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Study on Smart Downtime Monitoring System in Glove Production

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ABSTRACT
The manufacturing industry is pushing forward with the smart machineries, linked networks, and a smart environment to enhance Big Data's operations – gaining intelligence and actionable real-time insights for higher efficient and smart production. However, in many parts of the manufacturing industry, manual monitoring system is still the usual practice, especially the long-established plants that consist of legacy machines. The monitoring processes of the lines in Top Glove F31 such as recording the lines' downtime duration, checking the source of the stoppage, transferring the data into spreadsheet, and analyzing the downtime of the lines are all being carried out by human operators. There is a high tendency for the workers to overlook the maintenance of the system because of this work practice, and it will contribute to higher unplanned downtime of the lines. Thus, this project proposes to design an automatic downtime monitoring system that consists of sensors, PLC's programming, and IoT technologies that can decrease the dependency on workers and not prone to human mistakes to reduce the unplanned downtime of the lines and increase the efficiency of the system.
Keywords: Unplanned downtime, Programmable Logic Controller (PLC), IIoT, Cloud database.

1 INTRODUCTION

Conventional Monitoring system is closely related to the maintenance of the production line as a better monitoring system can increase the efficiency of the maintenance section. The downtime of the lines in Top Glove F31 are currently monitored and recorded in a book manually by staff. When the SCADA system gives out alert on the lines downtime, the staff has to go check the source of the problems at the lines and recorded the information such as the duration, the cause, department-in-charge of the root cause, the location and other related data. The staff later manually transfer the data from the book into Excel sheets. The analyzation of the downtime data is also done manually by the staff. They will arrange and sort the data to find the highest percentage of the cause of the downtime. The data is then stored in an Excel sheet for further references and actions. Besides that, machine performance monitoring system is also done by workers. There is a high tendency for the workers to overlook the maintenance of the system, and this will contribute to higher unplanned downtime of the lines. Automated machine downtime reporting and alarms are essential elements of contemporary manufacturing and industrial operations. These systems use sensors and monitoring technology to identify unscheduled downtime in machinery and equipment. Automated alerts are issued when a problem occurs, alerting the appropriate persons right away. This quick reaction reduces production halts and enables prompt maintenance or repairs. Root cause analysis for downtime explores the fundamental causes of equipment breakdowns. It is a methodical analysis of data, frequently aided by machine learning algorithms, to spot trends and determine the precise reasons of downtime events. Companies can implement preventive steps to lower future instances of downtime and enhance overall operational efficiency by addressing the core causes. It enables speedy decision-making and intervention when problems arise by enabling operators and management to monitor manufacturing processes in real-time. Meeting production goals, cutting downtime costs, and guaranteeing constant product quality all depend on this proactive strategy. Instant visibility into machine performance and downtime events is made possible by real-time downtime tracking.

2 BACKGROUND

Manufacturing and production systems are comprised of sophisticated technological equipment such as sensors, computer technology, Industrial Internet of Things (IIoT), and linked gadgets that reduce the use of manpower, which leads to the importance of asset management. Any abrupt and accidental breakdown of the intricacy system is

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imperative as complex equipment will require complex maintenance, thus increasing the duration of the maintenance. To address this impending problem that has a great impact on the efficiency of the whole system, maintenance is a pivotal element to minimize the breakdowns (Lundgren, Skoogh, and Bokrantz 2018).

TPM is a maintenance model that focuses on increasing the efficiency and effectiveness of maintenance (Cavalieri 2021). It is the process of maintaining and improving the integrity of production and the quality of the systems by utilizing machines, equipment, workers, and supporting processes. OEE is utilized as a metric to calculate the results (Rusman et al. 2019).

One of the challenges faced by the manufacturing industry is the legacy machine that has little to no connection to IoT. Typically, available visualization was confined to HMIs at the machine level. PLCs have been used extensively in industrial automation systems since the 1970s. Cloud platforms have progressed to the point where they are built to interact with these PLCs via established protocols. PLCs can send data to a cloud platform. Data is evaluated and supplied to systems and people in order to increase productivity, promote process improvement, minimize waste, and provide users with actionable insights (Fogg 2022) (Pivoto et al. 2021).

