University of Toronto
Faculty of Applied Science and Engineering
APS112
Conceptual Design Specifications (CDS)

Team #	154	Date	March 16, 2025

Project Title	Sleep Well Age Well
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State your document word count: 3290 words (word count excludes Cover Page, Executive Summary, Reference List and Appendices)

Please check off which components you are submitting for your assignment.

✔ CDS submitted as a PDF to Quercus with the following components:

- ✔Cover Page
- ✔ Executive Summary
- ✔ Introduction
- ✔ Problem Statement
- ✔ Service Environment
- ✔ Stakeholders
- ✔ Detailed Requirements (FOCs)
- ✔ Generation, Selection and Description of Alternative Designs
- ✔ Alternative Designs Selection Process
- ✔ Alternative Design Descriptions
- ✔ Proposed Conceptual Design Specification
- ✔ Measures of Success (MOS)
- ✔ Conclusion
- ✔ Reference list
- ✔ Appendices
- ✔ Attribution Table
- ✔ AI used Y/N?*

Executive Summary
The design document outlines a design following Dr. Tatyanna Mollayeva's concern about the lack of a product that allows retired adults to conveniently track their sleep and receive educational insights. The goal of this document is to identify our environment and stakeholders, as well as our key functions, objectives and constraints that must be addressed before the team can start the alternative design process.

The proposed design aims to collect sleep data and motivate users to regularly use the design. It is further expanded by various secondary functions such as measuring, storing, and interpreting sleep data, informing users about anomalies in their sleep patterns, and providing system assistance and support to users.

The design will target generally healthy retired adults aged 65 - 75, with the scope being limited to all genders, sexes, and ethnicities residing in the Greater Toronto Area. Given that many retirees live in private or retirement homes, this design will focus on average private housing based on recommended practices and legislations for collective dwellings in retirement homes.

Catering to both the functions and scope of the project, the key objectives to gauge a successful design include achieving over 90% accuracy compared to a polysomnography and maximizing early detection of sleep anomalies through detailed summaries every 3 months to enhance the secondary functions further, and keeping end-user costs under $68.28 as the scope targets a wide-range of healthy retirees, requiring the costs to encompass all economic levels.

Other heavily considered groups in the design process are main stakeholders due to their influence and close relation to both the design and user. These include medical insurance companies, sleep research and wellness organizations, and family members of users. Their considerations shape constraints such as compliance with relevant standards, regulations, and medical practices like weight and size which stem from sleep research and wellness organizations, and the overall restrictions of harm or deception practiced by the government and for the relief of the users' relatives.

The design space was explored using various idea generation techniques, such as brainstorming and morphological charts, both individually and as a team. The solutions were then narrowed down in five concrete steps: removing duplicates and unfeasible ideas, multi-voting, graphical-decision charts, and a weighted-decision matrix. The three alternative designs—Smart-Slumber PJs, SomniCloud Pillow, and Airflow Guard—best met the detailed requirements best while also being creative. Using a Pugh chart and the previous weighted-decision matrix, as well as observing the tradeoffs, the team identified the most important objectives and which design was most user considerate, leading to the Smart-Slumber PJs being chosen as the final design due to its user consideration and objective satisfaction.

The Smart-Slumber PJs will be presented with design specifications, drawings, and a plan to measure the device's success in not only satisfying the client's needs, but also the detailed requirements and novelty.

1.0 Introduction

Approximately 266,000 Canadian adults retire every year [1]. As these adults transition into retirement, their sleep patterns undergo a variety of changes (Figure 1), impacting their physical and mental health, cognition, and well-being [2]. The client, Dr. Mollayeva from the Kite Research Institute, who frequently works on sleep research, has requested a sleep tracking system catered to retired adults [3].

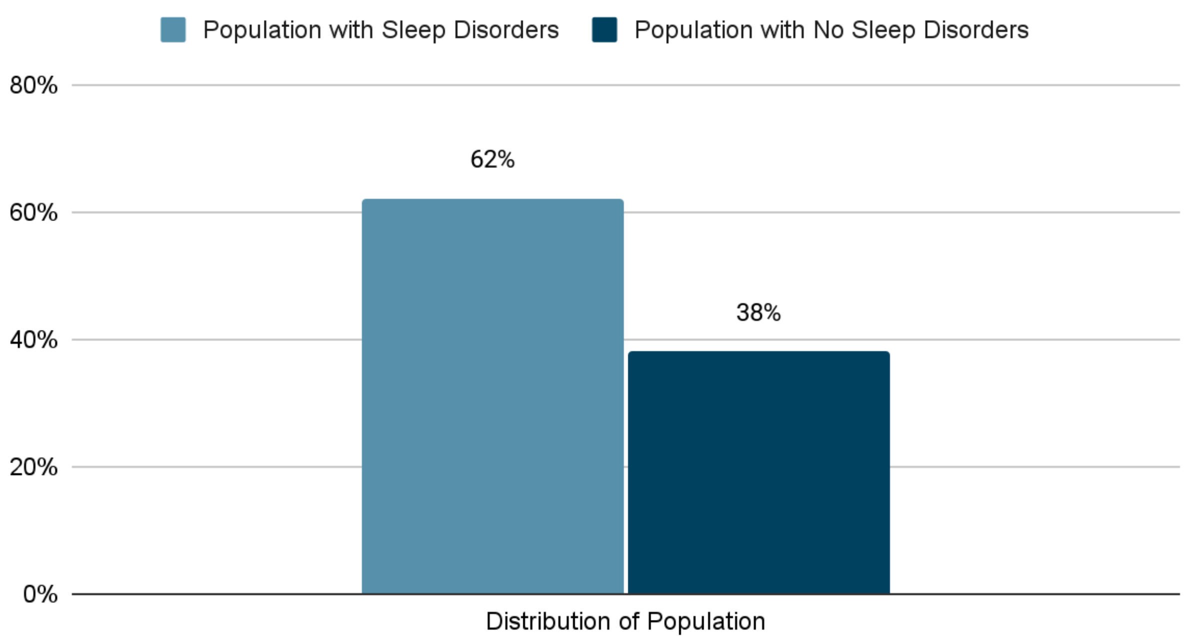


Figure 1. Population Distribution of Greater Toronto Area (GTA) Residents (65-75) with Sleep Disorders [4].

This document outlines the identified gaps, needs, key stakeholders, service environment, and detailed requirements that guided the idea generation and selection process, leading to the final design, its specifications, and its success metrics.

2.0 Problem Statement

Tracking and analyzing sleep patterns is key to maintaining a healthy lifestyle. Existing solutions, like watches, phone applications, or rings, are often expensive, challenging to use, and uncomfortable, making them unappealing to retired adults [5][6].

The current gap is the lack of a product that allows users to conveniently track their sleep. The client's need is a design of an easy-to-use sleep-tracking system that provides users insightful analysis on their sleep and its impact on daily life.

The scope is limited to retired adults of all genders, sexes, and ethnicities, aged 65-75 years, residing in the Greater Toronto Area, shown in Figure 2 (Appendix A.1). The system should be operable at the user's home and provide them necessary sleep details.

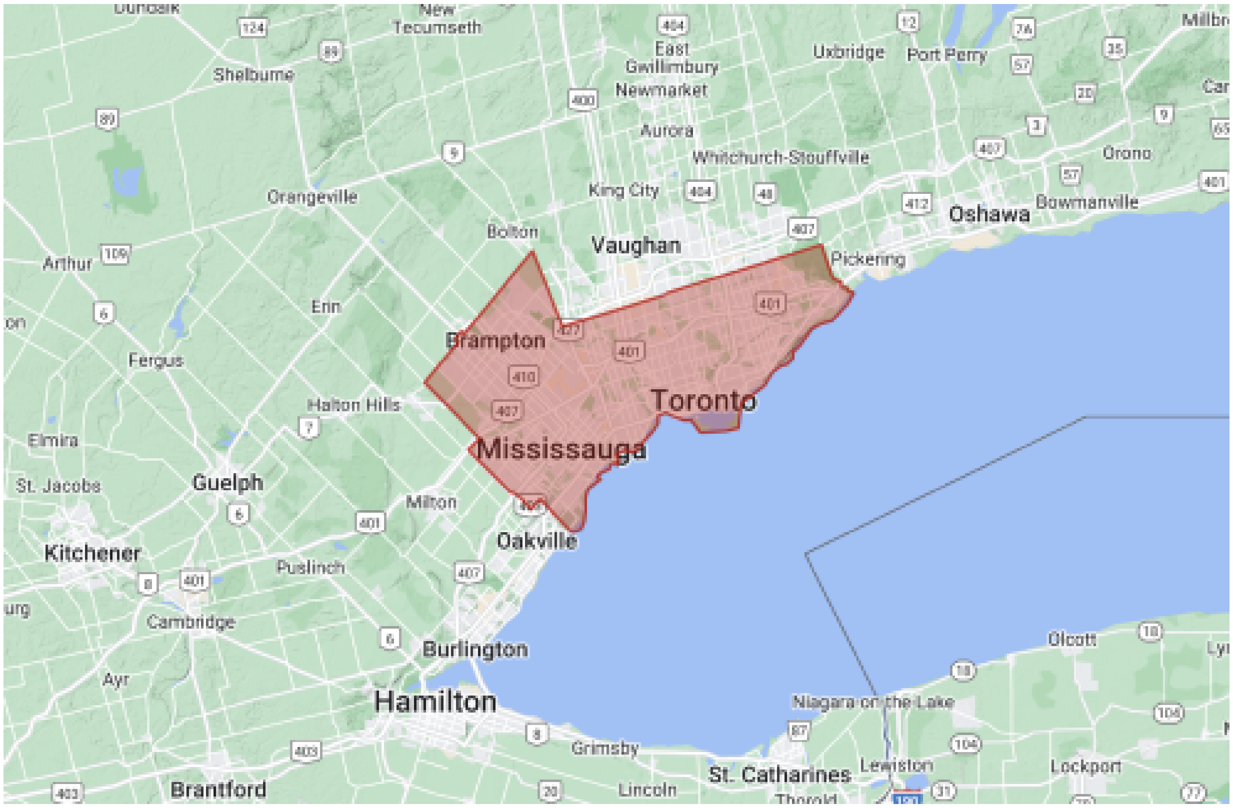


Figure 2. Adapted GTA [7].

3.0 Stakeholders

Table 1 lists the key stakeholders in this design, along with how they are positively and negatively impacted (Appendix A.2). Stakeholder adjustments were made after an evaluation on who the user interacts with during our second client meeting (Appendix A.5) (Appendix G.3).

Table 1. Stakeholders and their impact on the design.

Stakeholder	Justification	Impact	
		Pros	Cons
Family Members	Interested in monitoring and improving their loved one's health [8].	Enhances the ability to make informed decisions for the user	Data privacy
Sleep Research Organizations (Appendix A.3)	Dedicated to sleep research and education [5].	Potential mass sleep data collection	Need for alignment with ongoing research priorities
Sleep Wellness	Advocates for healthy sleep	Promote product's	Ethical concerns

Organizations	through research and promoting resources [9].	use.	related to data sharing.
Medical Insurance Companies	Interested in the health outcomes of their policy users [10].	Reduced healthcare cost through preventive care	Data privacy and ethical information use
Drug Marts	Health product retailers specializing in health products [11].	Increase product accessibility	Retail markup increases product cost

4.0 Service Environment

The design is intended for use in the Greater Toronto Area (GTA), including Toronto and the municipalities of Durham, Halton, Peel, and York [7], seen in figure 2. It will operate in the bedrooms of residences for retired adults.

4.1 Physical environment

Only 6.8% of retirees live in collective dwellings, whereas 93.2% of seniors live in private housing [12]. Thus, private housing, seen in table 2, will be considered the primary service environment.

Table 2. Properties of living spaces within service environment.

Living space property	Range
Temperature (°C)	21.0 - 26.0 (Appendix B.1)
Humidity (%)	30.0 - 60.0 RHL (Appendix B.2)
Bed size (cm)	98.0×189.0 to 183.0×212.0 (Appendix B.3)
Bedroom area (m^2)	10.0 - 16.8 [13]
Night-time noise levels (dBA) (Figure 3)	42.6 - 74.4 [14]

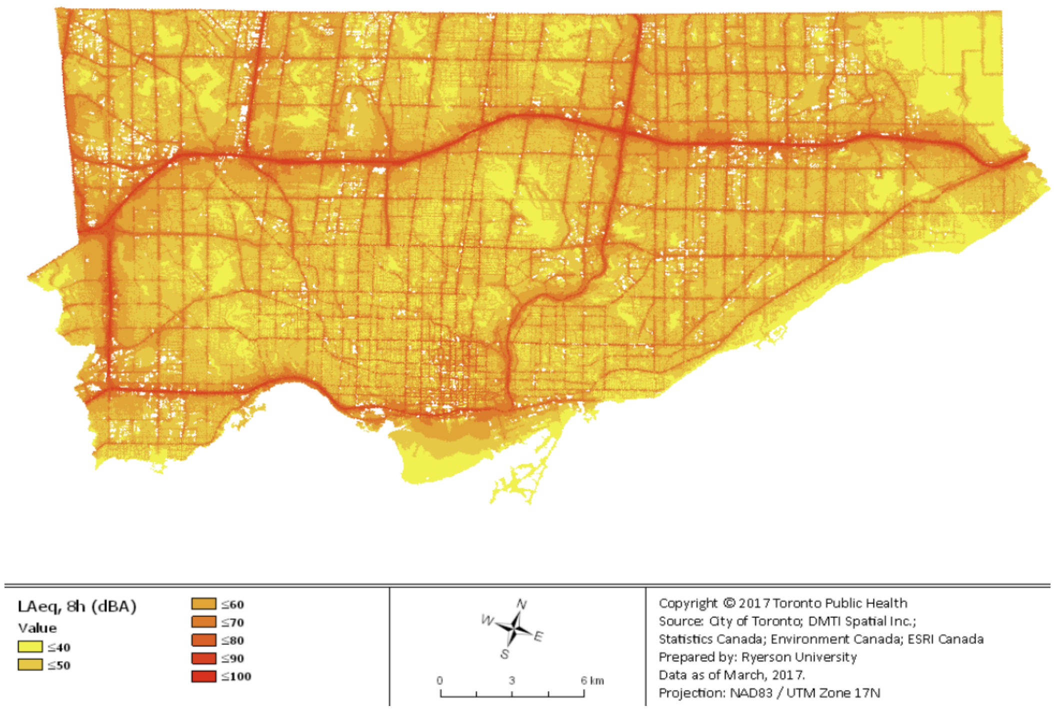


Figure 3. Night-time noise levels in the city of Toronto [14].

Retiree bedroom measurements, in figure 4, were considered as the design will be used here. It includes dimension limitations for the door, window, bed, lights, and wardrobe.

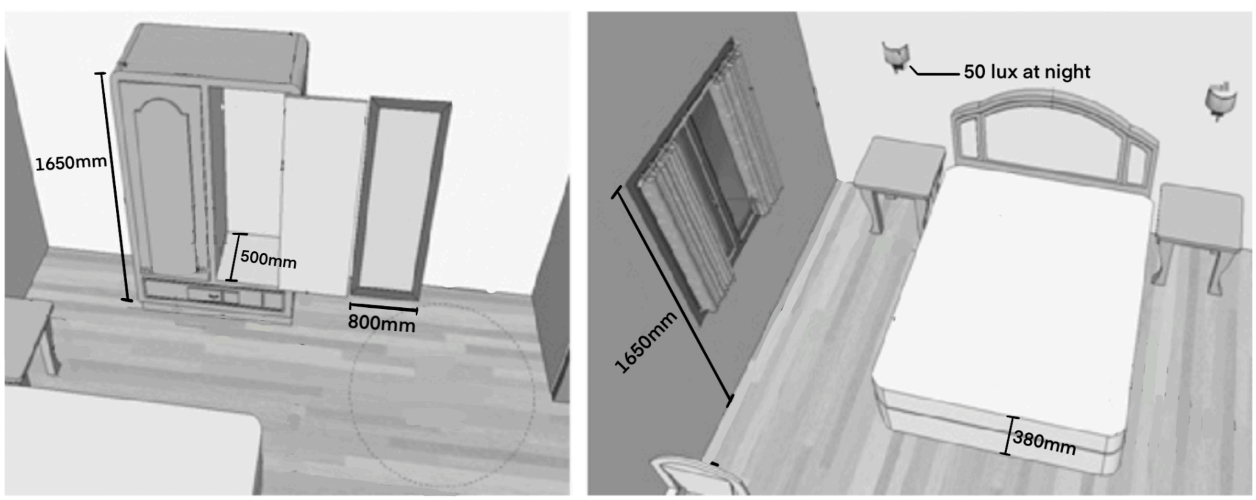


Figure 4. Dimensions based on average sizes for elderly bedrooms [15].

4.2 Virtual environment

The average Toronto house's fixed internet speed is 199.4 Mbps for downloading and 49.32 Mbps for uploading, while mobile internet speed is 129.68 Mbps for downloading and 18.69 Mbps for uploading (Appendix B.4).

5.0 Detailed Requirements

The section outlines the design's function, focusing on collecting data and motivating users, provides objectives to improve design quality, and details constraints from regulations.

5.1 Functions

The design requirements are outlined, linking the secondary functions to the primary functions, shown in figure 5.

Functions were identified using Functional Basis analysis of the client statement [6] (Appendix C), with each secondary function linking to a design functionality of primary functions.

