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STOPIA: A Wearable Sensor and IoT based Truck Driver Stress Monitoring System to Reduce Traffic Accidents

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ABSTRACT

Truck drivers are known to be a demanding profession as their workload affects their body condition. On the basis of these problems, it is necessary to take preventive measures to reduce material losses and casualties. Through the use of the literature review method, the authors reveal a visual representation of the prevailing trends in the existing body of research on how stress impacts truckers and stress control to minimize accidents. The representation of ongoing research and shortcomings in potential future investigations was then used as a reference in prototyping, the stages of which are presented in the form of flow charts. The results show that stress primarily causes driver fatigue, alongside various indicators that serve as benchmarks for identifying fatigue-related factors. It was also found that there is an undeniable link between stress and fatigue in truck drivers during work performance. As part of the research results, the authors propose a solution in the form of sensors and IoT-based wearable devices that can help measure stress indicators, namely STOPIA. With the implementation of STOPIA, it is hoped that accurate recognition of driver fatigue conditions can be achieved, reducing the risk of traffic accidents, and providing comfort and safety for truck drivers and the transportation industry. Thus, this technology has the potential to decrease accident risks, enhance driver management, and reduce accident-related costs in the transportation industry.

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1. INTRODUCTION

Traffic accidents are often caused by negligent drivers. More than 1.2 million people die each year on roads worldwide, making road traffic accidents the leading cause of death worldwide (Jelica Davidović et al., 2018). Indonesia is no exception, having a serious problem regarding drivers on the road, especially truck drivers. Identifying the problem occurs due to Indonesia's recent rapid economic growth and urbanization, the number of trucks on the road has increased dramatically, used for business purposes, truck drivers often become tired of driving for long periods of time (Di Milia 2006; Romo et al., 2014). When driving long distances, especially at night, truckers are more likely to experience fatigue, which can lead to involuntary shifting of focus from the road ahead, extended reaction times, slower responses to hazards, and falling asleep at the wheel. All these symptoms lead to performance degradation and increase the likelihood of accidents (Chu et al., 2012). Therefore, fatal road accidents are of great concern to society.

Previous research has shown that driver demographics are a significant contributing factor affecting fatigue-related truck accidents (Di Milia et al., 2013). Truck drivers usually have to face stressful working conditions, with long working hours and tight schedules (Arnold et al., 1997; Cœugnet et al. 2013), such as driving at night, irregular rest periods, etc. Data from the Ministry of Transportation, (2021) shows that the number of road traffic accidents in Indonesia for freight transportation is 12%, with a percentage of 61% of accidents caused by human factors, which are related to the ability and character of the driver. Based on this data, it shows that a solution is needed to monitor and measure the condition of truck drivers in driving. As a reference, solutions to similar problems can be found in the use of previous related technologies and are presented in **table 1**.

Table 1. Previous Research

TITLE	DISADVANTAGES
Habibi, A. M., Fariqi, M., & Anggriawan, R. 2020. Beware Alat Pendeteksi Kelelahan Berbasis Kecerdasan Buatan dengan Metode Pengolahan Citra untuk Mencegah Kecelakaan Berkendara. Jurnal Penelitian Transportasi Darat, 22(1), 37-46.	This tool is made using artificial intelligence and a camera and is managed through an application on a smartphone. This tool can slow down the speed of the vehicle temporarily. This tool has shortcomings, namely in detecting faces at certain angles.
Farahdina, U., & Pradana, R. L. 2019. GERING: Gelang Monitoring Tingkat Kelelahan Tubuh Berbasis Neural Network Terintegrasi Android Guna Menjaga Kesehatan Jantung. Jurnal Ilmiah Penalaran dan Penelitian Mahasiswa, 3(1), 161-176.	The tool made is used by people with heart disease on the hand and is in the form of a watch. The drawback is that this tool has a sensitive parameter level because it is intended for people with heart disease.

Based on the above novelty, the solution to the problem of accidents in driving is to monitor activities in real time. Miller et al., (2020) said that truck drivers do not do good rest time management, claiming to be in a hurry because they overslept. As an effort to increase awareness of good quality rest, STOPIA (Stress Tracking of Person in Action) comes as a breakthrough or novelty that focuses on monitoring fatigue caused by stress in truck drivers. The solution offered can recognize the fatigue condition of truck drivers in real time by detecting stress fatigue using wearable device sensors and the Internet of Things.

2. METHODS

This article was written using the systematic literature review method. The author conducted a literature review by searching for online journals available in the Google Scholar database, Emerald, Science Direct, SCOPUS, IEEE, Wiley Online Library, etc. First, the articles obtained were determined by the year of publication, the theory used, the source journal, and others. First of all, the articles obtained were determined by the year of publication, the theory used, the source journal, and others. This article uses descriptive analysis to create a visual representation of the prevailing trends in the existing body of research on how stress impacts truckers, stress control to minimize accidents during distribution. Due to the need to keep the article short and to the point, the results on the first analysis were ignored. In the second step of the analysis, 20 articles were thoroughly synthesized to find the main sources of information for the research of this article. All articles in this stage had the same input measurements, output metrics, and theoretical adaptations. The following two tables list the total search criteria and the results.

