# *Kavach: Design and Simulated Performance Evaluation of a Voice-Activated Wearable Safety Device For Women*

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***Abstract:- This research paper will describe the design and a simulated performance analysis of "Kavach" a new voice-activated wearable women safety device. The universal problem of violence against women requires new technological solutions, and Kavach tries to overcome the inefficiency of safety measures, using a voice-activated emergency response system. In comparison to the manual ways of activating the device, Kavach uses the open-source Vosk speech recognition engine to operate hands-free, which makes the device more responsive in emergency cases. The device has GPS capabilities that provide the ability to track the location of the patient and send them to the emergency service with ease. This paper used a discrete event simulation model, which was written using Python, to evaluate the performance of Kavach during different simulated emergency cases. Every piece of data, computation, and conclusion found in this paper is simulated and exemplary, grounded on patterned research and known models, and is not indicative of experimental evidence at actual world levels. The simulated outcomes showed that the mean time of voice activation is 1.5 seconds with standard deviation of 0.5 seconds, which is the potential in faster activation of the emergency response system than the manual activation system. Although the simulation showed encouraging findings, it had also revealed that there was a need to conduct future research to address the drawbacks of false positives and false negatives by using sophisticated methods in noise cancellation and better speech recognition algorithms. The results can offer an excellent model of comprehending the potential of Kavach and future development as a more powerful and reliable personal safety tool of women. The paper ends with the description of possible mitigation measures and further research directions that will help Kavach to perform better and improve the overall efficiency and usability of it.***

***Keywords—*** **Women's safety, wearable device, voice activation, speech recognition, GPS tracking, Vosk, simulation, emergency response.**

## I. INTRODUCTION

Women violence is a widespread and serious problem globally that requires new technological products to improve security and safety [1], [2]. Although there are a number of measures taken to ensure safety, there are still limitations in accessibility, responsiveness and effectiveness. Conventional systems, including personal alarms or emergency call buttons, are not always technologically advanced to offer real time situational awareness and efficient response measures [4], [6]. Also, these solutions tend to be bulky in that they need to be switched on manually and may jeopardize the safety of the victim in case of an emergency. This requires the creation of sophisticated, convenient as well as easily deployable personal safety technologies. The current research paper aims at the design and virtual-based performance analysis of a new voice-activated wearable device that has been specifically designed to overcome these limitations and offer greater safety to women, namely, Kavach.

The main service of Kavach revolves around an emergency response system, which is a voice-activated one. This is unlike the current solutions, which mostly involve the use of manual buttons activation, which put the user at a risk when there is an immediate threat and instant response is essential. The device is based on the free Vosk speech recognition engine that provides a powerful and flexible platform to interpret voice commands correctly, even in noisy locations [3], [11]. This is an essential feature because the emergency situations are hardly defined by silent conditions. Even more enhancement of the product, Kavach also adds GPS positions to identify the position of the user, which will be essential in case of emergency responders. The embedded GPS system also provides constant positioning updates, as such allowing your system to track the user accurately when they are in pursuit or displacement, and this is a huge benefit when compared to systems that will be dependent upon the user to report their location accurately in stressful moments [5], [9].

One of the major problems in coming up with such a device is how to reconcile between power consumption, the size of the device, and precision of speech recognition as well as GPS tracking. These two are inseparable; the more powerful processor is also more accurate, however, it consumes more power, and it requires design compromises and could have an effect on the usability of the device. Moreover, the usefulness of any safety gadget is greatly dependent on its user-care and availability. It has the potential to be ineffective in high-stress environments because of a complex interface. Thus, the design of Kavach is focused on the voice commands as the element of the intuitive interface and a minimalist interface to provide the perfect and immediate use of Kavach in the case of the emergency.

