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The Impact of IoT on The Storing Process of Leather Raw Material

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Abstract

A critical step in processing leather raw material is the storing that keeps them in good condition and not easily damaged through the right temperature and humidity level, as otherwise the quality of leather raw material would not be consistent and its economic value would be low. This particular study, therefore, is to conduct an experiment that uses the Internet of Things (IoT) which allows proactive monitoring in keeping a specific temperature and humidity level in their storing process. Hence the subsequent leather processing can be done at the optimal level. The experimentation showed positive results as the use of IoT made storing process of leather raw materials became more proactive and run three times more effective, from just 8 hours to 24 hours, and also brought about a positive effect on the economic efficiency and effectiveness as it enable users to produce more consistent quality of leather raw material whilst the total operating costs remained and even lower. Besides its economic impact, IoT has increased the workers' and their relatives' welfare and social life driven by better income and less time consuming. It also brings about some positive environmental effects as it reduced carbon emissions by keeping energy waste at a lower level.

Keywords: internet of things (IoT); proactive monitoring; consistent quality; efficiency; effectiveness

1. Introduction

Indonesia is one of the emerging markets that has placed leather-based industry as one of their national earning streams, significantly contributing to the developing economy. Whilst the industry is among the ten largest export-earning industries within the so-called non-oil and gas commodities, one of the main challenges confronting the national leather manufacturing industry is a lack of a domestic supply of leather raw materials. The main reason is due to an undeveloped supporting industry that failed to supply good quality leather raw materials.

The failures of providing good quality leather raw materials are primarily due to poor storing processes that cannot consistently provide a specific temperature and humidity over time. This situation affects the condition of such leather raw materials, not only just reducing the quality but could also damage them. To a certain extent, the lack of good quality leather raw materials has also impacted the economy as it stimulates more imported leather raw materials, which ultimately contribute to the trade deficit of these particular items. Further, as the imported leather raw material is much more expensive, the COGS (Cost of Good Sold) of the leather-based end-product such as shoes and bags become more expensive, hence less competitive in the marketplace.

Since the local leather raw materials are provided mainly by independent farmers and small-scale industries that lack capital intensive and technology, a simple and low-cost solution is needed to help them practice a better and more effective storing process. In the digital era, such a solution must consider the phenomena and the availability of easily accessible, adaptable, workable, and economically affordable technology. Using those drivers, this study is made to direct experimentation over the Internet of Things (IoT) in optimizing the storing process of leather raw materials.

Even though its widely known, the Internet of Things (IoT) is not as widely used as it could be. These phenomena are observable, especially in emerging or developing countries whose economy is agriculture driven by small-scale industries and farmers. As a result, some debates occurred about its possible causes, but mostly due to the technology illiterate and lack of capital.

The result of this study could be used as a cornerstone to help an independent leather farmer improve their storing process of leather raw material, hence

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increasing the quality of products to the leather manufacturers who use them to produce shoes, bags, and any other leather-based products for both national market and export orientation. It would also help the country to decrease the imported leather raw material as the quality of local or national ones is increasing, whilst the social and economic welfare of local independent farmers is also rising around the country.

The use of technology is proven to be able to help humans in carrying out their work and daily life. Technology makes human work and life more effective, efficient, and easy[1], [2]. One of the technologies that currently provide enormous benefits to human life is the internet[3], [4]. With the internet, people can work without distance and time restrictions[5] – [7]. In other words, with the internet, various jobs that previously could only be done at a particular place and time can now be done anywhere and anytime.

Moreover, in this era of the industrial revolution 4.0, the internet has a crucial role. Utilization of the internet, known as the internet of things (IoT), is a technology development that is very much needed in the industrial world because it is proven to be able to improve performance, effectiveness, and efficiency[8], [9]. IoT is a network-connected sensor for computing systems. With IoT, remotely connected objects and devices can be monitored or acted on[10], [11]. This system is always connected to the internet and can work automatically for data collection to take action without having to go through human intermediaries[12]. Therefore, IoT can change the role of human workers so that companies can empower human workers more efficiently[13]. In terms of development, IoT has also been proven to be able to be developed at a low cost[14]–[16]. Furthermore, with this efficiency, companies can reduce their expenses[17].