Table 2. Search Literature Review Criteria and Outcome

Features	Service Quality in Industries	Coherence among Stress and Fatigue in Truckers during Freight Distribution
Research Question	How stressed drivers can become an important aspect for the company?	Is there coherence between Stress and Fatigue in Truckers during Freight Distribution and work performance?
First Screening	22	20
	*The impact of stress and fatigue on truck drivers significantly affects their performance and company operations.	
Second Screening	14	11
	**Stressed drivers hold a pivotal position within the company's framework, their impact surpasses individual well-being, as their performance intricately shapes both company operations and customer contentment. Stressed drivers are more prone to errors, leading to delayed deliveries, compromised service quality, and potential harm to the company's reputation.	
Final Screening	19	
	***Following a full-text analysis, the three study contexts are taken into account collectively and either considered as an output or as a mediating or moderator variable. The study highlights the substantial effects of stress and exhaustion on truck drivers, significantly influencing their performance and the overall functioning of the company. Stress disrupts work efficiency by impeding concentration and decision-making abilities, while the effectiveness of drivers directly impacts delivery accuracy and service quality.	

These articles were divided into categories based on year of publication, theories used, journal source, etc. in the early stages of the research. Considering the current trends in the published literature on stress and fatigue in truckers during freight distribution was demonstrated using descriptive analysis. The results will yield a representation of the ongoing research and any shortcomings in potential future investigations. All stages of prototyping are presented in the form of a flow chart in **Figure 1** below.

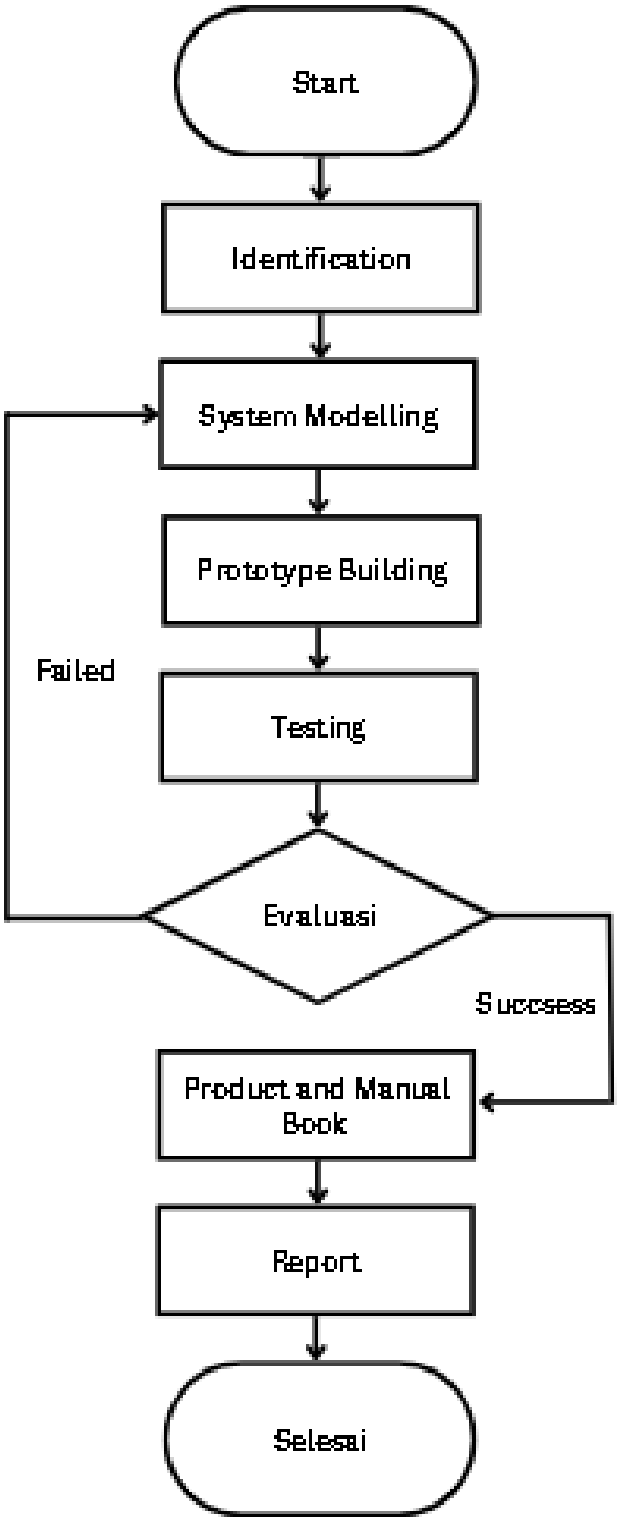

Figure 1. Flowchart of STOPIA

Flow chart description:

1. Start
2. Identification.
   The first thing to do is to identify the problem and the purpose of this activity so that further implementation is clear and directed.
3. System Modeling. Before making the tool, the coordination of the tool making plan is carried out first. At this stage, the PKM team determines the planning and analyzes the needs, namely Gy-max 30100, OLED 128x64 LCD I2C SPI 0.96 inch, Bluetooth HC-05, PULSE HEART RATE, and the application to be used, as well as the tools used in making STOPIA.
4. Tool making.
   Tool making is a stage where parts in terms of mechanics, hardware, and software are made, but still in the form of separate parts. The processes carried out are PCB manufacturing, soldering sensor components on PCB, case and battery assembly, making programs in tools and application programs.
5. Tool testing.
   After the tool is made, testing is carried out on the product, namely functional tests, safety tests, suitability tests. Functional tests are carried out using tests on one subject within a certain period of time that tests heart rate, temperature and oxygen. Safety tests are carried out with impact tests and battery life tests, suitability tests are carried out by assessing the ergonomic aspects of the test subject when wearing the product. The test will be tested as a whole from the functional performance designed so that the tool used can function and if there is an error, troubleshooting will be carried out.
6. Evaluation.
   Evaluation is carried out to measure the results of success and can find out the shortcomings in the tool. If there are still deficiencies in this tool, trials and troubleshooting are needed again in order to maximize the performance of the tool.
7. Product and Manual Book.
   After going through the evaluation process and indicating success the product will be released along with the manual book.
8. Reporting.
   Making progress reports aims to report progress results as evidence of the work process, making scientific articles that aim to publicize the results of activities and making final reports. At this stage the PKM team also submits IPR in the form of a manual book to obtain legal protection rights for intellectual property and is an output that must be achieved from the implementation of this activity.
9. Completed.

3. RESULTS AND DISCUSSION

3.1. The Correlation between Stress and Fatigue in Truckers during Freight Distribution

Stress can be caused by small, largely harmless incidents or major incidents and impact on the subject's well-being both directly and over time. Therefore, it is basically inevitable that most people experience stress, at least occasionally (McEwen BS et al., 2011). Depending on the source of stress and how long it lasts, stress can have both positive and adverse effects on a person (American Psychological Association, 2013). Truck drivers often consume large amounts of coffee and this can be bad for the truck driver's blood sugar and blood volume.

Stress due to fatigue in normal people is in the range of 101-110 Bpm and 37.5-38°C, and oxygen levels in the range of 80-90% (Farahdina et al., 2019). Lack of expertise behind the wheel of a truck can cause more stress when dealing with time constraints and cargo loading and unloading schedules (Apostolopoulos et al., 2021). Stress disrupts efficiency by interfering with concentration and decision-making, while the drivers' effectiveness directly influences delivery punctuality and service quality.

Stress-induced fatigue can lead to navigation errors, potentially harming the company's reputation and customer satisfaction. Hence, managing stress and fatigue is vital for operational excellence and customer loyalty in freight distribution. The company's image and customer loyalty are inherently linked to the dependability of its drivers. Hence, managing stress among drivers is not only an ethical consideration but also a strategic necessity to uphold operational excellence, bolster customer trust, and maintain the company's standing. The interrelation between Stress and Fatigue in Truckers during Freight Distribution and job performance is undeniable. Stress and fatigue significantly impede truck drivers, affecting their efficiency and decision-making capabilities. Amidst the intricate demands of freight distribution, the impact of stress and fatigue is magnified. The urgency to meet delivery schedules and navigate intricate routes heightens the potential for errors and accidents. Stress-induced fatigue can lead to suboptimal navigation decisions, resulting in delays and compromising service quality. This connection emphasizes the urgent requirement for stress management strategies customized to the distinct challenges of freight distribution. By addressing stress and fatigue purposefully, companies can enhance driver performance, ensure timely deliveries, and maintain high service standards, ultimately bolstering customer satisfaction and sustaining operational triumph.

3.1. Body Monitoring

Body monitoring in STOPIA is obtained from heart rate, blood volume pressure, temperature and oxygen levels. Heart rate is the pounding caused by the heart pumping blood throughout the body. The normal heart rate in humans ranges from 60-100 beats per minute, the human heart rate decreases between 10 and 30 beats per minute during sleep. A person's heart rate can be known through the pulse. Pulse rate is one of the physiological variables of the body that describes the body in a static or dynamic state. Blood pressure is the result of the pumping activity of the heart that takes place in contraction and relaxation. Normal adult blood pressure ranges from 120 mmHg systole and 80 mmHg diastole (Yusen et al., 2015). Blood pressure monitoring needs to be done to determine the condition of hypertension, hypotension and become a measure of stress in truck drivers while driving. Therefore, pulse rate is used as one of the indicators used to determine a person's fatigue level (Azizah et al., 2005).