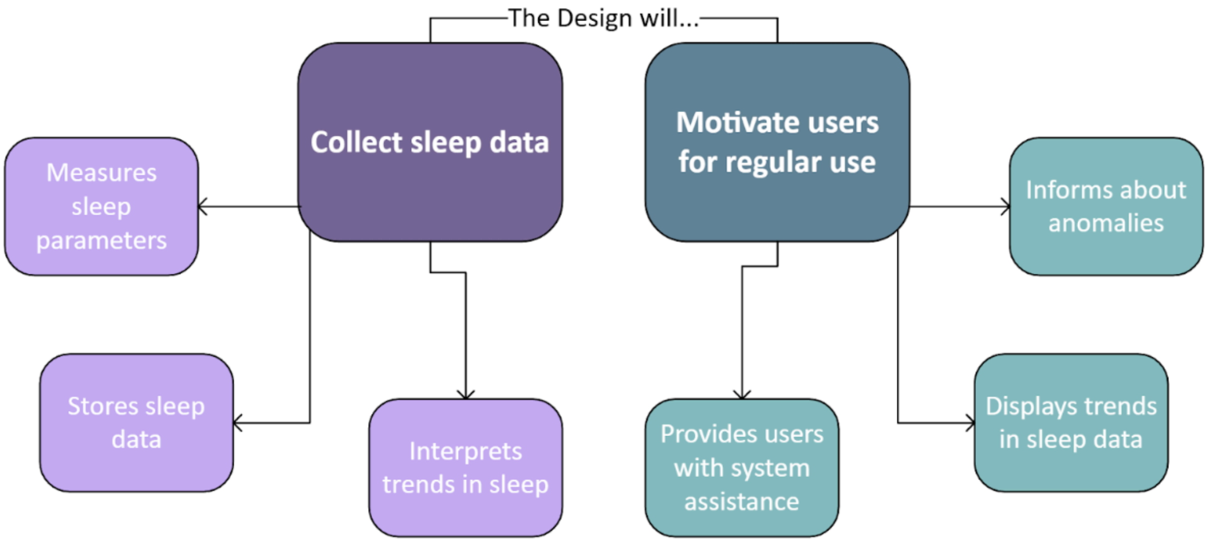


Figure 5. Primary and Secondary functions (33 words).

5.2 Objectives

Table 3 outlines the key objectives, each aligned with the overall goals, client statement priorities, and function satisfaction.

Table 3. Performance, Social and Financial Success Objectives.

Type	**Objective** (The design should…)	**Metric**	**Goal**	**Justification**
Performance	Optimize detection of sleep anomalies	Number of days measuring	Every 3 days (Appendix G.4)	Sleep surveys take 2 weeks to categorize health issues, but three days suffice in detecting them (Appendix G.4), making it essential to consistently track data to predict these issues, improving sleep health.
	Maximize accuracy of physiological measurements	% similarity between professional pulse oximeter, actigraphy, and thermometer	≥95% [16]	Accurate measurements “provide ongoing motivation to improve sleep routines and habits”, increasing awareness of sleep patterns and health [17].
Social	Consistently align collected data and user’s perception	% agreement between collected data and user perception	>70% [18]	Sleep-trackers contradiction of users’ real experience, leads to “confusion or annoyance” and reduced usage of the design[19].
	Ensure continuous usage time	Number of consecutive nights used	>6 nights [20]	Accurate sleep pattern characterization requires “multiple nights of sleep” due to variability, with wear duration affecting “longer-term characterization of sleep behaviour” [21].
Financial	Minimize cost	CAD($)	<$68.28 (Appendix E.1)	The client requested low cost to increase market demand and drive higher sales [6][22].

5.3 Constraints

The design is constrained by regulations, by-laws, and standards, as shown in Table 4. For further justification and digital/electrical constraints, refer to Appendix F.1 and F.2 respectively.

Table 4. Regulation constraints.

Constraint The design must:	**Metric**	**Limit**	**Justification**
Be light	Calibrated scale (kg)	Less than 2.3kg [23]	Design should accommodate individuals ranging from the 5th percentile female to the 95th percentile male in physical capability [24].
Not impede on regular movement	Standard calipers (mm)	Smaller than 255(l) x 125(w) x 100(h) mm if design is worn [23]	The design must not hinder movement, suit aging users, fit most body types, and stay within a small dimension for ease of use [25-26].
Not be invasive	Number of instances of direct physical contact with user	Design should only contact uninjured skin [27]	The design must qualify as not or only as a Class I non-IVD device under rules 3, 7, or 12 [27].
Be easily heard	Sound level meter for frequency and intensity (dB)	Auditory indicators: ● Between 60dB-100dB intensity [28-30] ● 500-2000 Hz frequency [28-29] Design's idle sound ≤10dB [30]	Hearing declines with age at 2.5dB per decade until 55, then 8.5dB per decade after, making it crucial to consider for the design's intended age group [31].
Be easily read	Font size and style (pt)	≥12 pt size Following style: ● Sans-Serif ● Serif [29][31]	The design must display legible text and clear information hierarchy to ensure visibility for the intended age group [29][31].

Not pose a risk to human health/safety	Number of hazards present (Appendix F.1)	Design must not contain harmful chemicals, lead, gas, vapour, dust, mist, or fumes [32-34]	Consumer products must not pose health hazards during normal or foreseeable use [32-34].
Contain no false information in any part of the design	True declarations percentage	All designs must include correct: ● Labeled identity ● Dealer information ● Declaration of contents if containing concealed artifacts [35]	Ensures the design prevents false claims and protects users from potential harm [35].
Not qualify as a medical/ in-vitro diagnostic device	Not qualify for any rules under SOR/98-282	Class I, II, III, or IV medical device [36] (Appendix F.1-2)	Medical device qualification would make the design infeasible due to regulatory requirements and compliance challenges [36].

6.0 Generation, Selection and Description of Alternative Designs

The following sections outline the process from generating over a hundred ideas to selecting three final designs.

6.1 Idea Generation Process

This section outlines the team's idea generation process, using eight methods to generate 120 ideas (Appendix H.10), forming the basis for selecting three alternative designs.

6.1.1 Morphological chart

Idea generation began with brainstorming (Appendix H.10) and a morphological chart to create ideas for secondary functions (Appendix H.1). The number of generated means are listed in Table 5.

Table 5. Means generated per secondary function

Secondary Function	Number of Means
Measure sleep parameters	13
Stores sleep data	7
Interprets trends in sleep	7
Provides users with system assistance	8
Displays trends in sleep data	13
Informs about anomalies	9

The team then leveraged generative AI to combine them into 60 complete solutions, selecting the best idea combinations from the morphological chart (Appendix H.2).

6.1.2 Individual Idea Generation

Each team member generated 10 ideas using seven idea generation techniques (Appendices H.3 - H.7) to address all secondary functions. Figure 6 showcases the number of ideas generated with each technique.

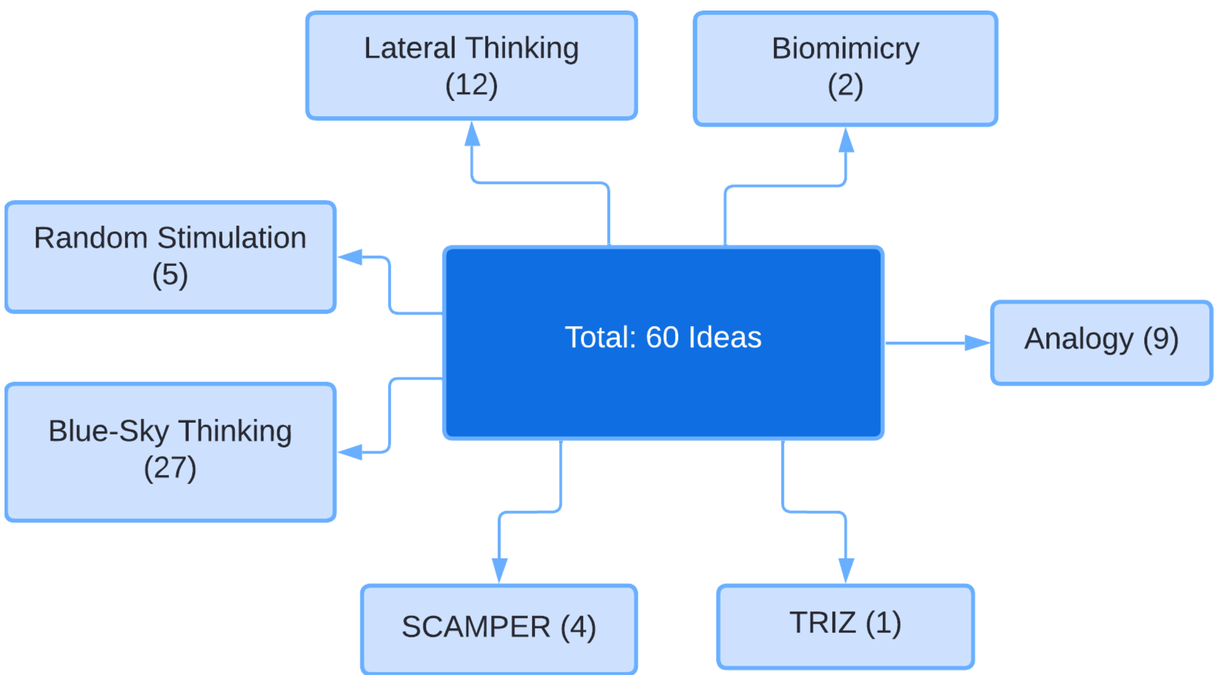


Figure 6. Number of ideas generated per tool.

6.2 Alternative Design Selection Process (Appendix I)

This section outlines the 5 steps, shown in Figure 7, of the design selection process (Appendices I.1-I.4), narrowing 119 solutions into 3 alternative designs.

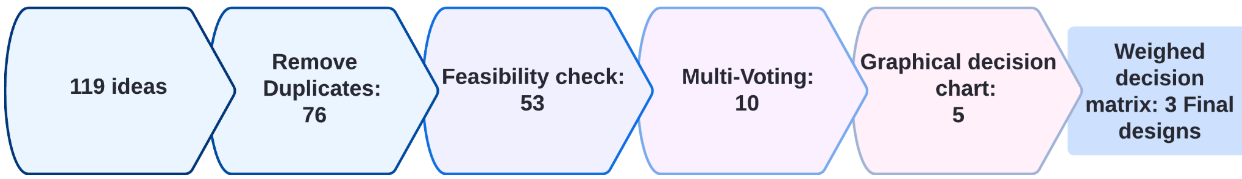


Figure 7. Selection methods and the resulting number of solutions after each.

The selection process began by eliminating duplicates and unfeasible solutions to achieve a list of realistic ideas leaving 76 solutions(Appendix I.1).

Multi-voting was then applied to assess function satisfaction and creativity, with team members casting ten votes. The top ten ideas were ranked in descending order shown in Appendix I.2.

Two Graphical Decision Charts were made to compare objectives satisfaction by different ideas: 1) "Optimize anomaly detection" vs. "Minimize cost" resulting in 3 leading ideas and 2) "Maximize measurement accuracy" vs. "Ensure continuous usage" resulting in 5 leading ideas (Appendix I.3). This method narrowed down to 5 ideas that best fit the objectives.

Lastly, a Weighted Decision Matrix (WDM) applied objective rankings (Appendix E.1) and raw scores (Appendix I.4) to determine 3 ideas that satisfied the most important objectives. Idea 111-“SmartSlumber PJ”, Idea 33-“SomniCloud Pillow” and Idea 73-“AirFlowGuard” scored the highest, becoming the three alternative designs.

6.3 Alternative Design Descriptions

The next sections describe the three chosen designs that address the secondary functions and constraints, including their descriptions, isometric, and orthographic diagrams.

6.3.1 Design #1 - Smart-Slumber PJ’s

The Smart-Slumber PJ’s feature sensor boxes within the wrist and waist to collect user's quantitative sleep data. After every sleep, a screen on the mat prompts users to rank sleep satisfaction and alertness (0-No, 1-Somewhat, 2-Yes) to gather qualitative data.

When not in use, the boxes can charge and transfer data into the mat. An algorithm combines all data, displaying trends and anomalies on the screen. A user manual is provided for system support (Appendix J.3).

The cotton pajama set has stretchy, thick elastic wrist and waist bands for comfort and zippers for easy box removal. The pajamas cost $3.3 and come in various sizes to fit all users [55].

Wrist and waist box dimensions, shown in Figure 11, were designed to meet the movement constraint. The former was calculated from average Canadian wrist diameters, while the latter is relative to it [56].

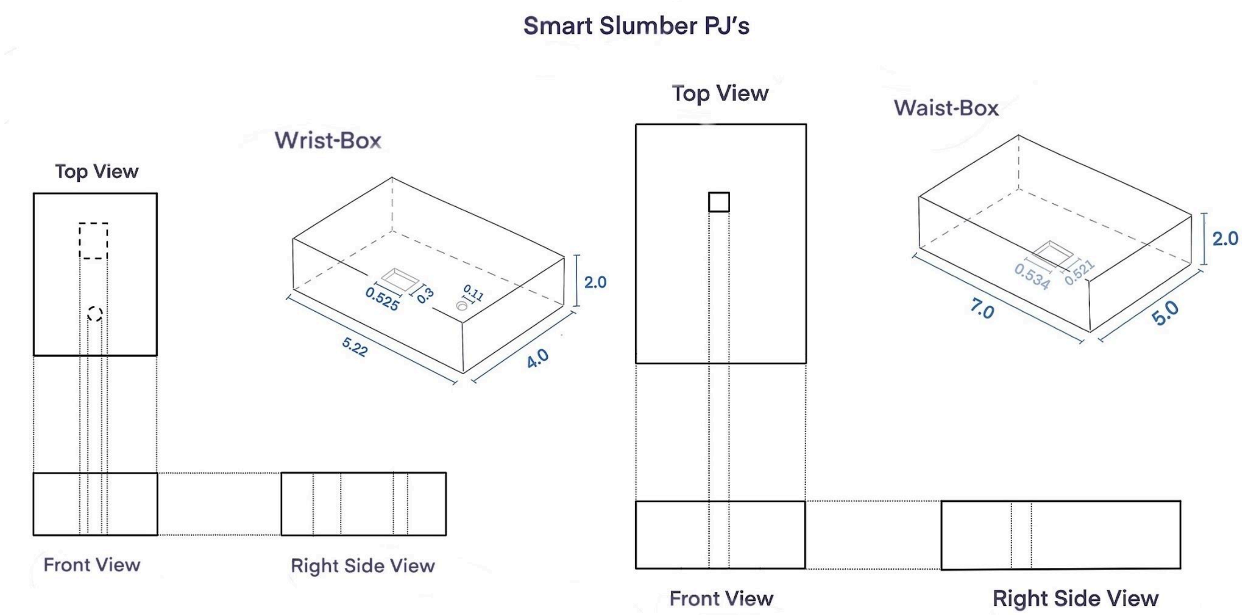


Figure 11. Waist and wrist box dimensions (cm).

The waist box contains a PPG sensor for heart rate and O2, while the wrist box has a thermal sensor and accelerometer for body temperature and movement. Both boxes include a microSD card for data storage and a rechargeable lithium-polymer battery.

Swirly circles indicate the NFC module and charger box alignment locations. The mat's dimensions, based on average folded large clothing size, accommodate all users, illustrated in Figure 12 [57].

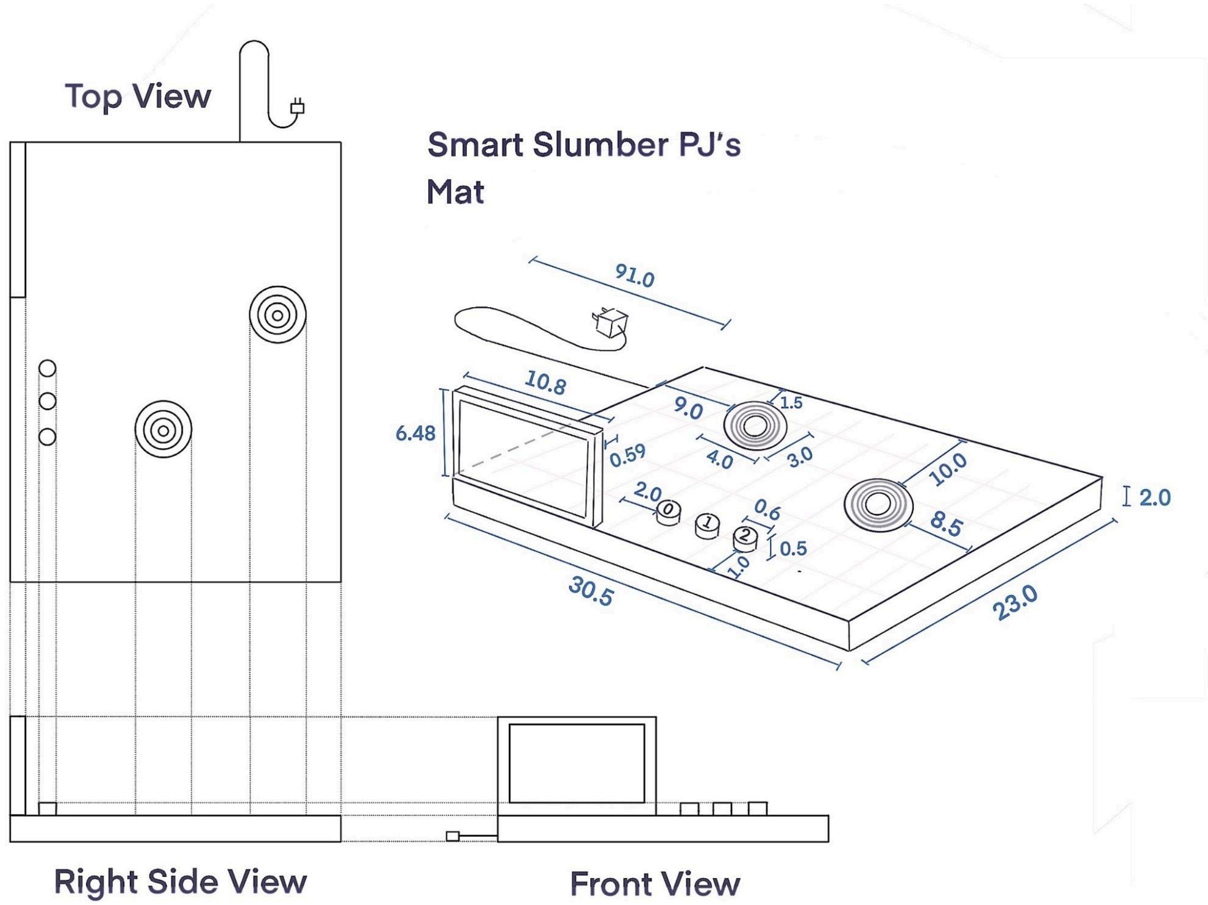


Figure 12. Mat dimensions (cm).

The mat features an LCD screen for questions and sleep summaries, buttons for responses, a wireless charging receiver for the Lithium-Polymer battery, and a power plug.

The mat and boxes all contain an ESP32 for data processing and an NFC module for data transfer. See appendix J.1 for component specifications, cost, and weight, secondary components used, and greater detail on each component's purpose, and appendix J.2 for electrical schematics.