Data collection is one of the most essential steps in implementing OEE tool as accurate data will provide accurate measurement of the efficiency of the system(Stark 2019). ("How to Manage Data Collected From Smart Sensors" 2022) had designed and developed Machine Utilization Data Acquisition system that provided access to the legacy machines for OEE data collection and analysis. The mechanism of system includes a machine stoppage detection sensor for the detection of machine downtime and Human Machine Interface (HMI) for cause of the downtime machine data logging (Singh, S., Sharma, R., & Sachdeva, n.d.). The system also receives:

1. Machine state changing event,
2. The reason of the downtime,
3. Job order start and stop time stamp,
4. Goods quantity produced.

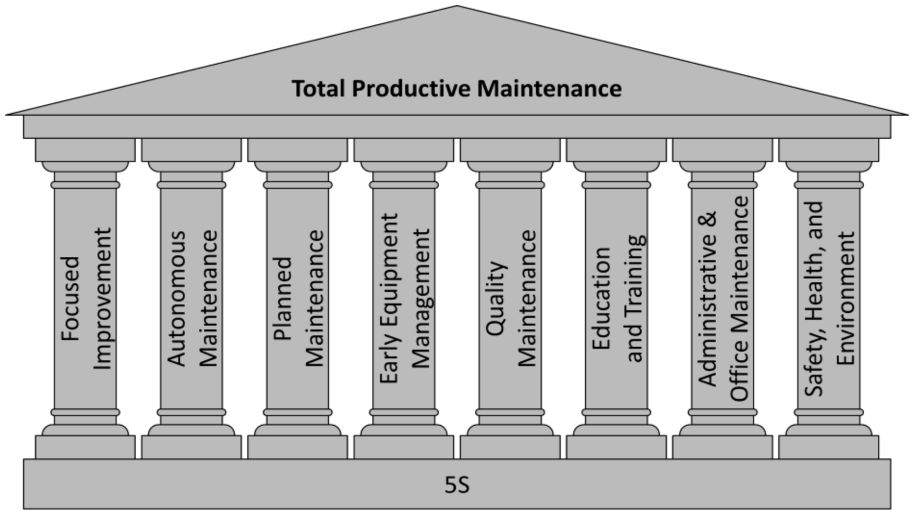


Figure 1: Eight Pillars of TPM

Open Platform Communications Unified Architecture (OPCUA) is an open interface standard that is independent of the application's manufacturer or system suppliers, the programming language, and the operating system of the application (Stark 2019). This flexibility is what made OPCUA suitable for small to medium plants. According to a system devised by (Zhou, Wang 2022), OPCUA server will be used for the machines and PLC that support OPCUA connectivity(Vatankhah Barenji, R., & Usher 2021). MUDAQ system will act as OPCUA server for the machines that do not support OPCUA (Aliev et al. 2021)(Kampker et al. 2020). The implementation architecture is shown in the figure below.

3 SYSTEM DESIGN ANALYSIS

3.1 Conceptual Design

Downtime monitoring system is a new, separate system from the existing SCADA system that can monitor and detect the downtime of the production lines. Sensors are installed and connected to the machines and gateways so that the data from the sensors can be transmitted.

The gateway then converted the data into JSON and transmitted it through Wi-Fi and LTE (4G) or via a wired Ethernet cable to the local or cloud based MQTT broker. Once it is on the cloud, the data may be saved, analyzed, and displayed in a way that allows the operator to easily detect any information and therefore respond to real time problems. The monitoring system will also link with the existing SCADA system that is used to monitor the production line to obtain the production line start and stop time, as well as the quantity of the glove produced.