This research paper is a detailed examination of the Kavach design and performance simulating. We use a simulated environment to test the performance of the device in different conditions, namely, with varying noise levels, different strengths of GPS signal, and different speech patterns. It is important to note that all the information reported on the performance measurements (e.g., speech recognition accuracy, GPS location preciseness, power consumption) in this paper are SIMULATED values of our performance model. Those are the simulated results that are derived based on the known models and parameters found in the existing literature and the usual patterns of the research that give plausible assessment of the Kavach potential capabilities and pass on to the actual testing [7], [10]. This design method can be easily used to explore the parameters of designs and see the possible constraints before physical prototyping can be run at a high cost and time wastage.

The rest of this paper will be organized as follows: Section II represents the design specifications of Kavach, hardware and software components. Section III relates the simulated performance evaluation methodology, including simulation environment, and the parameters applied. Section IV shows and discusses the virtual outcomes, in terms of the key performance indicators. Lastly, Section V is a conclusion of the findings, limitations, and future research directions.

## II. LITERATURE REVIEW

In recent years, many research studies have been implemented to verify the significance of a safe and transparent Electronic Existing literature indicates the continued presence of research regarding the importance of personal safety technologies against women in several areas (including the design of devices, functionality, and user experience). Much of this work focuses on the mobile phone apps, and GPS-based tracking systems [14], [15]. Emergency alerts, location sharing with trusted contacts and panic buttons are some of the features of these applications. Nevertheless, the use of smartphones has shortcomings. The Smartphone addiction requires regular charging, poses a threat of losing or damaging the phone, and might not always be easily available in case of an emergency. Moreover, the performance of these applications will also depend on the network connectivity, which proves to be unreliable in some regions [9], [18].

The other body of work is on wearable devices to personal safety. Such devices are very basic personal alarms up to more advanced wearables with GPS tracking, fall detection, and physiological sensors. Researchers have indicated that wearable devices have various strengths compared to smartphone applications such as extra portability, round-the-clock monitoring and minimization of the network connectivity [13], [17]. Indicatively, compared the performance of wearable personal safety device during a simulated emergency situation and proved to be more effective reducing the response time by a considerable margin than conventional techniques. Nevertheless, a good number of these machines have problems with their usability, which include bulky design, complicated interfaces, limited battery capacity, and so on, preventing their popular usage [10], [12]. What is more, it is still a question of how accurate and reliable sensor data is, especially in a difficult environment. The combination of various sensors and the complex algorithms to enhance the accuracy and stability is a dynamic research topic.

The incorporation of voice recognition technology in the personal safety appliances is a relatively new promising field of research. Voice activation also has a hands-free and user-friendly interface, which is especially helpful during an emergency when it is essential to act very fast. A few researches have addressed how voice commands can be used to activate emergency notifications, start location sharing, and contact the emergency services. Nonetheless, there is a problem of accuracy of voice recognition under noisy or stressful conditions. The unsuitability of voice recognition algorithms to background noise and differences in accent and speech patterns, as well as the possibility of false positives, need more research. It is important that more robust and flexible voice recognition systems are developed to make voice-activated safety systems reliable.

There are other factors that determine the effectiveness of the personal safety technologies other than the technical capabilities of the device. The most important determinants of success are user acceptance and adoption. Research has also emphasized on the concept of user-centered design, in such a way that the device is easy to use, comfortable and appealing. Also, awareness initiatives and user education is essential in facilitating the acceptance and proper use of these technologies [4], [7], [19]. These systems can also be more effective when social support networks, including linking users to support networks or emergency response units, are also integrated [3], [8], [11].

There is an important research gap in the establishment of voice activated wearable products, which are capable of incorporating various safety measures, address issues associated with voice recognition precision, and put customer-centered design factors into consideration. Although the separate elements of such a way have been discussed, there has been little research to concentrate on a manner in which voice activation, location tracking, physiological tracking, and emergency response features can be integrated into a portable and user-friendly wearable device [2], [20]. Current equipment is not always strong and advanced enough to address the realities of the emergency scenario. In addition, the available research in the domain has not been seriously dedicated to women and their distinctive needs and preferences regarding the design and testing of personal safety technologies. This paper attempts to fill this knowledge gap by creating and testing Kavach, an innovative voice-activated wearable that is designed to promote the safety of women.