Whilst there are quite some studies about how IoT add economic value, some other studies look into their impact on social and environmental value. The research of Shenkoya and Cho[18] shows that the IoT has positively impacted the daily lives of Japanese people. Still, the changes it has brought are mostly gradual rather than radical. In addition, rather than reducing job opportunities, IoT has created more chances and simplified the operation process. As such, IoT's very fast development opens opportunities for the use of IoT in everyday life, beyond the boundaries of smart cities and smart homes. Based on the critical factor of enabling technology, smart things in smart cities are becoming smarter to perform their tasks independently. These things communicate between themselves and humans with efficient utilization of bandwidth, energy efficiency, mitigation of harmful emissions, and reduction of e-waste to make cities green and sustainable[19].

As a result, IoT technology also has a great potential to support and enable sustainable development. As such, IoT to monitor urban environmental parameters aims to improve people's living conditions. In automating the process of measuring, transmitting, storing, and processing data about environmental conditions in urban conditions, IoT technology can be used in: monitoring environmental pollutants such as vehicles and industrial enterprises; climate change; disaster and accident warnings; assistance to persons with disabilities; detection of aging and defects in machinery and equipment; advertising and media; product and service evaluation; public safety in the city[20].

Based on the papers above, we could say that the Internet of Things (IoT) has been empirically proven capable of being implemented in various fields. For example, [21] research examined the use of IoT-based tools to monitor irrigation water, plant growth, and animal and plant life. Another example is the study by Muangprathub[22], which developed a smart farm in Thailand through the application of IoT that can monitor temperature, humidity, and soil moisture to improve the quality of plant growth and production results. IoT is also widely used for energy saving. Zhao[23] developed IoT to design environmentally friendly low-energy buildings in dense urban environments. Similar research was also conducted by Matsui[24], who developed IoT to develop sensors that help efficiently use electrical energy, water, and gas at home.

Several similar studies have also found that IoT has proven effective for monitoring room temperature and humidity to help save electrical energy use. For example, research was conducted by Matsui[25] about the use of IoT in monitoring temperature and humidity to save electrical energy and increase comfort in residential areas. Similar studies were also conducted; by Jung[26], who developed sensors that monitor temperature, humidity, and brightness to help automatically utilize 13 home appliances so that they are more efficient; and Park[27], who developed IoT to monitor temperatures in a shallow geothermal system for heating and cooling year-round in Korea.

The role of IoT in sustainability research, therefore, is broad, with scientific research across a wide variety of industries such as agriculture, water management, and recycling, and has the potential to play an important role in community management and stability through the development of smart cities. IoT technology is undergoing continuous and real change and has begun to identify consumer awareness and openness in accommodating these devices in their daily lives. Future studies are also beginning to focus on the

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relationship between IoT and other environmental components, such as marine protection, water stress, water scarcity, or waste management[28].

Previous studies have shown that IoT is capable of carrying out its responsibilities, but mostly related to the use in large organization and big business scale, hence hardly related to the improvement of the economic value of village community which give direct impact and benefits to small scale economies. Hence, this research would become one of the references that can be used for such purpose and provides community a new way of optimizing their storing process of leather raw materials that will increase and secure the consistency of their leather material's quality which elevate its customers' confidence, and ultimately creates higher economic and social value for the community.

2 Research Methods

This study used experimental research or experimentation that was conducted through four main stages, namely: Selection of the experimentation object, i.e., the storage of leather raw material. Observation and recording of the temperature and humidity of the storing process. Observation and recording of the work stages of the temperature and humidity controller of the leather raw material storage room. Extended observation and interview with some stakeholders about the social and environmental impact, its immediate and potential future impact.

To ensure the experimentation work well, this study uses some basic tools and materials such as Microcontroller Node MCU ESP8266, DHT11 Temperature, and humidity sensor, jumper cable, and 5v power cable, Arduino IDE, Notepad++, Microsoft visual studio 2015, Xampp, and MQTT Broker.

The microcontroller is connected to the temperature and humidity sensors, which will sense and capture the temperature and humidity level of the leather raw material storage room. As such, the microcontroller will send the collected data via the Message Queuing Telemetry Transport (MQTT) protocol to the application running on the server that functions to receive data and then store them in the database as history. Afterward, the MQTT will send data to web monitoring for real-time notifications stored in the leather warehouse supervisor room. If the temperature and humidity level exceed the threshold, the dashboard will flash, indicating that some actions need to be taken for necessary adjustment.

The design of the connection of the microcontroller to the sensor and the topology of the IoT-based temperature and humidity monitoring system is illustrated in figure 1 and 2, respectively.

