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IoT role in women safety: A systematic literature review

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Abstract

Safety has become a major concern for women, children, and even the elderly from all walks of life. Today, women can compete with men in every field, but unfortunately, this progress often comes at the cost of abuse, harassment, and brutality in public places and even at home. Women are not always allowed to leave their homes freely or go to work in peace. In such situations, they may feel helpless and unable to protect themselves or alert their family, neighbors, or the police. Due to the lack of safety measures, crime rates against women and children in India have risen to unprecedented levels. Therefore, systems must be in place to protect them during such times. Greater awareness and technological support are needed to reduce the number of crimes against women and children.The Internet of Things (IoT) is playing a key role in improving women's safety through various innovative applications and technologies. This review was conducted based on research articles published in reliable media, such as journal articles and conference papers. The results showed that different types of sensors are used to detect women's conditions, including pulse, movement, and body temperature, which can pose safety issues. Pressure sensors are the most commonly used in these devices. Moreover, these devices transmitted alerts using various technologies, such as the Global Positioning System (GPS) and the Global System for Mobile Communications (GSM). These were connected to small computers, such as Raspberry Pi, and microcontrollers, such as Arduino.

Keywords: IoT; GSM; GPS; Sensors; Raspberry Pi; Arduino

1 Introduction

Women's safety remains a pressing global issue, with many individuals experiencing various forms of violence and harassment in both public and private spaces. Despite the implementation of numerous preventive measures and legal frameworks, women still face significant threats to their security. Traditional approaches, such as public safety campaigns, self-defense training, and emergency hotlines, although valuable, often fail to provide real-time protection or intervention during critical moments.

The advent of the Internet of Things (IoT) offers new opportunities to address these safety challenges by leveraging interconnected devices, real-time monitoring, and advanced data analytics. IoT enables the creation of smart, responsive environments where devices like wearable sensors, mobile applications, and cloud-based platforms can work together to ensure the safety of individuals. These systems can provide immediate alerts, location tracking, and communication with emergency services or trusted contacts in dangerous situations.

IoT-based women's safety solutions have gained increasing attention in recent years due to their ability to operate autonomously, provide instant feedback, and offer discreet protection. Wearable safety devices, GPS tracking systems, and smart mobile applications are among the key innovations that have emerged in this domain. However, the

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effectiveness and adoption of these technologies depend on several factors, including technological infrastructure, privacy concerns, cost, and ease of use.

This paper presents a systematic literature review of IoT applications in women's safety, exploring the various technologies, frameworks, and challenges associated with their implementation. By analyzing the existing literature, we aim to provide an overview of the current trends in IoT-based safety solutions, assess their effectiveness, and identify potential areas for future research. This review also highlights the technological, ethical, and social challenges that must be addressed to create scalable and reliable IoT systems for women's safety.

The issue of women's safety has long been a global concern, with various forms of gender-based violence and harassment being reported across cultures, societies, and regions. According to the United Nations, one in three women worldwide experiences physical or sexual violence at some point in their lives, often within their own communities. Governments, non-governmental organizations, and activists have undertaken significant efforts to combat these problems, but traditional approaches alone have proven inadequate to address the growing complexity and frequency of such incidents.

Technology has historically played a role in advancing public safety, but the rise of the Internet of Things (IoT) presents new possibilities for protecting individuals in real-time. IoT is a system of interconnected devices and sensors that can collect, transmit, and analyze data without human intervention. Its potential to revolutionize safety systems is particularly significant, given its ability to create dynamic, context-aware environments where smart devices can monitor, detect, and respond to threats automatically [1].

The use of IoT in women's safety began with basic GPS-enabled devices designed to track a person's location. However, technological advancements have led to the development of more sophisticated systems that can not only track but also predict and prevent incidents based on various data points. These systems typically incorporate wearable devices, mobile applications, and cloud platforms that work together to provide real-time monitoring, emergency alerts, and communication with trusted contacts or authorities.

The growing interest in IoT-based safety solutions is partly driven by the increasing penetration of smartphones, advancements in sensor technologies, and the availability of cloud computing. Many women's safety devices now feature components such as GPS trackers, accelerometers, and microphones, which can detect sudden movements, sound abnormalities (e.g., screams), or changes in behavior that may indicate distress.

