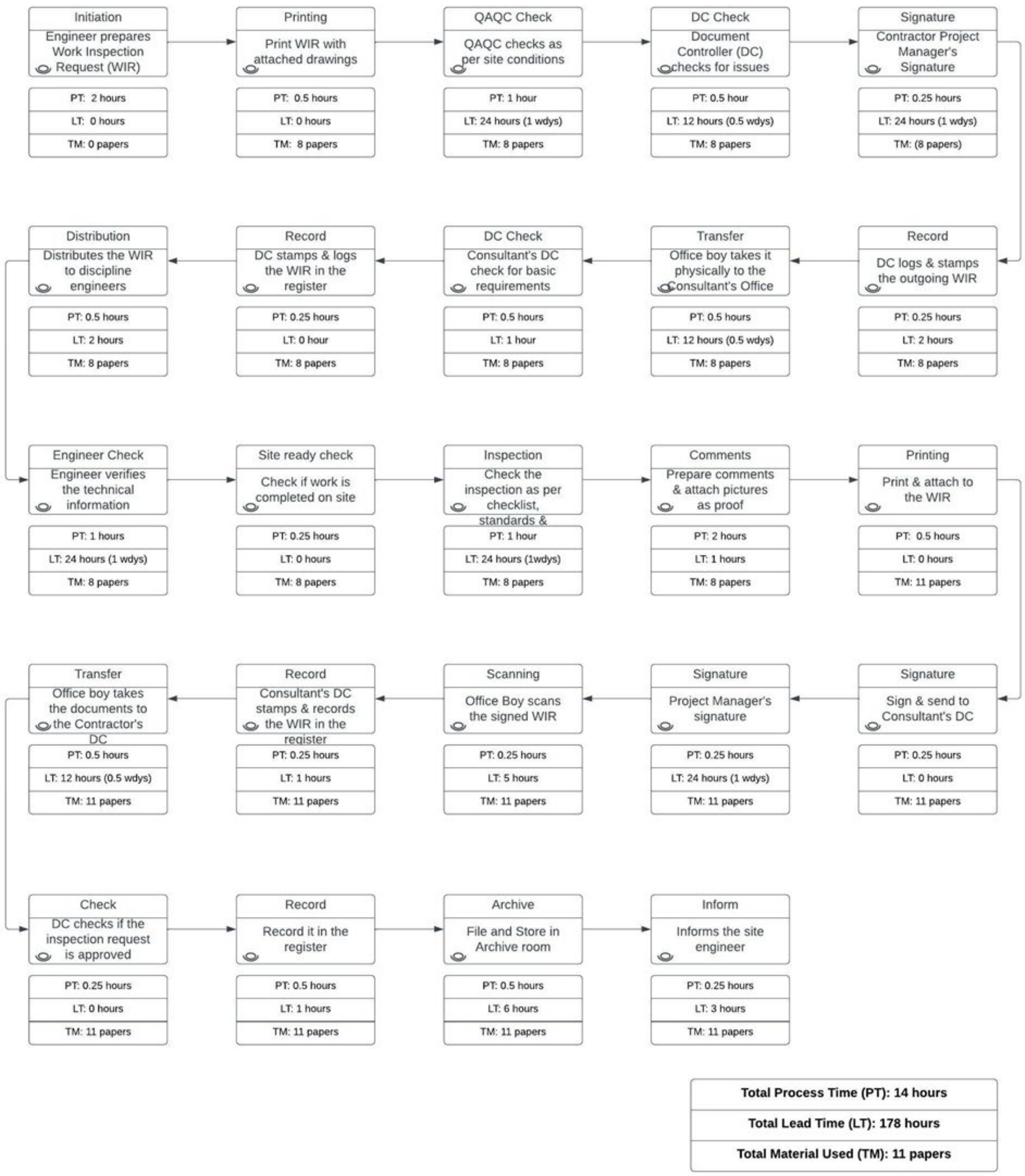

Figure 4. Value Stream Mapping of the Current Process

3.2. Challenges Identified in the process

In the interviews, inquiries about the weaknesses/ issues of the current processes were also made. The feedback received is summarized below.

At times, the paperwork is delayed in getting to the Consultant even though the work is ready on-site. This contributes to the delay in the project as the Contractor cannot continue work unless the current work is approved.