Figure 13 shows how the algorithm gathers the sensor and questionnaire data, which satisfy SATEDR (Appendix G.2), and displays a simple summary (Appendix J.4).

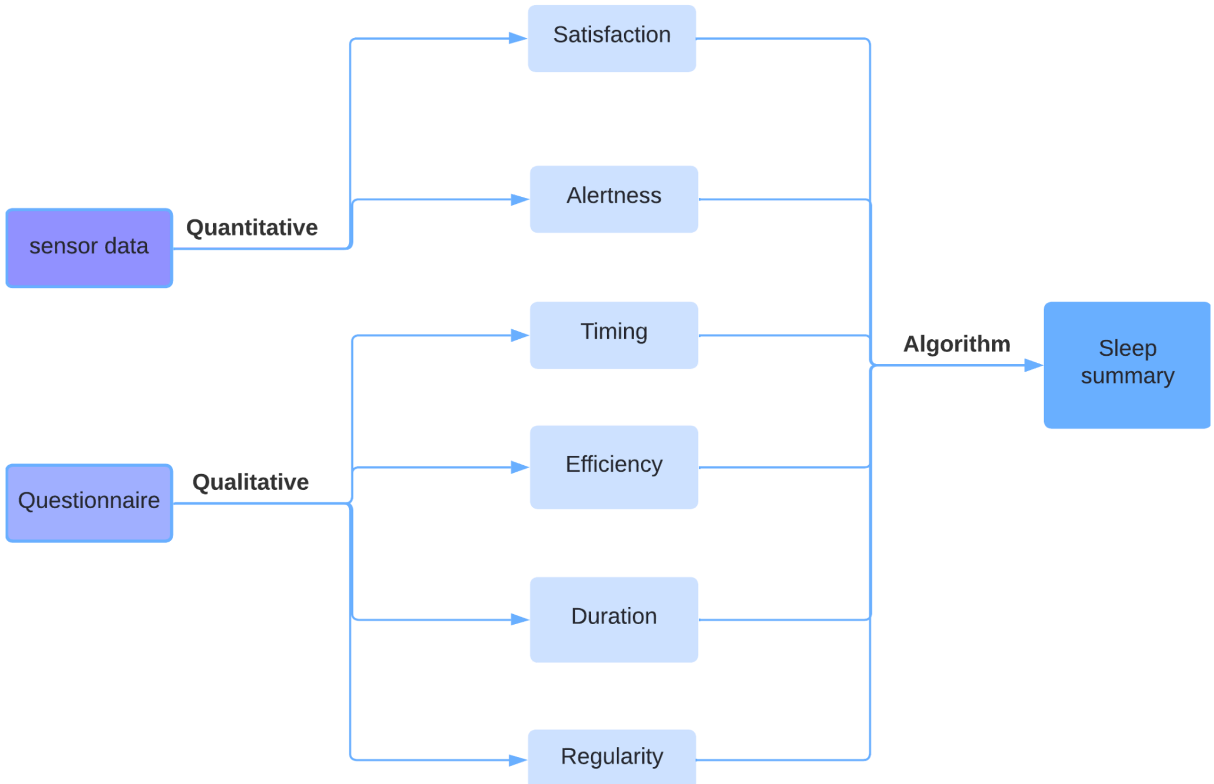


Figure 13. Algorithm methodology.

Tradeoffs occurred to meet constraints. A larger LCD was chosen for the required readability level, trading off the objective "Minimize Cost. A Lithium-Polymer battery was chosen for being flexible and lightweight, pertaining to weight constraints [58][59].

6.3.2 Design #2 - SomniCloud Pillow

Somnicloud is a pressure-sensitive smart pillow that monitors sleep patterns. The pillow features a thin removable sensor sheet that captures movement and temperature in real time. Figure 14 shows how the pillow's core is made of memory foam or latex, encased in a breathable fabric cover for comfort and support.

A list of pillow components and specifications can be found in Appendix K.1. Safety and reliability are prioritized with low EMF emissions, overcharge protection, and adherence to sleep industry standards for electronic components (Appendix F.2).

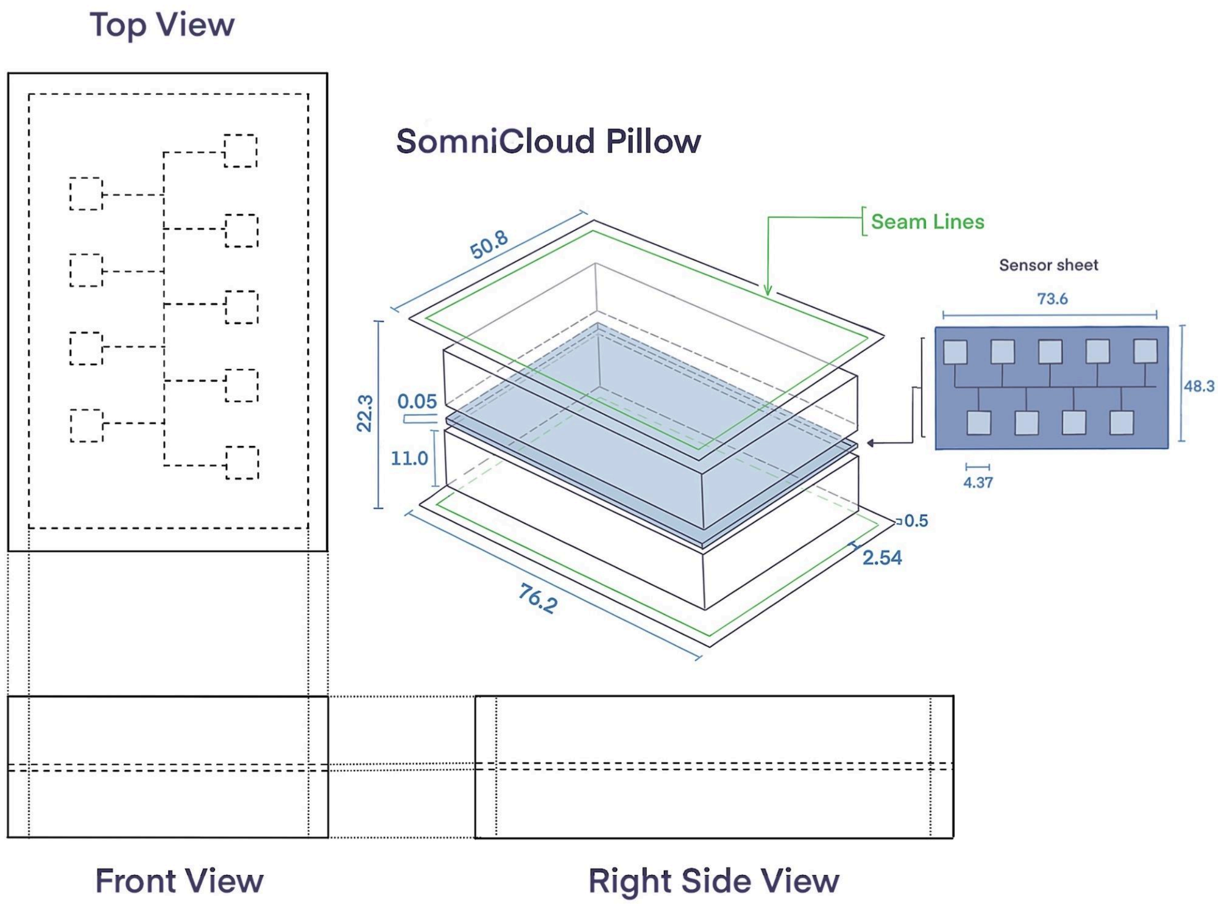


Figure 14. Pillow dimensions (cm).

SomniCloud syncs via bluetooth with a mobile application, visualizing sleep data through cloud-shaped icons for different sleep states. Users receive a daily sleep score and sleep trend insights. To enhance accuracy, the app periodically prompts users to complete a SATEDR questionnaire (Appendix G.2). Figure 15 shows how it offers tailored recommendations for sleep-quality improvement, based on sensor data and user feedback.

Figure 15. App UI.

High-precision physiological measurements require advanced skin sensors, driving up costs. SomniCloud balanced this by trading off a bit of accuracy for cost by opting for a sensor sheet with reasonable accuracy.

6.3.3 Design #3 - Airflow Guard

The Airflow Guard is a non-invasive sleep tracking system with a lightweight chest sensor that continually monitors user pressure and airflow during sleep, as shown in Figure 16.

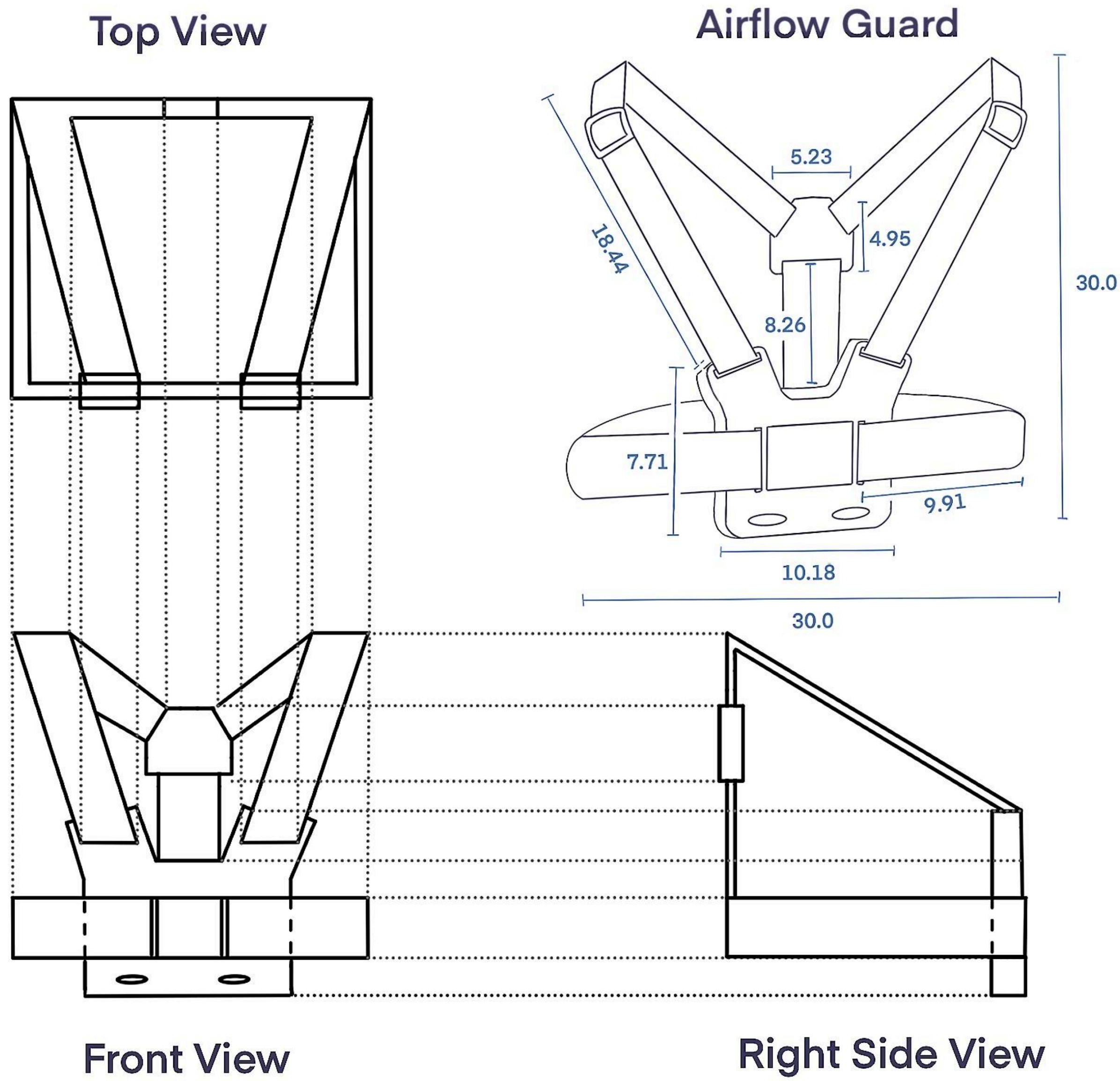


Figure 16. Airflow Guard dimensions (cm).

It ensures user comfort with a supporting lightweight wearable chest guard enclosed in a breathable fabric. It uses a strain gauge sensor to measure chest expansion, and a thermistor to measure airflow based on temperature differences between inhaled and exhaled air.

After a night of recording the user's sleep, the Airflow Guard uploads data to an online platform for processing into a hypnogram, shown in Figure 17, which are emailed to the user every morning, along with a sleep quality questionnaire (Appendix L.3).

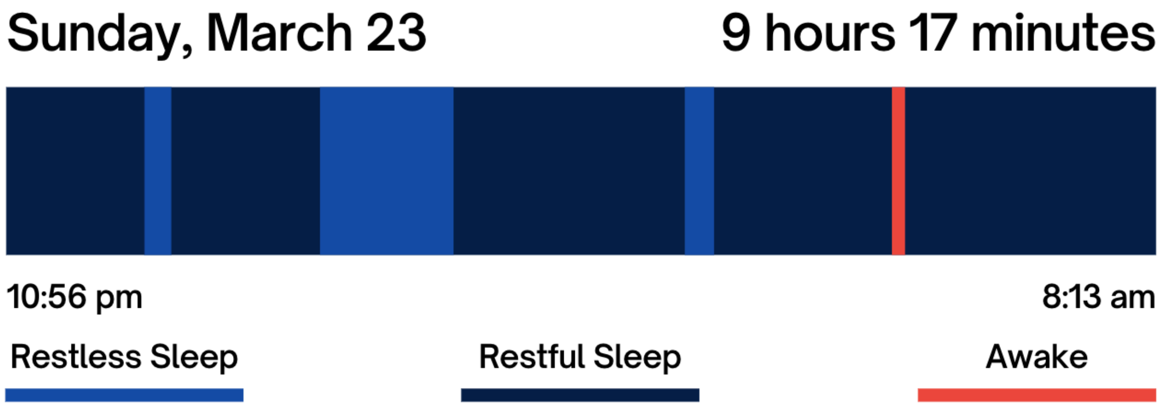


Figure 17. A hypnogram sent to the user about their night's sleep quality.

Users can reply to the email with product-related queries. After each 3-day cycle, the algorithm analyzes the data and sends another email to the user with a more detailed sleep analysis, including anomaly detections and irregularity warnings (Appendix L.4).

The LiFePO4 batteries chosen are costlier than the conventional lithium-ion batteries (Appendix L.1). While this affects the cost objective, it is necessary to meet safety constraints, as lithium-ion batteries are prone to combustion when overheated.

6.3.4 Alternative Designs' Satisfaction of Secondary Functions and Objectives

Table 6 and 7 showcase how the three chosen designs satisfy the secondary functions and objectives.

Table 6. Designs' satisfaction of secondary functions.

Secondary Functions	**Smart-Slumber PJ's**	**SomniCloud Pillow**	**Airflow Guard**
Measure sleep parameters	Sensors measure body temperature, motion, heart rate, and O2 levels.	Captures movements and temperature in real time.	Measures user's airflow and chest pressure.
Stores sleep data	SD cards store measured data.	Data is transmitted and stored in the mobile app.	The online platform stores data.
Interprets trends in sleep	Algorithm analyzes gathered data.	Cloud-shaped icons in app visualizes sleep states.	Online platform uses an algorithm.
Provides user	Manual provides device	Physical and digital	Customer service

with system assistance	assistance	manual included.	available via email.
Displays trends in sleep data	LCD shows summarized trends.	Real-time tracking detects and notifies of deviations.	Users will receive emailed visual summaries.
Informs about anomalies	Algorithm tracks anomalies for over 3 days, advising users to consult a doctor after.	Stored data in app lets users track progress and identify improvements/concerns.	Sends email alerts every 3 days about anomalies.

Note: Appendix K.2-K.3 has greater justification details for SomniCloud Pillow.

Table 7. Designs' satisfaction of objectives.

Objectives	**Smart-Slumber PJ's**	**SomniCloud Pillow**	**Airflow Guard**
Optimize detection of sleep anomalies	Sensors track for 3 consecutive nights. Boxes placed on mat, transfer data after sleep.	Pressure/temperature sheet captures real-time data, surpassing the 3-day goal.	Sleep data analyzed every 3 days to detect any anomalies.
Maximize accuracy of physiological measurements	Sensors maintain constant contact during sleep, achieving 95% similarity goal.	Embedded sensors track temperature and movement close to the user.	Embedded sensors, worn close to users, track physiological data.
Consistently align collected data and user's perception	Qualitative and quantitative data gathered simultaneously, achieving >70% matching.	Mobile app visualize sleep states with cloud-shaped icons.	The short gap between data collection and user's perception ensures >70% alignment.
Ensure continuous usage time	Pajamas worn overnight for several nights, with questions appearing when placed on mat, surpassing 6-day goal.	Low-power wireless connectivity, overcharge protection and removable sensors sheet support long-term useability.	Lightweight device prioritizes comfort, encouraging regular use.
Minimize cost	Total cost: $87.43 CAD, exceeding the $68.25 goal.	Total cost: $36.23 CAD, below the $68.25 goal.	Total cost: $9.90 CAD, below the $68.25 goal.

7.0 Proposed Conceptual Design Specification

Figure 18 showcases the evaluation methods and results for each design, deciding the final design.

