



A REVIEW STUDY OF INNOVATIVE WEARABLE TECHNOLOGY IN SAFETY, EFFICIENCY, HEALTH FOR WORKERS

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บทคัดย่อ

บทความนี้เป็นบทความวิชาการเพื่อศึกษาและอธิบายถึงความหมายของนวัตกรรมเทคโนโลยีอุปกรณ์สวมใส่ สำหรับผู้ปฏิบัติงานที่อาจเกิดเหตุการณ์ที่ก่อให้เกิดอันตราย ไม่ปลอดภัย หรือให้บริการทางสาธารณสุข รวมไปถึงการนำเสนอคุณลักษณะประโยชน์และ การนำนวัตกรรมเทคโนโลยีอุปกรณ์สวมใส่ สำหรับผู้ปฏิบัติงานไปพัฒนางานให้กับลักษณะงานในอุตสาหกรรมที่มีการทำงานในลักษณะมีความเสี่ยงต่อความปลอดภัยต่อผู้ปฏิบัติงานและผู้เข้ารับบริการ ซึ่งช่วยในการพัฒนาเครื่องมือหรือเครื่องมือเทคโนโลยีที่สามารถนำไปใช้ให้เกิดผลกระทบประโยชน์ในการทำงานได้สูงสุด บทความวิชาการนี้ผู้ศึกษาได้จัดประเภทของนวัตกรรมเทคโนโลยีอุปกรณ์สวมใส่ ตามคุณประโยชน์ของอุปกรณ์สวมใส่ได้ 3 ประเภท คือ ด้าน ความปลอดภัย ประสิทธิภาพการทำงาน และสุขภาพของผู้ปฏิบัติงาน ซึ่งจากผลการศึกษาผู้ศึกษาจากที่ได้ศึกษา ผู้ศึกษาสรุปถึงประโยชน์และการนำไปใช้ในแต่ละประเภทของคุณประโยชน์ของอุปกรณ์สวมใส่เพื่อเป็นแนวทางในการกำหนดกลยุทธ์และเป้าหมายให้การบริหารจัดการความปลอดภัยในองค์กรรวมทั้งนโยบายความปลอดภัยที่เกี่ยวข้องกับผู้ปฏิบัติงานให้มีประสิทธิภาพในการทำงานที่ดี และส่งผลต่อการบริหารด้านบุคคลในการกำหนดนโยบายหรือแผนการดูแลสุขภาพของผู้ปฏิบัติงานได้อย่างมีประสิทธิภาพ

Abstract

This article is an academic article to study and explain the meaning of wearable technology innovation. For workers who may have an incident that causes danger, is unsafe, or provides public services. Including presenting useful features and introducing innovative wearable technology. For workers to develop work for work in industries where work poses a risk to safety for workers and service recipients. This helps in developing tools or technology tools that can be used for maximum utility in work. In this academic article, the researcher has classified innovations in wearable technology. According to the benefits of wearable devices, there are 3 types: safety, and performance. and health of workers which from the results of the study, the study of the study researcher summarizes the benefits and uses of each type of wearable device as a guideline for setting strategies and goals for safety management in organizations as well as security policies related to operators. Work to have good work efficiency and affects personnel management in effectively setting policies or health care plans for workers.

Keywords: Wearable devices / Fatigue tracking device / Safety / Productivity / Worker

Introduction

Innovative wearable technology is a wearable device that collects, tracks, and displays data based on the wearer's daily activities. These data will be processed, and results will be produced in various formats such as via report format, sound, or sensor system. Therefore, applying innovative wearable technology to human

care and work is extremely important in today's era where the benefits of digital are increasingly used in humans¹. In this regard, the use has been designed to respond to functions that are more consistent with human activities. Both medical aspects are used to take care of a patient's health. Human work is designed to help enter work data and track work in a timely

manner to analyze the information to develop better work efficiency. or management in various organizations to drive policies to care for employees in terms of health and quality of life to be more consistent with everyone². Therefore, the output of innovative wearable technology is necessary and increasingly demanded in each industry. From the study, there is a summary of the framework for studying the concept of wearable technology innovation as divided as shown in Figure 1.

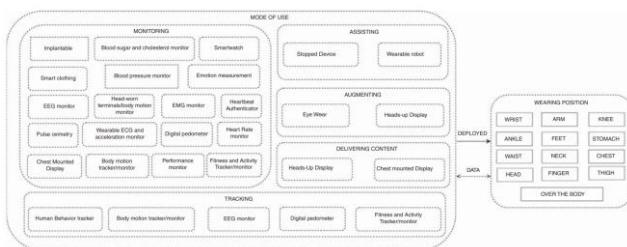


Figure 1. The categorization framework of wearable technology types 3.