To overcome the first point, some site engineers prepare the paperwork before the work is ready. Unfortunately, this results in another issue where the inspection request reaches the Consultant's discipline engineer, and the work is not ready.
Since the WIRs are physical papers, there are sometimes lost or misplaced, which is another source of delays.
The process gets held up when the printers or scanners from either the Contractor or Consultant's side are not working.
The DCs have to put in data to record in the excel register manually, so sometimes there is an error/ duplication or incorrect information recorded. This is because DCs received 100s of submittals per day.
The discipline engineers must conduct multiple on-site inspections, so they must take pictures on their phones and take notes before returning to the office to write up the comments and transfer the images from their phones to computers. During this process, the pictures can get mixed up, or comments that the engineer recognized on-site might be forgotten by the time they get to the office.

4. Results and Discussion

4.1. Improved Process

The following items can summarize the areas of improvement identified:
Reduction in use of paper by using electronic workflow system & iPads for inspections
Reducing redundancies of multiple checks by different people
Better archiving & record keeping
Reducing the overall process & lead time
Table 1 reports the suggested improvements under each corresponding process and waste type.

Table 1. Process Improvement Suggestions

Process ID	**Process Description**	**Lean Waste Type**	**Improvement suggestions**
1	An engineer prepares Work Inspection Request (WIR)	Avoid Defects	The electronic system will create a unique ID for each request, avoiding duplicates. Also, it will correctly file the request to the relevant disciplines.
2	Print WIR with attached drawings	Unnecessary Process	The implemented electronic workflow system will not require manual copies of WIR. Therefore, printing will be unnecessary.
3	QAQC checks as per site conditions	Extra-processing	Before creating the WIR in stage 1, the engineer already does the checks, so the QAQC check is redundant if the engineer does their job properly.
4	Document Controller (DC) checks for issues	Reduce Lead Time	In stage 1, the number of defects has been reduced. Also, the DC will receive WIR as they get approved rather than in batches, reducing lead time.
5	Contractor Project Manager's Signature	Reduce Lead Time	The Project Manager will receive WIR in the workflow system as they get approved rather than in batches, reducing lead time.
6	DC logs & stamps the outgoing WIR	Unnecessary Process	The electronic workflow system automatically stamps and logs the request as soon as the Project Manager submits it in stage 5.

7	The office boy takes it physically to the Consultant's Office	Transportation & Waiting	Since it is an electronic system, there is no need to transport it physically, and there is no waiting as the system immediately forwards it to the consultant DC after it is released from the contractor's side.
8	Consultant's DC check for basic requirements		
9	DC stamps & logs the WIR in the register	Unnecessary Process	The electronic workflow system automatically stamps and logs the request as soon as the Consultant DC checks in stage 8.
10	Distributes the WIR to discipline engineers	Transportation & Reduce Lead Time	The DC can forward the WIR to the respective engineers without having to leave the office and physically distribute it. Also, instead of receiving in batches, the DC will receive it as WIR is submitted, so there will be a reduction in lead time.
11	The engineer verifies the technical information	Reduce Lead Time	The Engineer will receive WIR in the workflow system as they get approved and not in batches once a day, reducing lead time.
12	Check if work is completed on site	Extra-processing	Since the WIR is raised when the work is ready, this process is redundant.
13	Check the inspection as per the checklist, standards & drawings		
14	Prepare comments & attach pictures as proof	Reduce Process time	Engineers have to come back to the site and write comments. Also, they have to connect their phones and transfer pictures to attach them to the comment sheet. The suggestion to use iPads for inspection will allow instant addition of comments & pictures to the WIR, reducing process time.
15	Print & attach to the WIR	Unnecessary Process	The implemented electronic workflow system will not require manual copies of WIR. Therefore, printing will be unnecessary.
16	Sign & send to Consultant's DC		
17	Project Manager's signature	Reduce Lead Time	The Project Manager will receive WIR in the workflow system as they get approved rather than in batches, reducing lead time.
18	Office Boy scans the signed WIR	Unnecessary Process	The WIR is already in the system, so unnecessary to scan it.

19	A consultant is DC stamps & records the WIR in the register	Unnecessary Process	The electronic workflow system automatically stamps and logs the request as soon as the Project Manager signs in stage 17.
20	Office boy takes the documents to the Contractor's DC	Transportation & Waiting	Since it is an electronic system, there is no need to transport it physically, and there is no waiting as the system immediately forwards it back to the contractor DC after it is released from the Consultant's side.
21	DC checks if the inspection request is approved		
22	Record it in the register	Unnecessary Process	The WIR is already in the system, and the record is being kept at every stage.
23	File and Store in the Archive room	Waiting, Transportation & Reduce Lead Time	The electronic system automatically archives the WIR at this stage, so the DC does not need to go to the archive store and file it.
24	Informs the site engineer	Reduce Lead Time	With the electronic system, DC can forward the information to the site engineer rather than give them a call and tell them about each WIR.