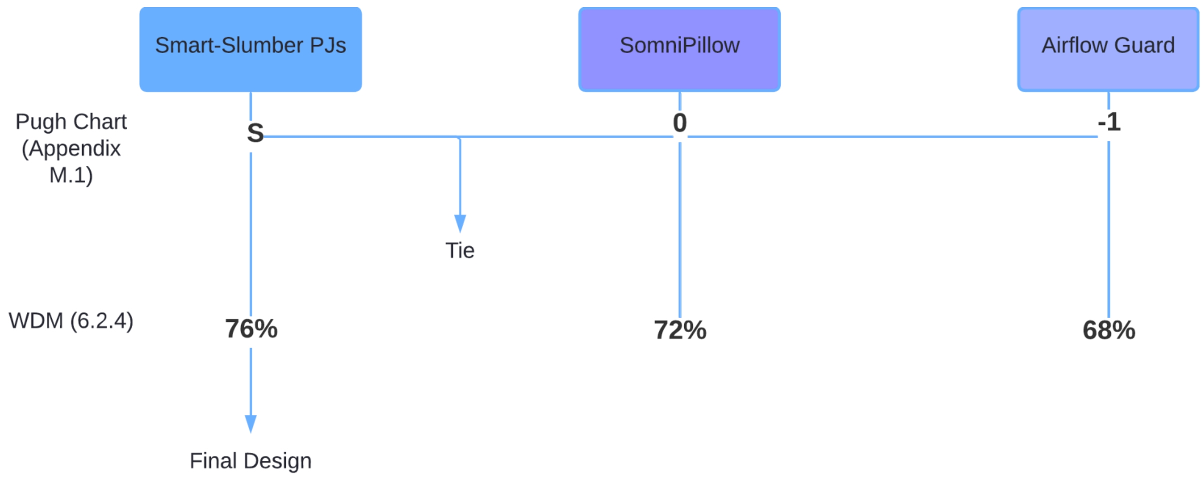


Figure 18. Evaluation process and results.

All designs meet the functions and constraints, however, the PJs ranked highest due to the weighted objectives. Despite scoring the highest, tradeoffs include a higher cost compared to both other solutions, and a slightly less continuous usage time compared to SomniCloud pillow.

However, the PJ caters towards older adult's technology preferences by not requiring a phone, making it easier for users to handle [60], and uses an NFC module over bluetooth to avoid electromagnetic radiation concerns [61].

The design in Figure 19, with a greater anomaly detection because more data types are captured, combined with its holistic user consideration, made it ideal for helping retirees easily track their sleep.

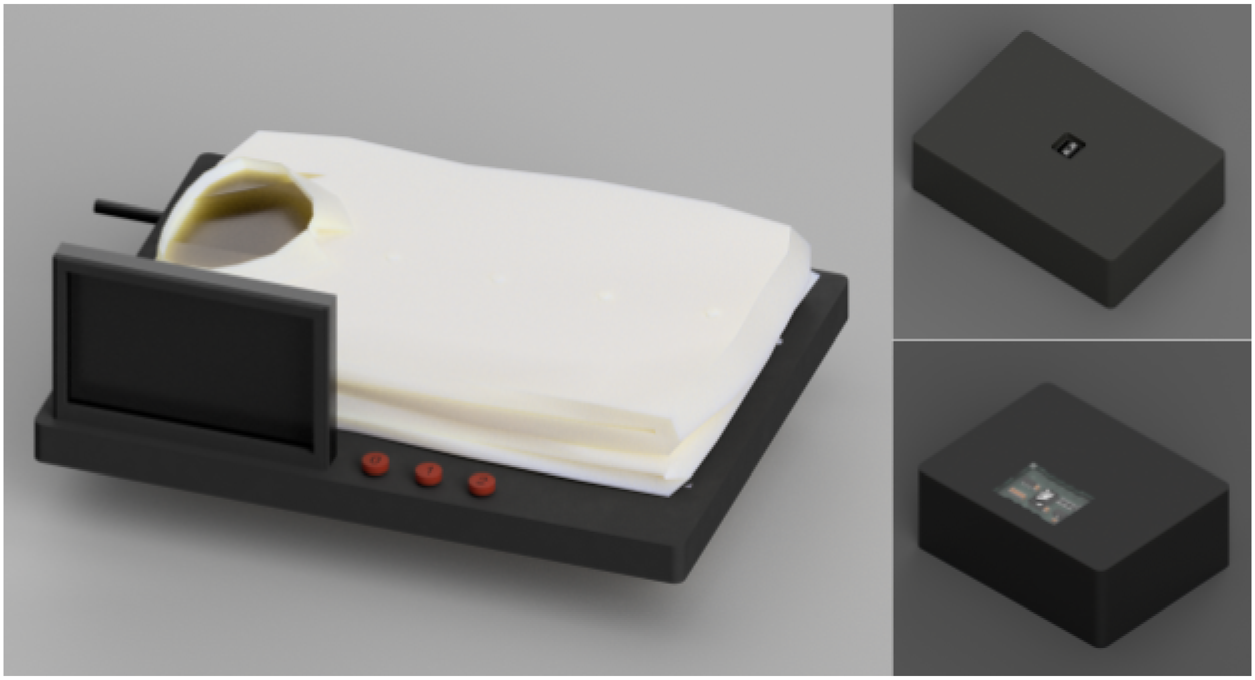


Figure 19. Final design's model.

8.0 Measures of Success (Appendix N)

The team will test the design's success in optimizing detection of sleep anomalies by creating a Python program using a Hidden Markov Model (HMM) to identify low-probability observations from unexpected transitions (Appendix N.3). The team's HMM anomaly detection efficacy will then be compared to a commercially-established algorithm for accuracy in detecting irregularities in physiological sleep data.

Finally, a Bland-Altman Analysis, a statistical methodology designed to compare output similarity of two devices, will utilize the outputs of both programs and calculate them into key values to yield a plot. Figure 20 showcases the step-by-step process. Refer to Appendix N.1-N.4 for the database, key value calculations, and Bland-Altman plot interpretation.

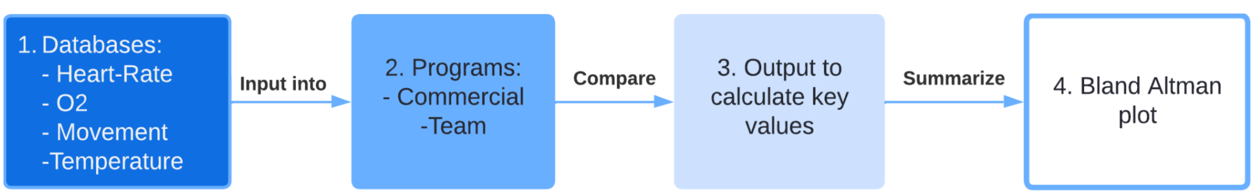


Figure 20. Step-by-step process.

If the plot shows data points falling within bounds of a narrow Limits of Agreement and having a bias line near zero, then the analysis for anomalies is as good as a commercial algorithm.

9.0 Conclusion

The design document, based on Dr. Mollayeva's request for a sleep tracker for retirees, addresses the gap, stakeholders, service environment, and requirements. Additionally, it covers the development and selection of the final design, the Smart-Slumber PJ's, achieved through client meetings and research. Moving forward, the team will begin preparation for the final presentation.

10.0 References

[1] J Orlando. "The Greying of Canada's Population." TD Economics. Available: https://economics.td.com/ca-demographics#:~:text=The%20Labour%20Force%20Survey%20estimates,older%20grow%20by%201%20million [Accessed: February 14, 2025]

[2] B. Miner and M. H. Kryger, "Sleep in the Aging Population," Sleep Medicine Clinics, vol. 12, no. 1, pp. 31–38, Mar. 2017, doi: https://doi.org/10.1016/j.jsmc.2016.10.008.

[3] "Tatyana Mollayeva." Kite UHN. Available: https://kite-uhn.com/scientist/tatyana-mollayeva. [Accessed: February 14, 2025]

[4] M. Fernandes et al. "Prevalence of sleep disorders in geriatrics: an exploratory study using sleep questionnaires." Science Direct. Available: https://www.sciencedirect.com/science/article/pii/S0197457224002635. [Accessed: February 14, 2025]

[5] R. Robbins et al. "Sleep tracking: A systematic review of the research using commercially available technology." National Library of Medicine. Available: https://pmc.ncbi.nlm.nih.gov/articles/PMC7597680/. [Accessed: February 14, 2025]

[6] Engineering strategies and practices II - Sleep Well Age Well [Client statement] Available: https://docs.google.com/document/d/1o3MS5X9WuPSJ5PJhliCShL4W7DNUynDxx_dQDXglWrc/edit?tab=t.0

[7] "City Halls - GTA municipalities & municipalities outside of the GTA," City of Toronto, Oct. 29, 2021. https://www.toronto.ca/home/311-toronto-at-your-service/find-service-information/article/?kb=kA06g000001cvbdCAA

[8] E. A. Read *et al.*, "Stakeholder Perspectives on In-home Passive Remote Monitoring to Support Aging in Place in the Province of New Brunswick, Canada: Rapid Qualitative Investigation," *JMIR Aging*, vol. 5, no. 2, p. e31486, May 2022, doi: https://doi.org/10.2196/31486.

[9] "Advocacy." Canadian Sleep Society. Available: https://css-scs.ca/advocacy/. [Accessed: March 22, 2025]

[10] E. Avramakis. “Why insurers need to care more about customers and how to do it in the digital age.” Swiss RE Institute. Available: https://www.swissre.com/institute/research/topics-and-risk-dialogues/digital-business-model-and-cyber-risk/why-insurers-need-to-care-more-about-customers.html [Accessed: February 28]

[11] “Innovating health & wellness services since 1962.” Shoppers Drug Mart. Available: https://corporate.shoppersdrugmart.ca/en/about-our-history/ [Accessed: February 28]

[12] E. and, “Report on housing needs of seniors - Canada.ca,” Canada.ca, 2016. https://www.canada.ca/en/employment-social-development/corporate/seniors-forum-federal-provincial-territorial/report-seniors-housing-needs.html

[13] P. S. and P. C. Government of Canada, “Information archivée dans le Web,” publications.gc.ca. https://publications.gc.ca/collections/collection_2017/schl-cmhc/nh15/NH15-631-1983-eng.pdf

[14] “ENVIRONMENTAL NOISE STUDY IN THE CITY OF TORONTO,” 2017. Available: https://www.toronto.ca/wp-content/uploads/2017/11/8f4d-tph-Environmental-Noise-Study-2017.pdf

[15] N. Rahmawati and B. C. Jiang, “Develop a bedroom design guideline for progressive ageing residence: A case study of Indonesian older adults,” Gerontechnology, vol. 18, no. 3, pp. 180–192, Sep. 2019, doi: https://doi.org/10.4017/gt.2019.18.3.005.00.

[16] D. Giavarina, “Understanding Bland Altman analysis,” *Biochemia Medica*, vol. 25, no. 2, pp. 141–151, 2015, doi: https://doi.org/10.11613/bm.2015.015.

[17] R. Robbins et al., “Accuracy of Three Commercial Wearable Devices for Sleep Tracking in Healthy Adults,” Sensors, vol. 24, no. 20, p. 6532, Oct. 2024, doi: https://doi.org/10.3390/s24206532.

[18] D. S. Lauderdale, K. L. Knutson, L. L. Yan, K. Liu, and P. J. Rathouz, “Self-Reported and Measured Sleep Duration,” Epidemiology, vol. 19, no. 6, pp. 838–845, Nov. 2008, doi: https://doi.org/10.1097/ede.0b013e318187a7b0.

[19] Anna Nolda Nagele and J. Hough, “‘The sleep data looks way better than I feel.’ An autoethnographic account and diffractive reading of sleep-tracking,” Frontiers in computer science, vol. 6, Feb. 2024, doi: https://doi.org/10.3389/fcomp.2024.1258289.

[20] K. Aili, S. Åström-Paulsson, U. Stoetzer, M. Svartengren, and L. Hillert, “Reliability of Actigraphy and Subjective Sleep Measurements in Adults: The Design of Sleep Assessments,” Journal of Clinical Sleep Medicine, vol. 13, no. 01, pp. 39–47, Jan. 2017, doi: https://doi.org/10.5664/jcsm.6384.

[21] T. Lau et al., “Minimum number of nights for reliable estimation of habitual sleep using a consumer sleep tracker,” SLEEP Advances, Aug. 2022, doi: https://doi.org/10.1093/sleepadvances/zpac026.

[22] A. Marshall, Principles of Economics, 1st ed. 2013. London: Palgrave Macmillan UK, 2013. doi: 10.1057/9781137375261.

[23] C. Zingale, V. Ahlstrom, and B. Kudrick, "Human Factors Guidance for the Use of Handheld, Portable, and Wearable Computing Devices," Federal Aviation Administration, William J. Hughes Technical Center, Atlantic City International Airport, NJ, Technical Report, Nov. 2005. [Online]. Available: https://hf.tc.faa.gov/publications/2005-human-factors-guidance-for-the-use-of-handheld/full_text.pdf

[24] U.S. Department of Defense, MIL-STD-1472G: Design Criteria Standard - Human Engineering, Jan. 2019. [Online]. Available: https://ia601700.us.archive.org/27/items/mil-std-1472-g-chg-1/MIL-STD-1472G-CHG1.pdf.

[25] E. Stefana, F. Marciano, D. Rossi, P. Cocca, and G. Tomasoni, "Wearable Devices for Ergonomics: A Systematic Literature Review," Sensors, vol. 21, no. 3, p. 777, Jan. 2021, doi: 10.3390/s21030777. [Online]. Available: https://pubmed.ncbi.nlm.nih.gov/33498904/

[26] V. Ahlstrom and B. Kudrick, "Human Factors Criteria for Displays: A Human Factors Design Standard (Update of Chapter 5)," Federal Aviation Administration, William J. Hughes Technical Center, Atlantic City International Airport, NJ, Technical Report, May 2007. [Online]. Available: https://rosap.ntl.bts.gov/view/dot/71695

[27] Health Canada, "Guidance on the Risk-based Classification System for Non-In Vitro Diagnostic Devices (non-IVDDs)," Health Products and Food Branch, Ottawa, ON, Canada, Guidance Document, Apr. 2015. [Online]. Available: https://www.canada.ca/content/dam/hc-sc/migration/hc-sc/dhp-mps/alt_formats/pdf/md-im/applic-demande/guide-ld/gd_rbc_non_ivdd_lg_scr_autres_idiv-eng.pdf [Accessed: Feb. 12, 2025].

[28] T. Weissgerber, C. Müller, T. Stöver, and U. Baumann, "Age Differences in Speech Perception in Noise and Sound Localization in Individuals With Subjective Normal Hearing," Front. Psychol., vol. 13, Apr. 2022, doi: 10.3389/fpsyg.2022.848285. [Online]. Available: https://www.frontiersin.org/journals/psychology/articles/10.3389/fpsyg.2022.845285/full [Accessed: Feb. 12, 2025].

[29] M. A. Farage, K. W. Miller, F. Ajayi, and D. Hutchins, "Design Principles to Accommodate Older Adults," Global Journal of Health Science, vol. 4, no. 2, pp. 2–25, Mar. 2012, doi: 10.5539/gjhs.v4n2p2. [Online]. Available: https://pubmed.ncbi.nlm.nih.gov/22980147/ [Accessed: Feb. 12, 2025].

[30] M.C. Branch et al., Outdoor Noise and the Metropolitan Environment, Department of City Planning, City of Los Angeles, 1970. [Modified from

http://www.wenet.net/~hpb/dblevels.html on 2/2000]. Sources: Temple University Department of Civil/Environmental Engineering (www.temple.edu/departments/CETP/environ10.html), and Federal Agency Review of Selected Airport Noise Analysis Issues, Federal Interagency Committee on Noise (August 1992). [Online]. Available: https://www.chem.purdue.edu/chemsafety/Training/PPETrain/dblevels.htm [Accessed: Feb. 12, 2025].

[31] Apple Inc., "Typography," in Human Interface Guidelines, [Online]. Available: https://developer.apple.com/design/human-interface-guidelines/typography. [Accessed: Feb. 10, 2025]. \

[32] Government of Canada, Canada Consumer Product Safety Act (S.C. 2010, c. 21), Justice Laws Website, 2010. [Online]. Available: https://laws-lois.justice.gc.ca/eng/acts/C-1.68/page-1.html#h-44309. [Accessed: Feb. 10, 2025].

[33] Government of Canada, Consumer Chemicals and Containers Regulations, 2001 (SOR/2001-269), Justice Laws Website, 2001. [Online]. Available: https://laws-lois.justice.gc.ca/eng/regulations/SOR-2001-269/index.html. [Accessed: Feb. 10, 2025].

[34] Government of Canada, Consumer Products Containing Lead Regulations (SOR/2018-83), Justice Laws Website, 2018. [Online]. Available: https://laws-lois.justice.gc.ca/eng/regulations/SOR-2018-83/index.html. [Accessed: Feb. 10, 2025].

[35] Government of Canada, Consumer Packaging and Labelling Act (R.S.C., 1985, c. C-38), Justice Laws Website, 1985. [Online]. Available: https://laws.justice.gc.ca/eng/acts/c-38/page-1.html#h-95939. [Accessed: Feb. 11, 2025].

[36] Government of Canada, Medical Devices Regulations (SOR/98-282), Justice Laws Website, 1998. [Online]. Available: https://laws.justice.gc.ca/eng/regulations/sor-98-282/page-13.html#h-1022100. [Accessed: Feb. 12, 2025].

[37] Canadian Sleep Society, “Canadian Sleep Society,” Css-scs.ca, 2018. https://css-scs.ca/

[38] CSRC, “CSRC,” CSRC, 2024. https://www.researchsleep.ca/ (accessed Feb. 14, 2025).

[39] “Canadian Sleep and Circadian Network |,” | Advancing Sleep Health Worldwide, May 08, 2020. https://worldsleepsociety.org/membership/societymembership/membersocieties/canadian-sleep-and-circadian-network/ (accessed Feb. 14, 2025).

[40] “Réseau sommeil,” Réseau sommeil, 2025. https://reseausommeil.ca/en/ (accessed Feb. 14, 2025).

[41] Stakeholders Ranking, "Stakeholders Ranking," Google Docs, 2025. https://forms.gle/FYc7cdWQ6tiE7eZD9 (accessed Feb. 14, 2025).

[42] "Review of Indoor Temperature Standards Re: TD1.3," 2015. Available: https://www.toronto.ca/legdocs/mmis/2015/td/bgrd/backgroundfile-81691.pdf

[43] "Ministry of Long-Term Care Long-Term Care Operations Division Cooling and Air Temperature Requirements for LTCHs A Summary of Changes in 2022," 2022. Accessed: Feb. 12, 2025. [Online]. Available: https://ltchomes.net/LTCHPORTAL/Content/Updated%20Cooling%20Requirements%20Summary%20-%20June%202022.pdf

[44] P. S. and P. C. Government of Canada, "Information archivée dans le Web," publications.gc.ca. https://publications.gc.ca/collections/collection_2018/sc-hc/H144-33-2016-eng.pdf

[45] "Humidified Air Shows Dramatic Impact on Patient Health CASE STUDY Residential Care Facilities." Accessed: Feb. 12, 2025. [Online]. Available: https://www.condair.com/m/0/20-72-rev-1-middletown-home.pdf

[46] Sleep Products Voluntary Dimensional Guideline for Bedding Products and Components. International Sleep Products Association, 2001.

