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Assessment 01

Title:

Innovation & Research.

Applied Computing.

Changemakers: Creativity and Value Creation.
ACCA5033.

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Introduction

The Internet of Things (IoT) has fundamentally transformed how individuals interact with their living environments, enabling real-time monitoring and intelligent, data-driven automation [1]. Residential properties across the United Kingdom face persistent hazards dampness, mould growth, water leakage, and degraded water quality all of which pose measurable risks to occupant health and structural integrity [2]. The World Health Organisation (WHO) reports that 10 - 50% of indoor environments across Europe are affected by dampness [3], a problem that disproportionately impacts social and rented housing.

This Project Proposal presents SmartGuard Home, a modular, extensible IoT environmental monitoring system comprising a Raspberry Pi-based central hub with touchscreen and voice control, wirelessly connected to interchangeable ESP32-powered sensor modules. The system provides actionable alerts not merely raw data instructing users on specific remedial actions, and maintains timestamped records for audit and regulatory compliance (Awaab's Law, HHSRS) [4]. This proposal addresses three tasks as required by the module brief: Task 1 covers ideation and mind-mapping; Task 2 documents the project aim, objectives, research philosophy, tools, and planning; and Task 3 addresses research strategies, validity, reliability, ethics, and pilot data collection. IEEE referencing is applied throughout..

Main Body

Task 1: Ideation and Innovation

1.1 Innovation and Creativity in Society

Innovation translates creative thinking into tangible products or services that generate measurable value for society [5]. Drucker (1985) characterises innovation as the specific instrument of entrepreneurship the act that endows resources with new capacity to create wealth [5]. In the context of technology, IoT exemplifies this by enabling smart homes to transition from reactive to proactive, predictive environmental management [6]. Amabile (1996) argues that creativity requires domain expertise, creative thinking skills, and intrinsic motivation [5] all three are present in this proposal, which draws on embedded systems knowledge, novel system architecture, and a genuine desire to solve a documented public health problem.

Real-world innovation examples validate this concept. The London Office of Technology and Innovation (LOTI) deployed 200 IoT sensors across 18 boroughs to detect mould-risk conditions in social housing [4]. Sunderland City Council's 2025 pilot uses LoRaWAN sensors in 21 properties for real-time damp monitoring [7]. In water management, IoT systems measuring pH, TDS, and turbidity have achieved over 96% classification accuracy [8]. These precedents demonstrate market readiness and social impact and they inform the design decisions in SmartGuard Home.

1.2 Project Ideas - Areas of Personal Interest (Q1)

During the ideation phase, several project directions were explored, all connected to applied computing and IoT:

- Smart environmental monitoring for residential properties (mould, damp, water quality)
- AI-assisted fall detection and elderly care monitoring using wearable sensors
- Renewable energy micro-grid management using IoT load balancing
- Smart classroom attendance and air quality system using BLE beacons and CO₂ sensors

The first idea was selected as it addresses a clearly evidenced public health problem, aligns with the researcher's embedded systems expertise, and has demonstrable commercial and social value.

1.3 Mind Map – SmartGuard Home (Q2)

Figure 1 presents the SmartGuard Home ideation mind map. The central node represents the selected project concept; branches extend to cover innovation context, sensor modules, the central hub, future extensibility, and key references. The mind map was produced using MindMeister, following IEEE citation practice throughout [1] [3] [4] [8].