3.2. Wearable System

Wearable on stopia uses sensors that detect heart rate, blood volume pressure, and oxygen and temperature levels in the body. the data is obtained using sensors mounted on the wrist like a clock. To be able to use the wearable system technology, the PKM team uses sensors consisting of Arduino mini pro for the microcontroller as a sensor support, Keyes XD-58C or PULSE HEART SENSOR which functions as a heart rate sensor (IC) and blood pressure, MAXIM GY-MAX30100 as a pulse oximeter detecting oxygen levels as well as body temperature, Bluetooth as a link from the device to android, and OLED as an indicator on the device (Wan J et al., 2017).

3.3. Internet of Things

The term 'Internet-of-Things (IoT)' was first introduced by Kevin Ashton to describe how IoT could be created by "adding radio frequency identification and other sensors to everyday objects" (L. Wang et al., 2014). Over time, the term has evolved into one that describes IoT as a network of entities connected through all forms of sensors, allowing these entities, which the PKM team refers to as Internet-connected constituents, to be discovered, identified, and even operated.

3.4. Working Principle of STOPIA

STOPIA (Stress Tracking of Person in Action) is a breakthrough that focuses on monitoring truck driver stress that can help business people manage their workers. STOPIA uses a pulse reading system to determine the truck driver's heart rate and blood pressure, in this system a 0.3V 0.72µA pulse oxymeter sensor is used to read the pulse rate per minute. STOPIA also uses a system for reading oxygen levels and body temperature using the MAX30100 0.3V 0.72µA sensor (Z. Zhang et al., 2015). The sensor reading results can be displayed on the user's android as shown in **Figure 2**.

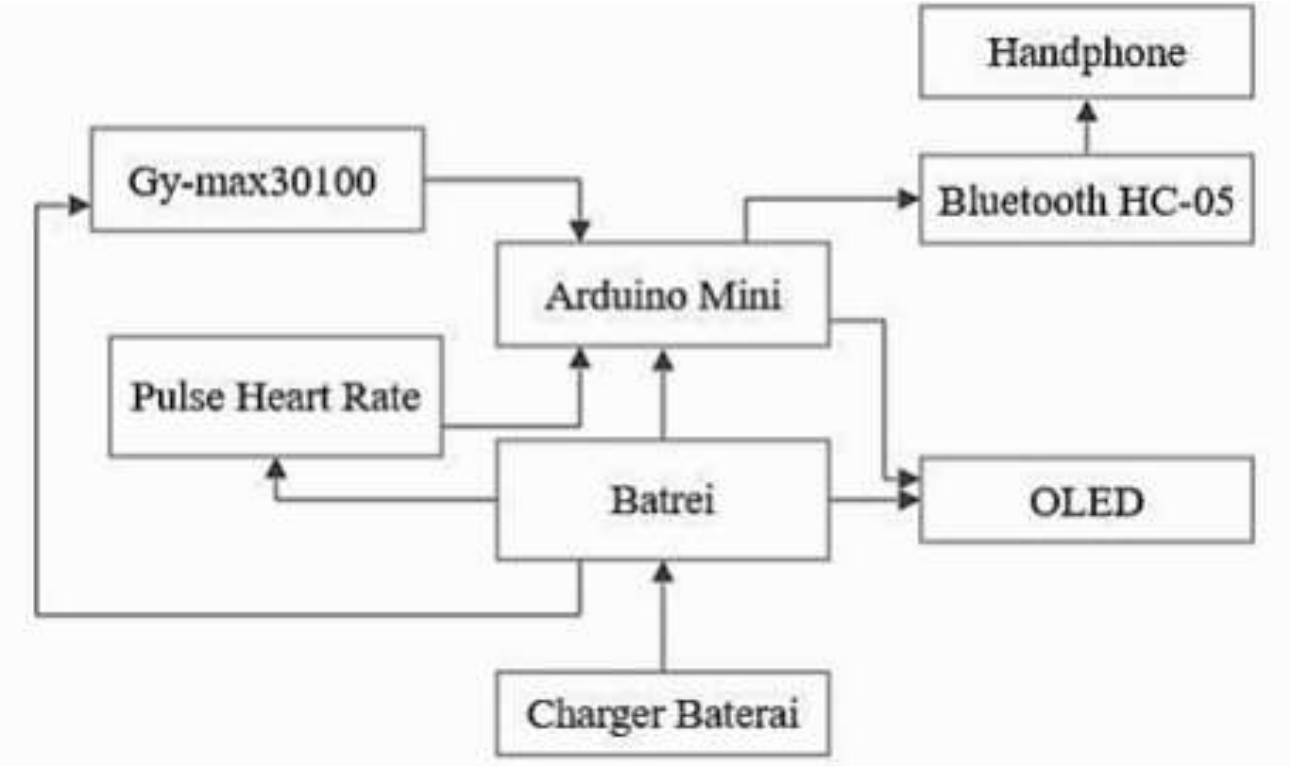

Figure 2. Diagram of STOPIA

The sensors are integrated through an android or truck driver's device, the results of reading data on body temperature, pulse rate, and O2 levels in the blood can be received by the arduino mini pro then sent a microcontroller input signal to the android regarding body temperature data, pulse rate, and O2 levels. Processing sensor reading data to classify truck driver stress levels using Neural Network. Sensor readings will be identified by color indicators in the application.