[47] "Canada's Mobile and Broadband Internet Speeds - Speedtest Global Index," Speedtest Global Index, 2024. https://www.speedtest.net/global-index/canada?mobile#market-analysis (accessed Feb. 12, 2025).

[48] L. Degroote et al., "Low-Cost Consumer-Based Trackers to Measure Physical Activity and Sleep Duration Among Adults in Free-Living Conditions: Validation Study," JMIR mHealth and uHealth, vol. 8, no. 5, p. e16674, May 2020, doi: https://doi.org/10.2196/16674.

[49] "USD/CAD (CAD=X) Stock Price, News, Quote & History - Yahoo Finance," Yahoo Finance, 2025. https://finance.yahoo.com/quote/CAD%3DX/?guccounter=1&guce_referrer=aHR0cHM6Ly93d3cuZ29vZ2xlLmNvbS8&guce_referrer_sig=AQAAAC6FFFdW6xgVG-_4ThVQE2VjQGwvFx0OmfnWXApNCZEZOo4L81pc8F3rgX7Bb6hVx1awvtOFM6nUIG6U8_iiQdFYrgUzp5MdS-2mLJTxLxv5zlizwO4WJ4_qZwxcRmsFkT9TPX88tG6MK82obHXwPN__-WLsrM9bVTyeyiva_0Xy (accessed Feb. 14, 2025).

[50] Bank of Canada, "Inflation Calculator," Bank of Canada. https://www.bankofcanada.ca/rates/related/inflation-calculator/

[51] Government of Ontario, Personal Health Information Protection Act, 2004, S.O. 2004, c. 3, Sched. A, 2004. [Online]. Available: https://www.ontario.ca/laws/statute/04p03#BK2. [Accessed: Feb. 14, 2025].

[52] Government of Ontario, Personal Health Information Protection Act, 2004, S.O. 2004, c. 3, Sched. A, 2004. [Online]. Available: https://www.ontario.ca/laws/statute/04p03#BK19 [Accessed: Feb. 14, 2025].

[53] Government of Ontario, Personal Health Information Protection Act, 2004, S.O. 2004, c. 3, Sched. A, 2004. [Online]. Available: https://www.ontario.ca/laws/statute/04p03#BK54 [Accessed: Feb. 14, 2025].

[54] CSA Group, Canadian Electrical Code, Part I: Safety Standard for Electrical Installations, 25th ed., CSA C22.1:21, 2021. [Accessed: Feb. 14, 2025].

[55] "Wholesale cotton pajamas sleep suit toddler pajama pajamas kid sleepwear nightdress plus size sexy nighties," *Global Sources*, 2021. https://www.globalsources.com/Womens-pajama/women-s-sleepwear-women-s-pajama-1196033828p.htm?source=Search_Product_to_PP. [Accessed: Mar. 22, 2025].

[56] "Average wrist circumference, by age," *Censusatschool.ca*, 2018. https://censusatschool.ca/data-results/2018-2019/wrist-by-age/. [Accessed: Mar. 22, 2025].

[57] D. I. Y. Hacks, H. T. Hacks, and H. T. on YouTube, "Shirt Folding Board From Cardboard and Duct Tape," *Instructables*. https://www.instructables.com/Shirt-Folding-Board-from-Cardboard-and-Duct-Tape/. [Accessed: Mar. 22, 2025].

[58] "LiPo Batteries: Powering the Future of Wearable Devices | LiPo_Battery_com," *Lipo-battery.com*, 2023. https://lipo-battery.com/lipo-batteries-powering-the-future-of-wearable-devices/. [Accessed Mar. 23, 2025].

[59] "Choosing Batteries to Use for Wearables: Beginner's Guide – Wearable Tech Tutorials and How-Tos." https://www.wearabletutorials.com/how-to-choose-batteries-for-wearable/. [Accessed Mar. 22, 2025].

[60] F. C. G. Online, "Addressing Phone Use Challenges for Older Adults: A Guide for Caregivers," *Family Caregivers Online*, Oct. 21, 2023. https://familycaregiversonline.net/addressing-phone-use-challenges-for-older-adults-a-guide-for-caregivers/. [Accessed: Mar. 22, 2025]

[61] G. says, "The Perceived Threat of Electromagnetic Radiation, Now and Then," *The Saturday Evening Post*, Nov. 03, 2021. https://www.saturdayeveningpost.com/2021/11/the-perceived-threat-of-electromagnetic-radiation-now-and-then/. [Accessed: Mar. 22, 2025].

[62] "Espressif ESP32 Development Board - Developer Edition," Adafruit. [Online]. Available: https://www.adafruit.com/product/3269. [Accessed: Mar. 22, 2025].

[63] "ESP32-WROOM-32 - Combo Wi-Fi/BT/BLE Module" Gridconnect. [Online]. Available:

https://www.gridconnect.com/products/esp32-wroom-32-wi-fi-802-11-bluetooth-module?srsltid=AfmBOord7hpeeguPCFQpAghkJ3O7Ye9esGEcqX5sg0T-AWANh5eUeatU. [Accessed: Mar. 22, 2025].

[64] "PN532 NFC RFID Wireless Module V3 User Kits Reader Writer Mode IC S50 Card PCB Attenna I2C IIC SPI HSU" AliExpress. [Online]. Available: https://www.aliexpress.com/item/1005006232576626.html?src=google&pdp_npi=4%40dis!CAD!3.53!3.53!!!!!%40!12000036391432632!ppc!!!&albch=shopping&acnt=631-313-3945&isdl=y&slnk=&plac=&mtctp=&albbt=Google_7_shopping&aff_platform=google&aff_short_key=UneMJZVf&=&albagn=888888&ds_e_adid=&ds_e_matchtype=&ds_e_device=c&ds_e_network=x&ds_e_product_group_id=&ds_e_product_id=en1005006232576626&ds_e_product_merchant_id=5308071469&ds_e_product_country=CA&ds_e_product_language=en&ds_e_product_channel=online&ds_e_product_store_id=&ds_url_v=2&albcp=19366866438&albag=&isSmbAutoCall=false&needSmbHouyi=false&gad_source=1#nav-review. [Accessed: Mar. 22, 2025].

[65] "PN532 NFC RFID module V4" LccHouse. [Online]. Available: https://www.elechouse.com/product/pn532-nfc-rfid-module-v4/. [Accessed: Mar. 22, 2025].

[66] "microSD Card Sizes: A Complete Guide to Capacity and Compatibility" Laxar. [Online]. Available: https://americas.lexar.com/guide-to-microsd-card-sizes/#:~:text=The%20SD%20family%20includes%20three,x%2011%20x%201%20mm. [Accessed: Mar. 22, 2025].

[67] "SanDisk Ultra 32GB 100MB/s Micro SD Card SDSQUNS-032G" BestBuy. [Online]. Available: https://www.google.com/url?q=https://www.bestbuy.ca/en-ca/product/sandisk-ultra-32gb-100mb-s-micro-sd-card-sdsquns-032g/13695879?cmp%3Dseo-13695879&sa=D&source=docs&ust=1742703471528422&usg=AOvVaw28wgdv1E7Xqmp0rzJCfS6a. [Accessed: Mar. 22, 2025].

[68] "The Difference Between SD and microSD Cards" WinRecovery Software. [Online]. Available: https://www.cardrecovery.com/articles/difference-between-sd-and-microsd-cards/. [Accessed: Mar. 22, 2025].

[69] "Lithium-Ion Polymer (LiPo) Battery (3.7V 1000mAh)" Canada Robotix. [Online]. Available: https://www.canadarobotix.com/products/588. [Accessed: Mar. 22, 2025]. Lithium-Ion Polymer (LiPo) Battery (3.7V 1000mAh) in Canada Robotix

[70] "3mm LED Specifications" Make-It.ca. [Online]. Available: https://www.make-it.ca/3mm-led-specifications/. [Accessed: Mar. 22, 2025].

[71] "Photodiodes" ThorLabs. [Online]. Available: https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=285. [Accessed: Mar. 22, 2025].

[72] "1000Pcs 5mm LED Diode Light Emitting Diode Assortment Kit Led Electronics Circuit Assorted Kit for Arduino, PCB Circuit DIY (5 Colors x 200Pcs)" Amazon. [Online]. Available: https://www.amazon.ca/1000Pcs-Emitting-Assortment-Electronics-Assorted/dp/B0BC1M4TXY. [Accessed: Mar. 22, 2025].

[73] “S1133 Ceramic package photodiode with low dark current electronic component” Global Sources. [Online]. Available: https://www.globalsources.com/Diode-diode-module/S1133-1190453464p.htm?source=Search_Product_to_PP. [Accessed: Mar. 22, 2025].

[74] “LED Light and Power Source Specification” Evan Designs. [Online]. Available: https://evandesigns.com/blogs/evan-designs-news-and-how-tos/led-light-and-power-source-specification. [Accessed: Mar. 22, 2025].

[75] “uxcell 10pcs Photosensitive Diode Photodiodes Light Sensitive Sensors,3mm Clear Flat Head Receiver Diode” Amazon. [Online]. Available: https://www.amazon.ca/uxcell-Photosensitive-Photodiodes-Sensitive-Receiver/dp/B07VLNGGMY. [Accessed: Mar. 22, 2025].

[76] “JZK 3 Packs ADXL345 3 axis Digital Acceleration of Gravity tilt Module for GY-291 Arduino, IIC/SPI Transmission” Amazon. [Online]. Available: https://www.amazon.ca/JZK-ADXL345-Digital-Acceleration-Transmission/dp/B096TVT8SN?dib=eyJ2IjoiMSJ9.A3gshBEcqNZAeJ0a08dlAToe51OTrBoam25WQZhpYr2DKaq0HarA52Bo_tWpuD-eRjvEQy02Xs3YAeVWYo7T0yvm9Fiwn53JRENZAHZzKgDEu_gfaxwE-HVVtEBBy8pIcOkuZKOn6Nag1JrbQUlttLLJYiE6cZuHgEMjXN4z3u9E7Ug2EzG9irqc43kWT62Zng1ih7jseCSMDo_OEpY9kDB_GvErhs686KPHpfL0OI4fhfbmGv_nMoXn1Od75G2zRM6y70bU2mtFiptcNFG1UP3jbTbBpRdV9ZPGrYiMbnoxAzZv5d43I2HB77QjbsPyUuRBhUs2cY_LQMCAaWmx5q9-tlV-W8D-6rKF1bJ1YDbb-m3WusXv-P-i31DrepXIS358fraPpB0NqITU1ON3ssRtGUp6P6d0knt2rpvFM1c_DEurXM0Y4nZRGvH1dX2Y.JKDqL7feyTezTWkKlrYBIu0BWxOA1v4dDtEQlnV3ZyQ&dib_tag=se&hvadid=604543004364&hvdev=c&hvlocphy=9197976&hvnetw=g&hvqmt=e&hvrand=5251572093119700017&hvtargid=kwd-299619231259&hydadcr=4517_13243338&keywords=adxl345&mcid=dba21be7408e32f19050eeafbb2e97b4&qid=1742092168&sr=8-5. [Accessed: Mar. 22, 2025].

[77] “LM35 Precision Centigrade Temperature Sensors” Texas Instruments. [Online]. Available: https://www.ti.com/lit/ds/symlink/lm35.pdf. [Accessed: Mar. 22, 2025].

[78] “20pcs/1pc LM35DZ/NOPB LM35DZ LM35 Centigrade TO-92 SMD Chip Precision Temperature Sensor” Ali Express. [Online]. Available: https://www.aliexpress.com/item/32451177699.html?src=google&pdp_npi=4%40dis!CAD!0.50!0.47!!!!!%40!12000038902436988!ppc!!!&albch=shopping&acnt=631-313-3945&isdl=y&slnk=&plac=&mtctp=&albbt=Google_7_shopping&aff_platform=google&aff_short_key=UneMJZVf&=&albagn=888888&ds_e_adid=&ds_e_matchtype=&ds_e_device=c&ds_e_network=x&ds_e_product_group_id=&ds_e_product_id=en32451177699&ds_e_product_merchant_id=106630103&ds_e_product_country=CA&ds_e_product_language=en&ds_e_product_channel=online&ds_e_product_store_id=&ds_url_v=2&albcp=19366866438&albag=&isSmbAutoCall=false&needSmbHouyi=false&gad_source=1. [Accessed: Mar. 22, 2025].

[79] “LM35 Temperature Sensor (TO-92)” rhydoLABZ. [Online]. Available: https://www.rhydolabz.com/lm35-temperature-sensor-to-92. [Accessed: Mar. 22, 2025].

[80] “Wireless Charging Module Electromagnetic Induction Charger PCBA Board 3W 5W DIY Wireless Charger for Cell Phone Mobile Device” Ali Express. [Online]. Available: https://www.aliexpress.com/item/1005006490124675.html?src=google&pdp_npi=4%40dis!CAD!3.10!1.79!!!!!%40!12000037394783059!ppc!!!&albch=shopping&acnt=631-313-3945&isdl=y&slnk=&plac=&mtctp=&albbt=Google_7_shopping&aff_platform=google&aff_short_key=UneMJZVf&=&albagn=888888&ds_e_adid=&ds_e_matchtype=&ds_e_device=c&ds_e_network=x&ds_e_product_group_id=&ds_e_product_id=en1005006490124675&ds_e_product_merchant_id=647605207&ds_e_product_country=CA&ds_e_product_language=en&ds_e_product_channel=online&ds_e_product_store_id=&ds_url_v=2&albcp=19366866438&albag=&isSmbAutoCall=false&needSmbHouyi=false&gad_source=1. [Accessed: Mar. 22, 2025].

[81] “SJZBIN 15W Qi Wireless Charger PCBA Circuit Board with Coil Pad Charging” Amazon. [Online]. Available: https://www.amazon.ca/SJZBIN-Wireless-Charger-Circuit-Charging/dp/B09FLCMGV9. [Accessed: Mar. 22, 2025].

[82] “5 inch 5.0" 800*480 TFT LCD Display Module SSD1963 Controller Board with GT911 XPT2046 Touch Panel card for Arduino 51 AVR STM32” Ali Express. [Online]. Available: https://www.aliexpress.com/item/1005004659788220.html?spm=a2g0o.productlist.main.9.52ba4Dzh4DzhXa&algo_pvid=4d3ffe63-919a-49c4-b68c-282348c3c136&algo_exp_id=4d3ffe63-919a-49c4-b68c-282348c3c136-4&pdp_ext_f=%7B%22order%22%3A%228%22%2C%22eval%22%3A%221%22%7D&pdp_npi=4%40dis%21CAD%2144.85%2124.37%21%21%2130.50%2116.57%21%402101eac917422471973707741ecef9%2112000030012623760%21sea%21CA%210%21ABX&curPageLogUid=B79HiXgLu6jn&utparam-url=scene%3Asearch%7Cquery_from%3A. [Accessed: Mar. 22, 2025].

[83] “ER-TFTM050-5” EastRising. [Online]. Available: https://www.buydisplay.com/download/manual/ER-TFTM050-5_Datasheet.pdf. [Accessed: Mar. 22, 2025].

[84] “4.3 inch TFT LCD module RGB interface 800*480 resolution IPS full viewing angle resistive capacitive touch LCD” GlobalSources [Online]. Available: https://www.globalsources.com/TFT-LCD/4-3-inch-TFT-LCD-module-1216627898p.htm?source=Search_Product_to_PP. [Accessed: Mar. 22, 2025].

[85] “Arduino GIGA Display Shield - 3.97 inch TFT Display 480*800 pixels - Touchscreen - IMU - Microphone” TinyTronics. [Online]. Available: https://www.tinytronics.nl/en/displays/tft/arduino-giga-display-shield-3.97-inch-tft-display-480*800-pixels-touchscreen-imu-microphone. [Accessed: Mar. 22, 2025].

[86] “DAOKI 100-Pack 6x6x5 mm Miniature Micro Momentary Tactile Tact Touch Push Button Switch Quality Switch SPST Miniature/Mini/Micro/Small PCB” Amazon. [Online]. Available: https://www.amazon.ca/C-J-SHOP-Miniature-Momentary-Tactile/dp/B01CGMP9GY/?tag=googleshopc0c-20&linkCode=df0&hvadid=706828873409&hvpos=&hvnetw=g&hvrand=1383235500422370387&hvpone=&hvptwo=&hvqmt=&hvdev=c&hvdvcmdl=&hvlocint=&hvlocphy=9197

976&hvtargid=pla-640514760452&psc=1&mcid=6f3ab773cfc734899df1f393683956d4&tag=googleshopc0c-20&linkCode=df0&hvadid=706828873409&hvpos=&hvnetw=g&hvrand=1383235500422370387&hvpone=&hvptwo=&hvqmt=&hvdev=c&hvdvcmdl=&hvlocint=&hvlocphy=9197976&hvtargid=pla-640514760452&psc=1&gad_source=1. [Accessed: Mar. 22, 2025].

[87] "AMS1117 3.3V 1A LDO Voltage Regulator SOT-223," iFuture Tech. [Online]. Available: https://ifuturetech.org/product/l1117-ldo3v3-linear-voltage-regulator-sot-223/. [Accessed: Mar. 22, 2025].

[88] "AMS1117-3.3V Voltage Regulator," PCBoard.ca. [Online]. Available: https://www.pcboard.ca/ams1117-3-volt-regulator. [Accessed: Mar. 22, 2025].

[89] "AMS1117-3.3 Voltage Regulator Step Down Power Supply Buck Module 4.2 V-10 V to 3.3V 800mA," Geekstory, Amazon.ca. [Online]. Available: https://www.amazon.ca/AMS1117-3-3-Voltage-Regulator-Supply-Geekstory/dp/B07NY8PN84. [Accessed: Mar. 22, 2025]

[90] "10Pcs 5V 1A 18650 Lithium Battery Charging Board TP4056 Lithium Battery Charging Board Micro USB Charge Module with Dual Protection Functions," Amazon.ca. [Online]. Available: https://www.amazon.ca/Lithium-Overcharge-Over-Discharge-Over-Current-Protection/dp/B07KYGL71L. [Accessed: Mar. 22, 2025].