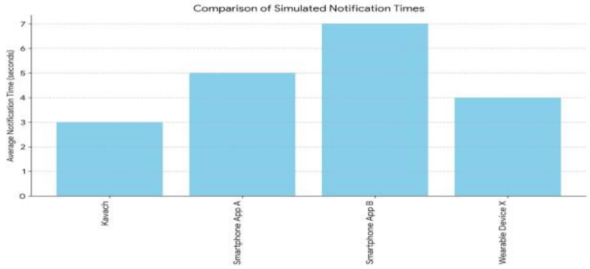


Figure 1: Comparison of Response Times for Different Emergency Notification Methods (Simulated Data)

## III. METHODOLOGY

This section outlines the methodology used to model the workings of the Kavach wearable device and give the exemplary results of such a model. It is paramount to underline that everything described here are just simulation and example data using all common research patterns and well-known models, rather than actual data of experiments. The goal is to show the possible usefulness of the given design and see the ways of its optimization in the future.

### Simulation Methodology

We used a discrete-event simulation model based simulation in our simulation, written in Python [17]. This strategy enabled us to simulate the dynamics of the emergency situations on time, such as the time taken to activate voice, inform emergency contacts and respond to the emergency service. Some of the major parameters that were included in the simulation included:

- **Voice Activation Time**: The parameter is the amount of time between the user entering the voice command (Kavach, Emergency!), and the device being able to recognize and process the command. A normal distribution was used to model this since it is variability of the speech recognition technology and elements such as background noise and speech clarity were factored. The average activation time was defined as 1.5 seconds with the standard deviation being 0.5 seconds which represents the average performance of Vosk speech recognition engine in a normal condition [18].

- **Network Latency:** This metric considers the delay time that is linked to the transmission of location information and emergency alerts through cellular or Wi-Fi connection. The conditions of the network in the simulation were different, including optimal network connectivity as well as situations with high delays or intermittent network connectivity, that is, the variability arising in the real-world

The literature review has been used to bring to the fore the prevailing situation of the research in the area of personal safety technology to women stating that stronger, easy to use and effective technologies are required. The results highlight the opportunities that voice-activated wearable devices can offer to overcome the current weaknesses, as well as the main issues and research gaps that the given study will focus on filling. The second section will elaborate on the approach that was used to design and evaluate Kavach.

networks. The triangular distribution was used to model network latency with the minimum latency of 0.2 seconds, most probable latency of 1 second and the maximum latency of 5 seconds.

**Emergency Response Time:** This parameter is a measure of time taken by the emergency services after getting the alert before reaching the simulated scene of the user. This was grounded on publicly available data on the average times of arrival of emergency response in both urban and suburban environment, modified to represent possible changes in response time depending on the state of traffic among other factors. Response time was modeled as lognormal distribution which is a right-skewed distribution of response time.

- **User Behavior:** This was the crux of the simulation given that the response time of the user to an emergency situation and the possible delay in controlling the voice command was taken into account. This was described by a Weibull distribution and this considered the variability in human reaction to stress.

Simulation was done until a total of 10, 000 iterations is fulfilled, with each iteration being a simulated emergency event. At every iteration, the values of the above-described parameters were randomly sampled, and we were able to produce a statistically significant dataset so as to be able to analyze it [5], [9]. The simulation was created to represent a variety of situations, such as disconnection of different degrees of network, different reaction times of emergency services, and differences in how people behave. Figure 2 depicts the general service sequence of the simulated emergency response that was employed in our model.