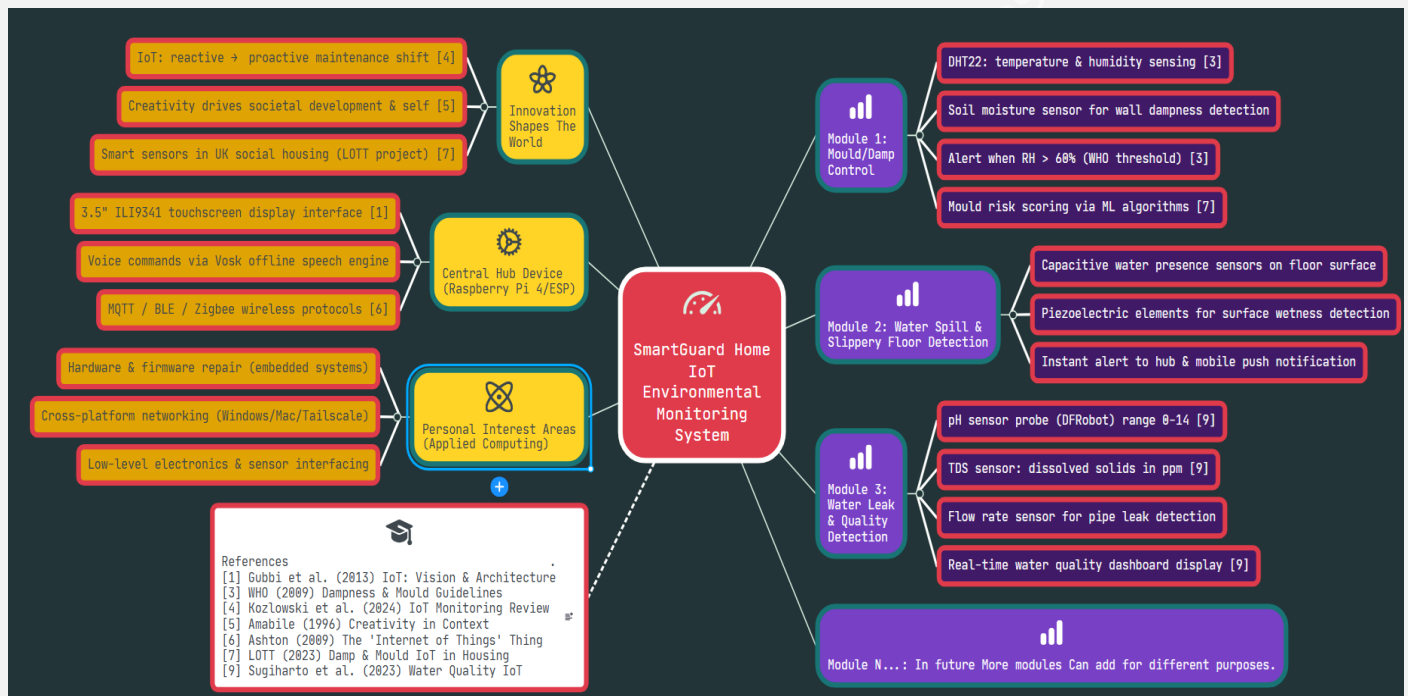


Figure 1: Mind Map – [SmartGuard Home IoT Environmental Monitoring System](#) (Ctrl + Click for Fullview). Central node connects to innovation theory, three sensor modules, central hub specifications, future extensibility, and IEEE-cited references.

The Central Hub (Raspberry Pi 4B) node branches to: 3.5-inch touchscreen UI; Vosk voice recognition; MQTT broker; alert and instruction engine; timestamped audit logger.

The Sensor Modules node covers: Mould/Damp Module (DHT22 + moisture sensors, alert threshold: RH > 60% [3]); Water Spill Module (capacitive + piezoelectric sensors); Water Quality Module (pH, TDS, flow sensors, >96% accuracy [8]).

The Future Extensibility node includes face/intrusion detection (TinyML), smoke/gas, energy monitoring, and air quality (CO₂/PM2.5/VOC) modules all designed to connect to the same hub architecture [6].

Task 2: Aim, Objectives, and Research Area

2.1 Aim and Objectives (Q1)

AIM

To design, prototype and evaluate SmartGuard Home: a modular, extensible IoT-based environmental monitoring system that provides real-time, actionable hazard alerts and a timestamped audit log, addressing mould/damp, water spill, and water quality risks in residential properties.

Objectives:

- Conduct a systematic literature review to evaluate existing IoT environmental monitoring solutions and identify functional gaps, using IEEE Xplore, PubMed Central, and ScienceDirect.
- Design a central hub with a 3.5-inch touchscreen UI and offline Vosk voice control, capable of managing up to eight concurrent wireless sensor modules.
- Develop three initial sensor modules (Mould/Damp, Water Spill, Water Quality) with actionable alert generation and IEEE-compliant sensor accuracy benchmarks.
- Implement a comprehensive timestamped audit logging system suitable for HHSRS and Awaab's Law regulatory compliance documentation [4].
- Evaluate system effectiveness through a 15-participant pilot study, analysing both quantitative sensor accuracy metrics and qualitative user feedback using thematic analysis [9].