[91] "TP4056 Type-C USB 5V 1A 18650 Lithium Battery Charger TP4056 Module Charging Board With Protection Dual Functions 1A Li-ion," DIY Electronic Kit Store , AliExpress. [Online]. Available: https://www.aliexpress.com/item/1005005237080994.html. [Accessed: Mar. 22, 2025].

[92] "TP4056 1A Li-ion Lithium Battery Charging Module With Current Protection – Mini USB," Robu.in. [Online]. Available: https://robu.in/product/tp4056-1a-li-ion-lithium-battery-charging-module-with-current-protection-mini-usb/. [Accessed: Mar. 22, 2025].

[93] "Stemedu 2PCS Micro SD Card Module TF Card Memory Storage Adapter Reader Board SPI Interface with Integrated Circuit Breakout for Arduino for Raspberry Pi," Amazon.ca. [Online]. Available: https://www.amazon.ca/Interface-Arduino-Raspberry-Storage-Breakout/dp/B08C4WY2WR. [Accessed: Mar. 22, 2025].

[94] "Arduino Module for SD Card," Addison Electronique. [Online]. Available: https://addison-electronique.com/en/arduino-module-for-sd-card.html. [Accessed: Mar. 22, 2025].

[95] "IRM-01-5 AC DC Converter," MEAN WELL USA Inc., DigiKey.ca. [Online]. Available: https://www.digikey.ca/en/products/detail/mean-well-usa-inc/IRM-01-5/7704616. [Accessed: Mar. 22, 2025].

[96] "IRM-01-5 AC/DC Power Module," MEAN WELL, Mouser.ca. [Online]. Available: https://www.mouser.ca/ProductDetail/MEAN-WELL/IRM-01-5 [Accessed: Mar. 22, 2025].

[97] "LM7805 3-Terminal Positive Voltage Regulator," Continental Device India Limited (CDIL). [Online]. Available: https://www.tme.eu/Document/8aa8ed83dc2f8e8a5f3ad4a71fd201bc/lm7805.pdf. [Accessed: Mar. 22, 2025].

[98] "10PCS L7805CV L7805 Positive Voltage Regulator IC TO-220 Output 1.5A 5V," Brand: HUABAN, Amazon.ca. [Online]. Available: https://www.amazon.ca/L7805CV-L7805-Positive-Voltage-Regulator/dp/B07RZCBMKC. [Accessed: Mar. 22, 2025].

[99] "Wholesale Memory Foam Pillows," Shenzhen Inzok Electron Co., Ltd. [Online]. Available:https://www.globalsources.com/Memory-foam/Memory-foam-pillows-1213395738p.htm?source=Search_Product_to_PP#Product [Accessed: Mar. 22, 2025].

[100] "Queen Pillow Cases - 2 Pack," Quanzhou Bonita Traveling Articles Co., Ltd. [Online]. Available: https://www.globalsources.com/Pillowcase/Pillowcase-1222747227p.htm?source=Search_Product_to_PP#Product. [Accessed: Mar. 22, 2025].

[101] "Force Sensor FSR-406 - 2kg Square 38mm," Botland. [Online]. Available: https://botland.store/pressure-sensors/1040-force-sensor-fsr-406-2kg-square-38mm-pololu-1645-5904422366650.html. [Accessed: Mar. 22, 2025].

[102] "Fsr406 High Accurate Resistance Type Thin Film Force Sensitive Resistor," Shenzhen Sanxiang Technology Co., Ltd. [Online]. Available: https://www.globalsources.com/Other-resistor/Thin-film-resistors-1218293455p.htm?source=Search_Product_to_PP [Accessed: Mar. 22, 2025].

[103] "MDU-6050 3-Axis Accelerometer and I2C Gyroscope - DFRobot Module," DFRobot. [Online]. Available: https://botland.store/gyros/3888-mpu-6050-3-axis-accelerometer-and-i2c-gyroscope--6959420908240.html. [Accessed: Mar. 22, 2025].

[104] "GY-521 MPU-6050 MPU6050 Axis Accelerometer Gyroscope Module," GODREAM FORDREAM CO., LIMITED. [Online]. Available: https://www.globalsources.com/Accelerometer-sensor/MPU6050-1178359561p.htm?source=Search_Product_to_PP. [Accessed: Mar. 22, 2025].

[105] "SHT31 - Digital Humidity and Temperature Sensor I2C - Adafruit 2857," Botland. [Online]. Available: https://botland.store/high-precision-temperature-sensors/5415-sht31-digital-humidity-and-temperature-sensor-5904422305949.html. [Accessed: Mar. 22, 2025].

[106] "SHT31 High-Precision Temperature and Humidity Sensor Module," HOTAI INTERNATIONAL CO., LIMITED. [Online]. Available: https://www.globalsources.com/Temperature-sensor/temperature-sensor-1220581757p.htm?source=Search_Product_to_PP. [Accessed: Mar. 22, 2025].

[107] "ESP32 WiFi + BT 4.2 - Platform with Module ESP-WROOM-32," Botland. [Online]. Available: https://botland.store/esp32-wifi-and-bt-modules/8893-esp32-wifi-bt-42-platform-with-module-5904422337438.html. [Accessed: Mar. 22, 2025].

[108] "ESP32-WROVER 4MB FLASH Memory ESP-32 SMD Module," GODREAM FORDREAM CO., LIMITED. [Online]. Available: https://www.globalsources.com/Wi-Fi/ESP32-WROVER-1177744135p.htm?source=Search_Product_to_PP. [Accessed: Mar. 22, 2025].

[109] "Lithium Ion Polymer Battery - 3.7v 2500mAh," Adafruit. [Online]. Available: https://www.adafruit.com/product/328. [Accessed: Mar. 22, 2025].

[110] "How To Measure Your Sleep Health – SATED Questionnaire," Reading Guru. [Online]. Available: https://www.reading.guru/how-to-measure-your-sleep-health-sated-questionnaire/. Accessed: [Accessed: Mar. 22, 2025].

[111] "[MARCH] Prewelded 20mm 30 40 50 80 100 mm stress analysis strain gauge single grid 120 Ohm," HT Sensor Technology Co., Ltd., Alibaba.com. [Online]. Available: https://www.alibaba.com/product-detail/Prewelded-20mm-30-40-50-80_1601300354210.html. [Accessed: Mar. 22, 2025].

[112] "High Sensitive NTC Thermistor 10K 6*30MM 1M Waterproof Temperature Sensor Probe For Refrigerator," Dongguan Guande Sensor Technology Co., Ltd., Alibaba.com. [Online]. Available: https://www.alibaba.com/product-detail/High-Sensitive-NTC-Thermistor-10K-6_1600303560564.html. [Accessed: Mar. 22, 2025].

[113] "MARCH ESP-32 ESP32 ESP32 Development Board WiFi Ultra-Low Power Consumption ESP32 Board," Shenzhen Robotlinking Technology Co., Ltd., Alibaba.com. [Online]. Available: https://www.alibaba.com/product-detail/ESP-32-ESP32-ESP32-Development-Board_60824135633.html. [Accessed: Mar. 22, 2025].

[114] "Li-polymer Cell Factory OEM Medical Equipment Battery UFX 302560 300mAh 3.2V LiFePo4 Battery," Guangdong Ufine New Energy Co., Ltd., Alibaba.com. [Online]. Available: https://www.alibaba.com/product-detail/Li-polymer-Cell-Factory-OEM-Medical_1600823068965.html?spm=a2700.galleryofferlist.p_offer.d_title.17f913a0SC3NEU&s=p . [Accessed: Mar. 22, 2025].

[115] "MARCH Portable PULUZ 5 in 1 Camera Belt Adjustable Body Mount Belt Accessories Chest Strap With Phone Clamp," Shenzhen Wbtd Technology Co., Ltd., Alibaba.com. [Online]. Available: https://www.alibaba.com/product-detail/Portable-PULUZ-5-in-1-Camera_1601287964236.html?spm=a2700.galleryofferlist.normal_offer.d_title.583513a09r9MoQ&selectedCarrierCode=SEMI_MANAGED_STANDARD@@STANDARD . [Accessed: Mar. 22, 2025].

[116] "How are LiFePO4 batteries safer than other lithium batteries?" RELION Newsletter. [Online]. Available: [https://www.relionbattery.com/knowledge/how-are-lifepo4-batteries-safer-than-other-lithium-batteries?srsltid=AfmBOoofwhVROkDkzUwKursQu0TW1H_8L5h2frj-B_AdO45hQTGEp25J]. [Accessed: Mar. 22, 2025].

[117] "MARCH TP4056 Charging Module Board 1A Lithium Battery and Protection Integrated Overcurrent Protection MICRO/TypeC/MINI," Shenzhen Wishope Technology Corporation Limited, Alibaba.com. [Online]. Available: https://www.alibaba.com/product-detail/TP4056-Charging-Module-Board-1A-Lithium_1601203558099.html. [Accessed: Mar. 22, 2025].

[118] "MARCH VICKO Charging IC Nano-ia Low-Dropout Voltage Regulator TPS78218DRVR 1.8V 150MA 6WSON Integrated Circuits," Video Electronics Technology Co., Limited, Alibaba.com. [Online]. Available: https://www.alibaba.com/product-detail/VICKO-Charging-IC-Nano-iq-Low_1601009897867.html.[Accessed: Mar. 22, 2025].

[119] S. Haghayegh, H.-A. Kang, S. Khoshnevis, M. H. Smolensky, and K. R. Diller, "A comprehensive guideline for Bland–Altman and intra class correlation calculations to properly compare two methods of measurement and interpret findings," Physiological Measurement, vol. 41, no. 4, p. 045001, 2020, doi: 10.1088/1361-6579/ab86d6 https://pubmed.ncbi.nlm.nih.gov/32252039/. [Accessed: Mar. 22, 2025].

[120] D. Jurafsky and J. H. Martin, Speech and Language Processing, Draft of January 12, 2025. [Online]. Available: https://web.stanford.edu/~jurafsky/slp3/A.pdf [Accessed: Mar. 22, 2025].

[121] DatasetEngineer, “Human Vital Sign Dataset,” *Kaggle.com*, 2023. https://www.kaggle.com/datasets/nasirayub2/human-vital-sign-dataset (accessed Mar. 23, 2025).

[122] A. Logacjov, Skarpsno, Eivind Schjelderup, A. Kongsvold, K. Bach, and P. J. Mork, “DualSleep dataset for accelerometer-based sleep/wakefulness recognition,” *DataverseNO*, Jun. 2024, doi: https://doi.org/10.18710/UGNIFE.

Appendix A: Problem Statement and Stakeholders

This section highlights the methods used to narrow down the scope and stakeholders, as well as provides greater detail about each of the stakeholders.

Appendix A.1: PICO

Figure A.1.1 below, adapted from client meeting notes, expands on PICO (population, intervention, comparison, outcome), as requested by the client (Appendix G.1).

Population	● Retired adults (age: 65-75) ● Normal physiology (assume no sleep disorders or major health issues) ● Male and Female

	● All Genders ● All ethnicities ● Living in the GTA
Exposure	● Record how individuals thought they slept ○ how energized they felt during the rest of the day ○ how well-rested they felt after they woke up ○ did they want to go back to sleep when their alarm went off ● Record objective sleep data (potentially including but not limited to) ○ Total Sleep Time ○ Waking Time, Bed Time ○ How long before sleeping did they use devices ○ Usage of any sleep inducing/preventing substances (melatonin, caffeine, etc) ○ Movement ○ Snoring ○ Heart rate
Comparison	● Compare their perception on time, quality and energy levels after sleep to the data collected from their sleep ● Compare sleep before and after receiving advice/information on their sleep
Outcome	● Patients are: ○ Informed of anomalies in their sleep patterns/time/quality ○ Prevented from developing sleep conditions ○ Kept from enduring suffering related to their sleeping habits

Figure A.1.1. Pico Chart

Appendix A.2: Engineering Notebook stakeholders brainstorming Notes

Below in the brainstorm that was used to develop the first stakeholder list, as seen in Figure A.2.1.

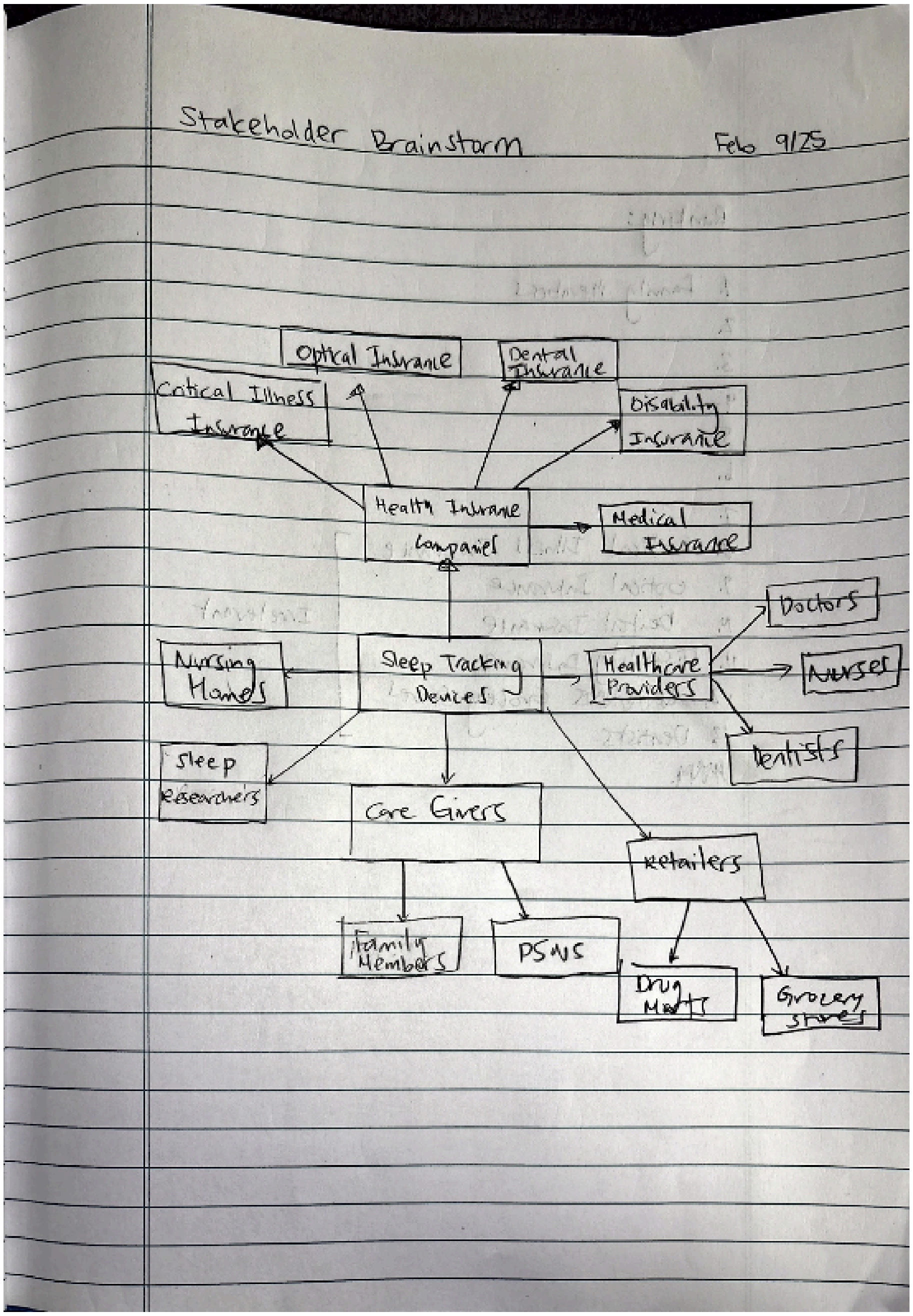


Figure A.2.1. Stakeholder Brainstorm

Appendix A.3: Stakeholder Analysis for Sleep Research Organizations

Below, in Table A.3.1, is a detailed analysis on multiple specific sleep research organizations in Canada.

Table A.3.1. Detailed stakeholder analysis on sleep research organizations in Canada

Stakeholder	Justification	Impact	
		Pros	Cons

Canadian Sleep Society (CSS)	A national organization dedicated to improving sleep for all Canadians through research support, clinical care promotion, education, and advocacy. [37]	Provides access to a network of sleep professionals for system validation.	Need for alignment with ongoing research priorities.
Canadian Sleep Research Consortium (CSRC)	Serves as a national hub of sleep scientists and clinicians advancing research and interventions to optimize sleep health throughout the lifespan. [38]	Facilitates partnerships between academia, government, industry, and community organizations.	Challenges in aligning with various organizational goals.
Canadian Sleep and Circadian Network (CSCN)	Focuses on creating a biobank for sleep and circadian research, supporting various projects across Canada. [39]	Provides a centralized repository for sleep research data.	Requires significant data management and storage resources.
Québec Sleep Research Network (Réseau Sommeil)	Aims to co-build projects and initiatives to advance sleep research, financially supported by the Fonds de recherche du Québec – Santé. [40]	Strong regional focus on sleep research initiatives.	Dependent on provincial funding cycles.

Appendix A.4: Influence Impact Matrix

Below, Figure A.4.1 displays the influence-impact matrix that was developed to determine the influence and impact of various stakeholders with respect to each other.

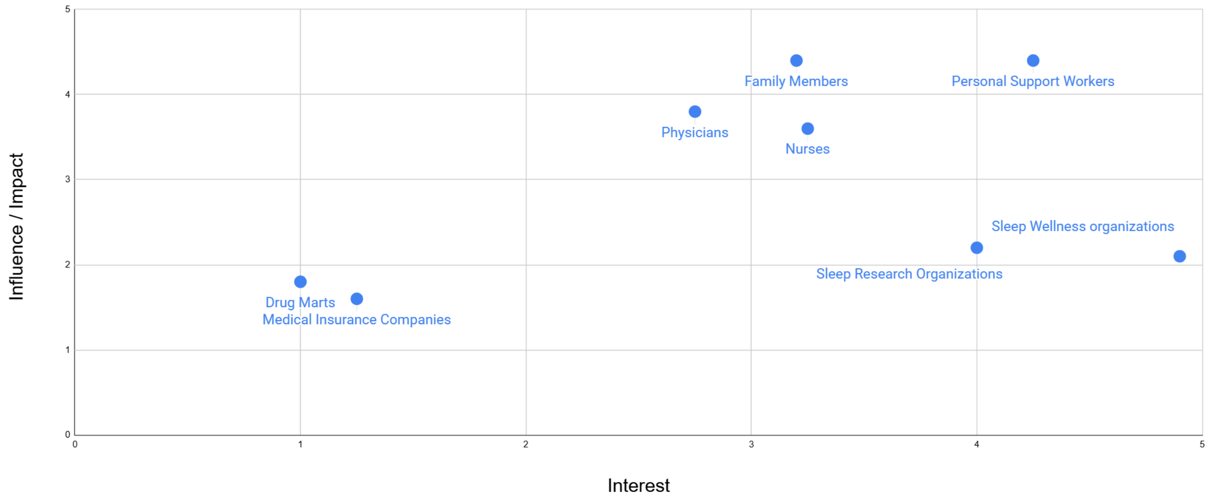


Figure A.4.1. Chart showing influence vs interest for different stakeholders adapted from [41]

Appendix A.5: Original Stakeholder List

The following table shows the original stakeholder list that was used in our PR, before changes were made for the CDS.