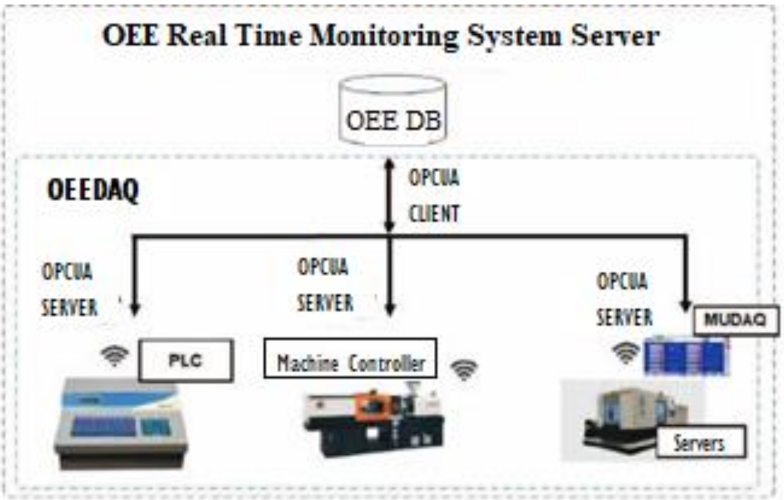


Figure 2: OPCUA Architecture

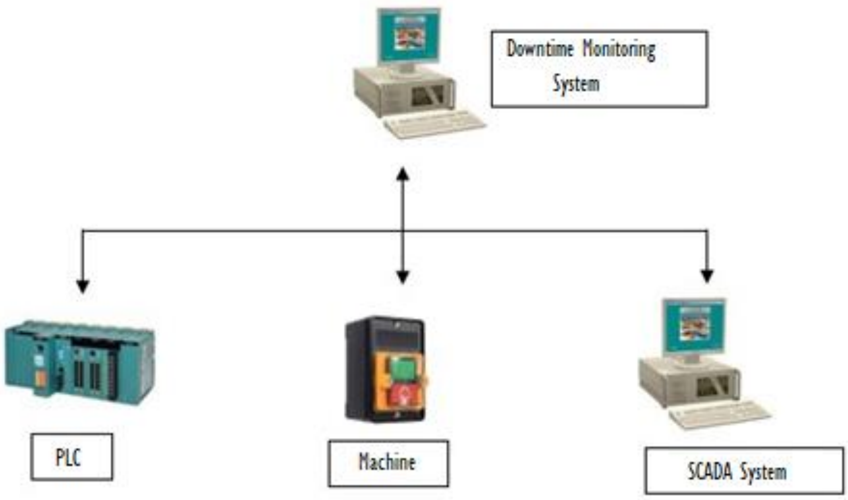


Figure 3: Smart Downtime Monitoring System Architecture

3.2 System Architecture

There are three main processes that are involved in this downtime monitoring system. The first one is the data exchange between the sensors embedded in machines and the PLC of the system, the second process is sending the data to the cloud, and the third one is analyzing the data in the cloud to generate a daily report of the downtime of the machines.

Photoelectric are installed and connected to the production line and gateways so that the data from the sensors can be transmitted from the production line to the PLCs. The gateways are routed from the PLCs to the system computers, where the software interprets and displays the data on HMI allowing for operators to analyze and react to the system events. Gateway are used to connect to the external network as all the data in factories are sent to a centralized cloud in the headquarter. Data from the cloud will be extracted in Microsoft Office and sent to a data analysis and visualization tool so that they can be sorted and analyzed so that the management and engineers can utilized the processed information. The data will be sorted in graphical or pictorial representation such as charts and graphs.

3.3 Software Design

PLC programming will be developed to program this downtime monitoring system. Ladder diagram, or also known as ladder logic as PLC programming will be used to design the system. In this simulation, the ladder logic is devised to control the pushbutton that act as sensors as well as the temperature monitoring. There is one pushbutton that will act as emergency button, three pushbuttons that will act as sensors and one PT 100 sensor.

