Final Project Report

Acoustic- Collision Detection Smart Watch Feature for Pedestrians Operating Smartphones

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PROBLEM IDENTIFICATION

The increasing popularity and prominence of smartphones have not only benefited users in innumerable ways, but the years have also witnessed a series of dangerous incidents with distracted pedestrians and drivers operating cell phones that need to be mitigated for users. While technology is developed for the benefit of its users, it is mandatory that it be put to the correct use at the correct time.

Firstly, vehicle commutes are one of the most popular means of travel, aside from which public transport is also being necessitated by governments for several reasons. This means there will be a growing number of pedestrians commuting by foot to bus stops and workplaces. As the number of passengers on foot has multiplied, a recent trend in the number of pedestrian accidents within Silicon Valley has gained prominence. Smartphones are becoming a major safety concern for pedestrians who commute daily to nearby hospitals, offices, universities, and other workplaces.

Secondly, travelers commuting on foot are consistently engaged in activities like texting, calling, video watching, surfing the internet, or playing games. Moreover, commuters on foot have been sighted bumping into objects like trees, trash bins, traffic lights, or vehicle traffic. Since 2009, the city has witnessed critical pedestrian injuries like sprains, concussions, fractures, and even immediate death. This trend is quickly advancing due to an increase in inattentive and distracted smartphone users.

Thirdly, a CBS Bay Area news article reported an incident at Greentree, San Jose, where a juvenile male driver speeding in a stolen Hyundai struck a pedestrian after which the car continued to move northbound and damaged a tree. The pedestrian was declared deceased. This was the 33rd fatal crash and the 19th pedestrian death of 2023. Injuries related to mobile phone distractions have increased from 0.58% in 2004 to 3.67% in 2010. State councils are taking measures by imposing fines on smartphone users for their distracted walking behaviors and drivers for violating the speed limits (CBS Bay Area, 2023).

Lastly, an important mitigation measure that will be the subject of discussion in the main report is a recent innovation in which product developers are working to enhance the sensing capabilities of smartphones and watches to alert pedestrians of an approaching object and assist blind pedestrians to follow an easy commute.

ANTICIPATED CUSTOMER WANTS AND NEEDS

For regular pedestrians use the Active outdoor mode of the smartwatch.

Customer Needs:

1. Collision alerts and a simplified user interface.
2. Customized ringtones to differentiate critical alerts.
3. Warning indications must be issued at sufficient proximity from the approaching obstacle to support the user's reaction time.
4. Waterproof feature to protect from unexpected rain.
5. Immediate emergency outreach (SOS) on collision detection.
6. Extended battery life to avoid frequent recharges and shutdowns.
7. Internet and 5G connectivity for enhanced user experience.
8. Affordability to purchase the product with ease.
9. Touch screen technology with advanced displays.

Customer Wants:

1. Display of an AI-generated satellite image of an approaching object.
2. Obstacle categorization to recognize the type of obstacle.
3. Temperature sensors
4. Sleep tracking system
5. Pulse detection
6. Pedestrians using “Blind Mode” of smartwatch.

Customer Needs (Additional features):

1. Virtual Assistant for Navigation: Guidance on Terrain (Curb, Side Walks, Trees, and Shrubs) and Against Approaching Vehicles
2. Consistent alerts on the number of steps and movements
3. Embedded offline GPS integration.
4. High-performance RAM

Customer Wants:

1. Tactile feedback: vibrating wristbands when an obstruction is detected.
2. Multiple Language

VALIDATION PROCESS RESULTS

Overview:

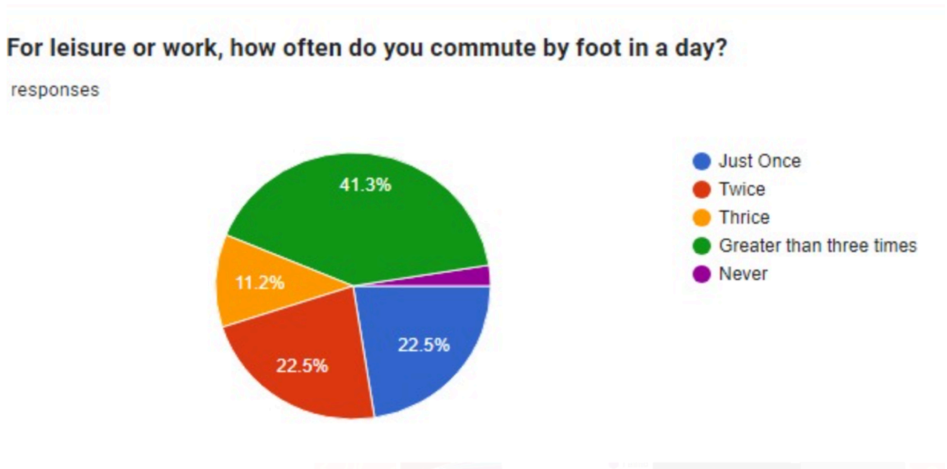
Acoustic Collision Detection Smart Watch Feature is a cutting-edge technology that improves the safety of pedestrians. It is designed for people who use their smartphones while walking or crossing streets. This function detects probable collisions with adjacent objects or vehicles using acoustic sensors and real-time processing and informs the user via the smartwatch. The objective is to prioritize safety, accuracy, use, and personalization while improving battery efficiency and cost-effectiveness.

To validate the customer needs and wants a customer survey analysis was conducted, to collect responses from 80 participants and the survey contained a total of 11 questions listed below

Analysis of the survey data provides valuable insights into the potential adoption of a smartwatch with an enhanced intelligence system for collision detection and obstacle alerts among pedestrians. Here are the key findings and observations:

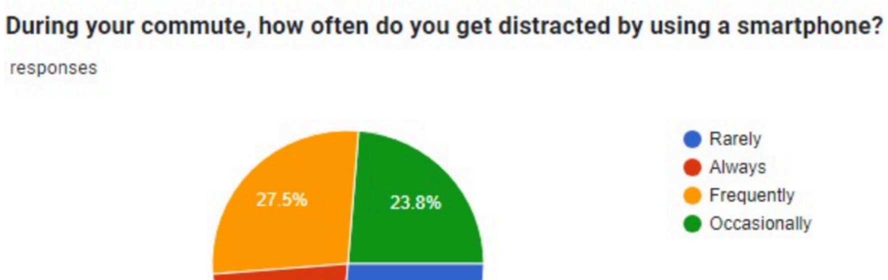
Commute Frequency: Over 40% of respondents commute by foot more than three times a day, indicating a significant portion of the sample engages in regular pedestrian activities.

Figure 1-Graphical analysis for Question 1



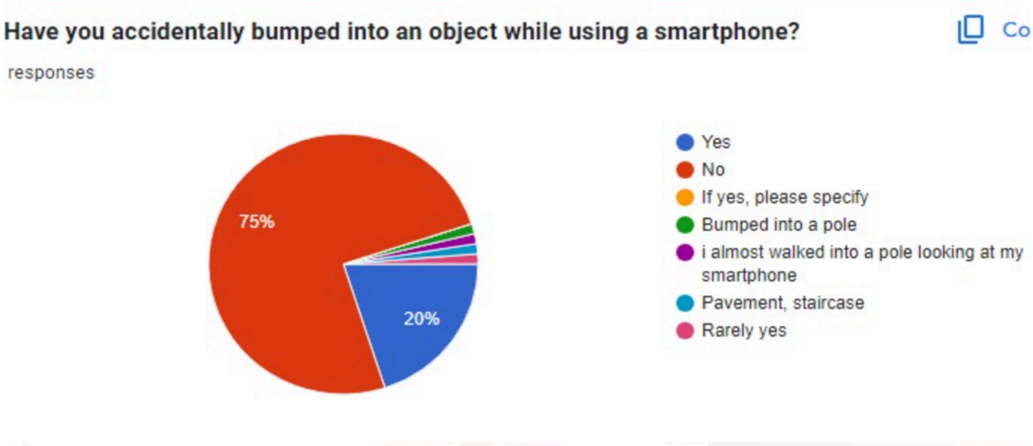
Smartphone Distraction: While 75% claim they are not distracted by smartphones during their commute, the 20% who admit to distraction highlight an opportunity for technology solutions that enhance safety.

Figure 2-Graphical analysis for Question 2



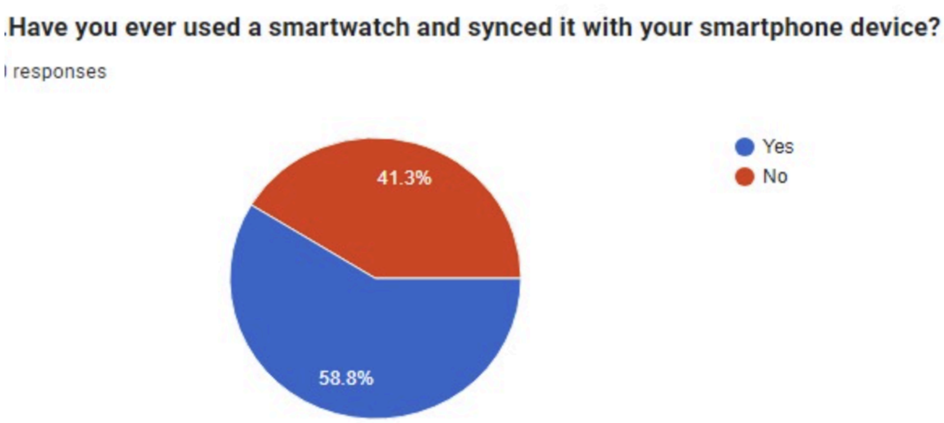
Smartwatch Usage: Most respondents (58.8%) have experience using a smartwatch, suggesting a familiarity with wearable technology.