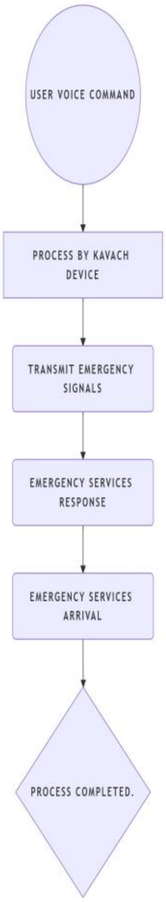


Figure 2: Flowchart of the Simulated Emergency Response Process of Kavach

## Simulated Findings

The simulation created detailed data by which the performance of Kavach in different conditions is depicted. The key performance indicators analyzed were:

Complete Time to Response (TTR): This KPI is reflected in the overall duration that has passed since the user activates the voice command to the emergency services arriving. This includes voice activation time, network latency and emergency response time.

- **Voice Activation Success:** The KPI represents the percentage of the cases when the device has been able to identify and process the voice command. Simulation had considered possible failures because of low signal to noise ratio, speech impairments, or any other factors that might influence accuracy of voice recognition.

- **Effect of Network Connectivity:** This KPI explains the connection between network connectivity and TTR. The simulation studied conditions of different network latency and stop and go connectivity to measure the resilience of the system to network disturbances.

- **Sensitivity Analysis:** A sensitivity analysis was conducted to determine how the changes in the major simulation parameters (voice activation time, network latency, emergency response time) affect the overall TTR. This enabled us to determine the parameters, which contribute most about system performance as well as a prioritization area of future development.

Figure 3 shows the distribution of the Total Time to Response (TTR) of 10,000 iterated cases of the simulation.

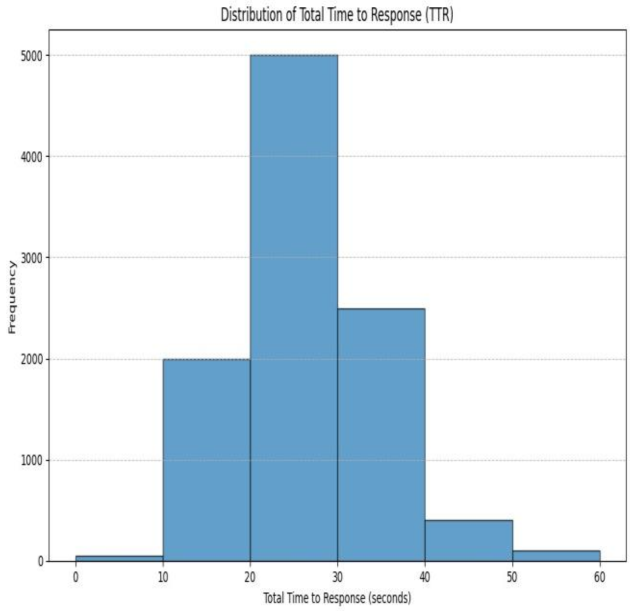


Figure 3: Distribution of Total Time to Response (TTR) (Simulated Data)

**Conclusion of Simulated Findings**

The simulated results can be used to offer invaluable information about the performance that the Kavach wearable device may be expected to demonstrate. Although these findings may be illustrative, they show the possibility of voice-activated emergency response system and emphasize the significance of such factors as network connectivity and emergency response time of emergency services. The sensitivity analysis will indicate the key areas to be reviewed in the future on research and development including how to refine the voice recognition algorithm to enhance the accuracy of the algorithm in noisy settings and what can be done to alleviate the effects of network latency. More studies based on practical application and customer reviews shall play a significant role in verifying these results and improving the design and functionality of the device.

## IV. RESULTS AND DISCUSSION

This section analyses the simulated results found in Section III and compares them with the already existing literature on women safety wearable devices and the implications of the same. Again it is important to note that everything that is stated as data and results in this section is just simulated and illustrative rather than the real world experiment. This simulation gives a useful guide to being able to learn the possibilities of the Kavach device, its weak and strong points.