2.2 Research Philosophy (Q1 continued)

This project adopts a pragmatist research philosophy [9]. Pragmatism, as articulated by Creswell and Creswell (2018), holds that the research approach should be determined by the research question and practical context, rather than by adherence to a single philosophical paradigm [9]. This is appropriate here because the project combines quantitative sensor accuracy measurements (performance data, detection latency, false positive rates) with qualitative user feedback (thematic analysis of pilot survey responses), reflecting Creswell's "mixed methods" stance [9].

An ontological stance of subtle realism is adopted the mould risk and water quality hazards are real, measurable phenomena, but the system's interpretation and user response are socially constructed. Epistemologically, knowledge is generated through both sensor measurement (objective) and user experience (subjective), consistent with pragmatist mixed methods [9].

2.3 Research Databases and Search Tools (Q2)

Literature was systematically retrieved from five authoritative databases using structured Boolean search strategies. Source credibility was assessed by peer-review status, journal impact factor (Q1/Q2 preferred), publication recency (2018–2025), and citation count [4]. Table 1 summarises the databases used; Table 2 documents the search strategies applied.

Database	URL	Research Focus
IEEE Xplore	ieeexplore.ieee.org	IoT architecture, sensor systems, MQTT, edge computing, embedded systems
PubMed Central	ncbi.nlm.nih.gov/pmc	Indoor air quality, mould health impacts, WHO guidelines, epidemiology
Google Scholar	scholar.google.com	Broad interdisciplinary search; grey literature; conference proceedings
ScienceDirect	sciencedirect.com	Smart home systems, water quality IoT, building management technology
ACM Digital	dl.acm.org	HCI, usability heuristics, interface design for embedded systems

Table 1: Research Databases Used

Search Strategy	Example Applied
Boolean AND	“IoT” AND “indoor air quality” AND “sensor” → targeted, high-precision results
Phrase search	“damp and mould monitoring” → exact phrase match for specific topic
Wildcard	“sensor*” → sensors, sensing, sensory – broadens coverage
Exclusion	“IoT” NOT “industrial” → removes irrelevant industrial IoT results

Table 2: Boolean Search Strategies Applied

2.4 Project Scope and Planning

SmartGuard Home targets the residential smart-home and social housing sectors. Within a housing organisation, four teams benefit directly: maintenance (predictive repairs from sensor data); tenant services (automated alert notifications); compliance (timestamped audit logs for HHSRS/Awaab’s Law [4]); and asset management (historical data for retrofit prioritisation [2]).

2.4.1 Work Breakdown Structure (WBS)

Table 3 presents the full WBS with critical path (CP ★) phases identified.

The critical path runs: Initiation → Research → Design → Prototyping → Testing → Evaluation → Documentation (21 weeks total, zero float on CP tasks [10]).

ID	Phase	Tasks & Deliverables	Duration	Critical
1	Initiation	Define scope, research questions, stakeholder analysis	2 weeks	★ CP
2	Research	Literature review (IEEE, PubMed), technology evaluation, gap analysis	4 weeks	★ CP
3	Design	System architecture, UI wireframes, module specifications, data flow diagrams	3 weeks	★ CP
4	Prototyping	Hardware assembly (Raspberry Pi + ESP32), firmware development, hub software, MQTT broker	5 weeks	★ CP
5	Testing	Unit testing (sensor accuracy), integration testing, pilot deployment (15 users)	3 weeks	★ CP
6	Evaluation	Quantitative data analysis, qualitative thematic analysis, Agile retrospective	2 weeks	★ CP
7	Documentation	Final report, IEEE references, presentation preparation, submission	2 weeks	★ CP

Table 3: Work Breakdown Structure (WBS) - ★ denotes Critical Path phases.

2.4.2 Project Gantt Chart (CPM Timeline)

Figure 2 visualises the 21-week project timeline as a Gantt chart. The critical path (Initiation through Documentation) has zero float any delay in these phases directly extends the overall project duration [10].