Despite the promise of IoT for improving women's safety, there are still significant challenges in its implementation. Connectivity remains an issue, especially in remote areas, and the ethical implications of constant surveillance and data collection raise concerns about privacy. Additionally, the cost and accessibility of these technologies can limit their widespread adoption, particularly in developing regions.

The current body of research highlights a range of IoT applications and solutions designed for women's safety, yet comprehensive analyses of their effectiveness, limitations, and future potential remain limited. This paper seeks to fill that gap by systematically reviewing the literature on IoT-enabled safety systems for women, offering insights into how these technologies have evolved and what needs to be addressed to make them more effective and accessible.

2 Key Technologies in IoT-Based Safety Devices

IoT-based safety devices for women integrate several key technologies to provide comprehensive protection and rapid emergency response capabilities. One of the foundational technologies is the Global Positioning System (GPS), which allows for accurate real-time location tracking. GPS plays a crucial role in sending precise location data to emergency contacts or authorities and can also enable geofencing, alerting users or their contacts if they leave or enter designated safe zones. Alongside GPS, Global System for Mobile Communications (GSM) facilitates communication by enabling devices to send alerts, make emergency calls, and transmit location data via mobile networks. These capabilities ensure that users can remain connected in times of crisis.

Motion sensors, such as accelerometers and gyroscopes, are used to detect sudden movements that might indicate a fall, struggle, or unusual motion patterns, triggering alerts accordingly. Additionally, pulse rate sensors monitor physiological responses, such as heart rate spikes, which could indicate stress or danger. By tracking the user's heart rate, these sensors can trigger an alert if abnormal stress levels are detected. For seamless data transmission and communication with cloud platforms, Wi-Fi connectivity is often integrated, offering high-speed connections and enabling real-time updates and monitoring.