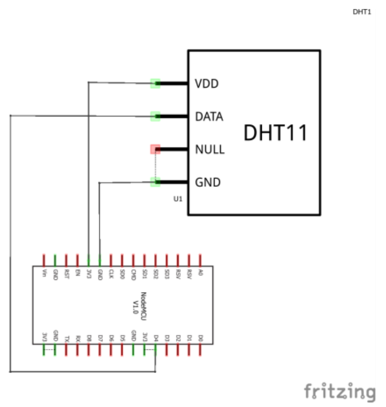

Figure 1. The design of the connection of the microcontroller

Figure 1 shows the core elements of a microcontroller. The core elements of a microcontroller are the processor, Memory, I/O peripherals. The processor is the brain of the device which processes and responds to various instructions that direct the microcontroller's function. Memory is used to store the data that the processor receives and to respond to instructions it's been programmed to carry out. It has two main types of memory namely program memory and data memory. I/O peripherals is The input and output devices are the interface for the processor to the outside world.

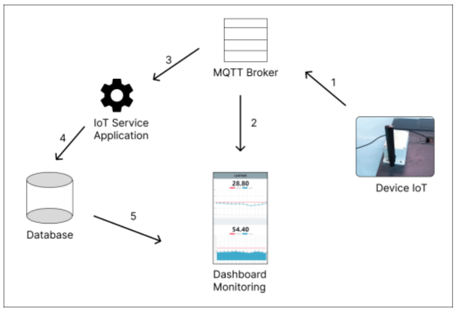

Figure 2. Database Mirroring Architecture

Figure 2 shows the IoT device is connected to MQTT through the internet network so that it is possible to transmit data remotely. The MQTT sends data and notifications in real-time to the monitoring dashboard, which has been subscribed to MQTT. The MQTT sends the data to the IoT service application, which functions to store data in the database. The IoT Service application saves the history data to the database. The database holds a history of the data and then displays them as information on the dashboard.

How the experiment has been done: Installing the IoT device, and then comparing it with the existing devices; Comparing the use of IoT-based versus the non-IoT based (manual) in checking the temperature. The use of IoT showed much higher consistency and reliability; Comparing the effectiveness and the efficiency of the use of IoT-based versus non-IOT based (manual) in supervising the temperature and humidity to be kept within acceptable level. The use of

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IoT showed better performance, from 8 hours a day and 6 days a week, to to 24 hours a day and 7 day a week.

3. Results and Discussions

As mentioned before, the experimentation consists of three stages, and likewise, the results and findings of the experimentation are also presented in three parts:

3.1 Selection of the experimentation object.

A particular leather raw material stored in a district village, Subang - West Java, Indonesia, was chosen as it represents the required characteristics. As such, it was built as a storage for leather raw materials collected from independent small-scale farmers from the community around for local materials and imported leather raw materials for those that local leather raw materials cannot provide.

Technically is acceptable for experimentation as the storage has been used for two years with a capacity to store the leather raw material for around 40 sheets of leather raw materials, which flows in and out regularly.

3.2 Observation and recording of the temperature and humidity of the storing process.

A temperature and humidity gauge in the form of an IoT-based microcontroller is installed. The measurement results of the IoT-based microcontroller and the manual devices are observed and recorded every hour for 24 hours (1/24 per day) and then compared to each other to ensure that the measurement results are valid. For this purpose, there are three devices used during the experimentation, namely the monitoring dashboard, the IoT-based sensor device, and The Manual sensors device. They are respectively illustrated in figure 3, figure 4, and figure 5.

Figure 3 shows the design of the monitoring dashboard. The monitoring dashboard will flash red in the background of the number if the actual temperature or humidity exceeds the pre-determined threshold. The example illustrated in figure 3 shows the color background of the temperature is white, which means that the temperature is still within the range of the expected level. In contrast, the color background of humidity is red, which means that humidity is already out of the threshold, signaling the need for adjustment.

Figure 4 shows IoT device. The IoT-based sensor device above is connected to the temperature and humidity sensing points and the internet network. The example illustrated in figure 4 shows how the sensing points connected through the internet network be installed and work and streamed to the IoT-based sensor device.

Figure 3. The monitoring Dashboard.

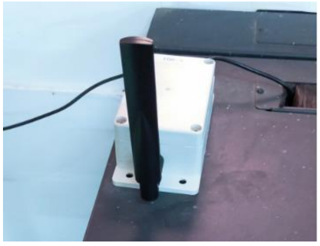

Figure 4. The IoT-based sensor device

Figure 5. The Manual Sensors Device.

Figure 5 shows the manual sensors device. The manual sensors device is used for comparison purposes whilst assuring the reliability of the IoT-based sensors device in capturing the information about the temperature and humidity level of the storage room.

Using the devices, comparative experimentations are conducted between the manual-based workflow versus the IoT-based workflow and how the differences occur from the perspective of effectiveness and efficiency of the underlying business process, i.e., storing the leather raw material. For this purpose, figure 6 and figure 7 are displayed to show their differences.