Source:

<https://www.emerald.com/insight/content/doi/10.1108/ITP-03-2017-0076/full.html>

Figure 1 shows the classification for the study of wearable technology innovation according to the type of activity of the wearer. If the focus is on the functionality of the wearer. It will provide benefits in terms of safety and occupational health in operations. This research uses data from the classification of work functions to promote the issuance of more specific safety and occupational health policies in operations³. both the production industry construction industry mining industry indicate the nature of working with heavy labor in a workplace with operational risks and limited working hours Operators are in such a hurry to carry out their work that they do not consider work safety. However, the negative effects are not only on the operational process but also on the work process and personnel management process as well. Therefore, the presentation of the division of wearable technology innovation into work process types is considered one of the conceptual frameworks for studying wearable technology innovation. However,

the researcher also sees that the study issues related to health care and efficiency are still interesting. This is because there is more awareness among workers in various industries. The construction industry also has an interest in the rate of work-related injuries. The rate of illness among workers This is based on the growth rate trends observed over the past seven years in the US healthcare personal protective equipment market¹². As shown in Figure 2.

U.S. healthcare personal protective equipment market size, by product, 2016 - 2027 (USD Billion)

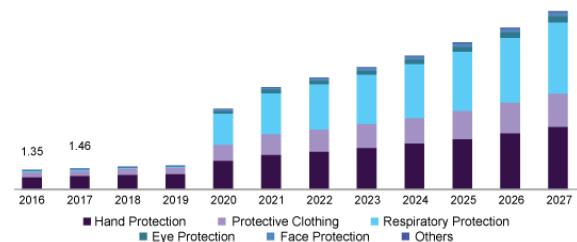


Figure 2. The trend of the U.S. healthcare personal protective equipment market by product in 2016-2027¹³.

Source: <https://www.grandviewresearch.com/industry-analysis/us-healthcare-personal-protective-equipment-market>

Figure 2 shows the growth of the US healthcare personal protective equipment market, which is increasing rapidly each year. Therefore, personal protective equipment for the healthcare industry in the future is important and the development of safety with advanced technology and various forms of equipment is important. Creating a wearable device architecture designed specifically for underground mine workers. It facilitates health analysis and performance optimization of the mining industry. This wearable technology assesses various parameters related to cardiovascular and fluid levels in the body. This allows for an overall analysis that can be applied to other industries. with slight modifications Therefore, further studies are needed to improve the safety and health of workers. Therefore, it was found that innovative wearable technology can help share information about human physiological movements and the environment from studies with operators. And

we study situations that cause work hazards such as dangerous situations, toxic gases occur in the factory, and fire situations.

Therefore, the study has seen researchers recognize the benefits of innovative wearable technology in terms of safety and health care for workers even more. In addition to the efficiency of work, innovative wearable technology can detect fatigue and evaluate fatigue that occurs from studies in the construction industry. In the study, innovative wearable technology was used with construction workers to study how fatigue occurs and how it affects work performance. In this regard, physical data based on wearing the wristband were taken⁴. It was found that the percentage of heart rate (%HRR) from the heart rate is a factor in education that poses a risk to work performance. or surface electromyography (sEMG) sensors to monitor performance in the construction industry. From research, it was found that working by using physiology in performing heavy labor

work was found. Using movement physiology affects performance, for example. Lifting loads in the construction industry, as shown in Figure 3.

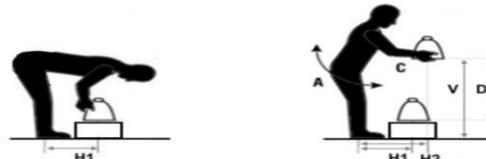


Figure 3. (a) measurement of the degree to determine task variables needed (b) measurement of the degree to the body which is required to twist or turn during the lifting task⁵.

Source:
<https://arxiv.org/ftp/arxiv/papers/2109/2109.15036.pdf>

This results from the results of the lifting study according to the NIOSH Equation Study, which is the equation for the risk of low back pain. that affects the safety and occupational health of workers to explain the principles of the NIOSH equation, the researcher has summarized the meaning of the NIOSH equation as shown in Table 1.