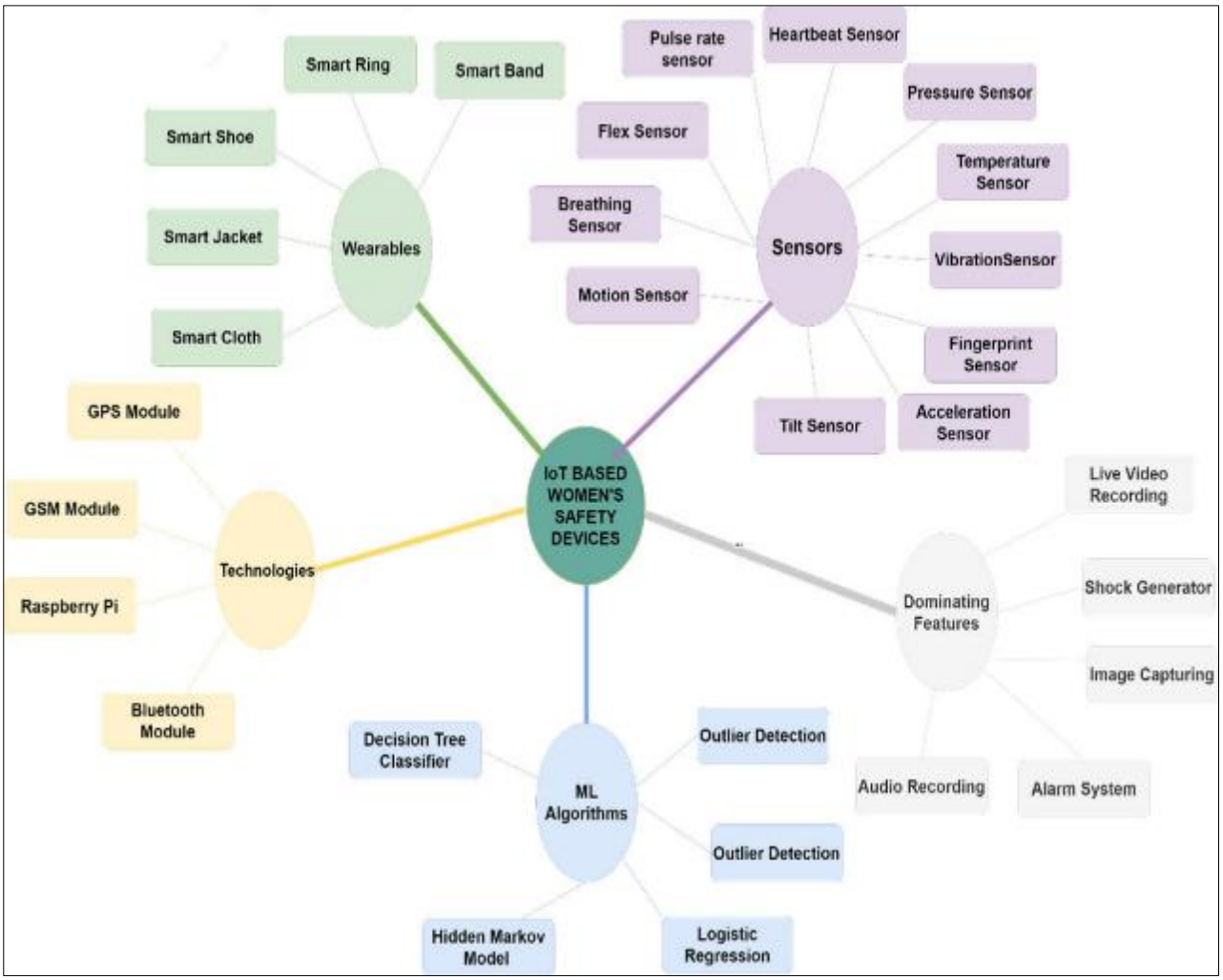

Figure 1 Devices of Women Safety system using IoT.

Microcontrollers act as the central processing units in these IoT-based safety devices, coordinating all the technologies. They process sensor data, run detection algorithms, and control the device's actions, such as sending alerts or activating emergency features. These components work together to create advanced safety solutions that monitor the environment and the user's physiological condition, respond to potential threats, and provide timely assistance by sending location data to emergency contacts. As these technologies advance, they are becoming more efficient and accessible, paving the way for even more sophisticated safety solutions.

These technologies work together to create comprehensive safety solutions. For instance, a typical women's safety device might use motion sensors to detect a potential struggle, verify the situation using pulse rate data, determine the exact location using GPS, and then send an alert with location information using GSM or Wi-Fi, all coordinated by a microcontroller.

The integration of these technologies allows for the creation of sophisticated, responsive safety devices that can provide real-time protection and rapid emergency response. As these technologies continue to evolve and become more miniaturized and energy-efficient, we can expect to see even more advanced and effective safety solutions in the future.

3 Related work

We diagnosed IoT-based devices for women's safety to the best of our knowledge. Shaista Khanam and Trupti Shah [2] proposed an algorithm for women's safety using an IoT-based fingerprint module. This paper presents a detailed

approach to women's safety. In this system, a fingerprint is required to activate the device, which includes an electric shock-generating circuit, GSM, and GPS modules for alerting and location tracking. However, during emergencies, it can be challenging to place the finger on the fingerprint module, and recognition may be impossible if there is any unwanted substance (moisture or dirt) on the finger. To avoid this problem, the fingerprint module will not be used in the proposed system.

Naeemul Islam, Md. Anisuzzaman, Sikder Sunbeam Islam, Mohammed Rabiul Hossain, and Abuja Mohammad Obaidullah [3] developed a device for the safety and security of women. This device employs three push buttons to define the types of accidents the victim may be facing. A PIC16F887A microcontroller is used to control the entire device. Since this is a 40-pin IC, it increases the size of the device, making it difficult for women and children to carry at all times.

Sharifa Rania Mahmud, JannatulMaowa, and Ferry Wahyu Wibowo [4] proposed an algorithm for women's empowerment. This paper discusses violence against women and various health issues they face. It is an application-based device. In the event of molestation, the software on the victim's phone will automatically send an emergency call to assigned contacts. This can only work if GPS is enabled on the phone; if not, the time taken to activate the GPS is a noted disadvantage of the project.