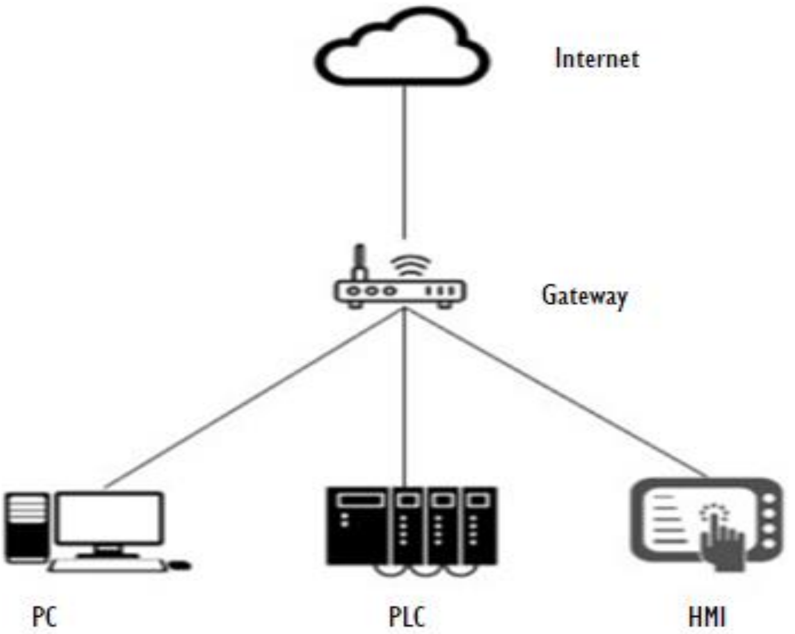


Figure 4: Gateway in F31

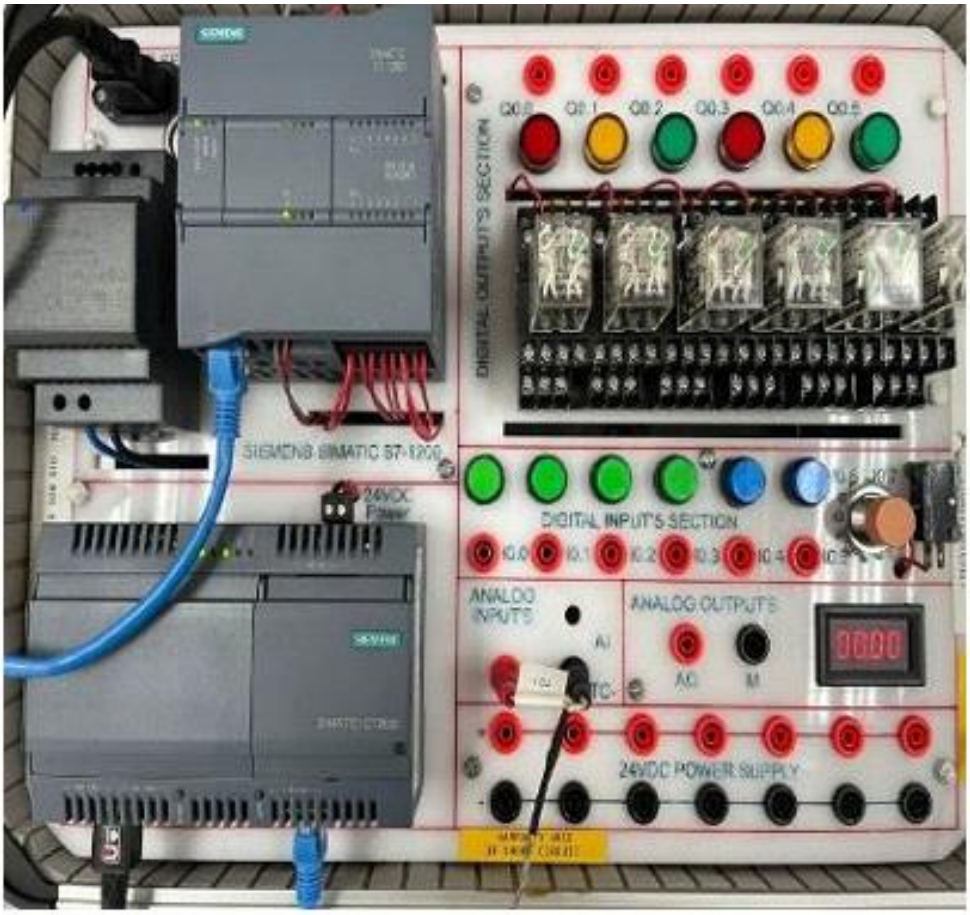


Figure 5a: Siemen S7 1200 Controllers

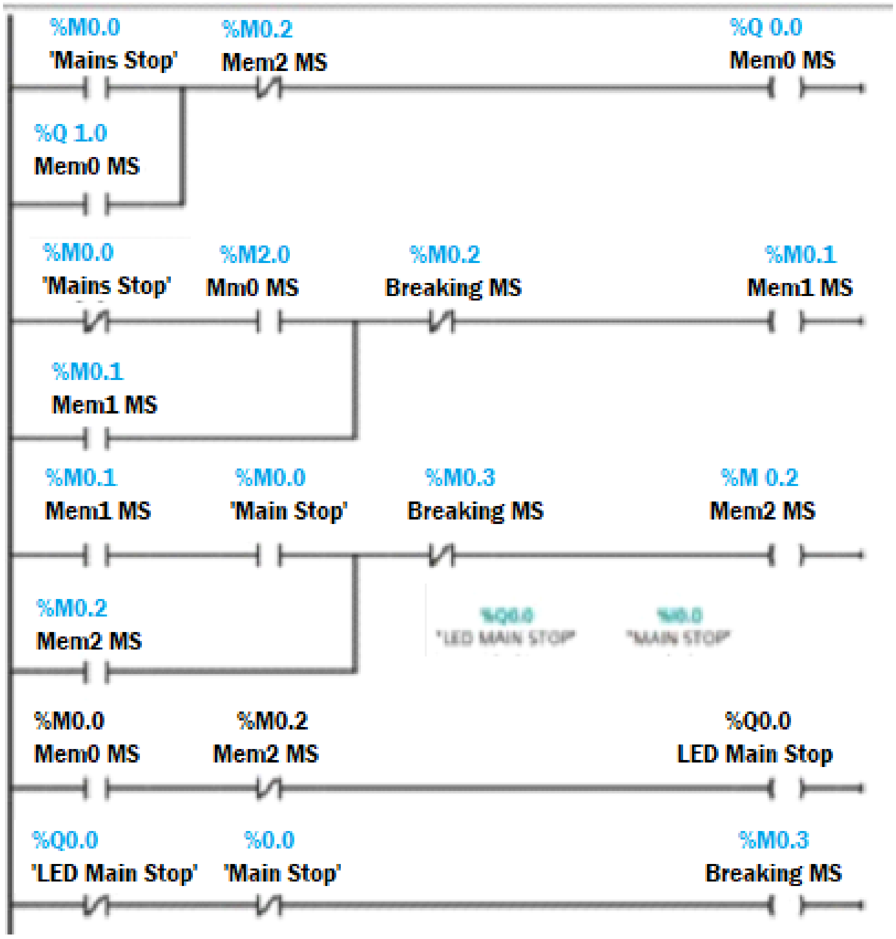


Figure 5b: Main Emergency Stop Button

4 RESULTS AND ANALYSES

4.1 Node-RED Dashboard

Fig. 8 shows the dashboard of the downtime monitoring system that is simulated using Node-Red.