Table 1 the NIOSH lifting equation variable meaning from Figure 2 (a) and (b)

Variable	Variable Name	Description
H	Horizontal location	Horizontal location of the object relative to the body position 1 and position 2
V	Vertical location	Vertical location of the object relative to the floor
D	Vertical travel distance	Distance the object moved vertically
A	Asymmetry angle	Asymmetry angle or twisting requirement
C	Coupling classification	Coupling of the workers grip on the object

Table 1 explains the parameters of the NIOSH lifting equation to consider the movement affecting human muscles. Therefore, a study of the use of innovative wearable technology in the construction industry shows interest in using innovative wearable technology to increase the potential to reduce safety and health risks for workers in their industry. However, stress is considered a factor affecting both work efficiency. Safety and mental health of workers as well. For example, researchers have studied the benefits of using innovative wearable technology to track stress

levels to take care of the mental health of construction workers as well. From the research, innovative wearable technology has been developed for workers in construction sites using the detection and study of electroencephalography (EEG) signals, as shown in the example of Figure 4.

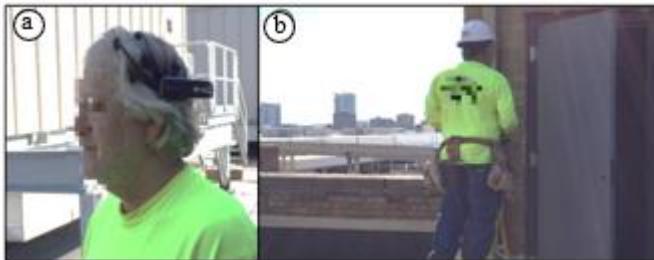


Figure 4. (a) EEG Collection from construction worker the position of wearing the device to detect EEG Signal (b) the integration of EEG device and safety helmet 6.

Source: <https://deepblue.lib.umich.edu/handle/2027.42/149965>

Figure 4 (a) shows the detection location of an EEG device to track the stress level of a worker during a working day. Figure 4 (b) shows a safety device that transmits EEG signals with a helmet to suit the actual work situation. As a result of the research, we studied electroencephalogram (EEG) data from while working, collected from healthy male workers with more than 3 years of experience in construction work, to study the mental and physical stress of the workers. The system developed in this study can use EEG signals to track stress levels, burnout, mental fatigue and emotional exhaustion of workers. In addition, additional studies have been conducted on other professional groups such as drivers, who have long working hours and work in stressful environments and situations, both in terms of time and environment, by using innovative wearable technology to follow up and detect physiological data and physical health data. Studies have shown that truck drivers are at risk for health risks such as sleep apnea, cardiovascular disease, obesity, diabetes, and stress⁷.

However, the use of innovative wearable technology while working also creates obstacles. This research has raised privacy concerns, data security and interoperability with existing systems. It conducted a study exploring truck drivers' perceptions of health promotion delivered through wearable devices and mobile health technology. However, health technology is used to promote health among trucking

workers. Studies have examined its effectiveness in improving the health of truck drivers. These barriers must be addressed to ensure the safe and effective use of wearable technology in the workplace. This leads to better safety, productivity, and overall health for truck drivers.

From all these studies, the researchers concluded by categorizing data based on the benefits that operators will receive. Currently, innovative wearable technology will focus on human-centered use to create maximum utility. Therefore, the study has divided the categories to be useful to practitioners and those involved in issuing policies to supervise and issue regulations more efficiently. Moreover, developers of wearable technology innovations should see the benefits of categorizing them according to the benefits of operators to develop wearable technology innovations that meet the objectives and needs of those involved. Issuing policies for better supervision and regulations.

Desire connected worker solutions

Researchers have developed a classification framework to align with operators and participants in publishing care and Regulations. Through a review of relevant literature, a study has been found that emphasizes people's understanding of the benefits of innovative wearable device technology classification. Execute tasks. Research has found that there is a connection in explaining the benefits of wearable device technology innovation more clearly. When searching and reviewing relevant literature, students searched international reference databases such as PubMed Central, ScienceDirect, MDPI and The Institute of Electrical and Electronics Engineers (IEEE) has determined the scope of research by defining wearability from year 2015-2023. Devices, fatigue tracking devices, safety, productivity, workers. Research has given students more confidence in the innovative classification of wearable device technology. The above research is shown in Figure 5.



Figure 5 Types of wearable devices related to workplace and work solution for (a) Occupational risk and hazard (b) Workplace wearable device (c) Connected worker solution ⁹.