AnandJatti, MadhviKannan, Alisha RM, Vijayalakshmi P, and Shrestha Sinha [5] developed a wearable device that utilizes physiological signals such as galvanic skin resistance and body temperature. Data is monitored using a cloud platform and analyzed using MATLAB simultaneously. If there is any unexpected deviation in the physiological parameters, a notification will be sent to the parents. However, body temperature may also change due to other reasons, so it is not reliable to consider body temperature as a parameter for designing a device for women's safety.

Sunil K Punjabi, SuvarnaChaur, UjwalaRavale, and Deepti Reddy [6] developed an intelligent device for women and children. In this device, they use a pressure switch. When the user feels unsafe, they must press the switch, and a notification will be sent to parents, followed by a call. If the call goes unanswered, it will be redirected to the nearest police station.

M. Kavitha and V. Sivachidambaranathan [7] proposed a device for women's self-safety using IoT. This device utilizes several biosensors to detect the user's physical changes. If any abnormalities are detected in women, a notification can be sent to a guardian according to the pre-application of the tool. A smart safety device for women using IoT was presented earlier [8]. This device requires human intervention to activate, such as pressing a button or shaking the device, etc. The hardware comprises a wearable "smart device" [9] that constantly communicates with a smartphone that has internet access. The implementation of the smart device is primarily divided into two sections: the first component ensures capturing the image of the culprit. It is automatically triggered when any suspicious movement is detected in front of the camera, and the device will capture the image of the attacker and send it as an attachment to the concerned email ID, along with the location of the victim.

Another safety tool proposed is the development of Suraksha, a women's safety device [10]. The incidence of crimes against women has decreased with the help of a device known as Suraksha. This paper presents the fundamental concept underlying Suraksha, which is to send a warning providing the instantaneous location of the distressed victim to the police so that the incident can be prevented and the offender arrested. However, this tool is not sufficient to protect women against crime. In another study, ProTech implemented an IoT women's safety tool [11]. Due to the increase in crime rates against women, their safety is a major concern in this era. For self-defense, the device delivers an electric shock to the attacker via a nerve stimulator and rings a buzzer upon pressing a button to help the individual defend herself. It also allows for evidence recording through a video camera, which is activated by the button and stores images in the Raspberry Pi. The prototype model includes a GSM and GPS module, which can be activated by voice command through an Android application. When the user says "emergency" in the mobile app, the device sends an SMS alert containing the user's location and automatically dials the pre-set emergency contact number.

A study proposed by B. Sathyasri will inform parents and police about the current location of women [12]. A GPS device is used to trace the victim's current position, while a GSM device sends messages to pre-defined numbers. This work discusses violence against women (VAW) and various health issues affecting women. We have designed and presented a skeleton of a user-friendly mobile application named Women Empowerment that can incorporate all relevant laws. Ruman et al. developed a safety assistant for women using Arduino to locate the victim, alert the concerned individual and the police, and also generate an electric shock for protection [13]. Sharma et al. used Raspberry Pi to design a smart shoe that functions as a tracker for women, children, and the elderly, equipped with a GPS module and a self-defense mechanism using a buzzer [14].

A research survey on women's safety using IoT was provided [15]. The scope of this survey focused primarily on mechanisms used for detecting human body sensors and highlighted the limitations of previous studies. Another study [16] provided a survey and assessment of existing works discussing parent tools for the safety of women. The researcher developed a unique parent tool to receive alerts. This tool is designed to work with sensors, and women in danger need to activate the button to send an alert to their guardian. Although the tool depicts an effective solution for potential victims, a shortcoming is observed, as the victim has to operate the tool for its activation, while individuals in danger are often immobilized, making specific actions difficult.

Reference [17] provided a literature review on recent and emerging technologies used for the protection and safety of women. The researchers conducted online searches on women's safety devices, showcasing new and emerging technologies. However, this study has effectively applied IoT-based technology by presenting an IoT-based women's safety architectural model. A women's safety jacket in [18] was designed using Raspberry Pi and a GPS module to track the female's location. While women can wear the jacket anywhere, there are times when wearing it is not feasible. The device proposed in [19] uses GPS, Raspberry Pi, and a camera. The tool operates automatically using a machine learning algorithm by taking values from connected sensors. A concern with this specific tool is that it cannot function without internet connectivity; in the event of a kidnapping, the kidnapper could take the victim to an area with no internet connection.