Figure 3-Graphical analysis for Question 3



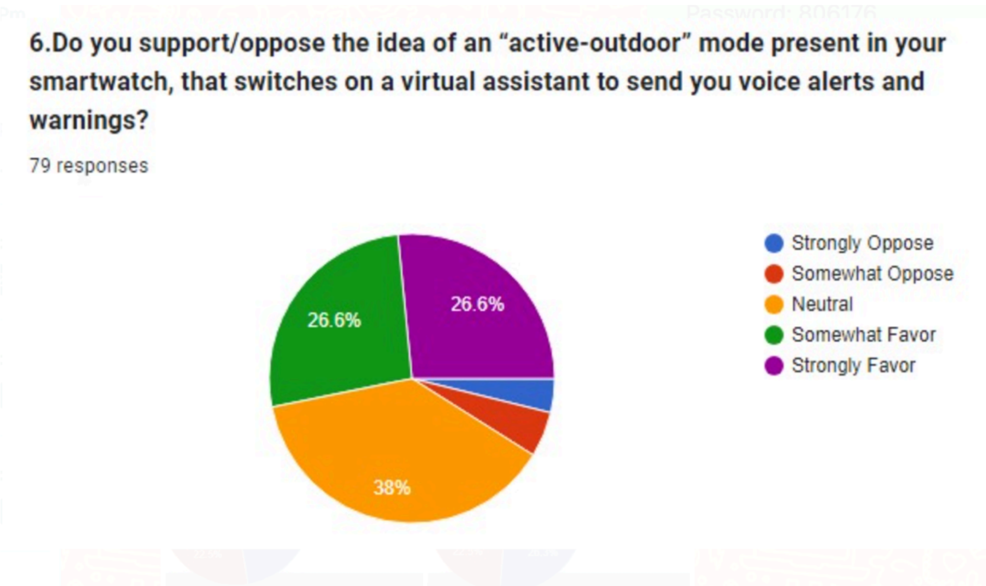
Interest in Collision Detection Smartwatch: Approximately 70% of respondents express a likelihood of purchasing a smartwatch with enhanced collision detection features, demonstrating a strong market interest in such devices.

Figure 4-Graphical analysis for Question 4



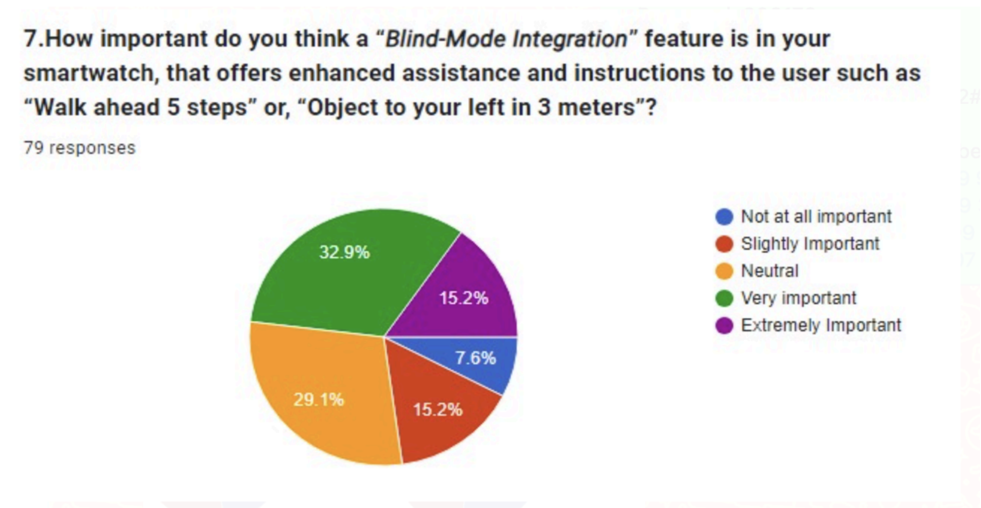
Active-Outdoor Mode: A considerable percentage (53.2%) either strongly or somewhat favors the idea of an "active-outdoor" mode in smartwatches, indicating user interest in voice alerts and warnings during outdoor activities.

Figure 5-Graphical analysis for Question 6



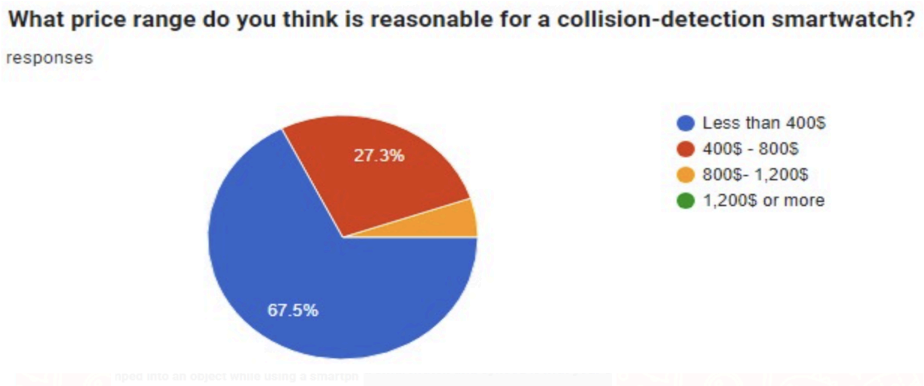
Blind-Mode Integration: Respondents consider the "Blind-Mode Integration" feature important, with 48.1% finding it slightly to extremely important, underscoring the need for enhanced assistance and instructions in smartwatches.

Figure 6-Graphical analysis for Question 7



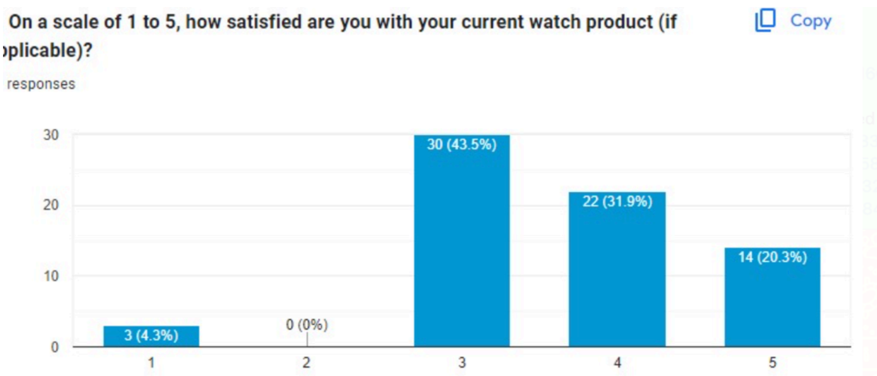
Price Expectations: The majority (67.5%) expect a reasonable price range for a collision-detection smartwatch to be less than $400, signaling price sensitivity among potential customers.

Figure 7-Graphical analysis for Question 8



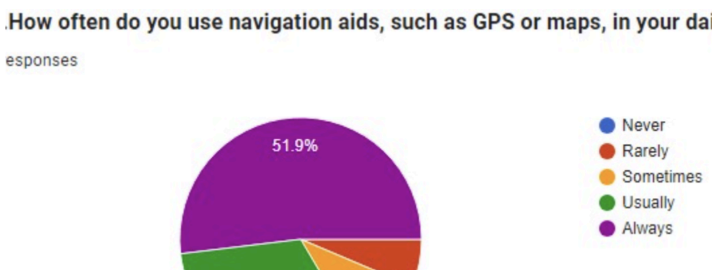
Satisfaction with Current Watches: Over 70% of respondents express satisfaction levels of 3 or higher (on a scale of 1 to 5) with their current watch products, indicating a generally content customer base.

Figure 8-Graphical analysis for Question 9



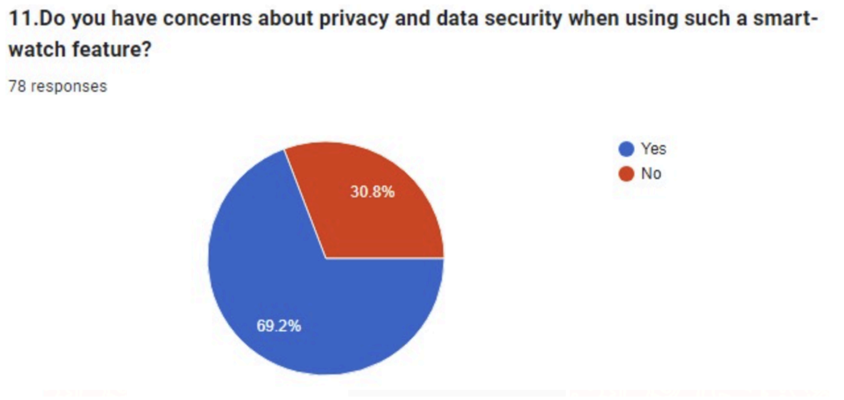
Navigation Aid Usage: A large portion (82.5%) report using navigation aids, such as GPS or maps, frequently, suggesting an active user base that could benefit from added safety features.

Figure 9-Graphical analysis for Question 8



Privacy Concerns: The data reveals that privacy and data security are significant concerns for the majority (69.2%). It shows the need for robust privacy controls and encrytions.

Figure 10-Graphical analysis for Question 11



The survey data in figure 10 indicates a strong market potential for collision-detection smartwatches. Respondents are open to such devices, provided they offer value in terms of safety features, pricing, and privacy protections. Manufacturers will leverage this user demand for creating intelligent safety solutions in the smart watch market.

Actual customer wants/needs list

Table 1-Customer Needs and Wants with Importance Rating determined using Customer Survey. This list was shortlisted after customer validation of 80 responses for a total of 11 Survey questions.

Customer Requirements	Need/Want	%weightage	Importance Rating
Customization of Blind Mode Integration	Need	14.29	9
Compatibility of Active Outdoor Mode	Need	11.11	7
Accuracy of Alerts	Want	12.70	8
Efficient Battery system	Need	12.70	8

Cost Effectiveness	Need	11.11	7
Privacy of User Data	Need	12.70	8
User-friendliness	Want	11.11	7
Safety	Need	14.29	9

SURVEY ANALYSIS OF QUESTIONNAIRE

In analyzing the survey data, several key insights emerge regarding the potential adoption and preferences related to the Acoustic Collision Detection Smart Watch Feature for pedestrians. Firstly, a notable majority of respondents (41.3%) report commuting by foot more than three times a day. This finding indicates a significant demand for solutions that enhance safety and awareness during pedestrian activities. Furthermore, over half of the respondents (58.8%) have previous experience using a smartwatch, suggesting a level of familiarity with wearable technology.