Source:

www.onlinelibrary.wiley.com/doi/full/10.1002/aisy.202100099

Figure 5 shows the different types of wearable devices. For operators and provides an overview of the three topics that will be described in this review report: Figure 4(a) Occupational risks and hazards related to the

health and safety of workers when working in the workplace. For Figure 4 (b), Wearables are relevant to work and workplace safety solutions^{10,11}.

However, this review of related research and literature reveals both the categorical benefits that wearable technology innovations offer workers. Better awareness of how to use it is also consistent with the development of developers who want to develop wearable technology innovations for commercial use as well. Therefore, in explaining the classification in this study, it is necessary to classify wearable technology innovations for operators according to their benefits in safety, efficiency of work and health of workers. The researcher also presents examples of innovations and applications. The researcher has summarized examples of wearable technology innovations according to the literature review, dividing the details as shown in Table 2.

Table 2. Examples of wearable devices to focus on the physical of workers.

Author and Year	Wearable Devices	Focus	Sensor Detection
Ghosh, A. et al. (2021) ¹²	Wrist-worn	cardiorespiratory and sweat Monitoring	Heart Rate Respiration rate Blood pressure
Kim, Y. et al. ¹³	Smart Helmet	Personal proximity warning system	BLE signal detection distance
De fazio, R. et al. (2022) ¹⁴	Smart Shirt	Monitor physical and environment	Heart Rate Blood oxygenation Temperature
Lee, D. et al. (2017) ¹⁵	Glove System	Stress Event Detection	Photoplethysmogram (PPG)
Zhang, X. et al. (2017) ¹⁶	Driver's Hat Driver's Chair	Fatigue Detection of Rail Driver	Electroencephalography (EEG)
Masci, F. et al. (2022) ¹⁸	Chest worn	Body posture impact of physical load	Heart rate Trunk posture



Chen, B. et al. (2019) ¹⁹	Backpack	Lift load detection	Electromyography (EMG)
Hinze, A. et al. (2022) ²⁰	Smart Shirt	Quality of health and safety	Heart rate variability Galvanic Skin Response

According to Table 2, the equipment classification and capabilities of each study differ in their ability to ensure safety, which is the primary objective of using wearable devices in the workforce. This is because the type of work is highly risky and potentially life-threatening. In addition, work efficiency is a crucial concern since it involves high levels of physical activity and requires extended periods of time. Performance assessments are a standard method to improve work performance. They help to evaluate and increase the outcomes.

Another method is the development of tools that enable better and faster collaboration among workers. Also, they could apply these tools to make wearable devices for the public. Finally, the available data indicates that there is limited observation and warning of work that poses health risks. This underscores the importance of enabling workers to perform pre-operational health care and assessments, as well as self-care, to mitigate potential hazards.

1. Safety

First, this studied a personal proximity warning system (PWS) based on smart helmets, which is well-suited for high-risk environments such as underground mines. The PWS can identify and respond to dangerous situations, as depicted in Figure 6¹⁴.

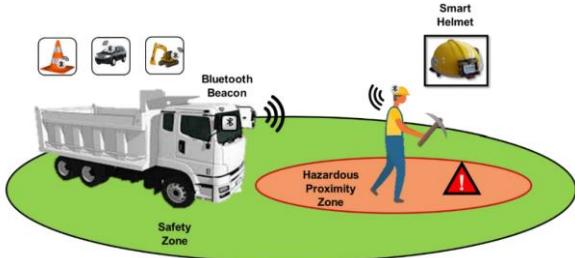


Figure 6. Overview of dangerous situations when using smart helmet¹⁴.

Source:

www.ncbi.nlm.nih.gov/pmc/articles/PMC9739423/

Next, this studied about wearable devices that were expected to evolve and integrate into clothing as part of the Internet of Things (IoT) technology¹⁴. The development of smart garments can detect various physiological and environmental signals, which can be useful for ensuring the safety of workers, as shown in Figure 7.

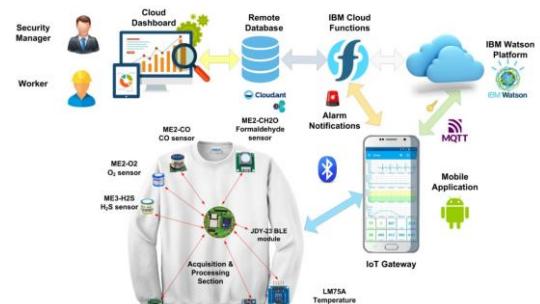


Figure 7. Smart Garment detection integrate flow visualization¹⁵.