1. PLANNED STOP: The button under the LED is the stop button for the entire line. If this button is pressed, the system will record it as planned stop.
2. EMERGENCY STOP: For simulation purpose, emergencies stop button are included in four locations in Line 1. For example, when the level sensor detected false latex level (sensor is turned on), an alert to the departments will be issued. If the stop button at Latex Tank is pressed, the system will record it as unplanned stop, and an alert will be displayed.
3. INFORMATION: There are five items in this group which is Product ID (type of product), PIC (department responsible), Shift (day or night shift), Last Downtime (the duration of the latest downtime), and Total Downtime (the total duration of the downtimes). User can insert Product ID, PIC, Shift and Remarks whenever there is a downtime that occurs.
4. TEMPERATURE MONITORING: The temperature gauge will display the real time temperature in the oven. When the temperature is out of the desired range, it will display the warning on the right side of the dashboard.

From the Firebase node in Node-Red, the data will be sent to Firebase for storage. All the data will be stored in different arrays, each one has their own unique ID. The data can be downloaded in JSON format. The data from the monitor is recorded in a csv file and sorted according to the elements stated below.

4.2 Data Display

There are six visualizations on the canvas that show the analyzed data of July unpanned downtime analysis. Planned downtime is not included in the analysis as the main objective is to analyze unplanned downtime based on technical issues.

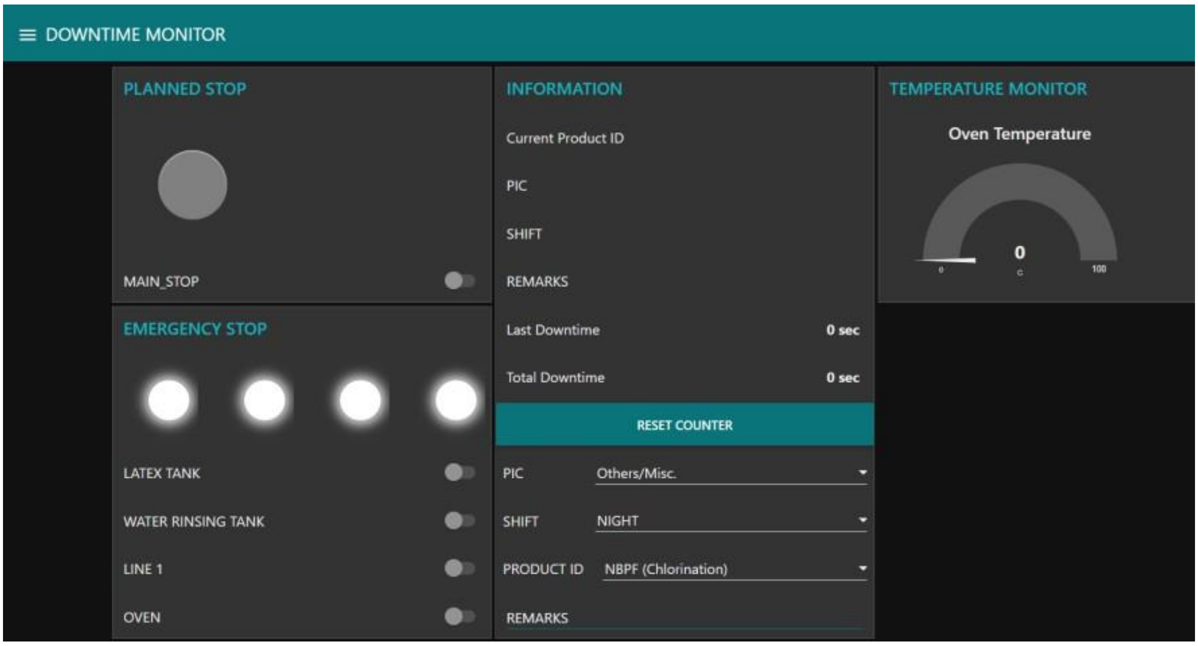
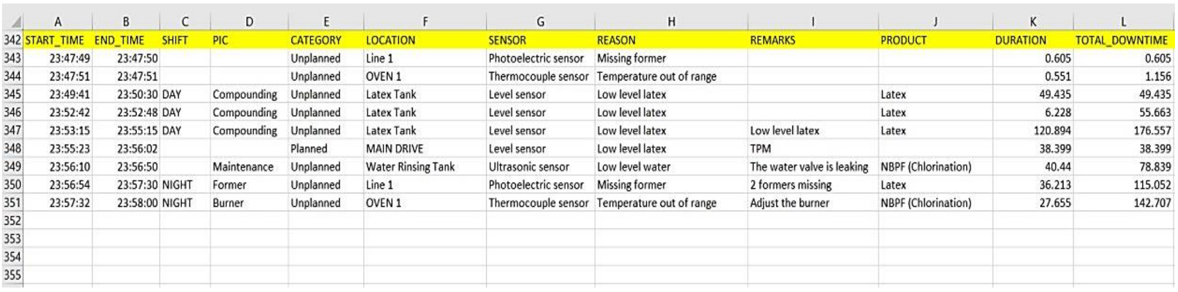