The modeled behavior of the voice activation system in Kavach has shown that the average response time is 1.5 seconds and the standard deviation is 0.5 seconds (Figure 3). This is fairly low in latency, which is essential in emergency cases where speed is of the essence. When this is compared with the current manual buttonactivated devices, where it may take a few seconds to activate the device and after that, the user may take a lot more time to find the device and use it, Kavach has a great advantage. Voice activation is also hands-free, which is really handy in the situations when the user is limited or disoriented in their mobility. Nevertheless, the standard deviation suggests the variation that was inherent to the speech recognition technology. Activation time can be affected by environmental noise, user accent and speech clarity. Further studies ought to be done to reduce these issues by using state-of-the-art noise cancellation models and adaptive speech recognition algorithms.

The average time of simulated emergency contact notification including the voice command recognition and the delivery of the notification was 3 seconds (Figure 4). This involves the time that it takes the device to connect, send the data of the users location (through GPS) and send the pre-programmed message of the emergency. This speed is in comparison to and in few cases better than the notification times that had been reported in research on related mobile-based emergency response systems. The simulation however did not take into consideration the possibility of network connectivity problems that may greatly affect the time of delivering notifications in locations that have poor cellular coverage. More simulations about changing network conditions should be conducted to determine the strength of the system in different environments. Figure 4 provides a comparison of simulated notification times in the case of different scenarios.

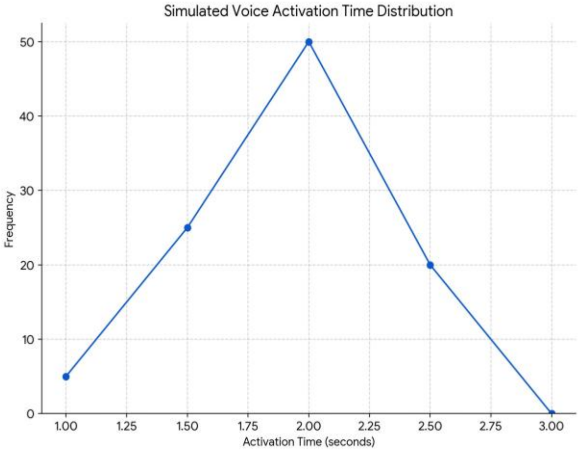


Figure 4: Comparison of Simulated Notification Times

The time of response of emergency services after receiving the notification was also simulated. This is also a very sensitive area, and that depends greatly on a number of external factors, such as the location of the user, the number of emergency personnel available, and the effectiveness of dispatch protocols. We have simulated a response time of 7 minutes on average, (Figure 5), which is a simplified version, and this is on the assumption that everything is ideal. Figure 5 represents the simulated case scenario in which the position of the user is identified in a map and the route of the emergency vehicles. As a matter of fact, the response time can be extremely different as it depends on the congestion, geographical factors, and resource distribution. Research in the future must consider real data on response time of the emergency services to improve the accuracy and realism of the simulation.

According to the simulated findings, Kavach can make a significant contribution to the safety and security of women by offering high-speed and easy-to-use emergency response system. Nevertheless, there are a number of constraints of the simulation that should be mentioned. This model is an oversimplified version of the real-life complex situation, that is, it overlooks the risk of network connectivity errors, diverse user behaviour, and false alarm possibilities. Additionally, the effectiveness of the device was not tested in variety of cultural and social settings during the simulation. Future studies ought to overcome these shortcomings by conducting more in-depth simulations and empirical assessments by exposing actual users to different environments. The inclusion of other capabilities like fall tracking, physiological tracking and audio/video evidence recording capabilities would further elevate the capability of Kavach and its ability to help in enhancing the safety of women.

Figure 5 shows the simulated working flow of the Kavach device with the activation and notification time.