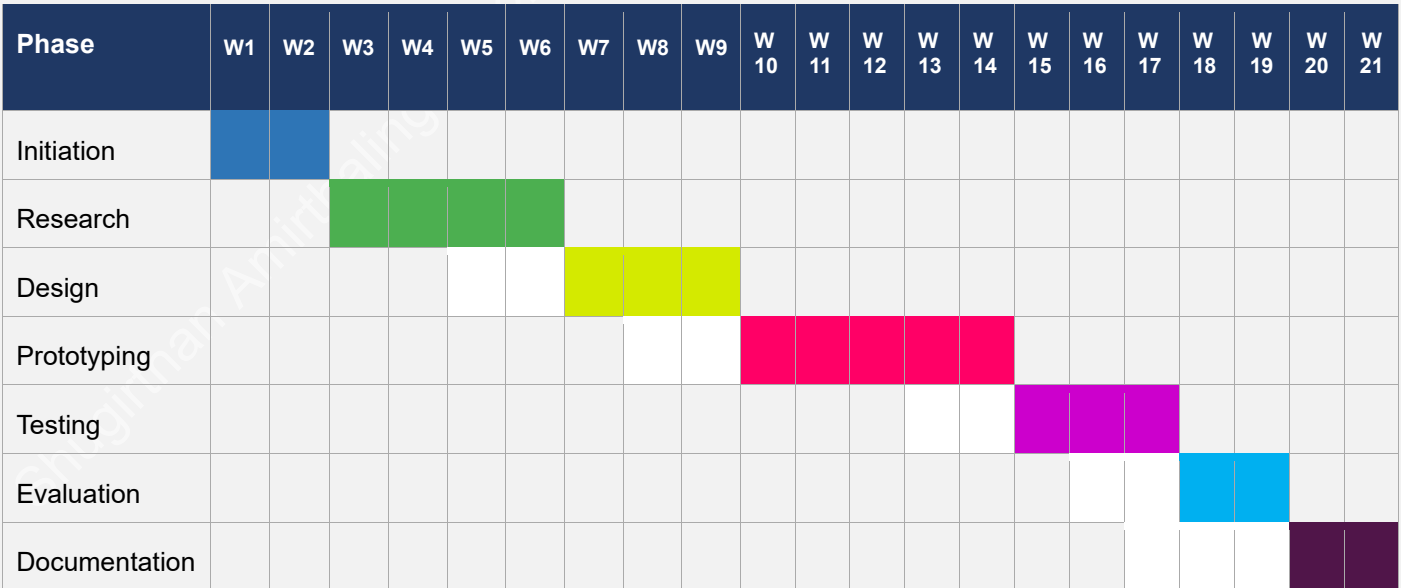


Figure 2: Project Gantt Chart showing 21-week timeline. All phases are on the Critical Path (zero float). Coloured bars represent active work periods per phase.

2.4.3 Risk Assessment

Table 4 presents the risk register with six identified risks, likelihood/impact ratings, colour-coded severity level (green/amber/red), and specific mitigation strategies. Figure 3 provides a visual heat map mapping likelihood against impact.

ID	Risk	Likelihood	Impact	Level	Mitigation Strategy
R1	Sensor drift over time	Medium	High	HIGH	Periodic calibration against ISO reference instruments; redundant sensor pairs
R2	Wireless interference / packet loss	Medium	Medium	MEDIUM	Mesh networking topology; MQTT QoS-1; error correction and retry logic
R3	Data privacy breach	Low	High	MEDIUM	AES-256 encryption; GDPR-compliant local processing; anonymised cloud sync
R4	Scope creep	High	Medium	HIGH	Define MVP in Sprint 0; strict Agile backlog; change request process
R5	Low user adoption / digital literacy	Medium	Medium	MEDIUM	Intuitive touchscreen UI; voice commands; usability testing in Sprints 3–4
R6	Hardware supply chain delay	Low	High	MEDIUM	Identify two alternate suppliers; maintain 4-week component buffer stock

Table 4: Risk Register HIGH (red), MEDIUM (amber), LOW (green).