Figure 6: Downtime Monitor Dashboard



	A	B	C	D	E	F	G	H	I	J	K	L
342	START_TIME	END_TIME	SHIFT	PIC	CATEGORY	LOCATION	SENSOR	REASON	REMARKS	PRODUCT	DURATION	TOTAL_DOWNTIME
343	23:47:49	23:47:50			Unplanned	Line 1	Photoelectric sensor	Missing former			0.605	0.605
344	23:47:51	23:47:51			Unplanned	OVEN 1	Thermocouple sensor	Temperature out of range			0.551	1.156
345	23:49:41	23:50:30	DAY	Compounding	Unplanned	Latex Tank	Level sensor	Low level latex		Latex	49.435	49.435
346	23:52:42	23:52:48	DAY	Compounding	Unplanned	Latex Tank	Level sensor	Low level latex		Latex	6.228	55.663
347	23:53:15	23:55:15	DAY	Compounding	Unplanned	Latex Tank	Level sensor	Low level latex	Low level latex	Latex	120.894	176.557
348	23:55:23	23:56:02			Planned	MAIN DRIVE	Level sensor	Low level latex	TPM		38.399	38.399
349	23:56:10	23:56:50		Maintenance	Unplanned	Water Rinsing Tank	Ultrasonic sensor	Low level water	The water valve is leaking	NBPF (Chlorination)	40.44	78.839
350	23:56:54	23:57:30	NIGHT	Former	Unplanned	Line 1	Photoelectric sensor	Missing former	2 formers missing	Latex	36.213	115.052
351	23:57:32	23:58:00	NIGHT	Burner	Unplanned	OVEN 1	Thermocouple sensor	Temperature out of range	Adjust the burner	NBPF (Chlorination)	27.655	142.707
352												
353												
354												
355												