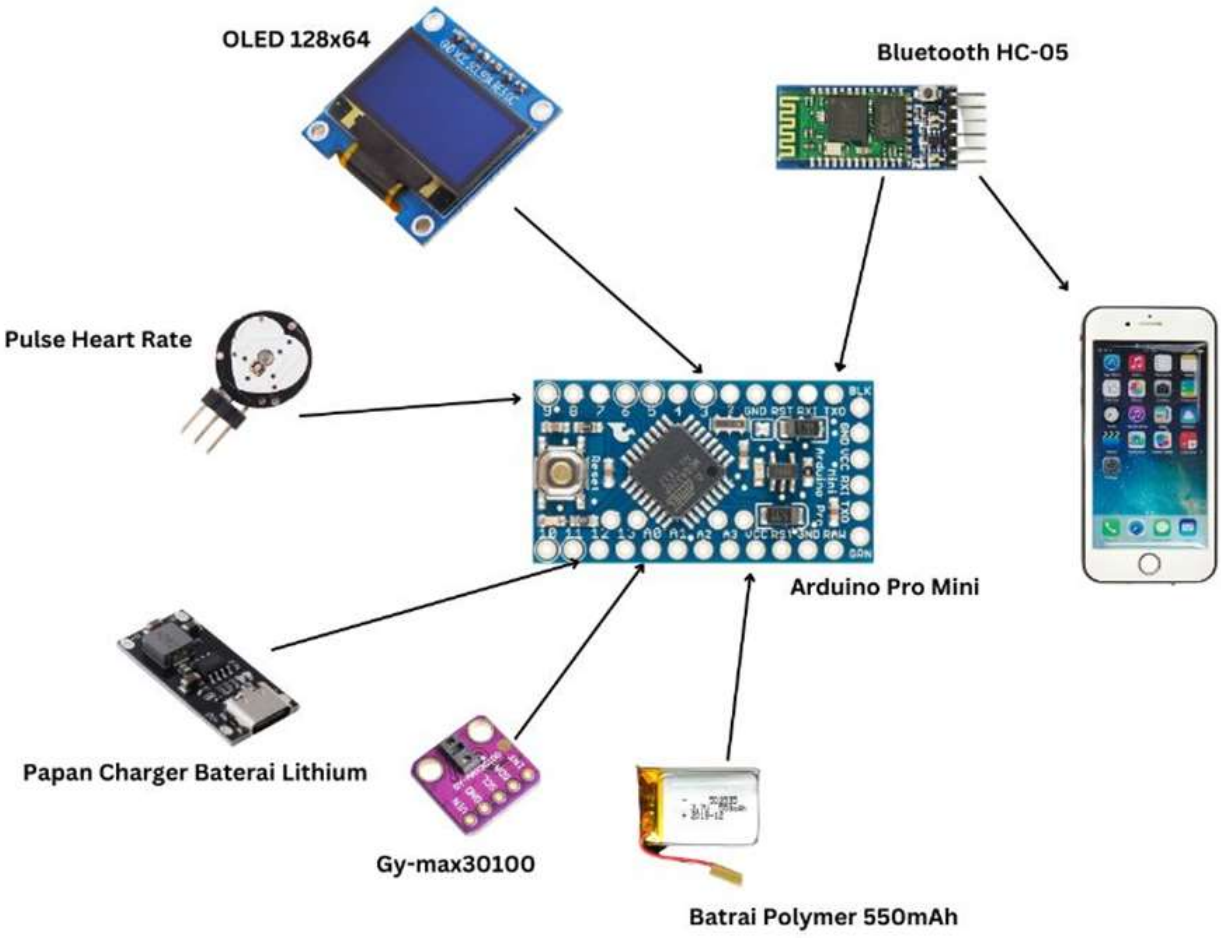

Figure 3. System Configuration

The color indicator is divided into 3 colors: green, yellow and red. In the case of green color, the truck driver is still fit and not tired. The yellow case indicates that the truck driver is getting sleepy and STOPIA will give a warning to stop every 3 minutes with a warning duration of 30 seconds. In the case of red, STOPIA will give an emergency alarm for 5 minutes, and if the alarm is not stopped by the 3rd minute, STOPIA will automatically warn the industry operator about the condition of their truck driver and also give an emergency call to the local authorities (police, hospital, etc.) if the alarm has lasted for 5 minutes.

3.5. Advantages of STOPIA

The advantages of the innovation/expansion of the technology made are that in addition to detecting fatigue due to stress, it can also detect body conditions in real time using temperature and oxygen sensors on truck drivers. In addition, the PKM team's tool can also send information on the condition of the truck driver directly to the industry through the internet network to their devices to provide the necessary notifications. This can make the industry feel calm because the condition of the delivery of goods and their drivers will be continuously monitored, so that the industry can manage truck drivers with full control and do not need to worry about accidents and insurance costs due to accidents.