Incorporating the suggested improvements results in a change in the process flow diagram. The updated diagram is reflected in **Figure 5**. In addition, the suggested improvements help remove certain steps from the current process, as reflected in the diagrams.

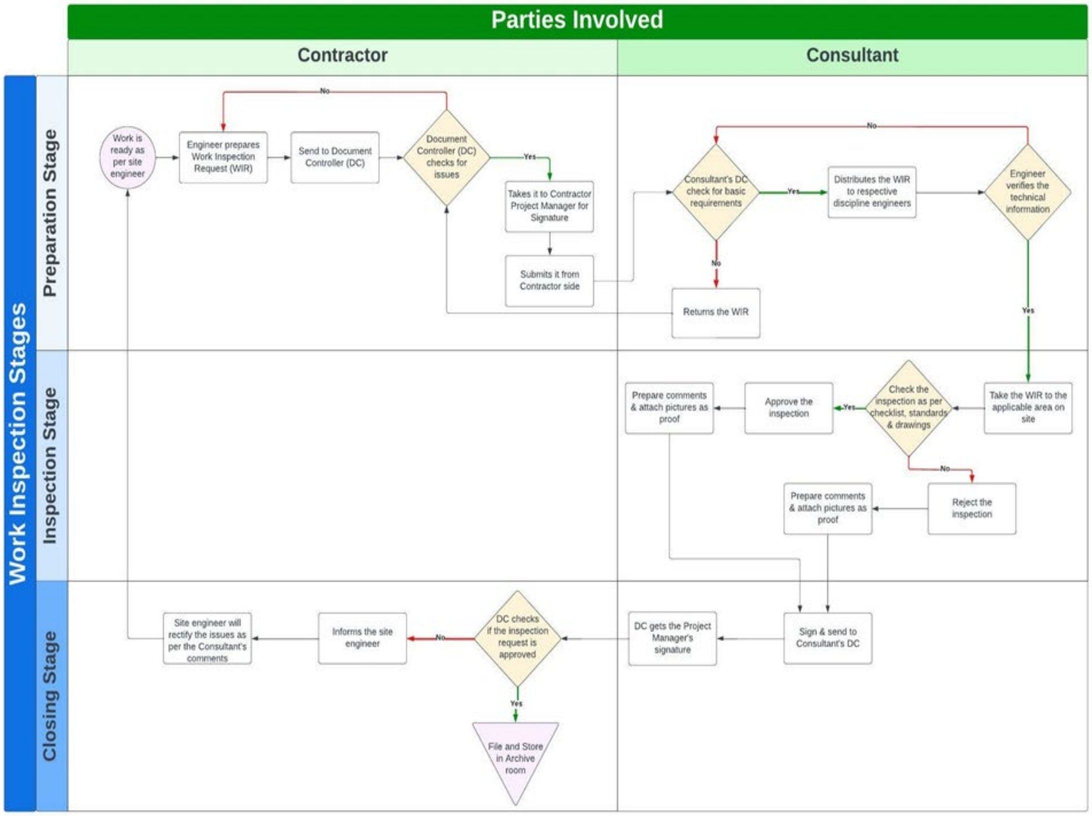

Figure 5. Improved Process Flow Diagram

The value stream mapping was also updated to reflect the improvements shown in **Figure 6**. As a result, the total process time and lead time equated to 8.25 hours and 69.25 hours, respectively. In addition, the total amount of material (papers) used was reduced to 0.