Figure 7: Data generated from csv file

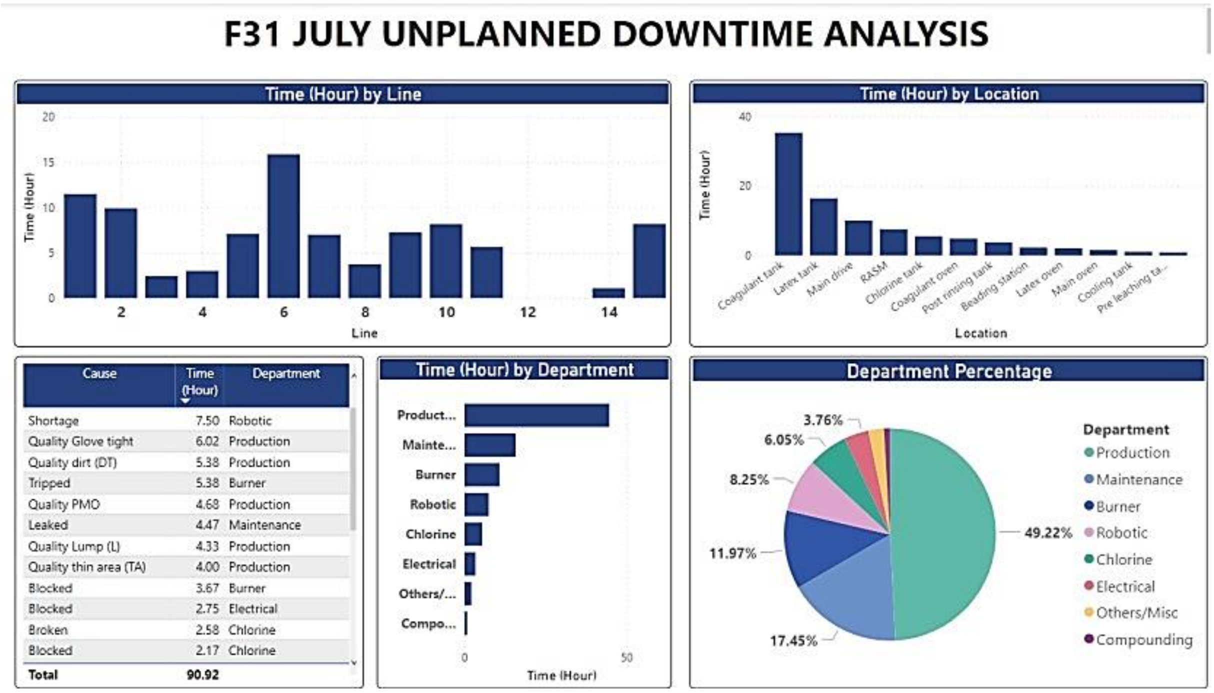


Figure 8: July Downtime Analysis

4.3 Discussion and Analysis

The display by Power BI provides several important data for the engineers such as the duration of the downtime in each line, the location of the area that caused the downtime, cause of the downtime, and the department that is responsible for the downtime. All these information is displayed in graphs, pie charts, and tables that are easy for the reader to understand. The reader can also filter the data by clicking on the visualizations and the category's slicers and highlight the data according to the different elements. The filtering will also allow the reader to discern the highest or lowest contributor to each element. For example, we will know the line that cause the highest downtime, the PIC or the department that is responsible for it. One of the preventive measures that can be done to reduce the unplanned downtime is Total Productive Maintenance and 5S Lean Maintenance by the team, especially by the three biggest contributors to the unplanned downtime.

Table 1: Suggestion of Maintenance Plan

No	Department	Problem	Action
1	Production	1. Quality problem due to dirty tanks, holder track and cotton rags. 2. Inaccurate percentage of chemicals in production	1. Apply Seiso from 5S which is to proactively keep the workplace clean. 2. Apply Seiketsu from 5S to create a set of standards in the production method
2	Maintenance and SCADA	1. Faulty equipment such as leaking ASV and piping 2. False reading from the sensor	1. Planned Maintenance 2. Calibrate sensor
3	Burner	1. The machine often tripped.	1. Planned maintenance and replace old machines

5 CONCLUSONS

All of the objectives of this smart downtime monitoring system has been successfully fulfilled and delivered. Although the project cannot be done in the actual production line, the simulation of the project in Control System Lab has been completed. A study in Singapore used the same concept to design a Machine Utilization Data Acquisition (MUDAQ) and several subsystems to monitor OEE of the factory automatically. The same concept can be applied to this smart downtime monitoring system as the fundamental principle is all the same.

This newly designed system has the aim to increase the overall efficiency of the factory. With the dashboard of the downtime monitoring system, arising problems can be located and addressed methodically by lines, locations, PIC, and the cause of the problems, thus increasing the productivity as the downtime duration can be reduced. From the analysis of the downtime system using Power BI, we can identify which department that contributes to the highest downtime duration, and this will allow them to take a preventive measure so that the problem will not repeat again. Total Productive Maintenance (TPM) and 5S can be arranged by the engineers so that the machines that frequently cause downtime can be restored to a better condition.

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