3.6. Prototype Design of STOPIA

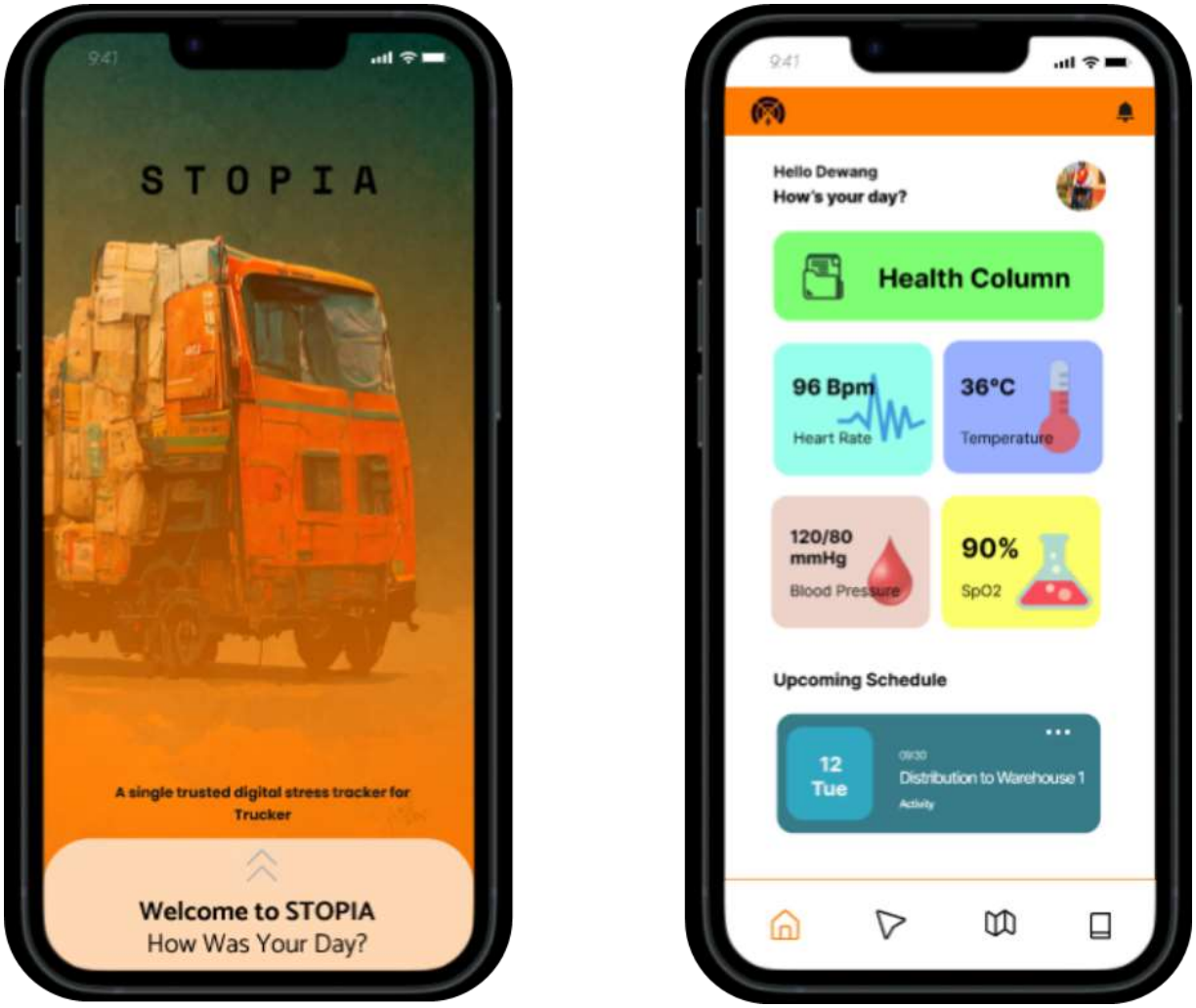

Figure 4. Home Page Design Prototype

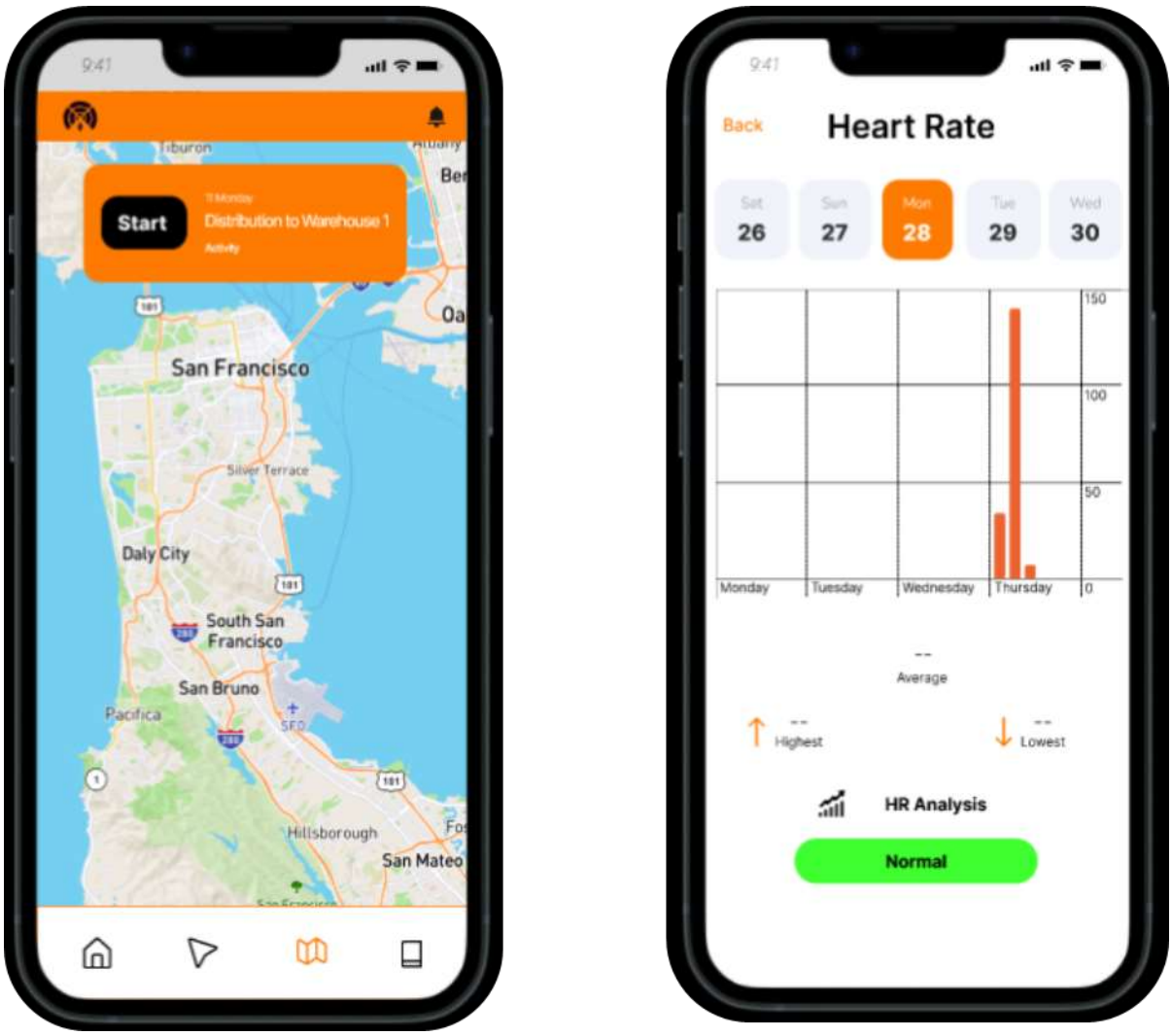

Figure 5. Tracker Design Prototype

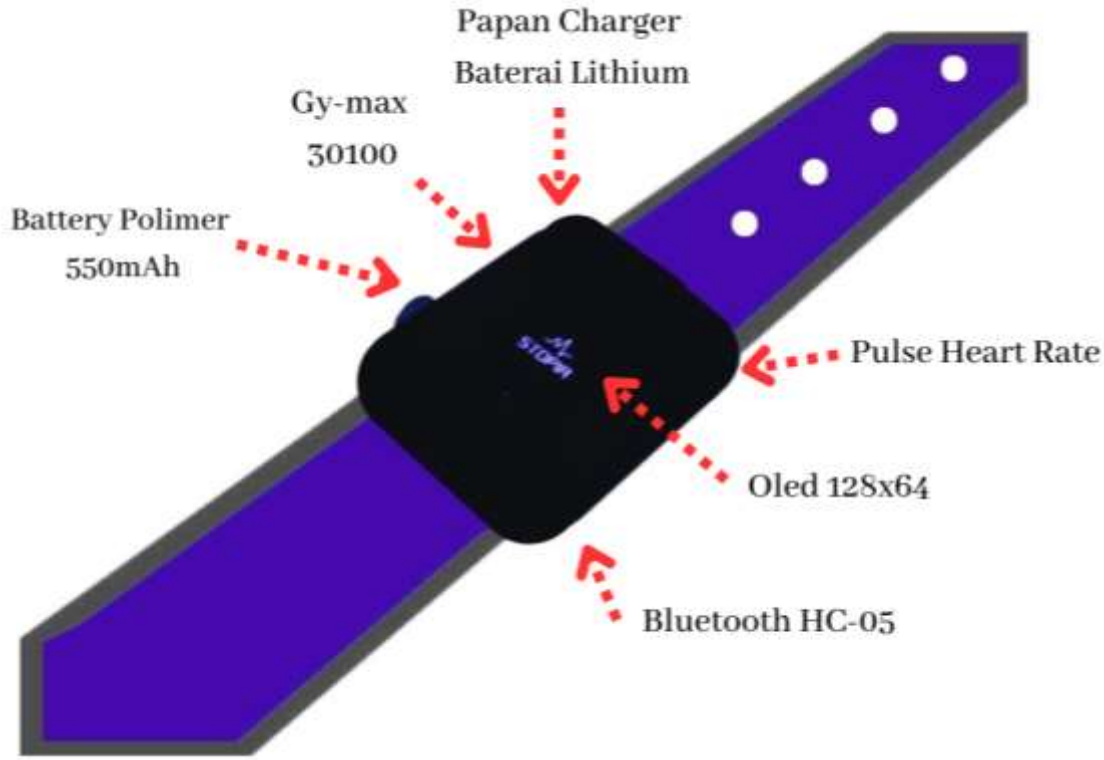

Figure 6. Watch Top View Design Prototype

Figure 7. Watch Side View Design Prototype

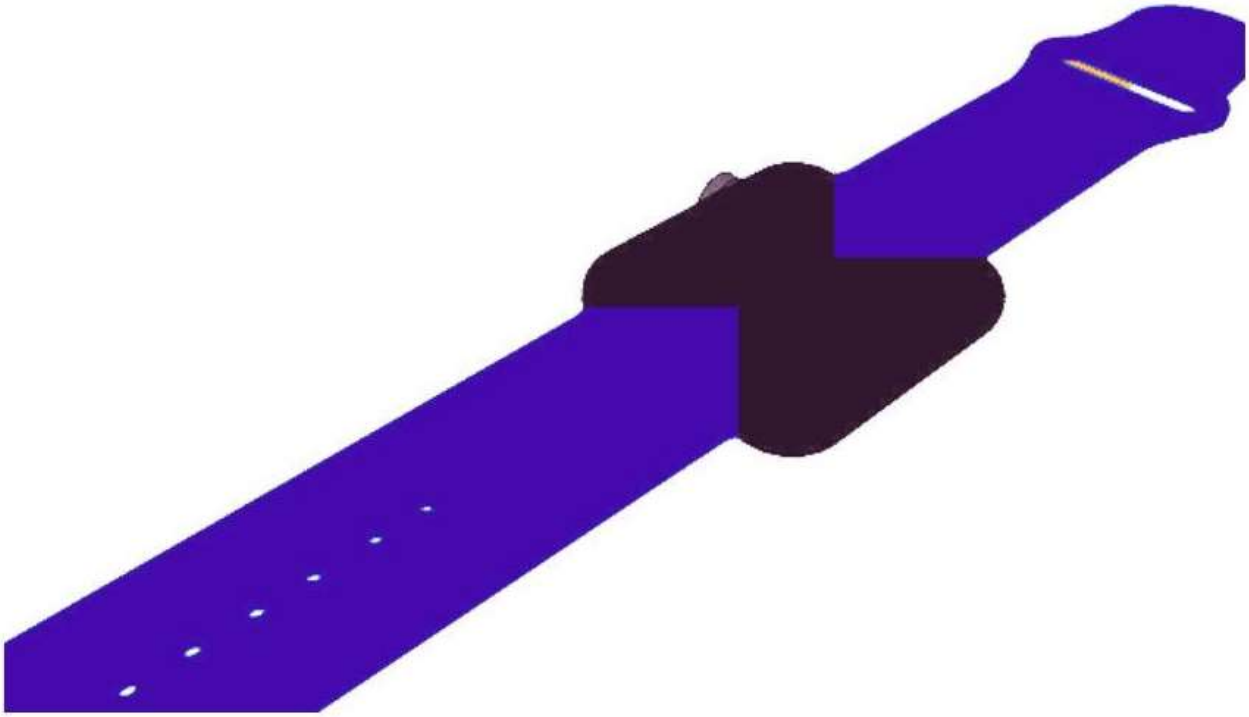

Figure 8. Watch Back View Design Prototype

4. CONCLUSION

In order to address the serious issue related to traffic accidents caused by truck driver fatigue, this article proposes an innovative solution through the development of STOPIA technology (Stress Tracking of Person in Action). The urgency of this problem is becoming more prominent due to data showing a high level of accidents caused by driver fatigue. The STOPIA solution aims to real-time monitor stress-induced fatigue in truck drivers using wearable device sensors and Internet of Things technology. With the implementation of STOPIA, it is hoped that accurate recognition of driver fatigue conditions can be achieved, reducing the risk of traffic accidents, and providing comfort and safety for truck drivers and the transportation industry.

The advantage of STOPIA technology also lies in its ability to detect not only stress-induced fatigue but also overall body conditions using temperature, oxygen, blood pressure, and heart rate sensor. Information about the truck driver's condition can be directly transmitted to the industry through the internet network, offering benefits such as continuous monitoring. Thus, this technology has the potential to decrease accident risks, enhance driver management, and reduce accident-related costs in the transportation industry.

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