Source: www.mdpi.com/2076-3417/12/6/2926

Next, this studied wearable devices such as smart gloves that can detect stress events from drivers in real time. The study suggested that drivers on the road, especially those working under time constraints or pressure, may experience stressful events¹⁵. Smart gloves can measure weather and environmental conditions and provide personalized feedback to the driver¹⁶.



(a)

(b)

Figure 8. (a) Smart glove with sensor for detection description and (b) Driving Simulation via smart glove detection¹⁶.

Source: [www.ieeexplore.ieee.org/document/7736144](https://ieeexplore.ieee.org/document/7736144)

Finally, this study focused on a wearable glove with stress analysis and alarm modules integrated into an end-terminal application, as shown in Figure 8 (a). The Euro-truck driving simulator v2 further complements the application, which interfaces with a Logitech G29 driver interface, featuring a throttle pedal, brake pedal, and steering wheel, as illustrated in Figure 8 (b). In other studies related to the transportation industry, researchers proposed a wireless wearable EEG system for detecting fatigue in high-speed train driver smart hats, as depicted in Figure 9 (a).



Figure 9. (a) Concept of smart hat (b) Driving Simulation for fatigue detection¹⁷.

Source: www.mdpi.com/1424-8220/17/3/486

Figure 9 (b) shows the experiment setup and driving scenario with a headband prototype for wireless wearable EEG data collection¹⁷. This design is for the uniform of train drivers who work in trains. In addition, this system includes an early warning system that detects drivers' fatigue and notifies them through a massage chair to prevent high-risk events. Figure 10 (a) shows the massage chair interface between the cloud and Bluetooth, which is installed in the chair and sends fatigue warnings to drivers. The working principle of smart chair was designed to be an early warning system when signal from Brain Computer Interface (BCI) system which detects driver's alertness level. The smart chair alerts drivers immediately with eight message head positions via Bluetooth. Figure 10 (b) shows the massage chair prototype built in an electrical circuit.



Figure 10. (a) Concept of massage position and Bluetooth receiver position (b) Smart chair prototype¹⁷.

Source: www.mdpi.com/1424-8220/17/3/486

2. Productivity

First, this study focused on wearable devices for safety improvement, Lee W et al. explored wearable devices for enhancing productivity by reducing the workload of workers. This review reports on such a study that focused specifically on the construction industry, a sector concerned about workers' workload as shown in Figure 11 (a).



Figure 11. (a) Example of stooping while doing work of a worker (b) Using the side body of the construction worker to carry heavier materials¹⁸.

Source:
www.sciencedirect.com/science/article/abs/pii/S0926580517305228

As shown in Figure 11 (a), workers are stooping while doing work in front of the body that is a neutral human posture. While Figure 11 (b) the position of the

construction worker represents how work with non-neutral posture movement affects performance and productivity working. This outcome focused on the physiological status of duty workers in-out activities of a workday¹⁸. Finally, this studied an Ergonomic safety behavior was measured via a chest-worn device, and data was collected from electrocardiogram (ECG) signal during working hours about on-duty activities.

Also, off-duty activities were tracked, such as sleep quality that measured health and well-being of worker. Masci F et al. studied the biomechanics of loggers, paying particular attention to the physiological effects of workload, posture, and bio-harness measurements, which be detected by wearable sensors to identify critical factors affecting loggers¹⁹.



Figure 12. (a) ECG device detected via chest-worn (b) Logger activities on workday¹⁹.

Source: www.mdpi.com/1660-4601/19/13/7695

Figure 12 (a) shows wearable device detection for loggers with more posture position as lifting heavy loads, and repetitive movement of logger that caused injury. However, Figure 12 (b) shows the activity of loggers on working day that affects workload and performance. The data collection measured what activities affect loggers and guidelines for demand workload to logger by individual. Wearable sensor devices were utilized in the study for detection and analysis, and were found to be effective in improving productivity, reducing musculoskeletal disorders, and promoting physical activity among workers. However, there was limited evidence available on the safety of wearable devices in the workplace.

3. Health

First, this studied of Ergonomic detection is a major concern for workers engaged in physical activity. Chen B et al. studied this issue by focusing on detecting lifts using a hip exoskeleton, as shown in Figure 13 (a), (b), (c), and (d).