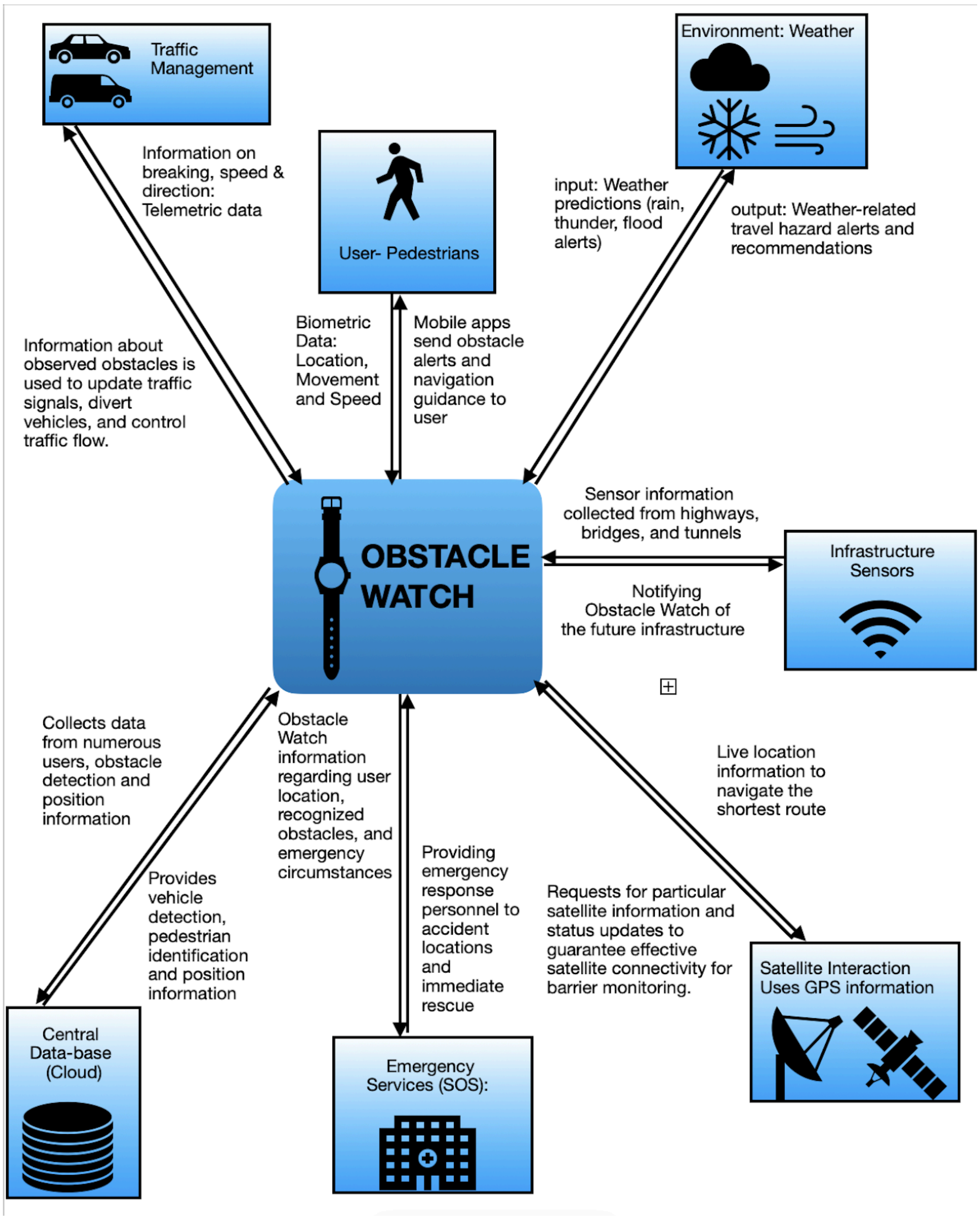
Secondly, the survey indicates a substantial willingness among respondents to embrace innovative features. Nearly 70% of participants expressed interest in purchasing a smartwatch equipped with enhanced intelligence for collision detection and obstacle alerts. Moreover, the majority (75%) report that they rarely get distracted by their smartphones during their commutes, which suggests that users may appreciate a complementary technology that augments their awareness without causing distractions.

Lastly, the survey highlights concerns related to privacy and data security. A significant majority (69.2%) express apprehension about privacy when using such smartwatch features, emphasizing the importance of robust privacy controls and data security measures in the development of this technology. Overall, the survey data underscores a substantial market for collision-detection smartwatches, given the demand for safety-enhancing features and the existing interest in smartwatch technology. To succeed in this market, manufacturers must prioritize user privacy and data security, and ensure that their products align with user preferences and commuter habits.

In summary, the survey data reveals a promising market for smartwatches equipped with collision-detection features, with most respondents expressing interest in purchasing such devices. This interest is fueled by the desire for enhanced safety during pedestrian activities and an evident familiarity with smartwatch technology. However, data security and privacy concerns must be addressed to gain users' trust. Overall, these findings provide valuable insights for the development and marketing of Acoustic Collision Detection Smart Watch Features and similar wearable technologies.

CONTEXT DIAGRAM

Figure 11-Context Diagram for Acoustic- Collision Detection Smart Watch feature for pedestrians using smart watch



INTERFACES

Table 2-Interfaces for Acoustic- Collision Detection Smart Watch

Interface	Input/Output	Type	Description
Infrastructure sensors	Input & Output	Analog	Sensors to capture ambient sounds, motions to detect potential hazards like horns or fast approach

Bluetooth/Wi-Fi Module	Input & Output	Wireless	Communicate with the paired smartphone and receive/send data.
Sensor Analysis software	Input & Output	Software	Analyze data to determine user motion direction and sound.
Smartphone Interfacing App	Input & Output	Software	Communicate between the smartwatch and smartphone, relay alerts, and possibly pause distractions.
User Profile & Preferences	Input & Output	Software	Store and provide customization settings like alert sensitivity, notification preferences, etc.
Haptic Feedback Algorithm	Input & Output	Software	Determine vibration patterns based on the level of threat and user settings.
History Log	Output	Data	Display past alerts with timestamps for user review.
Tutorials & Guides	Output	Data	Provide guidance on how to use the watch effectively.
Vibration Patterns	Output	Alert	Different patterns to signify the level of threat, e.g., single vs. repeated vibrations.
Visual Alerts	Output	Alert	Color-coded warnings on the watch display indicating the threat level.
Audible Alerts	Output	Alert	Beeps or voice warnings for hazards, played through earphones or the phone's speakers.
Battery & System Health	Output	Safety Protocol	Check system health and warn users if the battery is low or a malfunction is detected.

SCOPE OF THE SYSTEM UNDER CONSIDERATION

Physical Boundaries:

In a smartwatch, physical boundaries are associated with tangible components and constraints proposed by Hardware Components, Accessibility Features, and Battery life.

- Hardware components refer to the physical components of a smartwatch such as sensors, displays, buttons, and haptic feedback mechanisms.
- Enclosures refer to the durable and seamless titanium alloy casing or housing of the smartwatch that is designed for durability.
- Accessibility features are created to elevate the experience of users who are visually impaired. These features are tactile buttons and voice dictation. A virtual assistant is activated by using the Blind Mode Feature for directional assistance. For automatic activation and deactivation, the feature has an integrated calendar setting. A visually

impaired user can take advantage of the virtual assistant to dictate his outdoor schedule. Operation is similar for an athlete who uses an active outdoor mode.

- Battery Life is the power source of the smartwatch which supports the required functionality.

Business Boundaries:

These boundaries encompass various aspects of the business ecosystem associated with the smartwatch which includes Market Segments, Distribution, Partnerships, Pricing strategies, and Regulatory compliance.

- Market segments represent the target market of consumers, who prefer the bind mode integration such as the elderly aged 55+ or the visually impaired. Another category that desires the Active outdoor mode is teens aged 14-19 years and 20+
- Distribution refers to retailing the product to customers directly firsthand or distributing to 3rd party vendors and wholesalers' cross-country.
- Partnerships are directed to organizational collaborations that offer technological solutions for the visually impaired.
- Pricing Strategy is set on the features and customer requirements and expectations of such a product. Previously a customer survey conducted through this report highlights the preferred price range of consumers.
- Regulatory Compliance would mean adhering to disability regulations and standards.

Process Boundaries

In a smartwatch with blind mode integration relates to functional and operational aspects of a device's lifecycle.

- Design and Development: The Blind mode integration is defined such that it is only accessible to people with visual impairment. A regular user does not require detailed instructions from a virtual assistant.
- Quality assurance: Testing and quality control ensures that the Blind mode functions as intended. Some types of testing are usability, performance, compatibility, security, integration, privacy (UAT) User Acceptance Testing and (UI) User Interface Testing. Quality control must be an ongoing process to ensure the blind mode and active outdoor mode are reliable, accessible. .
- User training and support: This domain offers specialized training on customizing to a Blind Mode. On-call support is accessed by voice dictation to the Virtual Assistant. It syncs with GPS navigation to call out distances, destinations, speed and time to the user. Sound haptics are also encompassed in this design.
- Software Updates: These are attributed to every feature, display and app embedded within the watch.
- Accessibility Testing: To refine and enhance user experience usability and accessibility testing is required.

Information Boundaries

Concentrate on the data and information managed by the smartwatch system with active outdoor and blind mode integrations. This culminates user data, accessibility settings, health, alert filtering, virtual assistant, obstacle detection, and network data.

- Personal user preferences regarding virtual assistant guidance, alerts, and notifications must have a privacy lock.
- Accessibility settings on the configuration and customization of the smartwatch must be shielded.

- The Machine learning algorithm is constructed such that it creates prediction models and analyzes live data gathered from radars (LIDAR, SONAR, gyrometers, altimeters) and transmits the result to a microcontroller to issue the alert.

OPERATIONAL REQUIREMENTS AND TECHNICAL PERFORMANCE MEASURES

Table 3-Operational Requirements and Technical Requirements for Acoustic- Collision Detection Smart Watch

Operational Requirement	**TPM**	**Unit**	**Target Value**
Sensor Technology: Aims to detect obstacles within a certain range	Range for Accuracy	Meters	2-5 meters
Auditory feedback from a virtual Assistant for Navigation	Clarity and Sound Quality	THD (Total Harmonic Distortion)	<=1% is Excellent
Real-Time Processing: To analyze data as quickly as possible	Latency	Milliseconds	< 100 milliseconds
Machine Learning Algorithms: For better decision-making and Predictions	Measures how well the model fits the data	R^2	0-1, Better fit of data
Smartwatch Battery Optimization: To ensure an elevated performance	Battery Life	Hours	>2 days
Bluetooth Connectivity: Ensures synced devices.	Data Transfer Speed	Megabits per second	≥ 2 Mbps
App Integration: To communicate and share data from watch to phone	Compatibility	None	Yes or No
Privacy Controls: To ensure encryption of sensitive data	User Consent	None	Strong
Alert Filtering: Categorization of sound haptics based on severity of a predicted collision.	Precision	Percentage	≥ 90%
Cost Management	Budget Adherence	Percentage	>95%

R^2 (square): It is a measure of how best the Model fits the data.