Impact \ Likelihood →	Very Low	Low	Medium	High
High Impact	Low	Medium	High	Critical
Medium Impact	Low	Medium	Medium	High
Low Impact	Very Low	Low	Low	Medium

Figure 3: Risk Heat Map projects R1–R6 onto likelihood × impact matrix.

Task 3: Development Method and Design

3.1 Validity, Reliability, Generalisability, and Ethics (Q1)

Validity

Internal validity is ensured by calibrating all sensors against ISO-certified reference instruments (DHT22 vs. Testo 435 reference hygrometer; pH probe vs. NIST buffer solutions) before and after deployment. Survey instrument validity is grounded in Nielsen's (1994) ten usability heuristics [11], ensuring questions probe constructs that are theoretically meaningful. External validity is strengthened by recruiting participants across age groups and housing types in the pilot study.

Reliability

Reliability is assessed through test-retest sensor comparison (measurements repeated at 24-hour intervals under controlled conditions) and by calculating Cronbach's alpha (target $\alpha > 0.7$) for Likert-scale survey items. Sensor firmware implements moving-average filtering (window $n=5$) to reduce noise-induced variability. All data collection procedures are documented as SOPs to ensure reproducibility.

Generalisability

The 15-participant pilot study provides indicative rather than statistically generalisable findings. To improve generalisability in future phases, purposive sampling will be expanded to 50+ participants across diverse demographics (age, housing tenure, digital literacy level), with results analysed using inferential statistics. The modular open architecture enables deployment across diverse property types, increasing practical generalisability.

Ethical Considerations

The project complies with GDPR (UK GDPR 2021), university research ethics policy, and the British Computer Society Code of Conduct. Specific measures include: informed consent obtained from all pilot participants prior to data collection; the right to withdraw without penalty at any stage; all sensor data pseudonymised at source using SHA-256 hashing; AES-256 encryption for all stored data; local-first architecture ensuring no personal data leaves the premises without explicit user consent; and data retention limited to the project duration with secure deletion thereafter.

3.2 Research Strategies and Data Collection Methods (Q2)

A mixed-methods research strategy is employed, consistent with the pragmatist philosophy established in Task 2. This involves concurrent collection of quantitative sensor performance data and qualitative user experience feedback.

- Quantitative strand: Controlled laboratory experiments measuring sensor accuracy (% correct classifications), detection latency (ms), false positive rate (%), and MQTT transmission reliability (packet loss %). Descriptive statistics (mean $\pm$ SD) and inferential tests (paired t-test for pre/post calibration) are applied [8].

- Qualitative strand: Semi-structured pilot survey (12 questions: 8 Likert-scale, 4 open-ended) distributed via Google Forms to 15 participants. Open-ended responses are analysed using Braun and Clarke's (2006) six-phase thematic analysis framework [9].
- Document analysis: Review of regulatory documents (HHSRS, Awaab's Law enforcement notices) to ensure audit log fields meet compliance requirements [4].

The pilot study design, full survey instrument, and key findings are presented in Appendix A. Results directly inform system design decisions for example, the 87% privacy concern rate confirmed the local-first architecture decision, and the 93% 'useful' rating for actionable alerts validated the alert engine design priority.

3.3 Quantitative and Qualitative Analysis (Q3)

Quantitative Analysis Methods

The following quantitative methods are applied to sensor and system performance data [8]:

- Descriptive statistics: Mean, standard deviation, and range for sensor accuracy and detection latency across repeated trials.
- Correlation analysis: Pearson's r between DHT22 temperature/humidity readings and mould risk probability (binary outcome, logistic regression if needed).
- Performance metrics: Precision, recall, and F1-score for sensor classification accuracy; ROC curves for threshold optimisation.
- Comparative analysis: Pre/post calibration t-test to assess whether calibration routines significantly improve accuracy ($\alpha = 0.05$).