In [20], the author proposed a device using IoT-based technology with GPS and GSM modules to track location and send messages; however, the device is designed in such a way that the victim has to activate the button to trigger it. After triggering, the device takes 3 seconds for the first buzzer. The user has to again activate the button for the second buzzer, which takes another 10 seconds. This device relies on human interaction, which takes time for activation. During an attack, no one can control the tool. Upon changing locations, the victim must repeat the activation process. The device should be designed to activate automatically. It is designed to send a URL location to the victim's guardian [21], but the downside is that it may not work in areas without internet access.

In [22], a women's safety gadget covering all the issues of previously designed devices is created using GPS and GSM modules to track location and inform guardians. It includes a hidden camera and audio recorder to assist police investigations. However, the device activates the buzzer upon activation, alerting the attacker who could then seize the device. The device should be designed so that no one can detect it. A system designed for the protection of women in danger in [23] utilizes GPS and GSM technology to send a customized message for help during an alarming situation. Like many other devices designed with human interaction, this model also has the disadvantage of requiring human involvement. It works by pressing the button.

A beacon device introduced in [24] is designed using GPS and GSM modules with Bluetooth capability. The device takes readings from the victim's posture and predicts whether the woman is in danger based on her posture. A smart ring [25] designed for women's safety includes a buzzer with an activation button. After activation, it sends the current location via GPS and captures the attacker's photo through the Raspberry Pi camera to emergency contacts. It also has an electric shock generator that can deliver a shock to the attacker. It shares the same drawback of requiring human interaction as seen in many other devices. A low-cost smart shoe tool [26] is activated by tapping one foot in front of the other three times, which turns on the GPS and GSM. It has been analyzed using a decision tree classifier. Values from the woman's movement sensor are fed to the decision tree classifier.

A smart band or watch [27] with a button can collect data such as location, body posture, and pulse rate and send it to the predefined number using GSM through Raspberry Pi. The readings are collected from the pulse rate sensor; however, the drawback is that the pulse rate can change for various reasons. Another smart device [28] for women's safety is automated to collect pulse rate and stress using outlier detection

4 Challenges and Limitations

When discussing the challenges and limitations of IoT-based devices for women's safety, several key factors emerge [28]:

- Many devices require user interaction for activation (e.g., pressing a button), which can be impractical in high-stress situations where the victim might be immobilized or unable to act quickly.
- Devices often depend on specific environmental conditions, such as GPS and internet connectivity. In areas with poor signal, these devices may fail to provide accurate location tracking or alerts.

- Systems based on physiological parameters (e.g., heart rate or body temperature) may trigger false alarms due to normal fluctuations caused by stress or environmental conditions, leading to user desensitization or lack of trust in the system.
- Collecting sensitive data (location, health metrics) raises privacy concerns. Unauthorized access or data breaches could compromise user safety rather than enhance it.
- Many IoT devices are reliant on batteries that need regular charging. A depleted battery can render the device useless in emergencies, and users might neglect maintenance.
- Difficulty in integrating with local law enforcement or emergency response systems can hinder the effectiveness of alerts sent from these devices, delaying help when needed.
- The cost of advanced devices may limit accessibility for some users. Affordable solutions may compromise on features, reducing their effectiveness.
- Users may require training to effectively use these devices, and there may be a lack of awareness regarding their functionality, leading to underutilization.
- In some cultures, social stigma or fear of repercussions may deter individuals from using such devices, limiting their adoption and effectiveness.
- Many devices do not incorporate context-aware features, which can lead to misinterpretation of situations. For example, a loud noise may be misinterpreted as a threat, causing unnecessary alerts.

Despite the promising advancements in IoT technology for women's safety, these challenges highlight the need for continued research and development to create more reliable, user-friendly, and context-aware solutions that prioritize user safety and privacy. Addressing these limitations will enhance the effectiveness of IoT devices in real-world scenarios, ensuring that they serve their intended purpose of protecting women's safety[29].