Latency: The time it takes for the data to flow through the processing pipeline. It refers to minimizing the delay between data processing and arrival.

Total harmonic distortion (THD): A metric used to measure the harmonic content introduced by a system. Lower THD values indicate better sound quality.

HOUSE OF QUALITY

Procedure for House of Quality:

1. Determine the consumer attributes and engineering characteristics that are required.

2. Ascertain relationships between customer attributes and engineering characteristics (weak, moderate, strong).

3. Based on importance, assign relative weights to consumer attributes.

4. Calculate the impact scores and prioritize the engineering characteristics.

5. The QFD matrix can be used to direct product development and quality improvement.

Customers - Pedestrians and Smartphone Users, Parents and Guardians, Elderly Population, Commuters and City Dwellers, Smartwatch Manufacturers, Insurance Companies, Health and Fitness Enthusiasts, Government and Municipal Authorities, Safety Advocacy Groups, Businesses and Corporations

Figure12 - Legend for attributes in House of Quality

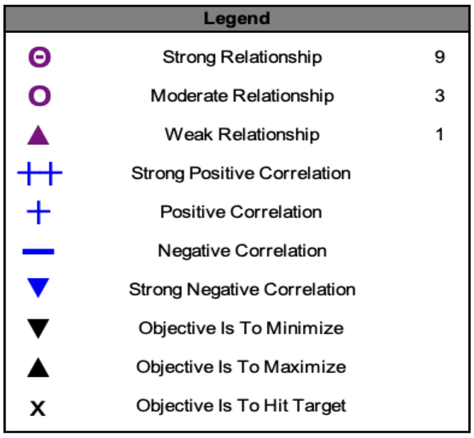
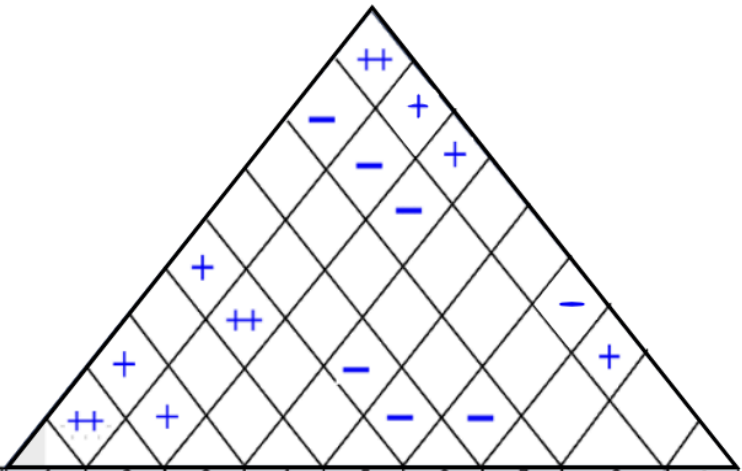


Figure 13 -House of Quality



Row #	Relative Weight	Weight / Importance	Quality Characteristics (a.k.a. "Functional Requirements" or "Hows") / Demanded Quality (a.k.a. "Customer Requirements" or "Whats")	Column # 1: sensor Technology	Column # 2: Machine Learning Algorithms(Heptic Feedback Algorthim)	Column # 3: Smartwatch Battery optimization	Column # 4: Bluetooth connectivity	Column # 5: APP Integration(smartphone Interfacing APP)	Column # 6: Privacy Controls	Column # 7: Alert Filtering	Column # 8: Cost Management	Column # 9: Active Audio Feedback (Virtual assistance)
1	14.3	9.0	Safety	Θ	O	O	O	▲	Θ	Θ	▲	O
2	12.7	8.0	Alert Accuracy	Θ	Θ	▲	▲	▲	Θ	▲	▲	Θ
3	11.1	7.0	User-Friendliness	O	O	O	O	▲	Θ	Θ	▲	Θ
4	14.3	9.0	Customization(Blind mode integration)	Θ	Θ	▲	▲	Θ	O	▲	▲	O
5	12.7	8.0	Battery Efficiency	▲	O	Θ	O	O	▲	O	▲	▲
6	11.1	7.0	Compatibility(active outdoor mode)	▲	▲	O	Θ	Θ	▲	▲	▲	Θ
7	12.7	8.0	Privacy	▲	▲	▲	Θ	Θ	O	O	▲	O
8	11.1	7.0	Cost-Effectiveness	O	▲	O	▲	Θ	O	▲	O	▲
			Target Values	Range Accuaracy (2-5 meters)	Processing Efficiency (4 Quad)	Extended Battery Life (2-3 days)	Data Transfer Speed(≥ 2 Mbps)	Seamless Compatibility(iOS and Android compatibility)	User Consent(Clear and informed consent)	Low False Positives(≥ 90%)	Efficient Resource Use(Within specified budget)	Clarity and sound quality
			Weight / Importance	474.6	392.1	296.8	366.7	519.0	481.0	354.0	122.2	461.905
			Relative Weight	13.7	11.3	8.6	10.6	15.0	13.9	10.2	3.5	13.32

PRIORITIZATION OF OPERATIONAL REQUIREMENTS

Result: Operational requirements have been prioritized in Figure 12 . Operational requirements Importance ratings were calculated by forming a relationship matrix between Customer Importance ratings and operational requirements relevance ratings. The result summarizes that Seamless compatibility (rated: 541.3) is extremely critical for app integrations, and data transmissions from a smartwatch to a phone. If interfaces are incompatible the system is dysfunctional since the visibility of alerts will be canceled.

The second in line is the user consent with an overall rating of 449.2. User consent during user ID setup on the device is necessary to activate "Blind mode/Active Outdoor mode" or to receive any navigation guidance from a virtual assistant or alerts, and notifications. This section also includes user preferences and customizations. The 3rd on the list is "Range Accuracy" at 338.1. This operational requirement states that an alert, vibration, or instructions from a virtual assistant must be extremely accurate in its timing. It must occur within the safest clearance (2-5 meters) between an approaching obstacle and the user to ensure safety. For which SONAR and LIDAR sensors must be highly responsive. Range Accuracy is followed by Low false positives, which determines the possibility of an error and processing efficiency.

MAINTENANCE CONCEPT

Figure 14-Maintenance Flow Diagram

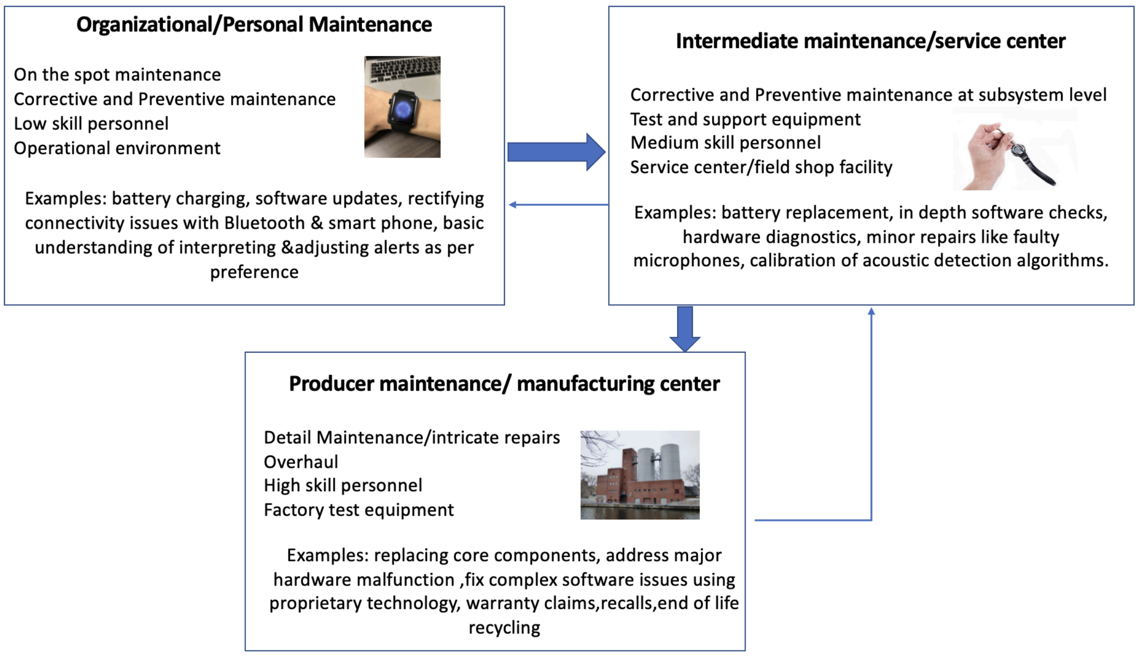
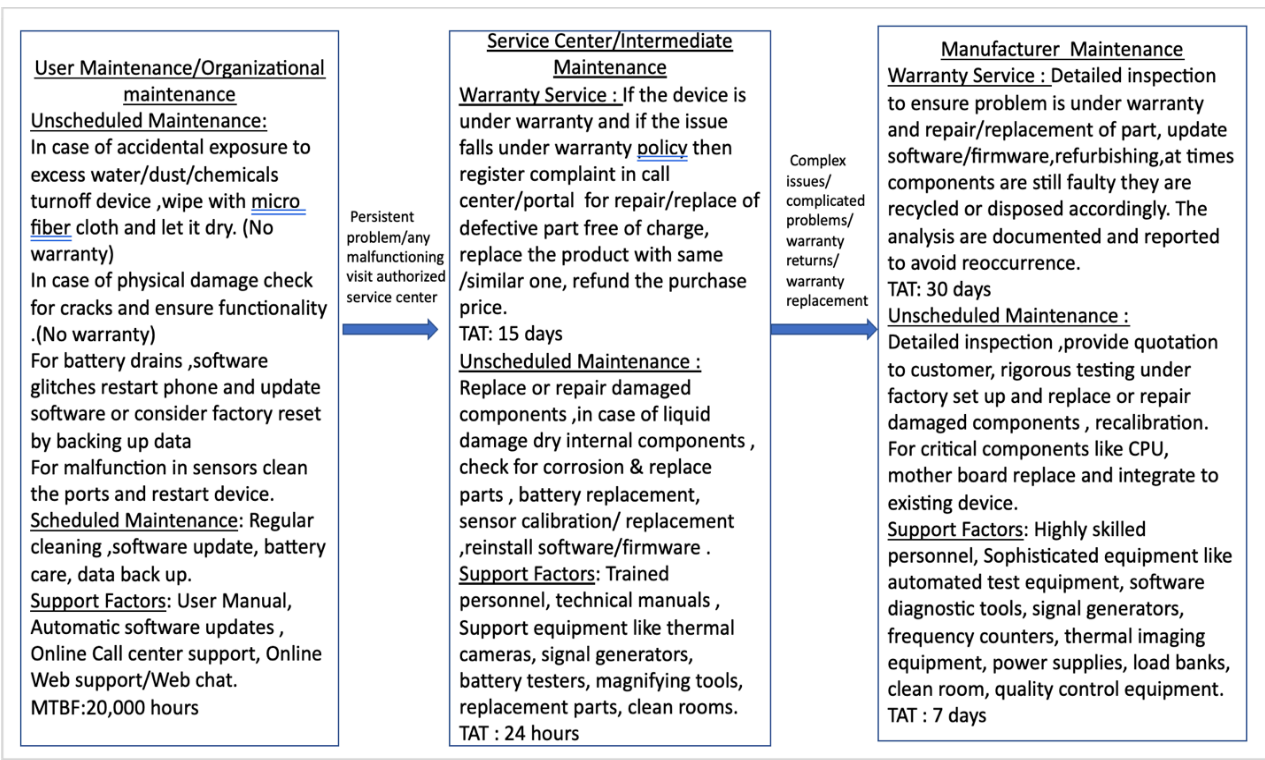


Figure 15 -Repair Policies



WARRANTY POLICY

The Acoustic-Collision Detection Smart Watch is covered by a limited warranty and covers a duration of 12 months from the date of purchase. The warranty is originally valid for the purchaser and is non-transferable.