Table A.5.1. List of stakeholders from the PR.

Stakeholder	Justification	Impact	
		Pros	Cons
Nursing Homes	Houses seniors that use the product [8].	Enhanced resident care	Increased workload and cost for staff training
Personal Support Workers	Assist with the user's daily activities.	Improve care quality [7]	Increased workload and training requirements
Family Members	Interested in monitoring and improving their loved one's sleep health.	Enhances the ability to make informed decisions for the user	Data privacy
Nurses	Interested in the well-being of patients correlating to sleep [9].	Acquire sleep quality data of patients	Difficult trusting the accuracy of sleep data from patients
Physicians	Provide necessary medical care and suggest preventive measures [10].	Gain sleep history of patients	Difficult trusting the accuracy of sleep data from patients

Sleep Research Organizations (Appendix A.3)	Dedicated to sleep research and education [5].	Potential mass sleep data collection	Need for alignment with ongoing research priorities
Medical Insurance Companies	Interested in the health outcomes of their policy users.	Reduced healthcare cost through preventive care	Data privacy and ethical use of information
Drug Marts	Retailers specializing in health products.	Increase product accessibility	Retail markup increases product cost

Appendix B: Service Environment

The following appendix has all the supporting information regarding the Service environment section of the document.

Appendix B.1: Temperature ranges

This appendix encompasses the results of the research for average temperature ranges considered in the scoped service environment.

Minimum temperature range is derived from the Toronto Municipal Building Code [42], which states temperature ranges should range 21°C to 26°, while maximum temperature range is taken from both the Toronto Municipal Building Code and the Ontario Ministry of Long Term Care specified range of 22°C to 26°C. [43]

Appendix B.2: Humidity levels

This appendix encompasses the results of the research for average relative humidity levels (RHL) ranges considered in the scoped service environment.

Safe indoor RHL range from 30% to 55% according to Health Canada [44]. In addition, a case study realized by Condair concluded that in retirement homes, the recommended humidity levels are between 40% and 60%, as it minimized the transmission of viruses. [45]

Appendix B.3: Bed sizes

This Appendix covers the research on standard bed sizes in North America, defined by the International Sleep Products Association (ISPA) shown in Table B.3.1. And follow the following standards [46]:

Table B.3.1. Standard bed sizes in North america [46]

Size	Dimensions	
	Inches	Centimeters

Twin or Single	38.5×74.5	98×189
Twin XL	38.5×79.5	98×202
Full or Double	53.5×74.5	136×189
Queen	60×79.5	152×202
King	76×79.5	193×202
California King	72×83.5	183×212

Appendix B.4: Internet speeds

This appendix covers the research on internet speeds in the scoped service environment.

A study conducted by SpeedTest for the SpeedTest Global Index shows the average internet speeds in Canada, Ontario and Toronto demonstrated in Table B.4.1. [47]

Table B.4.1. Average upload and download internet speeds in Canada, Ontario and Toronto. [47]

Mobile	**Canada**	**Ontario**	**Toronto**
Download (Mbps)	91.18	98.61	129.68
Upload (Mbps)	10.72	12.71	18.69
Fixed			
Download (Mbps)	222.28	183.89	199.40
Upload (Mbps)	67.91	37.17	49.32

Appendix C: Functions Identification Methods

The approach for identifying the Primary and Secondary Functions of the Detailed Requirements was based on the concepts taught in lectures and Perusall readings on “Functional Basis”. As shown in Figure C.1, five Secondary Functions were identified, which were then refined into two distinct Primary Functions using the Functional Basis techniques.

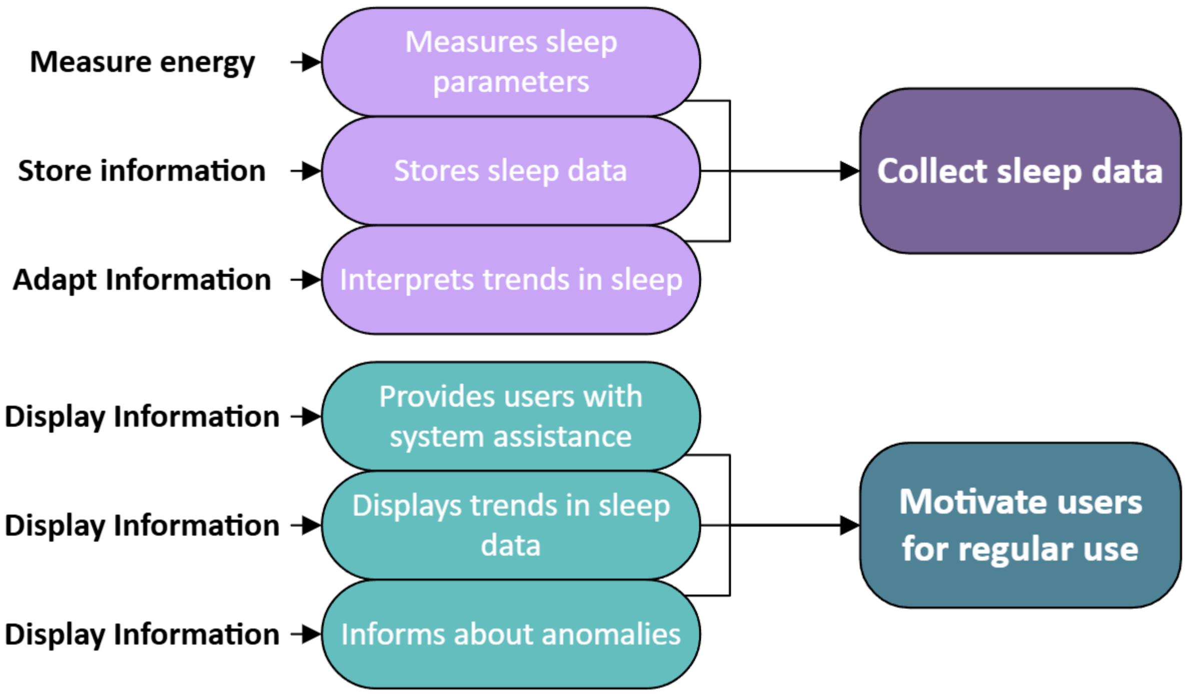


Figure C.1. Brainstorming using Functional Basis, leading to two distinct Primary Functions

Appendix D: Interview with Dr Indra Narang (University of Toronto professor, Paediatric Respirologist and Sleep Medicine specialist) - Engineering Notebook

This appendix covers the interview done with University of Toronto professor Dr. Indra Narang about industry standards in sleep research.

Questions and interview notes are detailed in Figure D.1 below.

10/02 → Virtual environment (3) - Interview with Dr. Indra Narang (UofT Prof and Sleep Doc.)

→ introductions and explanation of the project

Questions:

1) How long does data need to be collected for it to be considered enough to make a summary on?
2) How long does a typical sleep ~~condition~~ disorder take to develop and become an issue?
3) After how long of recurrent symptoms should I contact a doctor in order to prevent a sleep disorder?

Interview:

1) 7 days minimum → include weekend because it's different.

2) 3 months for sleep apnea, → bigger risk factor in adulthood
   - weight → on
   - neck width
   - 1 week - 3 months for parasomnia → therefore reviews should be in different time frames.

3) - If not unwell at time and still with symptoms after 3 months.
   - Chronic → >3 months
   - consider outside factors

4) What are the main differences between adults and children?
   - More common in retired adults. - Poor sleep hygiene
   - behavioral factors have influence - harder to treat

Figure D.1. Interview notes from Joao de Campos Carvalho

This interview gave us insight on how specific timeframes need to be considered in the design when informing the user about anomalies in their sleep patterns.

Appendix E: Objectives

The methodology, as well as any additional information and metrics gathered in the objective sections are showcased in the tables below.

Appendix E.1. Pairwise Comparison

Objective pairwise comparison, shown in Table E.1.1, voted and ranked during team discussion.

Table E.1.1. Pairwise comparison to vote for objectives.

	Maximize accuracy of physiological measurements	Optimize early detection of sleep anomalies	Consistently match collected data and user's perception	Have continuous usage time	Minimize cost	Overall
Maximize accuracy of physiological measurements	-	0	1	0	0	1
Optimize early detection of sleep anomalies	1	-	1	1	1	4
Consistently match collected data and user's perception	0	0	-	0	1	1
Have continuous usage time	0	0	0	-	1	1
Minimize cost	1	0	1	1	-	3

Ranking:

1. Optimize early detection of sleep anomalies
2. Minimize cost
3. (Tied for 3rd) Consistently match collected data and user's perception
4. (Tied for 3rd) Have continuous usage time
5. (Tied for 3rd) Maximize sleep-wake accuracy

Appendix E.2. Minimize Cost Objective

This appendix covers the price research for the "Minimize price" objective of the design. It has the objective of determining boundaries for the end cost for the user.

The price was obtained from a study on the performance of six "low cost" sleep tracking devices as specified by the JMIR foundation [48]. The prices were converted to CAD$ based on the current currency exchange rate [49] and, considering the study is from 2019, the prices were then accounted for inflation rates using the inflation calculator from the Bank of Canada [50]. Resulting in the data listed in table E.2.1 below:

Table E.2.1. Price analysis of low cost sleep tracking devices

Device	Price 2019 (CAD)	Price 2025 (CAD)
Geonaut onCoach	\$39.40	\$46.88
iWowni5	\$40.20	\$47.84
MyKronoz ZeFit4	\$75.67	\$90.04
Nokia Go	\$78.82	\$93.78
VeryFit 2.0	\$47.21	\$56.18
Xiaomi Mi Band 2	\$62.99	\$74.95
Average	\$57.38	\$68.28

Appendix F: Constraints

This section provides greater detail to each of the constraints and why they were chosen through further research about the laws and regulations.

Appendix F.1. Further Justification for Present Constraints in Project Requirements Main Body

The following appendix contains justifications on the constraints mentioned in the body of the document. Table F.1.1. below shows details on the justifications for the constraints.

Table F.1.1. More research claims to justify constraints

Constraint The design must:	**Guideline/Topic**	**Further Explanation**
Be light	Weight	The physical and ergonomic aspect of a design in frequent use by individuals becomes increasingly important for older demographics. "The appropriate physical dimensions for such devices are based on the knowledge of the size, strength, reach, etc., of the existing population of users." [23] - It is standard to meet the needs of the 5th percentile female to the 95th percentile male in terms of physical capability (Central 90 percent accommodation) [24] It is recommended to keep a design's weight to be less than 5.1 pounds = 2.3 kg. [23]
Not impede on regular movement	Wearable Components	Any one wearable component of the design must not greatly alter the physical activity in relation to "human anatomical, anthropometric, physiological, and biomechanical characteristics" [23]. Individuals of older age must be able to comfortably utilize the design – especially important due to reduced physical capability due to aging. - It is standard to meet the needs of the 5th percentile female to the 95th percentile male in terms of physical capability [24] No component should exceed the following dimensions: - 4 inches (100 mm) high, by 10 inches (255 mm) long, by 5 inches (125 mm) wide – if it qualifies as a wearable device. [23]

Not be invasive	Physical Contact	Rules 1 to 16 of Risk-based Classification System for Non-In Vitro Diagnostic Devices (non-IVDDs) indicate what type of devices and their impact on human health. Design should not or only qualify for a Class 1 non in-vitro device under the following rules: - Rule 3 - Rule 7 - Rule 12 ('Although a device may be Class I by Rule 12, other applicable rules may move the device to a higher classification.' [27]) If the design qualifies for any other rule, the design is unfeasible. Therefore, the design will at most contact uninjured skin in adherence to Rule 3, 7, and 12 under Risk-based Classification System for Non-In Vitro Diagnostic Devices (non-IVDDs) by Health Canada. [27]
Be easily heard by the listener	Sound	"Hearing performance decreases with increasing age" [28] where hearing loss is 2.5 dB per decade from birth to 55 years of age, and 8.5 dB per decade after 55 years of age [29]. For reference, the University of Purdue provides a scale of loudness for each decibel level with a scale of 10 dB, located at reference: [30]. To accommodate hearing loss, design principles and standards from the Canadian Centre of Science and Education state that any sound indicators must be at least 60dB for older individuals measured from both ears individually [29].
Be easily read by any person	Typography	The design must be able to display legible text, convey information hierarchy, and communicate important content [31]. According to the Canadian Centre of Science and Education and Apple Inc., for elderly individuals it is standard to: - Use a Sans Serif and/or Serif typeface with a ≥ 12 pt size [29][31]. - Use uppercase sparingly only to highlight important content [29].

Not cause physical harm to human health or safety	Canada Consumer Product Safety Act
	
	S.C. 2010, c. 21
		Under S.C. 2010, c. 21, Prohibitions 7 to 10, no person shall knowingly manufacture, import, advertise, sell, or distribute a consumer product that has the potential to be a danger to human health or safety [32].
		
		The design must not have or exceed the recommended amount of harmful materials as described under:
		- Consumer Chemicals and Containers Regulations, 2001 (SOR/2001-269) [31]
		- Consumer Products Containing Lead Regulations (SOR/2018-83) [34]
		
		Therefore, the design must not have any:
		- gas, vapour, dust, mist or fumes of any kind [33, under Part 1 Toxic Products].
		    - i.e cleaning agents, pesticides, and automotive fluids
		- toxic, corrosive, flammable or pressurized materials [33, under part 2 and Part 3 Corrosive and Flammable Products].
		    - I..e drain cleaners, oven cleaners, and some industrial solvents, aerosol cans, propane cylinders, and certain spray paints.
		- does not release more than 90 mg per kg of lead enclosed in the design [34].
		
		Definition of danger to human health or safety:
		"any unreasonable hazard — existing or potential — that is posed by a consumer product during or as a result of its normal or foreseeable use and that may reasonably be expected to cause the death of an individual exposed to it or have an adverse effect on that individual's health — including an injury — whether or not the death or adverse effect occurs immediately after the exposure to the hazard, and includes any exposure to a consumer product that may reasonably be expected to have a chronic adverse effect on human health" [35].

Not contain false information within any part of the design	Consumer Packaging and Labelling Act	Design must not be labeled "containing any false or misleading representation that relates to or may reasonably be regarded as relating to that product." R.S.C., 1985, c. C-38 [35]. All products that come into contact with a person will have

		the following mandatory labelling: - product identity (must be in both english and french) [35] - product net quantity (must be in both english and french)[35] - dealer's name and principal place of business [35]
Not be intended or qualify in any capacity as a medical/ in-vitro diagnostic device	Medical Devices Regulations SOR/98-282 FDA	Medical Devices Regulations (SOR/98-282) Schedule1 (Section 6) Part I and II should be used to classify the design based on the design's characteristics and intended purposes as a medical device [36]. If the design qualifies for any rule, the design qualifies as, at least, a Class 1 medical device. Any design qualifying as a medical device is deemed infeasible.

Appendix F.2. Digital (Data) and Electrical Constraints

The following appendix contains justifications on the digital and electrical constraints mentioned in the body of the document. Table F.2.1. below shows details on the justifications for the constraints.

Table F.2.1. Further claims for electrical and data constraints

Constraint The design must:	**Guidelines/Topic**	**Justification**
Securely store user information	Data Security Personal Health Information Protection Act (PHIPA), 2004, S.O. 2004, c. 3, Sched. A	"Rules [under PHIPA] for the collection, use and disclosure of personal health information about individuals that protect the confidentiality of that information and the privacy of individuals with respect to that information, while facilitating the effective provision of health care" [51]. Under PHIPA Section 12 (1) and (2), a custodian (person or person who oversees a design) will take the necessary measures to ensure personal medical information is protected from "theft, loss and unauthorized use or disclosure and to ensure that the records containing the

<table>
<tr><td></td><td></td><td>information are protected against unauthorized copying, modification or disposal.” [52]

Information regarding all types of permitted use of stored health data can be found under PHIPA Section 37. [53]</td></tr>
<tr><td>Not expose users to electrical hazards</td><td>Electrical Safety

Canadian Electrical Code (CEC), Safety Standard for Electrical Installations</td><td>If a design is to have electrical components, it must adhere to the Canadian Electrical Code, Part 1, Safety Standard for Electrical Installations, mainly:
- Proper grounding and insulation to prevent electric shock.
- Clear labeling indicating voltage, current, and safety certifications.
- Compliance with specific standards for low-voltage devices, which many wearables fall under

Relevant Sections of the CEC [52]:

Section 4, Conductors:
- 4-004 Ampacity of Wires and Cables: maximum possible current that conductors can carry [54]

Section 12, Wiring Methods:
- 12-200 Flexible Cables: guidelines for the use of flexible cables in a design being used for data/power transmission [54]

Section 10, Grounding:
- 10-000 General: relevant to wearable components that need to be grounded for electrical safety [54]

Section 16, Class 1 and Class 2 Circuits:
- 16-300 Class 2 Circuits: low-energy circuits often used in wearable devices [54]

Section 64, Energy Storage Systems:
- 64-200 Installation of Batteries: guidelines for batteries that could be used in a design [54]</td></tr>
<tr><td>Not be a fire hazard</td><td>Flammability of Electrical Components

Canadian</td><td>Relevant Sections of the CEC, Safety Standard for Electrical Installations :

Rule 64-81:
- Certain battery types, such as lithium-ion,</td></tr>
</table>

	Electrical Code (CEC), Safety Standard for Electrical Installations	valve-regulated lead-acid, or nickel-cadmium, can experience thermal failure when overcharged **[54]** Section 2-322 Flammable material near electrical equipment: - Flammable material shall not be stored or placed in dangerous proximity to electrical equipment **[54]**

Appendix G: Client Meeting Notes

The following appendix includes excerpts of team member's notes from both client meetings.