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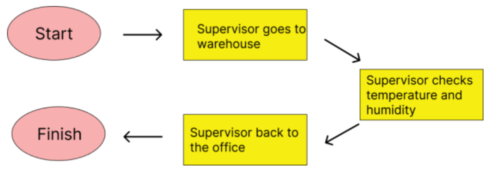

Figure 6. The Manual-based workflow

Figure 6 shows the manual-based workflow. The workflow is time-consuming because the supervisor must go to the storage room every hour. It is required as the supervisor must ensure that the temperature and humidity of the storage room are not outside the threshold.

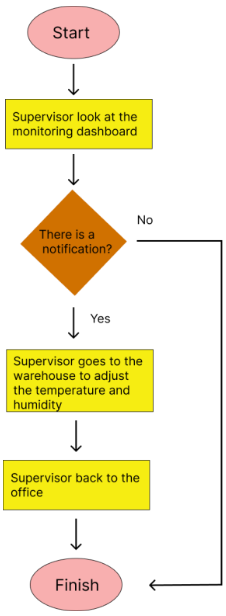

Figure 7. The IoT-based workflow

Figure 7 shows IoT-based workflow. This shows that the use of IoT can facilitate the work of the leather raw material storage room supervisor. With IoT, supervisors do not need to go to the storage room once an hour to check the temperature and humidity. He simply saw the temperature and humidity data from the dashboard. Supervisors only need to go to the storage room when a notification indicates that temperature or humidity adjustments are required.

3.3 Observation and recording of the work stages of the temperature and humidity controller of the leather raw material storage room.

Researchers conducted full observation and recording of all work stages that the storage room supervisor carried out. The indicators and parameter that were used are the temperature and humidity level provided by the IoT device. The experiment was conducted for six weeks of observation with the data provided seven days per week and 24 hours per day continuously, which brought the result as follows:

The results of using IoT on every hour interval each day are shown in Table 1, whereas the manual monitoring is shown in table 2 as comparison. Whilst the experiment was conducted in 6 weeks which gave similar result of every and each respective day of observation (appendix ….?), table 1 was provided as example of one day observation that showed that the empirical data could be and were fulfilled after working hours through the IoT-based monitoring rather than left blank through the manual based monitoring.

Table 1. IoT-based monitoring result.

Date	Location	Type	0	1	2	3	4	5	6	7	8	9	10	11
2022-01-05	Leather	Temp	28.9	28.3	28.2	28	27.9	27.9	27.9	28	27.9	27.2	27.7	28.3
	Room	Humi	**74**	**72**	**72.6**	**72.8**	**73.1**	**74.3**	**74**	**74.4**	**71.9**	63.5	62.4	56.4
Date	Location	Type	12	13	14	15	16	17	18	19	20	21	22	23
2022-01-05	Leather	Temp	28.6	29.2	29.1	29.1	29.9	**30.4**	**30.4**	30	29.8	29.5	29.3	29.1
	Room	Humi	52.5	51.1	52.5	54.9	54.2	56	60.6	62.1	65.5	69.1	**72**	**72.6**

As such, Table 1 shows the IoT-based monitoring result. The red and yellow cells indicate that the temperature or humidity exceeds a predetermined threshold. The red color also indicates the highest number in 24 hours in the day that crossed the threshold. While the yellow color only shows number that exceed the threshold.

Table 2. Manual Check Temperature and Humidity

Time	Temperature	Humidity
00:00	-	-
01:00	-	-
02:00	-	-
03:00	-	-
04:00	-	-
05:00	-	-
06:00	-	-
07:00	28	74.5
08:00	27.9	71.9
09:00	27.5	63.5
10:00	27.7	62.4
11:00	28.3	56.5
12:00	28.3	52.5
13:00	29.1	51.1
14:00	29.5	52.4
15:00	29.1	54.9
16:00	29.7	54.2
17:00	-	-
18:00	-	-
19:00	-	-
20:00	-	-
21:00	-	-

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Time	Temperature	Humidity
22:00	-	-
23:00	-	-

Table 2 shows manual check temperature and humidity. The temperature and humidity column with a dash means that the supervisor does not check because the working hours are from 07:00 to 16:00, or only eight working hours.