A standard warranty covers defects in materials and workmanship of the product, malfunction of sensors due to manufacturing defects, reduced battery capacity or failure under normal use, and software or firmware malfunction.

The warranty does not cover damage resulting from shipment, misuse, poor storage, not adhering to product instructions, unauthorized modifications or repairs, physical damages due to accident, excess exposure to water or chemicals, issues related to the app not being installed by the company, situations beyond the control of the manufacturer.

If a purchaser's claim fits the standard requirements of warranty coverage, the company will either replace the item with a new or refurbished item or repair it using new or refurbished parts. Components, craftsmanship, and freight for the return will all be paid for by the manufacturer. To claim the warranty, file a complaint with the call center or portal, get the issued ticket number, and follow the instructions in the email that was provided to the registered email address.

Table 4-*Maintenance Details*

Level of maintenance		1	2	3,4
Components of smart watch	**Criteria**	**Organizational maintenance**	**Intermediate Maintenance**	**Manufacturer/Depot maintenance**
Electronic visual displays using Liquid Crystal Displays	**Done where**	Done at the operational site	Done at the authorized service center/store	Done at the factory/ manufacturing set up with test facility
	Done by whom	Done by users themselves with minimum skills	Done by service technicians with medium skills	Done by service experts with high level of skills
	On whose equipment	Users smart watch	Users smart watch	Users smart watch
	Type of work accomplished	Visual inspection with cleaning using a microfiber with a screen cleaning solution. External adjustments such as turning off the display when not in use for extended periods.Avoiding static images for extended periods to avoid burn in from image persistence.Operational check on brightness & contrast as extremely high settings can lead to quicker wear.	Detailed inspection and system checkout for software or firmware updates.Backlight replacement.Specialized equipment can be used to attempt to revive stuck pixels.Diagnosis and replacement of faulty capacitors that cause power issues.	Complicated factory adjustments and advanced calibrations to ensure uniformity and accuracy in screens,major hardware overhaul for components of display,addressing other systemic issues related to display.
Recharageable Battery for smart watch	**Done where**	Done at the operational site	Done at the authorized service center/store	Done at the factory/manufacturing set up with test facility
	Done by whom	Done by users themselves with minimum skills	Done by service technicians with medium skills	Done by service experts with high level of skills
	On whose equipment	Users smart watch	Users smart watch	Users smart watch
	Type of work accomplished	Visual inspection to ensure periodic partial charging rather than drain out or 100% charge at all times.Always use recommended charger.External adjustments such as avoiding extreme temperatures for extended battery life and effeciency.	Detailed inspection and safety check for swelling , leakage or visible signs of damage to battery.Firmware updates for smart battery management systems.Disgnostic test and battery replacement if necessary.	Complicated factory adjustments and advanced calibrations for smart battery management system.Uverhaul and rebuild battery as per standards.
Sensors used by smart watch for obstacle detection	**Done where**	Done at the operational site	Done at the authorized service center/store	Done at the factory/manufacturing set up with test facility
	Done by whom	Done by users themselves with minimum skills	Done by service technicians with medium skills	Done by service experts with high level of skills
	On whose equipment	Users smart watch	Users smart watch	Users smart watch
	Type of work accomplished	Software updates as some updates may include calibration or improvements for sensors.Users are suggested to avoid physical damage as it could damage sensors.Operational checkout by restarting the device if there are issues.Visual inspection by cleaning ports regularly.	Detailed inspection and disgnostic check to ensure sensors functioniong and also to make sure there are no residues on sensors .Calibration of sensors or replacment of sensors.Software and firmware updates.	Complicated factory adjustments to inspect damages and corrosion to replace or perform advanced calibrations to ensure sensors are functioning as intended .For example accelerometers are calibrated to ensure precision in motion sensing.High level of expertise and care are equipped to identify problems to perform complex equipment repair and modifications.Software and firmware update at factory test setup.
Central Processing unit	**Done where**	Done at the operational site	Done at the authorized service center/store	Done at the factory/manufacturing set up with test facility
	Done by whom	Done by users themselves with minimum skills	Done by service technicians with medium skills	Done by service experts with high level of skills
	On whose equipment	Users smart watch	Users smart watch	Users smart watch
	Type of work accomplished	Regular software updates to fix bugs and optimize CPU performance,avoiding overloading of apps simultaneously,periodic restaring can clear software glitches.	Detailed inspection and diagnostic test to ensure CPU's condition and replace if necessary. Inspect the check for overheating.Complicated adjustments and repairs on CPU.Update firmware to optimize CPU.	Complicated factory adjustments and advanced diagnostics to check deep rooted issues such as over heating,lagging,processing errors which are not visible at service center.Firmware is reinstalled.Surrounding components are tested for malfunction.If issues are found and if parts are defective entire motherboard or main circuit is replaced.

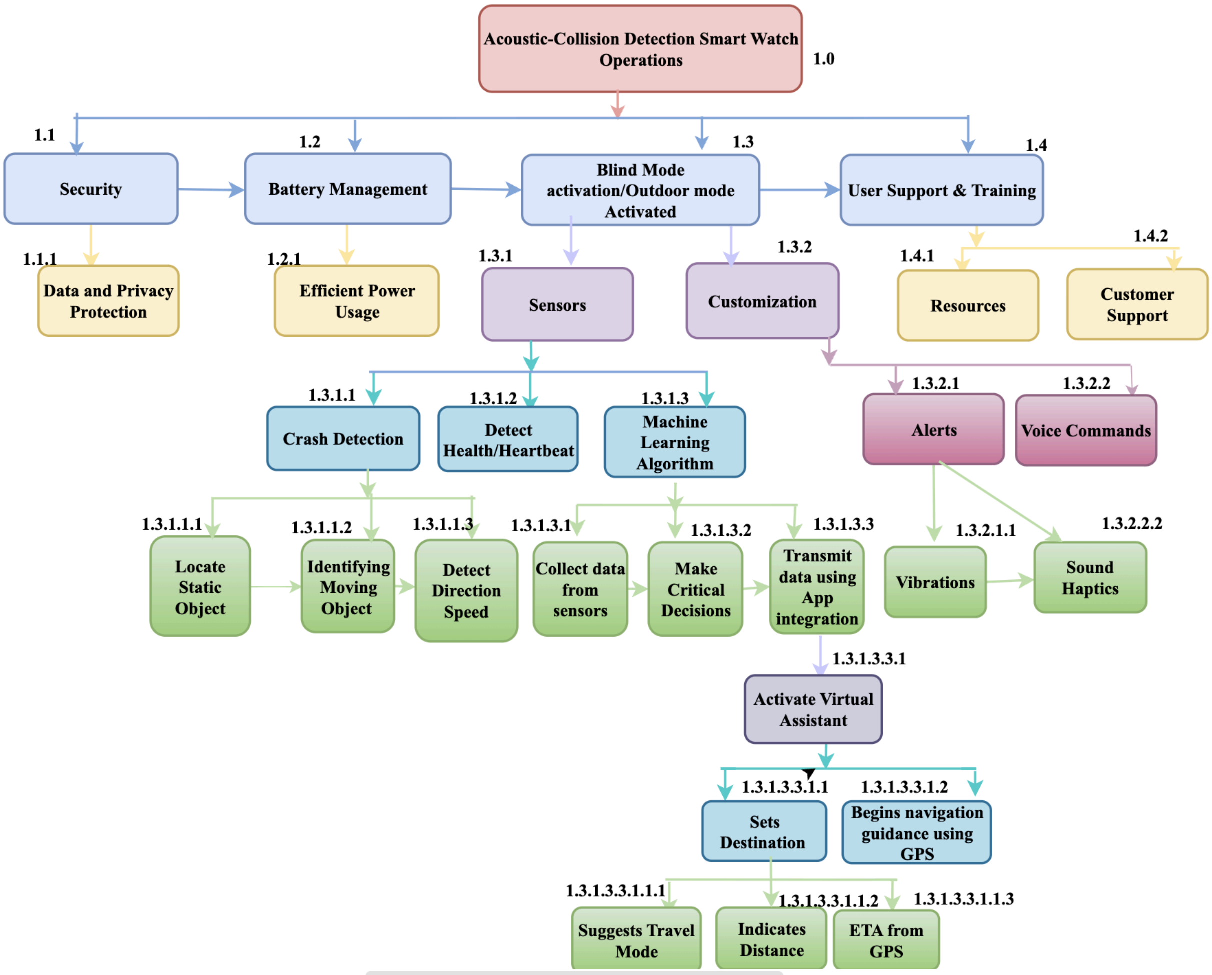
FUNCTIONAL ANALYSIS AND REQUIREMENT ALLOCATION

Description: The functional analysis diagram in Figure 16 aims to highlight all the functions taking place in the hardware and software operations of the smart watch. This diagram does not focus on the manufacturing of the watch, rather it focuses on its compatibility with the interfacing systems and functionality of components within the casing. The diagram indicates sequence and hierarchy of each action performed. Followed by this will be the functional requirements which display the TPM (technical performance measures attributed to each node) . Operation of the Blind Mode feature is most critical in Figure 16. It is followed by Sensors and Customization by user, since sensors detect and gather information, and customization filters unnecessary information relayed to the user.