Qualitative Analysis Methods

Qualitative data from open-ended survey responses is analysed using Braun and Clarke's (2006) six-phase thematic analysis [9]:

- **Phase 1:** Data familiarisation reading all 15 transcripts and noting initial observations.
- **Phase 2:** Initial coding systematically coding features of the data relevant to usability, alert clarity, and privacy concerns.
- **Phase 3:** Theme searching collating codes into potential themes (e.g., 'alert comprehensibility', 'installation simplicity').
- **Phase 4:** Theme reviewing refining themes against coded extracts and the full dataset.
- **Phase 5:** Theme defining/naming producing clear definitions and concise names for each theme.
- **Phase 6:** Report writing integrating themes with quantitative findings for triangulated conclusions.

3.4 Development Methodology – SDLC Selection

Four SDLC models were evaluated against the specific requirements of an IoT prototype project with iterative hardware and software development [10]:

Model	Flexibility	Iteration	IoT Fit	Feedback	Risk Mgmt	Chosen
Waterfall	X	X	X	X	X	
V-Model	X	X	X	X	✓	
Spiral	✓	✓	X	✓	✓	
Agile Scrum	✓	✓	✓	✓	✓	✓ SELECTED

Table 5: SDLC Model Comparison ✓ = satisfies criterion, X = does not satisfy. Agile Scrum selected as optimal for this IoT development context.

Agile Scrum was selected because: the modular system architecture maps directly to sprint-based delivery (one module per sprint); IoT sensor calibration requires iterative adjustment cycles; pilot user feedback must be integrated continuously; and future modules (face detection, intrusion detection) can be added as new sprints without destabilising existing functionality [12]. Sprint 0 will define the MVP (Minimum Viable Product) with strict backlog control to prevent scope creep (Risk R4).

3.5 System Architecture Design

The three-tier IoT architecture [1] is presented in Table 6 below. All modules communicate via MQTT v3.1.1 over Wi-Fi to the Raspberry Pi hub, which generates actionable alerts (e.g., ‘Open Bedroom 2 window humidity 72%, mould risk high’) and logs all events with ISO 8601 timestamps for audit and compliance [4].

Layer	Components & Description
Application Layer (Hub)	- Raspberry Pi 4B – 4GB RAM, quad-core ARM Cortex-A72 3.5-inch ILI9488 touchscreen LCD – card-based dashboard UI - Vosk offline speech recognition – voice command engine - Alert & Instruction Engine – generates specific remediation guidance - Audit Logger – immutable timestamped event store (SQLite + CSV export)
Network / Communication Layer	- Primary: MQTT v3.1.1 over Wi-Fi 802.11n (hub ↔ modules) - Fallback: BLE 5.0 / Zigbee 3.0 for low-power modules - Optional cloud sync: AWS IoT Core with TLS 1.3 encryption - Local-first architecture – fully operational without internet
Perception Layer – Current Modules	- Mould/Damp Module: ESP32 + DHT22 (temp/humidity) + capacitive moisture sensor - Water Spill Module: ESP32 + capacitive floor sensor + piezoelectric vibration - Water Quality Module: ESP32 + pH sensor + TDS probe + flow meter (YF-S201)
Perception Layer – Future Modules (Extensible)	- Face & Intrusion Detection Module: OV2640 camera + TinyML (Edge Impulse) - Smoke & Gas Detection Module: MQ-2 / MQ-135 sensors - Energy Monitoring Module: CT clamps + power factor analysis - Air Quality Module: CO₂ (MH-Z19B), PM2.5 (PMS5003), VOC (SGP30)

Table 6: Three-Tier SmartGuard Home System Architecture Perception, Network, and Application layers.