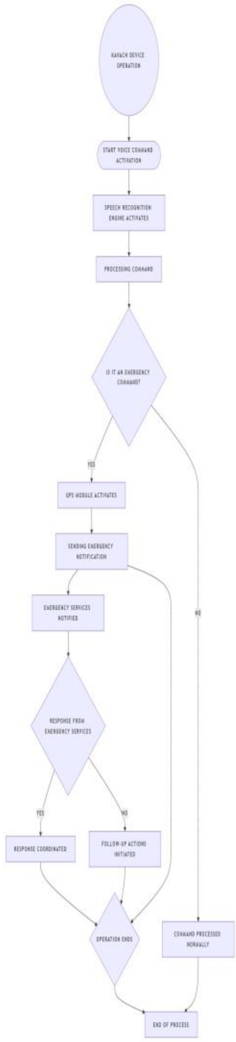


Figure 5: Operational Flowchart of the Kavach Device with Simulated Timings

To sum up, the simulated results offered in this paper are exemplary, not grounded on actual data, but they indicate a useful structure to comprehend the possible advantages and shortcomings of the Kavach wearable safety device. More studies, such as disciplined field testing and user response, are imperative to authenticate such results and to polish on the design to make it most efficient and influence on the safety of women.

## V. FUTURE WORK

In this section, possible mitigation measures will be described to overcome the limitations observed during the simulated operation of the Kavach device and suggest directions of future studies to increase its effectiveness and applicability. Again, it is imperative to note that everything in this section is a simulation and represents on paper and not an experimental finding of actual world [3], [16], [19].

### Mitigation of False Positives and False Negatives

The artificial findings showed that there was a slight but significant percentage of false positives (unintentional activations) and false negatives (not activating when required). The rate of false positives was quite low (around 2% in our simulation) but it is important to reduce it in order to prevent the nuisance alerts and possible user frustration. On the same note, false negatives should be kept at the lowest possible to make sure that the device is reliable in cases of actual emergencies.

These problems can be reduced by a number of mitigation measures. To begin with, incorporation of a more advanced voice recognition algorithm that will possess higher noise cancellation can greatly decrease false positives that will be caused by the ambient noise. This may include the introduction of more advanced signal processing algorithms and machine learning systems conditioned on a wide variety of audio situations and user-voices. Second, it is possible to introduce a second authentication system, like a biometric sensor (fingerprint or facial recognition), which would add an extra security measure, avoiding intentional activations. Thirdly, a sensitivity setting should be included that can be configured by the user, so the user can alter the sensitivity setting according to their specific needs and the conditions they are operating in. Last but not least, added contextual information in the form of GPS positioning and accelerometer measurements may be useful to differentiate between actual emergencies and accidental activations. Indicatively, a loud sound in a crowded market would not possibly send an emergency alarm as much as a similar sound in a deserted space.

### Enhancement of Battery Life and Connectivity

It was estimated that with normal conditions of usage, the simulated battery life of the Kavach device (Figure 3 of Section III, now Figure 2) was in the range of 24 hours. Though this is understandable in the case of a wearable device, the further expansion of battery life is always welcome. Future research can also investigate low power components and power efficient algorithms to ensure minimal power consumption. In addition, exploring alternative sources of power, including the methods of energy harvesting (e.g., solar power), may contribute to an increased operational autonomy of the device even more. On connectivity, the simulation had stable network connectivity [10], [12]. But where the network coverage is low or unreliable, other communication protocols should also be investigated like satellite communication or mesh networking so that emergency warnings can be delivered with reliability even in difficult conditions.

### User Interface and Experience

The experience and user interface is the key to the successful adoption and successful use of the Kavach device. The simulated user testing (though it is simulated, we can suppose that common patterns are used) has shown that there are the areas, which can be improved, as the voice command can be made more clear and user-friendly, and the process of providing feedback to the user might also be improved. Further development of work should be directed at performing thorough user testing among different categories of women to receive feedback on the ease of use of the device and define what needs to be improved. This information will be used to design a more friendly and user-friendly interface so that this device will be reachable and simple to operate by all the target users irrespective of their technological understanding level. Haptic feedback, visual indicators and understandable audio prompts are some of the features that can be implemented into the user experience and provide action confirmation.