Table 5-*Requirement Analysis for Functional Diagram*

Operational Requirement	Nodes	TPM	Target values
Sensor Technology	1.3.1	Range	Range b/w 2-3 meters
Crash Detection	1.3.1.1		
Machine Learning Algorithm	1.3.1.3	R^2	0-1, Better fit of data
Alerts	1.3.2.1	Total harmonic Distortion	<=1%
Sound Haptics	1.3.2.2.2	Total harmonic Distortion	<=1%
Real -Time Processing	1.3.1.3	milliseconds	<100 milliseconds
Battery Optimization	1.2	Hours	>48 hours
Efficient Power Usage	1.2.1		
Privacy Controls	1.1.	% Acceptance	>50%
Data and Privacy Protection	1.1.1		
Cost Management	1.3	Budget	>95%
Customization	1.3.2		

Figure 16-*Functional Analysis for Acoustic Collision Detection Smart Watch Operation*



LIFE CYCLE COSTING

Life cycle costing is made up of the CBS (Cost break-down structure) shown below which gives a general outline of cost categories associated with developing and manufacturing a technologically advanced acoustic-collision detection smartwatch system. It collectively points out every dollar associated with design, development, manufacturing, and distribution that decides the cost of a collision detection Smartwatch.

Below is a Cost Breakdown structure of all the phases and Sub-phases. It quantifies all the costs that will be added to the Life cycle costing. (COST ESTIMATING , March 2020)

Table 6 -*Cost BreakDown for Miscellaneous Costs*

Miscellaneous Costs	Amount ($) (per year)
Warranty and returns	$100,000
Legal and Compliance	$200,000
Contingency	$500,000
Total Miscellaneous Costs	$8,00,000.00

Table 7-*Cost Breakdown for Project Management and Contingency Cost:*

Project Management and Contingency Cost	Amount ($) (per year)
Project Management and Oversight	$300,000
Project Contingency	$500,000
Total Project Management and Contingency Cost	$800,000

Table 8-Cost Breakdown for Manufacturing and Production Cost

Manufacturing and Production Cost	Amount ($) (per year)
Manufacturing Setup	$3,000,000
Tooling and Molds	$500,000
Production Run	$10,000,000
Total Manufacturing and Production Cost	$13,500,000

Table 9 -Cost Breakdown for Software Development and Integration Cost

Software Development and Integration Cost	Amount ($) (per year)
Operating System	$300,000
App Development	$500,000
Software Updates	$200,000
Total Software Development and Integration Cost	$1,00,000

Table 10-*Cost Breakdown for Marketing and Sales Cost*

Marketing and Sales Cost	Amount ($) (per year)
Marketing and Advertising	$2,000,000
Sales and Distribution	$3,000,000
Retailer Commissions	$1,000,000
Customer Support	$500,000
Sales and Marketing Collateral	$100,000
Total Marketing and Sales Cost	$6,600,000

Table 11-*Cost Breakdown for Overhead and Administrative Costs*

Overhead and Administrative Costs	Amount ($) (per year)
Office Space and Utilities	$500,000
Employee Salaries and Benefits	$1,200,000
Research and Development	$300,000
General and Administrative	$150,000
Total Overhead and Administrative Costs	$2,150,000

Table 12-Interest rate & Present Value specification

Interest Rate	10%
Used excel Financial Formula to estimate PV	
(Present Value)	=POWER (1+Discount rate, Years) *Total cost (for 5yrs)

Figure 17-*Shows the life cycle costs over a 5-year period and estimates the Net Present worth*

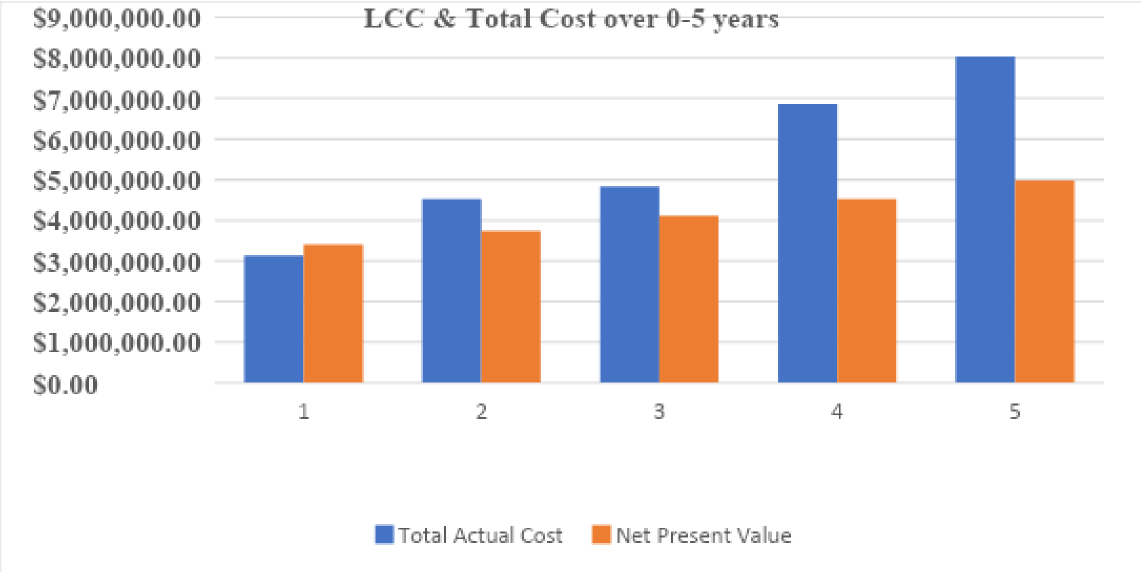
Project Phase	Cost Category	Years	2024	2025	2026	2027	2028	Total Actual Costs
Phase 1	Designation		1	2	3	4	5	
Research and Devlopment	Cr	Market Research And Analysis	$ 50,000.00					$ 50,000.00
		Feasibility Studies	$ 20,000.00					$ 20,000.00
		Concept Development	$ 80,000.00					$ 80,000.00
		Business Case Development	$ 30,000.00					$ 30,000.00
Phase 2								
Design and Manufacturing Setup	Cd	Designing and Prototyping	$300,000.00	$350,000.00	$400,000.00	$500,000.00	600,000	$2,150,000.00
		Intellectual Property	$50,000.00	$60,000.00	$70,000.00	$90,000.00	110,000	$ 380,000.00
		Engineering and Development	$500,000.00	$600,000.00	$700,000.00	$900,000.00	1,100,000	$ 3,800,000.00
		Regulatory Compliance	$60,000.00	$75,000.00	$90,000.00	$120,000.00	150,000	$ 495,000.00
Phase 3								
Production and construction	Cp	Materials and Components	$200,000.00	$220,000.00	$240,000.00	$280,000.00	320,000	$ 1,260,000.00
		Manufacturing and Production	$500,000.00	$1,600,000.00	1,320,000	$2,730,000.00	$3,040,000.00	$ 9,190,000.00
		Software Development and Integration	$100,000.00	$190,000.00	$270,000.00	$290,000.00	350,000	$ 1,200,000.00
Phase 4								$ -
Operations and Support	Co	Marketing and Sales	$660,000.00	$777,000.00	$945,000.00	$1,091,000.00	1,450,000	$ 4,923,000.00
		Overhead and adminitrative Expenses	$430,000.00	$ 458,000.00	$559,000.00	$ 572,000.00	$602,000.00	$ 2,621,000.00
		Miscellaneous Costs	$80,000.00	$96,000.00	$120,000.00	$144,000.00	160,000	$ 600,000.00
		Project Management and Contingency	$80,000.00	$96,000.00	$120,000.00	$144,000.00	160,000	$ 600,000.00
		Total Actual Cost	$ 3,140,000.00	$ 4,522,000.00	$ 4,834,000.00	$ 6,861,000.00	$ 8,042,000.00	$ 27,399,000.00
		Total Present Value of Cost	$17,012,623.33	$18,713,885.66	$20,585,274.23	$22,643,801.65	$24,908,181.82	
		Income (20% of Actual Costs)	$3,768,000.00	$5,426,400.00	$5,800,800.00	$8,233,200.00	$9,650,400.00	$32,878,800.00
		Total Present Value of Income	$20,415,148.00	$22,456,662.80	$24,702,329.08	$27,172,561.98	$29,889,818.18	
		Net Present Value	$3,402,524.67	$3,742,777.13	$4,117,054.85	$4,528,760.33	$4,981,636.36	

Note:

Net Present value= Total Present Value of Income – Total Present Value of Cost

Income was estimated at a 20 percent profit over the actual costs.

Figure 18-*The bar plot shows the relationship between total actual cost and net present value.*



Description: From the above plot depicted in Figure 18 it can be summarized that the Actual costs are greater than the net present value, which is a concern for the firm. It must analyze and optimize the budgets more precisely. The net present value could improve if the income made exceeds 20%. Furthermore, it is necessary that the product sells at its actual value and consistently maintains demand with upcoming features. For an escalated demand of the product to take shape, it holds mandatory to analyze customer feedback when a product is released to its target market. If the response is highly positive, the profit margins will widen, i.e., the income level shall rise and as a result the Net present values will escalate.

FMECA ANALYSIS:

Table 13: ***An FMECA plan for acoustic collision detection smart watch system***

Ref. No.	Process Descr.	Potential Failure Mode	Potential Cause of Failure	Potential Effects of Failure	Current Controls	O	S	D	RPN *	Recommended Actions and Status	Responsible Activity
1.0	Notification discrepancies	Connectivity loss with smartphone	Bluetooth connection issues	Disconnected data sync & missed alerts	Compatibility checks & device pairings	3	6	8	144	Implement fail safes	Systems engineer
2.0	Low battery warning through beeps	Battery drainage/sudden shutdown	Inefficient power management	Inoperability , Shortened device battery life	Optimize power consumption algorithms	2	9	7	126	Improve battery optimization	System engineer
3..0	Security alerts through dashboard warnings	Inadequate privacy controls	Software vulnerabilities	Unauthorized access to user data/authenticity failure	Encryption & regular security updates	3	9	3	81	Enhance privacy features	Security team
4.0	No expected Auditory trigger signals	Delayed audio feedback	Software glitches	User receive collision alerts with delay	Optimize audio processing algorithms	3	9	2	54	Optimize audio processing, Proactive monitoring system	Software development teams

***O-Occurrence**, *S- Severity, *D- Detectability, *RPN- Risk Priority Number

Assumptions:

The analysis is based on pedestrians who own smartphones activate and utilize the Smart Watch's Acoustic Collision Detection function. The acoustic sensors that are integrated into the smart watch are probably sensitive and calibrated enough to detect potential collisions. The significance of precise sensor calibration in maintaining consistent performance and minimizing false positives or negatives across various environmental conditions is highlighted in the analysis.