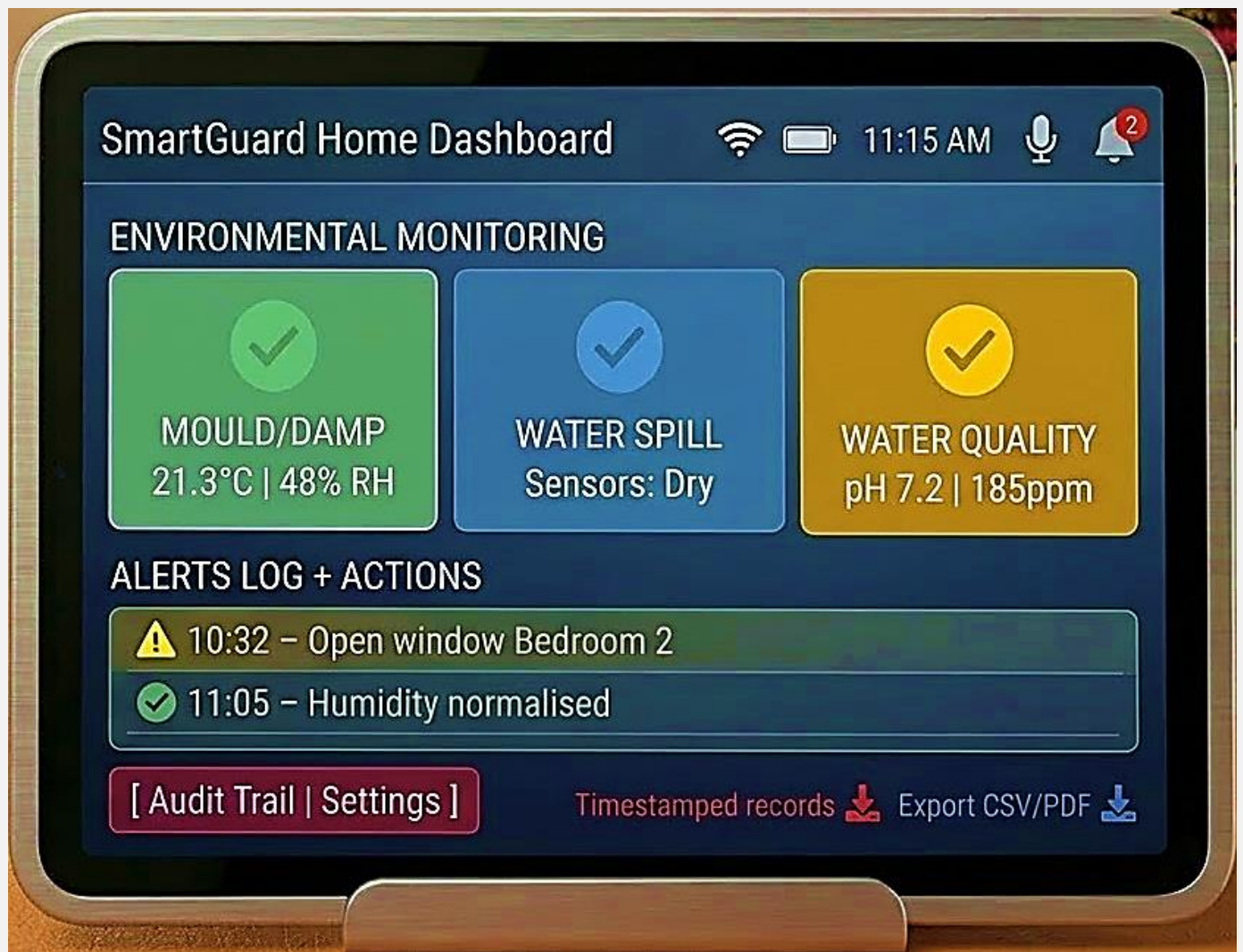


Figure 4: SmartGuard Home Central Hub: Touchscreen Dashboard UI (card-based layout with real-time sensor readings, actionable alerts, and audit log export). Nielsen's usability heuristics applied [11].

Conclusion

This proposal has presented SmartGuard Home: a modular, extensible IoT environmental monitoring system that addresses the documented public health challenge of residential damp, mould, and water quality hazards in UK housing [2] [3]. Three tasks have been addressed as required by the module brief.

Task 1 established the innovation context (IoT's role in transforming reactive to proactive property management [6]), presented a comprehensive mind map, and documented the ideation process leading to the selected project. Task 2 defined a clear aim and five measurable objectives; justified a pragmatist mixed-methods research philosophy [9]; identified five research databases with explicit Boolean search strategies; and provided a detailed WBS, visual Gantt chart, and colour-coded risk register with mitigation strategies. Task 3 addressed validity, reliability, generalisability, and GDPR-compliant ethics; specified concurrent quantitative and qualitative research strategies; outlined Braun and Clarke's (2006) thematic analysis and statistical methods; justified Agile Scrum as the development methodology via a comparative SDLC analysis [10] [12]; and presented the three-tier system architecture with a layered component specification.