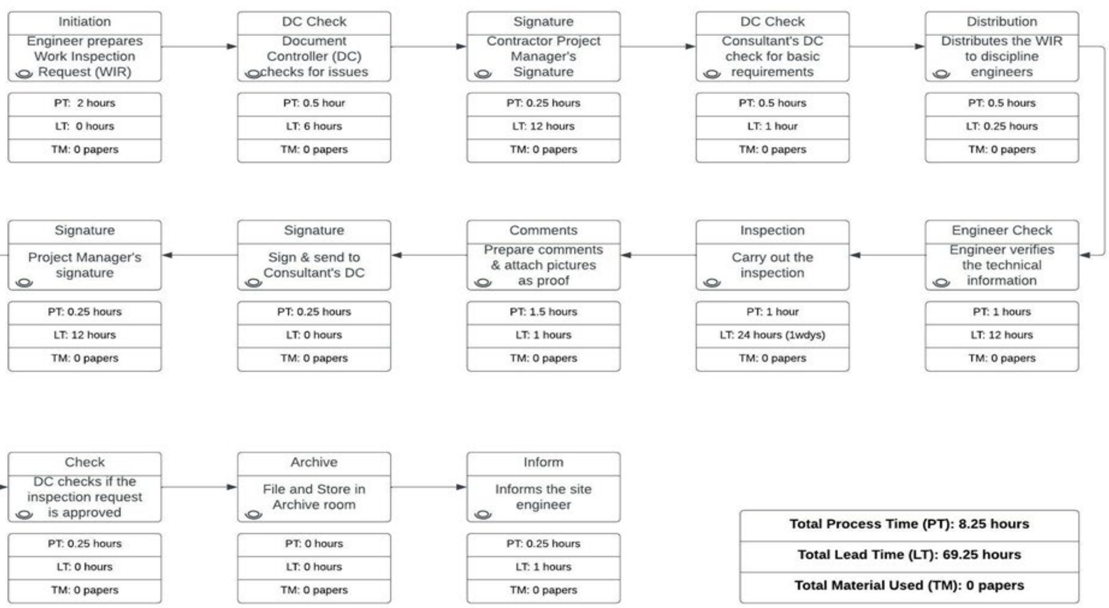

Figure 6. Value Stream Mapping of the Improved Process

4.2. Comparison between Current and Improved Processes

The current and improved processes can be based on the calculated process time, lead time, and total material used. **Table 2** reflects the percentage improvement from the current to the suggested improved process. It can be concluded that there is a reduction in both the process and lead time from the current process to the suggested improved process. In addition, the material used was reduced drastically to 0.

Table 2. Comparison between the current and improved process

	Current	**Improved**	**% Reduced**
Process Time (hours)	14	8.25	41%
Lead time (hours)	178	69.25	61%
Material Used (No. of papers)	11	0	100%

4.3. Current vs. Improved Process from Sustainability Perspective

Sustainability encourages enterprises to adopt technology to help them be paperless software companies to save the environment. As Paper is the largest part of office waste, scientists discovered that it takes 24 trees to create just one ton of virgin paper used in offices. In this study, the electronic device was a replacement process to reduce paper waste and ensure the innovation stays environmentally friendly. Furthermore, the digital solution will reduce the usage of the printer to save time and energy by having a soft copy that allows employees to add notes or signatures to all documents and to be stored in files or the cloud to be referred to any time; thus, all files easily can be shared in a short time.

Finally, adopting online file storage programs will reduce paper consumption in workplaces and reduce the impact of climate change because papers create pollution in the form of carbon emissions. **Table 3** evaluates the sustainability performance of the company after improving the process. The main indicators considered were environmental, economic, and social. The weight for the indicators was assigned based on expert opinions and research [15][16]. The explanation for the scores for each indicator is detailed in the table. The results show that the new process design is more sustainable when compared with the current design.

Table 3. Sustainability Index

Sustainability Indicators		**Weight p-**	**Current Process**		**Improved Process**	
			Score*	**Weighted Score**	**Score***	**Weighted Score**
Environment	Carbon Footprint	0.15	3	0.45	7	1.05
	Waste Management	0.15	4	0.6	6	0.9
Economic	Cost	0.20	3	0.6	7	1.4
	Inventory/ Storage Cost	0.15	2	0.3	8	1.2
Social	Safety	0.15	2	0.3	9	1.35
	The motivation of the Staff	0.20	2	0.4	8	1.6
Total Weighted Sum			2.65		**7.50**	

* Score ranges from 1 – 10, with 10 being the best.

4.3.1. Environment Indicators

Carbon Footprint

In terms of carbon footprints, they indicate the amount of carbon dioxide (CO_2) emitted by burning fossil fuels. They are expressed as a weighted amount of tonnes of CO_2. On a global scale, paper emits 2500 Mtonnes of CO_2 annually, 8% of global emissions, while IT emits 860 Mtonnes, 2.7% of global emissions [13]. Thus, the carbon footprint indicator was assigned based on the percentage of CO_2 emissions, which is (3:7) with a higher ranking for the lower percentage.

Waste Management

Waste management based on sustainable principles maximizes materials' usefulness while minimizing landfill and incinerator usage. In other words, it conserves resources. However, in business, approximately half of the waste is made up of paper, making disposal of waste a major threat to the environment. Furthermore, as this paper is dumped in landfills, it decomposes, and toxic methane is released, along with ink leaching into soil and water sources, further damaging the environment. Whereas, considering that an average person changes their electronic devices every four years [14], waste disposal for electronic devices is considered low compared to paper waste. Thus, the waste management score was assigned as per the approximate ratio (4:6) of the disposed waste, with a higher ranking for lower disposal.