Assumptions:

1. The severity, frequency, and probability of detection are estimated on a scale of 1 to 10, where 1 represents the lowest impact or likelihood, and 10 represents the highest whereas 1 represents the certainty to detect a failure and 10 represents the difficulty in detecting a failure.

2. Risk Priority Number (RPN) is calculated as the product of severity, frequency, and probability of detection.

3. Severity, frequency, and probability of detection are subjective estimates based on historical data , industry standards, expert judgment, and assumptions.

Allocating MTBF performance measures to system

Figure 19: ***Assigned MTBF measures to critical system functions.***

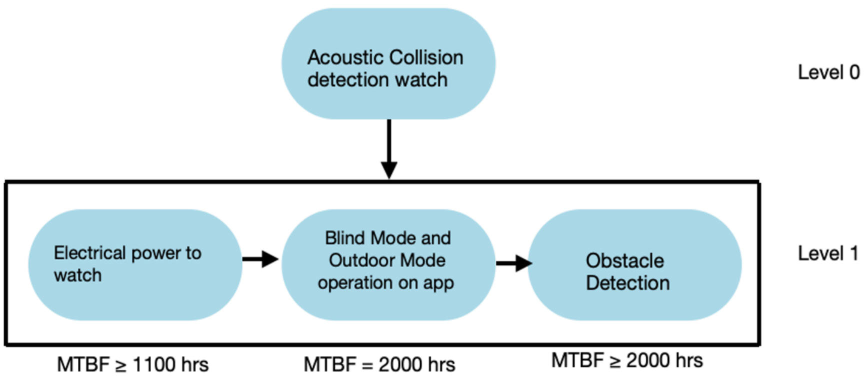
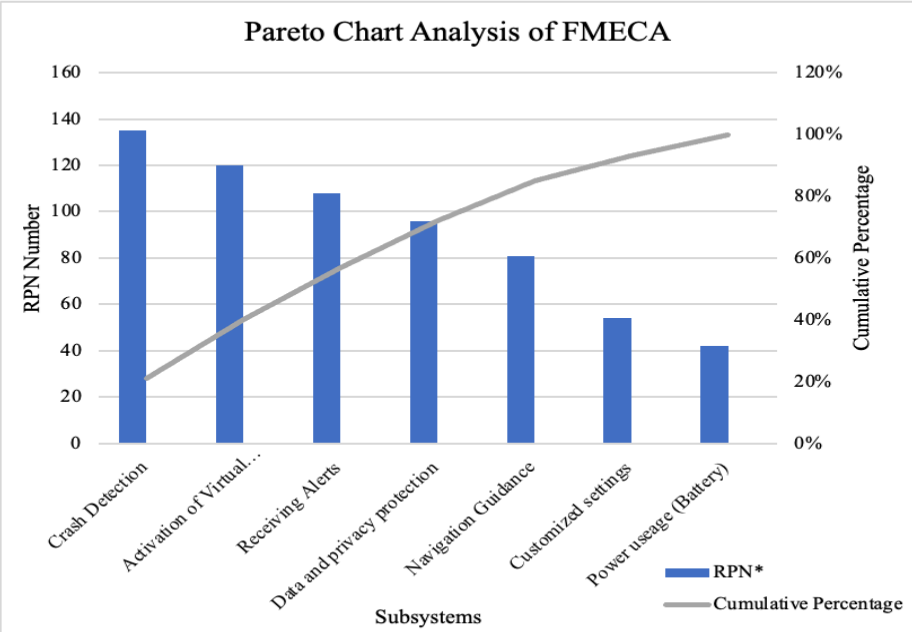


Table 14: ***Pareto Chart Analysis of FMECA***

Subsystems	O	S	D	RPN*	Total percentage	Cumulative Percentage
Crash Detection	3	9	5	135	21%	21%
Activation of Virtual Assistance	3	8	5	120	19%	40%
Receiving Alerts	2	9	6	108	17%	57%
Data and privacy protection	4	6	4	96	15%	72%
Navigation Guidance	3	9	3	81	13%	85%
Customized settings	3	9	2	54	8%	93%

Power usage (Battery)	2	7	3	42	7%	100%
			Total	**636**		

Figure 20: ***A pareto Chart analysis shows Crash detection and activation of virtual assistance as critical failure points.***



DESIGN FOR RELIABILITY:

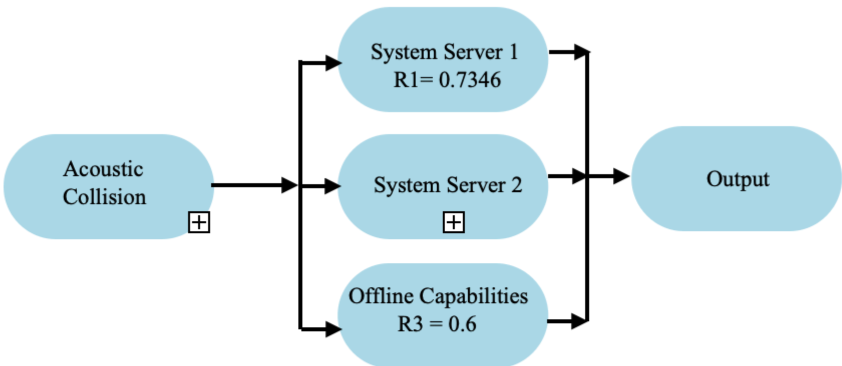
1. A pareto chart analysis of FMECA was conducted. An RPN of 137 shows crash detection and activation of VA holds the highest priority.
2. System servers are arranged in parallel to achieve highest reliability of 0.971 since series system reliability is low 0.734.
3. If any server fails, the other servers will still generate output.
4. A standby A,B, C system with two redundancies is also feasible.
5. In the table, Operating cycle time and downtime have been assumed.
6. Actual operating time= Operating cycle time-downtime
7. No of failures/ fraction of failures was estimated by iteration until a decent value for reliability was obtained.

Table 15: ***Calculations for Reliability***

Subsystem	Operating Cycle (hrs/yr)	Downtime (hrs/yr)	Actual Operating Time (hrs/yr)	No of Failures (per yr)	Lambda (Failure rate)	MTBF (hrs)	Reliability
Crash Detection	8760	73	8687	0.023	2.64763E-06	377,696	0.977073619
Virtual Assistance	6240	182.5	6057.5	0.040	6.60338E-06	151,438	0.959632272
Alert System	8395	219	8176	0.091	1.11546E-05	89,649	0.910607921
Navigation Guidance	2920	164.25	2755.75	0.138	5.00771E-05	19,969	0.863963147
Power output (Battery)	6750	164.25	6585.75	0.004	6.07372E-07	1,646,438	0.995908632
						Reliability in Series	**0.734646257**

The table above lists different subsystems of the product, their operating cycles, downtime, actual operating time, number of failures per year, failure rates (Lambda), Mean Time Between Failures (MTBF), and individual reliability. These metrics give a detailed view of how often each subsystem fails and its operational dependability.

Figure 21: *Shows the arrangement of system servers in a parallel fashion.*



Reliability of a parallel server and offline system

R (parallel) 1- (1-R1)*(1-R2)*(1-R3)

1-((1-0.7346)*(1-0.7346)*(1-0.6))= **0.971825**

DESIGN FOR MAINTAINABILITY:

Designing for maintainability in an obstacle detection smartwatch feature involves creating a system that is easy to maintain, update, and troubleshoot throughout its lifecycle.For an obstacle detection smartwatch we have considered preventive maintenance for four sections -

Software updates ,Battery , Data Security , Calibration of Sensors.Table gives the average time for preventive maintenance and the mean time between maintenance for the states systems.Table provides an overview of various maintainability related parameters , formulas used and calculated values.

Table 16: ***Preventive maintenance table***

Preventive Maintenance	Maintenance Time(Hrs)	MTBS(Hrs)	FPT	MPT*FPT
Software update	5	2160	0.000462963	0.0023148
Battery	1	8000	0.000125	0.000125
Data Security	4	3500	0.000285714	0.0011429
Calibration of Sensors	3	4250	0.000235294	0.0007059

Table 17: ***Maintainability parameters***

Maintainability parameters	Formulas	Results
Application failure rate	$\lambda = \lambda a + \lambda b + \ldots$	7.10901E-05 failures/hr
Mean Corrective Maintenance (MCT)	$Mct = \lambda a*Mct\_a + \lambda b*Mct\_b+ \ldots)/(\lambda a+ \lambda b+\ldots)$	171.1374485 hrs
Mean Preventive Maintenance (MPT)	$Mpt = \sum (fpt_i)(Mpt_i) / \sum fpt_i$	4.026 hrs
Mean Active Maintenance(M)	$M = ((\lambda*Mct) + (fpt*Mpt)) / (\lambda + fpt)$	12.74921266 hrs
Mean time Between Failure (MTBF)	$MTBF = 1/(\lambda a + \lambda b + \ldots)$	14066.65607 hrs
Mean time Between Preventive Maintenance (MTBS)	$MTBS = 1/(fpt1 + fpt2+ \ldots)$	774.7193579 hrs
Mean Time Between Maintenance (MTBM)	$MTBM =1/(1/MTBF+1/MTBS)$	734.2790304 hrs
Mean Downtime (MDT)	$MDT = ADT + M$	17.74921266 hrs

Inherent Availability (Ai)	Ai=MTBF/(MTBF+Mct)	0.987980058
Achieved Availability (Aa)	Aa=MTBM/(MTBM+M)	0.982933426
Operational Availability (Ao)	Ao=MTBM/(MTBM+MDT)	0.97639821

DESIGN FOR SUSTAINABILITY:

Table 18: ***Resources consumed***

Resource Name	Life Cycle Stage of Consumption	Amount Consumed (Qty)	Unit of Measurement	Functional Unit	Potential Annual Volume of Consumption (Qty)
Recycled plastic	manufacturing	5	grams	1 watch	5* 5M
Titanium metal alloy	manufacturing	5	grams	1 watch	5*5M
Solar Filaments	manufacturing	5	grams	1 watch	5*5M
SurlynIonomer	packaging	100	grams	1 watch	100*5M
Transient nanocomposite	manufacturing	14	grams	1 watch	14*5M