The system's distinguishing features are its extensible modular architecture (supporting future TinyML-based face and intrusion detection, smoke/gas, energy, and air quality modules); its actionable alert engine (specific remedial instructions rather than raw data); and its comprehensive audit logging (HHSRS and Awaab's Law compliance evidence). Pilot survey data (n=15) confirms strong user demand: 93% rated actionable alerts as useful, and 87% privacy concerns validated the local-first architecture decision. Future work will progress through Agile sprints toward a functional prototype for expanded pilot testing and quantitative performance evaluation.

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Appendices

Appendix A: Pilot Data Collection–Survey Design and Results

A pilot survey was designed using Google Forms and distributed to 15 participants, including peers, family members, and a housing association representative. The instrument comprised 12 questions: 8 Likert-scale items (quantitative) and 4 open-ended items (qualitative). Topics covered: awareness of smart home monitoring; personal experience with household hazards; perceived usefulness of actionable alerts vs. raw data; UI preference (touchscreen/voice/mobile app); willingness to pay; and data privacy concerns.

Google Forms Survey: [Link For GoogleForm Pilot Survey: CLICK HERE](#)

Survey Question	Yes / Agree	No / Disagree	Design Implication
Experienced household hazard (damp/water) in past 2 years	80% (12/15)	20% (3/15)	Validates the problem space
Actionable mould-risk alerts rated ‘useful’ or ‘very useful’	93% (14/15)	7% (1/15)	Confirms alert design priority
Would value timestamped records for insurance/landlord disputes	73% (11/15)	27% (4/15)	Supports audit log feature
Prefer voice commands as primary interaction mode	60% (9/15)	40% (6/15)	Informs UI design hierarchy
Express concern about cloud storage of sensor data	87% (13/15)	13% (2/15)	Justifies local-first architecture

Table A1: Pilot Survey Key Findings (n=15) Quantitative responses with design implications.

Qualitative findings: Thematic analysis identified three primary themes: (1) Alert clarity participants strongly preferred specific actionable instructions over generic warnings; (2) Privacy and data sovereignty 87% expressed concern about cloud storage, directly informing the local-first architecture [13]; (3) Installation simplicity participants requested plug-and-play module setup without technical knowledge, informing the hub’s guided setup wizard design.

Appendix B: Detailed Quantitative Analysis Plan

The following quantitative analyses are planned for Phase 5 (Testing) and Phase 6 (Evaluation):

- Sensor accuracy: Mean $\pm$ SD for humidity (DHT22), pH, TDS, and flow rate readings versus reference instruments. Target: $\geq 95\%$ classification accuracy [8].
- Detection latency: Time from threshold breach to hub alert generation. Target: < 500 ms for critical alerts [14].
- False positive/negative rates: Confusion matrix analysis for each sensor module classification model.
- MQTT reliability: Packet delivery ratio under 2.4 GHz Wi-Fi congestion (simulated). Target: $> 99.5\%$ QoS-1 delivery [15].
- Statistical significance: Paired t-test ($\alpha=0.05$) comparing pre/post calibration sensor accuracy to validate calibration routines.

Appendix C: Validity, Reliability, Ethics – Detailed Framework

This appendix supplements the Task 3 discussion with operational detail on validity and ethics assurance measures:

- Validity: Sensor calibration against ISO reference instruments; survey questions grounded in Nielsen's heuristics [11]; expert review by a housing professional prior to pilot deployment.
- Reliability: Test-retest sensor comparison at 24-hour intervals ($n=10$ trials); Cronbach's alpha (target $\alpha > 0.7$) for Likert survey items; firmware moving-average filtering (window $n=5$) to reduce noise.
- Generalisability: Limitations acknowledged ($n=15$ convenience sample); purposive sampling expansion planned for Phase 6; modular architecture supports deployment across diverse property types.
- Ethics: GDPR (UK GDPR 2021) compliant; university ethics approval obtained; informed consent documented; data pseudonymised, AES-256 encrypted, retained only for project duration; BCS Code of Conduct adhered to throughout.