Based on the data from the monitor using IoT-based monitoring tools and manual tools, it can be seen that the results of recording temperature and humidity from IoT-based monitors are more complete than the results of manual monitoring. This is one of the advantages of IoT, which can automatically record data and report it remotely and fully operational for a day[29],[30]. While the results of temperature and humidity monitoring that are carried out manually rely on human power to record, it is only carried out for eight hours of work. Hence, the data obtained only includes data collected during those eight hours. Recording temperature and humidity using an IoT-based monitoring tool also produce data with red and yellow marks to help supervisors determine the hours that are prone to increase in temperature or humidity. By knowing these vulnerable hours, supervisors can take action more quickly. In other words, supervisors can carry out their duties more effectively and efficiently. In other words, IoT helps manage big data so that users can make the right decisions based on the collected data[31]–[33].

3.4 Transmit data with IoT.

Data were obtained and captured by a sensor that was read through the microcontroller, and then the microcontroller sends (publishes) data with certain topics to the MQTT broker via the internet network. Any changes captured by the sensor will be sent in real-time, and every device or system that subscribes to the broker with the same topic will receive the data through the microcontroller. In this study, an application has been installed on a server that stores data from MQTT to the database. It is the concept of IoT so hardware devices can be connected in real-time with software devices through the internet network.

3.5 Obstacles or challenges during study.

Two obstacles or challenges have been experienced during this study. The first one was the difficulty of finding the right sensor devices in the country. Therefore it had to be imported from abroad, which required a recalibration process with the paired thermometer before its use. This obstacle has been tackled accordingly, and no impact as recalibration efforts have been well conducted. Another obstacle was the unstable internet connection which caused some data transmission failures. This particular obstacle has also been well addressed by providing a backup connection, which minimized the impact when the main internet connection was unstable in some instances.

3.6 Observation and interview about the social and environmental impact.

Extended observation is conducted to investigate how adopting IoT-based monitoring affects social life and environmental aspects. It is found that, on top of the economic impact that increases productivity by 300 percent due to the longer capacity to run the storage from just 8 hours a day to 24 hours a day, it also brings higher quality consistency to the leather raw material. Such an increase in productivity helps the farmers to receive better remuneration and revenue and, therefore, makes it more affordable to support the educational cost of their children, which will bring a longer-term social impact to their off-springs. If we count five working men per one storage and there are 500 stores around the area, then we talk about 2500 social impacts. And if the offspring are two for each family, we reach around 5000 life of better education level and social leverage. The number might even become larger if other hundreds are centered around the countries.

Turning head to investigate the potential environmental impact, the IoT would help optimize the energy used to maintain the temperature and humidity, which are only 30% of the previous way of storing. Whilst reducing the energy consumption to just 30% (i.e., 70% reduction) of their current use is already a good result, it might even be reduced further if Artificial Intelligence (AI) is used. However, the inclusion of AI is not in the scope of this study. Hence it becomes a part of the recommendation for further studies.

From the result and findings above, it can be concluded that this research has succeeded in producing a tool to monitor temperature and humidity based on IoT. This success can be seen from the tool's ability to provide temperature and humidity data remotely in real-time and provide notifications if the temperature and humidity are outside the specified threshold. In this study, the dashboard will flash red if the temperature is > 30. Likewise, if the humidity is > 70, the humidity dashboard will flash red. The results of monitoring temperature and humidity are displayed in the form of historical data, which are marked to determine when the temperature and humidity exceed the threshold. The storage room supervisor can analyze and take action from the historical data during these vulnerable hours. Supervisors do not need to go to the leather raw material storage room every hour and anticipate when to be on standby to take action, which minimizes direct human interaction and increases the cleanliness of storage. As such, it brings another good

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impact as it decreases the probability of a bad contagious bacterial effect on the leather raw material.

4. Conclusion

It could be concluded that the use of IoT has a positive impact not just on its economic value but also on social and environmental dimensions.

Based on the experiment, the storing process of leather that used IoT was more efficient and effective compared to the baseline or benchmark of the previous manual-based storing process. The use of IoT based made storing process of leather raw materials run three times more effective, from just 8 hours to 24 hours, and also brought about a positive effect on the economic efficiency and effectiveness of the subsequent process as it provided a quality supply of leather raw materials. The experiment also showed that there was no sophisticated and expensive infrastructure needed as the IoT-based monitoring could be operated through a regular computer and the internet connectivity was smoothly run under limited bandwidth.

On the other side of coin, the use of IoT had also increased the welfare and social life of the workers as their income increased, which eventually gave them an opportunity to give their children a better education and healthier environment. In addition, It also brought about some positive environmental impacts as it reduced the carbon emission by keeping the energy waste at a lower level. Finally, this research was not a prototype design anymore as it has been already used and run as expected not only in the object of experimentation but also in some other similar premises.

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