4.3.2. Economic Indicators

Cost

The reduced material used is 100 % due to switching from manual papers to an electronic workflow system with iPads for inspection. Implementing the improvements would involve the cost of the workflow system and buying the required number of iPads. However, recurring costs would be reduced, such as buying paper & printer ink and the printer. Looking at the cost for a year, assuming a new project is starting, **Table 4** shows the estimated costs for the two processes. For the calculations, it was assumed that there are 260 working days in a year. The score for the Cost indicator was assigned based on the ratio of the calculated costs (3:7) with a higher ranking for the cheaper price.

Table 4. Cost Comparison

Manual Process	**Price**	**Electronic Process**	**Price ($)**
Papers	• $ 40 / 500 papers • Estimated usage per day: 800 papers • Working days in 2022: 260 days • The total paper used: 208000 papers • Cost for a year: $ 16,640	Software cost	• $ 640/ month for a team of 40 • Total: $ 7,680
Printer with Scanner	$ 9,400	iPad cost	• $ 600 / iPad with cellular • Assume eight iPads, 2 per discipline team • Total iPad cost: $4,800
Printer's ink	• Ink Capacity: 23,000 papers • Ink Usage Frequency: 9 / year • Cost of ink set: $ 500 • Total replacement cost: $ 4,500		
Total Cost	**$ 30,540**	**Total Cost**	**$12,480**

Inventory/ Storage Cost

The inventory or storage for the current process includes the archive room where all the processed WIR are stored and the equipment room where the printer & scanners are located. The cost includes area cost & utilities, which are mainly the electricity used. In the improved process, the storage includes the iPad storage areas and electricity costs for charging the iPads. The cost for the storage is shown in **Table 5**. The scores were assigned as per the approximate ratio (2:8) of the total calculated cost, with a higher ranking for the cheaper process.

Table 5. Inventory or Storage Cost for the Current or Improved Process

	Current Process	Improved Process
Area Cost Assuming QAR 100/ sqm	- Area: 16 sqm - Area Cost: 1600 QAR per month - 19,200 QAR per year	- Area: 3 sqm - Area Cost: 300 QAR per month - 3,600 QAR per year
Electricity Cost Assuming QAR 0.13/ kWh	- Assuming the printer is used 50% (4 hours) of the 8-hour working day and is on standby the other 50 % of the time. Power usage on average for a printer is 40 W. This equates to 210.86 kWh per year. There is only one printer with an inbuilt scanner. - Electricity cost: 210.86 x 0.13 = 27.41 QAR per year	- Assuming an iPad is charged daily, it will use around 12 kWh per year. In total, there will be eight iPads. - Electricity cost: 12 x 8 x 0.13 = 12.48 QAR per year
Total Cost	**QAR 19,227.41**	**QAR 3,612.48**

4.3.3. Social Indicators
Safety
Replacing paper with an iPad is one of the safest methods in offices, especially when fires break out, as paper helps speed up the ignition. However, the fire risk would be high, especially in the archive storage room where many paper is filed. This is why it is important to know the paper's risks. The priority in workplace environments is to implement the requirement of safety and security, and thus will be fulfilled when the improved process is achieved. The scores were assigned as per the approximate ratio (2:9) of the total calculated safety with a higher ranking for a safer process.

Motivation
Nowadays, modern technology such as the iPad is immensely used by employees as it has been proven to enhance their work performance. This is due to several factors, such as organization, editability, and customization. iPad has various writing apps that include different fonts and unique features which can easily be customized to fit their needs. Unlike iPad, writing on paper can be frustrating as erasing and changing things can be difficult, messy, and more time-consuming, especially if written in pen. Therefore, iPad note-taking is more effective as employees have all their documents organized in one place, making them more motivated to work properly.
Furthermore, the improved process removes redundant steps, decreasing the staff's workload. The scores were assigned as per the approximate ratio (2:8) of the total calculated for the motivation of the staff with a higher ranking of the improved process that makes the employee more motivated and has positive impacts on the social indicator.

6. Conclusion
This paper presented a lean-based methodology for enhancing the work-inspection request process performance in a construction project. The process includes 24 steps and has been reduced to 13 steps by introducing an electronic workflow system, iPad for inspections, and removing redundancies. As a result, process time was reduced by 41 %, lead time by 61 %, and the material used by 100 %. A cost comparison of the two processes showed that the electronic system (improved process) is cheaper than the manual system (current process), considering annual costs. Furthermore, the lean-based methodology was linked to sustainability indicators grouped into environmental, economic & social. The improved process was found to be more sustainable.

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Biography

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