Table 19: ***Emissions/Affluents***

Emission / Effluent	Life Cycle Stage of Occurrence	Amount Emitted (Qty)	Unit of Measurement	Functional Unit (per Unit of Product or Service)	Potential Annual Volume of Emission (Qty)
Carbon dioxide	Raw Material Extraction	8.1	kg	1 Watch	5M*8.1
Nitrogen-di-Oxide	Manufacturing	0.3	parts per billion(ppb)	1 watch	0.3*5M
Water	End-of-Life	0.1	Gallons	1 watch	0.1*5M

Table 20: ***Sustainability Strategies***

Lifecycle Stage	Sustainability consideration	Sustainability strategy	Resources Affected	Metrics
Resource extraction and processing materials	Enhancing product life, by reducing the need for replacements	Recycled plastic- watch straps Reused metal to make alloys for watch casing	Recycled titanium metal alloy.	Percentage of recycled materials used

Construction & production	Renewable energy for charging	Mini solar filaments on straps absorbs sunlight for wireless charging	Electricity	Kilowatt generated per charge
Disposal at end of life	Transient electronic components for watch. (Li et al. 32136-32148)	Materials made of transient nanocomposite disintegrate in water enabling collection of recyclable components	Transient Nanocomposite material .	Percentage of materials recycled
Design & Packaging	Diminish packaging waste.	Surlyn lonomer packaging produced using plastic waste	Plastic material	Percentage of plastic reduced for packaging.
Product Use	Promote sustainable usage and maintenance to prolong the watch's life	Increase device lifespan through user education, efficient charging, software updates, and maintenance	Education materials, software updates, maintenance tools	Rate of user engagement with energy-saving features or practices

DESIGN FOR USABILITY:

Below the usability considerations for the following project are mentioned in the form of question and answers.

a) What are the points of system human interaction in your system?

A user will interact with an acoustic collision smart watch on these 6 levels which is noted by the frequency of usage.

- Visual displays: Receiving notifications on alerts, text messages, calls represented by its critical nature
- Sound Haptics:
  1. Virtual assistance (eg, Siri or Alexa) for voice recognition and feedback
  2. The calling and texting interface for initiating communications
- Information control (Cognitive Capacity): Blind Mode/Outdoor mode applications capturing and recording data as generated (on activation). Setting outputs as customized by the user.
- Auditory feedback: Guidance from navigation (GPS-Online/Offline) systems

b) What are the functions performed by the Humans?

- User customizes the Blind mode and Outdoor mode durations using calendar settings
- A user dictates instructions to the voice assistant embedded in the software system.

- Based on collision alerts and notifications, a user may depict body movements for his/ her protection as per the instruction of the voice assistant. This can be to prevent a crash or respond to an emergency.
- Using GPS navigation a user commutes to and from a destination, by foot or by vehicle.
- Using SOS, calling or texting a user is able to communicate.

c) What are the important human factors and usability considerations?

1. Anthropometric factors

- User Size and Shape: Design the smartwatch with adjustable straps and a flexible form factor to comfortably fit users with diverse body sizes, shapes, and wrist dimensions.
- Ergonomics: Create a smartwatch interface with easily accessible and operable buttons, accommodating diverse hand sizes and dexterity.

2. Human Sensory factors

- Auditory Perception: Develop clear and distinct acoustic signals for collision detection, considering variations in users' hearing abilities and frequency sensitivities.
- Visual Perception: Provide clear visual cues on the smartwatch display for users with hearing impairments, complementing auditory signals for enhanced clarity.

3. Physiological factors

- Heart Rate and Stress Monitoring:Integrate physiological sensors for heart rate and stress, adapting collision alerts based on the user's physiological state.
- Comfort and Wearability: The smartwatch for extended comfort, accounting for factors such as skin sensitivity and potential material allergies.

4. Information processing and psychological factors

- Cognitive Load: Minimize cognitive load with concise information and prioritize critical details in collision alerts.

- User Trust and Confidence: Build trust through accurate detection, transparent communication, and managing user expectations.
- Feedback and Affordances: Offer timely feedback and intuitive affordances for smartwatch interactions and collision alerts.

5. User Training and Familiarity: Design an intuitive interface and provide clear instructions for easy user adoption.

d) What would be some features or aids that could improve the human interactions in our system?

- Biometric Authentication:

Fingerprint, facial recognition, or iris scanning for secure access.

Continuous authentication for ongoing security during usage.

- Multi-Modal Interaction:

Combination of sensory and gesture inputs for a holistic user experience.

- Customizable Accessibility Features:

Text-to-speech and speech-to-text capabilities for users with visual or hearing impairments.

- Offline Functionality:

1. Enhanced System functionality even in the absence of a network connection.
2. Offline storage and synchronization when reconnecting.
3. Seamless transition between online and offline modes.

(A figure illustration was required here)

SYSTEMS ENGINEERING MANAGEMENT PLAN (SEMP)

The Systems Engineering Management Plan is a document that lists all the systems engineering activities that are overseen by management and planning teams beginning from conceptual design to production phase. The activity sequence begin from problem identification and terminates at Usability Analysis.

Firstly, the SEMP plan is divided into 11 weeks and 4 phases. The phases are attributed to conceptual, preliminary, detailed design and production phase.

Secondly, on observing the SEMP chart below, it is observed that conceptual and preliminary design lasted for 6 weeks whereas detailed design and production phase totalled to a duration of 5 weeks. The reason is that, if stronger intensity of effort and time commitment is emphasized at early stages, making design changes and the cost incurred to implement them is fairly small. This facilitates a smooth flow of project activity during the later stages. As a result durations of the last two phases are fairly small.

Figure 22: An SEMP management plan lists all the systems engineering activities

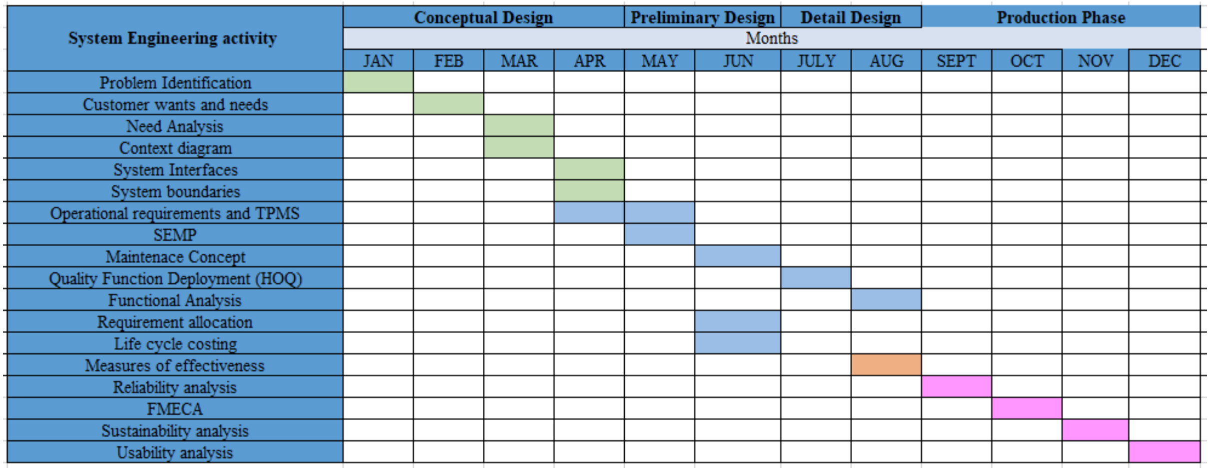


Figure 23: Timeline for phases

Phase	Start time	End time
Conceptual design	JAN	APR
Preliminary design	MAY	JUNE
Detail design	JULY	AUG
Production Phase	SEPT	DEC

MBSE

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APPENDIX

Validation Process Details

This section depicts a customer-specific survey that was added to prioritize and quantify the attributes of customer requirements. There was a requirement added to fill out the survey, whose intention was to track the target market. Below the survey is listed with a total of 11 questions.

Hello customers, below is a quick survey to fill out, please answer only if you are a smartphone and a smartwatch user.

1.For leisure or work, how often do you commute by foot in a day?

- ☐ Just once

- ☐ Twice
- ☐ Thrice
- ☐ Greater than three times
- ☐ Never

2. During your commute, how often do you get distracted by using a smartphone?

- ☐ Rarely
- ☐ Occasionally
- ☐ Frequently
- ☐ Always

3. Have you accidentally bumped into an object while using a smartphone?

- ☐ Yes
- ☐ No
- ☐ If yes, please specify……………………………………………

4. Have you ever used a smartwatch and synced it with your smartphone device?

- ☐ Yes
- ☐ No

5. How likely are you to buy a smartwatch with an enhanced intelligence system that alerts you of approaching obstacles?

- ☐ Very Likely
- ☐ Strongly Likely
- ☐ Less Likely
- ☐ Not Likely

6. Do you support/oppose the idea of an "active-outdoor" mode present in your smartwatch, that switches on a virtual assistant to send you voice alerts and warnings?

- ☐ Strongly Oppose
- ☐ Somewhat Oppose
- ☐ Neutral
- ☐ Somewhat Favor
- ☐ Strongly Favor

7. How important do you think a "*Blind-Mode Integration*" feature is in your smartwatch, that offers enhanced assistance and instructions to the user such as "Walk ahead 5 steps" or, "Object to your left in 3 meters"?

- ☐ Not at all important
- ☐ Slightly Important
- ☐ Neutral
- ☐ Very important
- ☐ Extremely Important

8. What price range do you think is reasonable for a collision-detection smartwatch?

- ☐ Less than 400$
- ☐ 400$ - 800$
- ☐ 800$- 1,200$
- ☐ 1,200$ or more

9. On a scale of 1 to 5, how satisfied are you with your current watch product (if applicable)?

- ☐ 1 - Very Dissatisfied
- ☐ 2-3 - Dissatisfied
- ☐ 3-4 - Satisfied
- ☐ 5 - Very Satisfied

10. How often do you use navigation aids, such as GPS or maps, in your daily life?

- ☐ Never
- ☐ Rarely
- ☐ Sometimes
- ☐ Usually
- ☐ Always

11.What concerns, if any, do you have about privacy and data security when using such a smart-watch feature?

…………………………………………………………