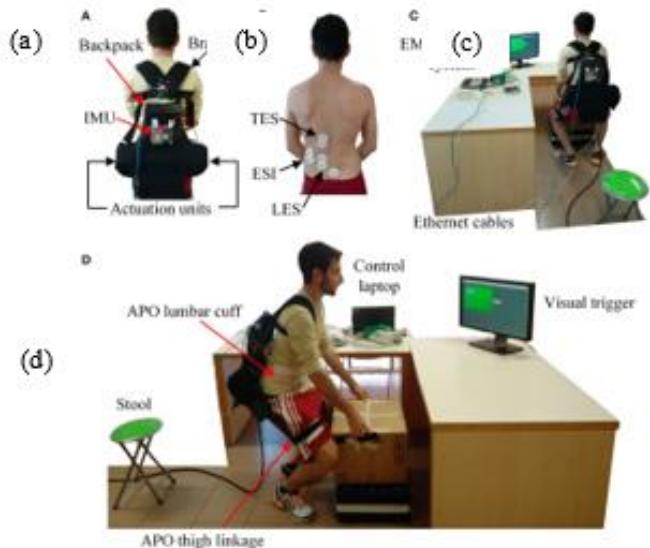


Figure 13. (a) Backpack for lift detection (b) The positions of back biomedical sensor pad electrode paste sheet (c) Back view of ergonomic detection activity simulation (d) Subject demonstrate how to lift box experimental set up²⁰.

Source: www.frontiersin.org/articles/10.3389/fnbot.2018.00017/full

To improve workers' health and well-being in the workplace, the industry has started motivating workers to wear wearable devices. As Figure 13 (a) shows, the subject is wearing an active pelvis orthosis (APO) that includes an inertial measurement unit (IMU) and commercial Electromyography (EMG) recording system. Also, inside the shirt of subject place electrode used to measure EMG levels. Figures 13 (c) and (d) show an experimental demonstration of lift detection via back worn which the subject got a task for operating lift activities²⁰. The lift condition can be divided into two types: the first position is for monitoring body posture (front left, front, front right). When lifting a load, different techniques can be used (stoop, squat, freestyle). One is stoop lifting, where the knees are almost straight, and the hips and spine are bent

forward. Another one is squat lifting, where the knees are fully bent, and the spine is upright.

A third one is freestyle lifting, where the person uses their preferred method to lift the load. Finally, we conducted a study on smart shirts for health and well-being of forestry workers, and emphasized the need for a monitoring solution in the industry that prioritizes self-awareness for any health detection²¹.

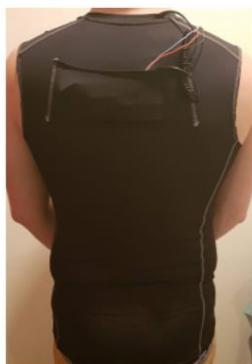


Figure 14. Smart Shirt for body-worn detection (prototype version)²¹.

Source: www.sciencedirect.com/science/article/abs/pii/S2352648321000465

Finally, this studied the main functions: lightweight for wearing, comfortable to wear during on-duty, recognized to use long term and suitable for daily use shown in Figure 14. Wearable technological features such as biofeedback can help in preventing and detecting primary health concerns for workers and allow for early intervention before any high-risk events occur in the future.

Challenge and path forward

Wearable technology is being developed and studied in all the previously listed garments and equipment in technological innovation research. However, these gadgets are still in the development stage, and even if one understands how to use them, they are not yet ready for widespread use. Working together based on investment and R&D considerations Since this section lacks analysis from the standpoint of individuals involved in policy release, it is necessary to include the breakeven point in development. The

strategic planners of the organization's direction will oversee monitoring and publishing requirements if the latter fail to acknowledge their significance. The only way to address the premise of innovative education in wearable device technology is through expansion or development. Wearable technology innovation and development still need to be delayed since the investment in this area is greater than that of decision-makers. Hence, the difficulties that businesses experience will have an impact on everything from product development to commercial production. In the future, they intended to integrate cutting-edge wearable technology into operations from the perspective of operators.

Conclusion

According to these studies, advances in wearable technology are currently popular and have a significant impact on several businesses. Innovative wearable technology is emerging in various professional groups. Associations of industries research data on cutting-edge wearable technology in a range of fields including calculating the work's efficacy and efficiency. Identify the circumstances that could lead to operational dangers or workers physical and mental health care. The researcher discussed the advantages of wearable technology advancements and provided instances that aligned with the interests of operators and those responsible for issuing regulations to be followed and additional organizational requirements.

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