4.1 Future Directions

The future directions for IoT-based devices aimed at enhancing women's safety can be explored through several innovative and strategic avenues[30-33]:

4.1.1 Integration of Artificial Intelligence (AI)

- Predictive Analytics: Implement AI algorithms to analyze behavioral patterns and predict potential threats before they occur. This can include recognizing unusual patterns in heart rate or movement that may indicate distress.
- Natural Language Processing (NLP): Develop systems capable of understanding and responding to voice commands for activation during emergencies, reducing reliance on physical buttons.

4.1.2 Enhanced Connectivity

- Mesh Networking: Utilize mesh networks to maintain communication between devices even when traditional cellular networks fail, allowing for consistent location tracking and alerts.
- Offline Functionality: Design devices that can operate independently of internet connectivity, using local processing capabilities to provide alerts and maintain communication.

4.1.3 Multi-Modal Sensors

- Diverse Sensor Integration: Combine various sensors (e.g., audio, motion, temperature, and heart rate) to create a more holistic understanding of the user's environment and context, allowing for more accurate threat assessment.
- Wearable Technology: Expand wearable options, such as jewelry or clothing, that discreetly integrate safety features without compromising on style or comfort.

4.1.4 User-Centric Design

- Customization and Personalization: Allow users to customize their safety features according to their specific needs and preferences, including tailored alerts and emergency contacts.
- User-Friendly Interfaces: Develop intuitive interfaces for easy access and understanding, minimizing the learning curve for users.

4.1.5 Community Engagement and Awareness

- Social Connectivity: Integrate community-based alert systems that allow users to share their locations and safety status with trusted friends or community members in real-time.
- Awareness Campaigns: Educate communities about the availability and use of safety devices, empowering more individuals to adopt these technologies.

4.1.6 Data Security and Privacy Enhancements

- Robust Encryption: Implement advanced encryption techniques to secure personal data, ensuring that users' information is safe from unauthorized access.
- Transparent Data Policies: Establish clear user consent and data management policies, allowing users to control how their data is used and shared.

4.1.7 Collaboration with Law Enforcement

- Direct Communication Channels: Create systems that allow devices to communicate directly with law enforcement agencies, ensuring faster response times during emergencies.
- Training and Integration: Provide training for law enforcement on the functionalities of these devices, fostering better collaboration in emergency situations.

4.1.8 Research and Development

- User Feedback Mechanisms: Continuously collect and analyze user feedback to refine and enhance the design and functionality of safety devices.
- Collaboration with Experts: Partner with sociologists, psychologists, and safety experts to better understand the needs and fears of potential users, leading to more effective solutions.

4.1.9 Global Perspective and Inclusivity

- Cultural Adaptation: Consider the cultural context in which devices are used, ensuring that solutions are adaptable and respectful of local norms and practices.
- Affordable Solutions: Focus on developing cost-effective devices that are accessible to a wider audience, particularly in low-income communities.

The future of IoT-based women's safety devices lies in a multi-faceted approach that combines technological advancements with user-centered design, community engagement, and robust privacy protections. By addressing current limitations and harnessing innovative technologies, we can create more effective solutions that empower women and enhance their safety in various environments.

5 Conclusion

The evolution of IoT-based devices for women's safety marks a significant advancement in personal security technology. As highlighted throughout this review, these devices leverage innovative technologies such as GPS, GSM, and various sensors to offer real-time monitoring and emergency alerts, significantly enhancing personal safety. However, the effectiveness of these systems is often hampered by challenges such as the need for user interaction, connectivity issues, and concerns about data privacy and security.Moving forward, addressing these challenges is crucial for the development of more reliable and user-friendly safety devices. By incorporating artificial intelligence for predictive analytics, enhancing connectivity through mesh networking, and focusing on user-centric design, we can create systems that not only empower women but also provide seamless and unobtrusive protection.Moreover, fostering community engagement and collaboration with law enforcement will further strengthen the impact of these technologies, making them an integral part of women's safety strategies. As we navigate the future of IoT in this context, a holistic approach that prioritizes inclusivity, affordability, and cultural sensitivity will be essential. By embracing these future directions, we can help ensure that women everywhere can feel safer and more secure in their daily lives, ultimately contributing to a broader societal shift towards equality and empowerment.

Compliance with ethical standards

Disclosure of conflict of interest

Authors have declared that no competing interests exist

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