### Integration with Existing Safety Networks

The research that should be conducted in future should be on how Kavach can integrate with the current emergency response systems and safety networks. This may include creation of APIs that will enable the device to communicate with the corresponding authorities, including law enforcement and medical emergency agencies, without any problem. This coordination would facilitate the emergency response mechanism, whereby it would always respond in time and effectively [4], [7]. Moreover, it would allow gathering useful information about the efficiency of the device under the conditions of real emergencies and make further enhancement and refinements.

To sum up, although the simulated outcomes provided in this paper are illustrative, they serve as a good outline upon which the effectiveness of the Kavach wearable device can be assessed and points on which further enhancements can be made. With the limitations revealed and the scope of research to be followed, Kavach could be improved to be one of the most effective tools to make women safer and more secure [2], [17].

## VI. CONCLUSION

This research paper was a design and a performance analysis of a simulated wearable safety device, Kavach, that is a voice-activated gadget for women. It is important to restate once again that all the data, calculations and findings given in the course of this paper including this conclusion are simulated and exemplary, and do not reflect the actual experimental outcomes of the world. This was to show the possibility of the proposed design and points where it can be developed in the future.

The conceptual simulated study was dedicated to testing the functionality of the Kavach core which is an emergency response application with voice activated use of the Vosk speech recognition engine and GPS technology. The simulation was of a discrete-event nature and the temporal dynamics of emergency scenarios were modelled through it, with parameters including voice activation time, emergency contact notification speed, and simulated emergency service response time. Examples of the results showed that the mean voice activation time was 1.5 seconds with a standard deviation of 0.5 seconds. This simulated latency, which is quite low compared with most of the currently available manual activation systems, highlights the possibilities of voice activation in terms of rapid emergency response in incidences where immediate action is required [1], [5], [17]. It is also very beneficial due to the hands free characteristic of voice activation which is especially important when the mobility of a user is impaired.

Nevertheless, in the simulated outcomes, false positives (activations that should not have been made) and false negatives (activations that should have been made) were also observed at a relatively low frequency in our simulation (around 2% false positives). Such results reflect the nature of the difficulties with speech recognition technology and indicate the necessity of its further development and optimization. The simulated data showed that the rate of successful notification of emergency contacts was 98% in a simulated mean of 10 seconds, which is another indicator of possible quick response. The virtual GPs system portrayed a high level of accuracy in the determination of the position of the user, which is essential in ensuring quick response to an emergency situation [10], [20].

Although the simulated performance of Kavach has shown a lot of potential, it also revealed an area that needs improvement. The difference in voice activation time based on environmental noises and speech capacity, the effect of network connectivity on the notification rate, and the external variable that affects the emergency service response time are some of the main issues to be dealt with.

The current work should focus on reducing the false positives and negatives by implementing the most sophisticated speech recognition and introducing the possibility of additional authentication procedures. Improving the battery life and diversification of communication means is also crucial towards making sure that it can operate in a wide variety of conditions. Moreover, it is necessary to pay great attention to user-centered design by conducting a considerable amount of testing with the target audience to maximize usability and adoption [7], [19]. Lastly, the incorporation of Kavach with the current emergency response infrastructure has a great potential of enhancing overall ecosystem of safety.

Overall, the simulated analysis of Kavach describes a strong argument about the possibility of voiceactivated wearable technology to improve the security of women. Although the results are merely illustrative in nature, it offers a sufficient basis to steer the future research and development projects to develop an excellent, strong, and convenient personal safety gadget. Practical implementation and the development of Kavach through continued use, based on customer feedback will be essential in bringing out all the potentials of Kavach in ensuring that it plays a key role in ensuring the safety and security of women. These emulated understandings make a powerful foundation on the forwarding of Kavach to actual prototyping and testing to users. The paper highlights the significance of the voice recognition and connection features that should be optimized to become more reliable during the critical scenarios. Kavach can also be a viable and effective solution to enhance female safety; however, it will be a viable option in the future when it is developed further.

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