Appendix G.1. Client meeting #1 engineering notebook notes

This appendix details the client meeting notes and all information gathered through the questions asked to the client.

Client Meeting #1 **February 3rd, 2025**

Client Self-introduction:

- Name preference: Tatyanna, Dr. Tatyanna
- Went to the top medical school in Soviet Union Moscow at age 16
- Worked on Infectious Disease Prevention in the Soviet Union
- Immigrated with husband to Canada to practice medicine
- Has PhD in sleep studies
- Studied circadian Rhythms

Questions:

1. Are there particular sleep parameters you are most interested in capturing (e.g., REM percentage, wake after sleep onset)?

- Asked the team to define the target audience.
- The client accepts various parameters, including:
    - Muscle activity.
    - Sleep paralysis.
    - Perceived vs. actual sleep quality.
- Consider how gender, ethnicity, and age may affect readings.
- PICO framework: People, Intervention, Comparison, Outcome.

2. How important is usability, such as user comfort and interface, of the system compared to accuracy in measurement?

- Both are equally important, but it depends on the context.
- Clinical vs. Personal Use:

    - Clinical requires accuracy.
    - Personal requires comfortability.
- Educational devices may be a better option.

3. Based on your past papers, it seems you've compared accuracy to polysomnograms. With that in mind, to what degree of accuracy are you looking for? Would you consider polysomnograms the 'gold standard' and how closely would you like us to approach this standard?

- Polysomnography is effective for diagnosing only 3 out of 8 sleep disorders.
- Primarily used to eliminate specific disorders.
- Consider heart activity as well.

4. After some research, we noticed that most sleep trackers are purely digital. Do you envision the solution to be purely digital, hybrid (paper plus tech), or fully analog?

- No strong preference, but the client wants something simple and inexpensive.
- Consider the user's perspective when designing the solution.
- Older users may prefer analog solutions.

5. What software did you use in your research on sleep patterns in people aged 60+, and what aspects of that software are working well or not?

- Depends on the specific pathology being studied.
- Current tools are expensive.
- Cost-effectiveness is an important factor.
- Proper use of scientific knowledge is essential.
- The goal is to confirm or dispel user concerns about sleep.

6. Should the design consider specific health conditions or personal aids, or is it intended for generally healthy users?

- Users should be able to see their condition.
- Ideally, they should be able to measure it themselves.

- ● Consideration for specific conditions: Insomnia and circadian rhythm (C/R) disorders cannot be diagnosed through current measurement methods alone.

7. How do you envision this technology being used? Is it for long-term sleep tracking of retired adults, or for short-term research? Will this data be used for other sleep studies on older individuals?

- ● Existing technology for technicians and clinics is too advanced and out of scope.
- ● The focus should be on prevention rather than diagnosis.
- ● The solution should be low-cost and accessible.
- ● Designed to monitor normal sleep physiology, not complex medical conditions.
- ● Sleep disorders cannot be cured, only managed.

Note: "Existing technology for technicians and clinics is too advanced and out of scope"
- *This includes medical devices, invasive devices, and devices that require stringent regulation under the Medical Devices Regulations SOR/98-282*

Appendix G.2. Client Meeting #2 - SATEDR Notes

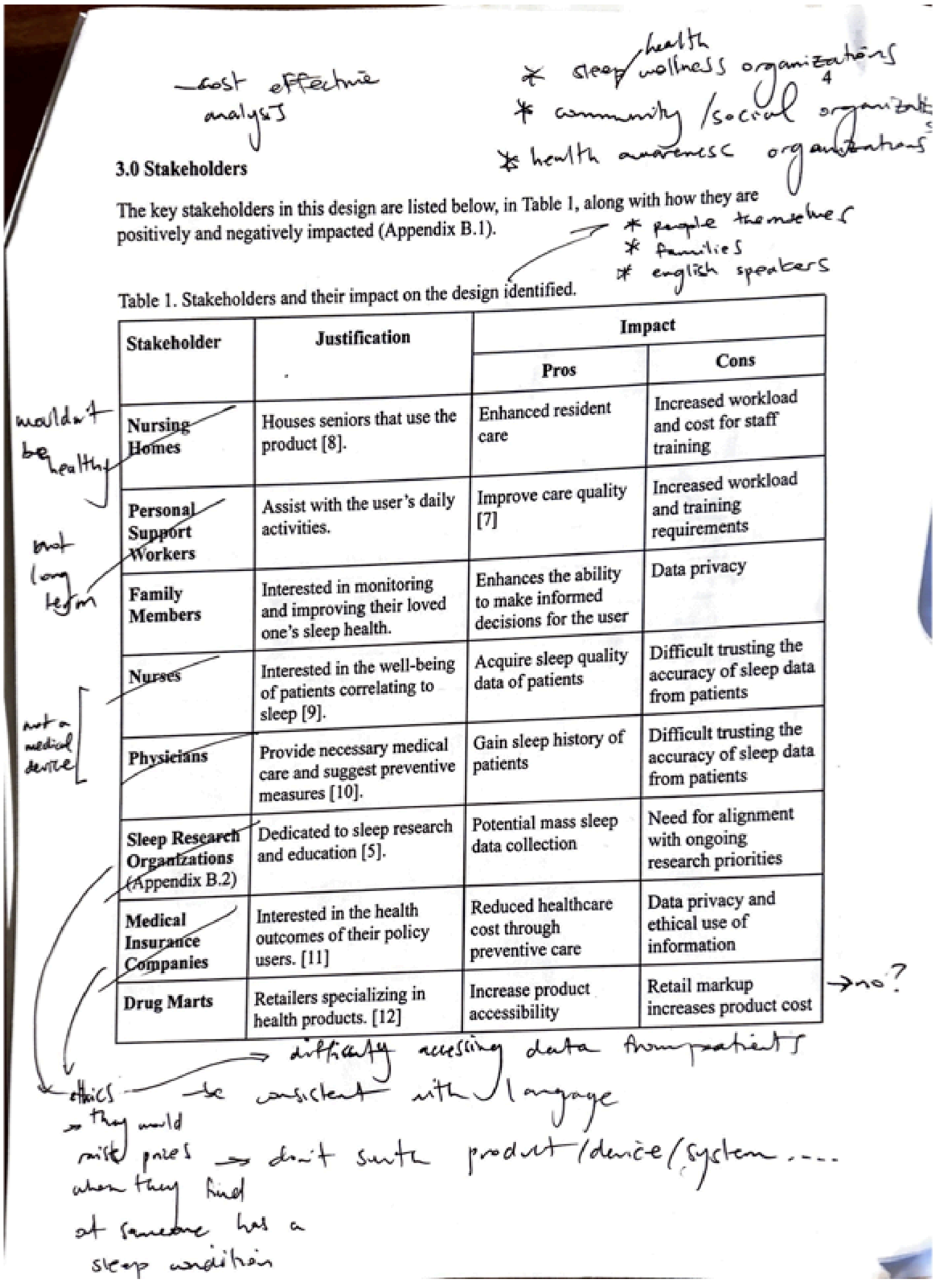
SATEDR was introduced by the client as a method for setting parameters on sleep. The table below was adapted from the client meeting notes, showcasing the questions asked for each parameter to help measure sleep (Table G.2.1).

Table G.2.1. SATEDR questionnaire

Satisfaction	Are you satisfied with your sleep?
Alertness	Do you stay awake all day without dozing?
Timing	Are you asleep between 2:00am - 4:00am?
Efficiency	Do you spend less than 30 minutes awake at night?
Duration	Do you sleep between 6-8 hours per day?
Regularity	How regularly do you maintain your sleep habits?

Appendix G.3. Client Meeting #2 - Stakeholder Notes

The following appendix contains Thisha's notes from the client meeting regarding the stakeholder section of our PR, as seen in Figure G.3.1 below.



—cost effective analysis

* sleep/health wellness organizations
* community/social organizations
* health awareness organizations

4

3.0 Stakeholders

The key stakeholders in this design are listed below, in Table 1, along with how they are positively and negatively impacted (Appendix B.1).

* people themselves
* families
* english speakers

Table 1. Stakeholders and their impact on the design identified.

Stakeholder	Justification	Impact	
		Pros	Cons
~~Nursing Homes~~	Houses seniors that use the product [8].	Enhanced resident care	Increased workload and cost for staff training
~~Personal Support Workers~~	Assist with the user's daily activities.	Improve care quality [7]	Increased workload and training requirements
Family Members	Interested in monitoring and improving their loved one's sleep health.	Enhances the ability to make informed decisions for the user	Data privacy
~~Nurses~~	Interested in the well-being of patients correlating to sleep [9].	Acquire sleep quality data of patients	Difficult trusting the accuracy of sleep data from patients
~~Physicians~~	Provide necessary medical care and suggest preventive measures [10].	Gain sleep history of patients	Difficult trusting the accuracy of sleep data from patients
~~Sleep Research Organizations (Appendix B.2)~~	Dedicated to sleep research and education [5].	Potential mass sleep data collection	Need for alignment with ongoing research priorities
~~Medical Insurance Companies~~	Interested in the health outcomes of their policy users. [11]	Reduced healthcare cost through preventive care	Data privacy and ethical use of information
Drug Marts	Retailers specializing in health products. [12]	Increase product accessibility	Retail markup increases product cost

wouldn't be healthy

not long term

not a medical device

→no?

difficulty accessing data from patients

ethics — be consistent with language

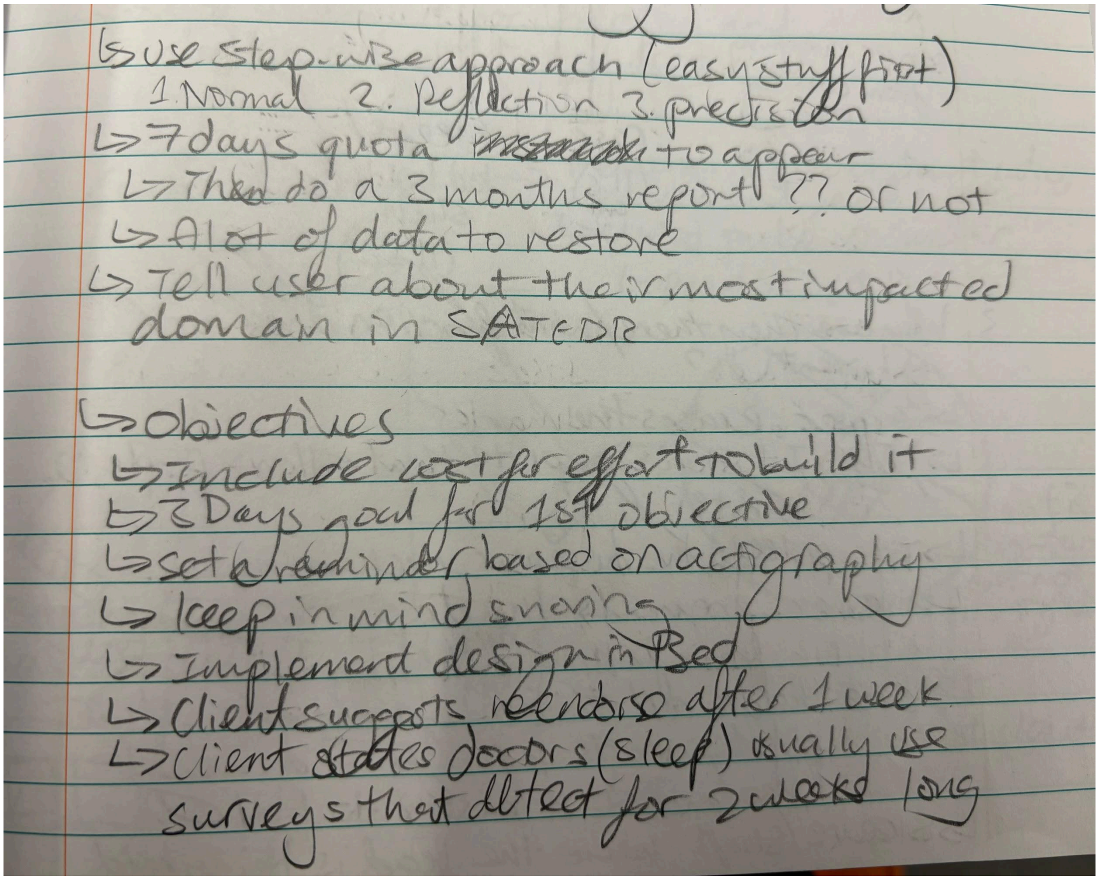
→ they would miss prices → don't say product/device/system ....
when they find out someone has a sleep condition

Figure G.3.1. Client meeting notes regarding the stakeholder section.

Through our discussion, the client suggested we remove and/or replace many of the stakeholders from our list. Many of the justifications given by the client to remove stakeholders were investigated by the team, and once deemed reasonable, were subsequently removed from the list.

Two of the stakeholders recommended for removal by the client, Sleep Research Organizations and Medical Insurance Companies, were kept in our final list. This is because the client explained that these stakeholders would have a negative effect on the product, but negatively impacting stakeholders remain valid stakeholders.

Appendix G.4. Client Meeting #2 - Objective 1 Notes



↳ Use step-wise approach (easy stuff first)
1. Normal 2. Reflection 3. precision
↳ 7 days quota to appear
↳ Then do a 3 months report ?? or not
↳ A lot of data to restore
↳ Tell user about their most impacted domain in SATEDR

↳ objectives
↳ Include cost for effort to build it
↳ 3 Days goal for 1st objective
↳ set a reminder based on actigraphy
↳ keep in mind snoring
↳ Implement design in Bed
↳ Client suggests reendorse after 1 week
↳ Client states doctors (sleep) usually use surveys that detect for 2 weeks long

Figure G.4.1. Client meeting notes regarding goals for objective 1.

The client agreed with our 3-day goal for our objective, “Early detection of sleep anomalies”. Our client also provided us with justification, stating that although sleep surveys take 2 weeks to categorize health issues, three days are sufficient enough in detecting them.

Appendix H: Idea Generation

This appendix describes the methods used for idea generation such as merging ideas from the morph chart, blue sky thinking, analogy, lateral thinking, SCAMPER, biomimicry and TRIZ with examples of an idea created using a specific technique.

Appendix H.1: Morphological chart

This appendix outlines the methodology and organization of the use of the morphological chart in the idea generation process.

The process began with the creation of a morphological chart to systematically break down the problem into its core components and generate specialized means to address each secondary function. The chart, shown in Table H.1.1, served as a foundation for exploring a variety of approaches and solutions.

Table H.1.1. Morphological chart used for merging parts ideas to create full solutions.

Measure sleep parameters	Store sleep data	Interpret trends in sleep	Provide user with system assistance	Display trends in sleep data	Inform about anomalies
Polysomnography (Tech)	Store data in computer memory (Tech)	Calculate trends using a proprietary computer algorithm (Tech)	Provide support over a telephone line for any user inquiries. (Both)	Show trends on a Line graph (Tech)	Report trends with Email report (Tech)
Audio recording (Tech)	Store data in Usb/ Flash drive (Tech)	Use a large language model (AI) to interpret the trends and convert them into understandable text (Tech)	Have AI provide support to the user. (Tech)	Show trends on a Bar graph (Tech)	Automated phone call (Tech)
O2 levels and ECG measurements with a wristband/ ring (Tech)	Store in paper notebook, written by user (Analog)	The user uses a industry standard formula for calculating sleep trends (Analog)	The design includes a Manual book with assistance to any issues. (Both)	Show trends with a Word cloud (Tech)	GUI (Display on a screen) (Tech)
Questionnaire (Analog)	Store data on the cloud (Tech)	Analyze data with the Sleep Quality Scale (SQS) (Analog)	A person is sent to the users house to provide In-person assistance (Both)	Explain trends with AI generated phrases (Tech)	Mail paper report (Analog)
EEG measurement with brainwave monitor (Tech)	Store on mechanical number counter, being operated by the user (Analog)	Pre-established data thresholds to indicate anomalies (tech)	Email assistance (Tech)	Use emojis to show quality of sleep levels with emotion (Tech)	Carrier pigeon (Analog)
Chest sensor that measures pressure and airflow happening in the chest. (Tech)	Print data on paper (Tech)	A trained personnel uses a industry standard formula for calculating sleep trends (Analog)	Multiplayer video game leadership board with friends to motivate and teach (Tech)	Show trends with a Candlelight stock graph (Tech)	Text message (Tech)
Pressure sensors (Tech)	(Tech) User scans sleep data sheet and uploads it online.	(Analog) User manually calculates averages for every sleep data type.	Sleep discount, where if they use the device and the manual for it, they get a discount on any sleep related thing (analog)	Painting (Tech)	Teddy Bear that talks about your sleep anomalies (Tech)
Actigraphy, movement sensor			A chatbot with full knowledge of how our sleep system works,	Digital Drawing (Tech)	Talking Monkey (Analog)
Premade sleep sensors available from texas instruments (tech)				AI lullaby that composes lyrics and sings you about your sleep data (Tech)	Alert notification system on an app (Tech)
Owl that watches you and in its mind, tracks you. (Analog)				Song (Tech)	
Clock with buttons with “wake” and “sleep” buttons to estimate in-bed time				Color spectrum indicators (Tech)	
(Tech) A mic that records the noises made while the patient sleeps.				Shows you the sleep debt you have accumulated over the week. (Tech)	
Custom pajamas that have a built in actigraphy, heat sensor, and heart rate monitor.				Owl presses buttons to tell user how they slept such as their sleep length and how much they moved (analog)	
Bed sheet with sensors					
Small magnetic clip with sleep outsourced sleep sensor					

Each secondary function was associated with multiple means, facilitating comprehensive exploration and innovation.

Appendix H.2: Use of AI for Morph Chart

After creating the original idea generation table without any use of AI, the team used Microsoft Copilot to combine the solutions from the table into unique ideas. This allowed us to optimize the time we spent on the CDS. To do so, we provided Copilot with our morph chart and the prompt “can you make 60 unique combinations of this table, where one combination takes one option from each row and combines it into a paragraph without rewording it in any way, then download it into a txt file for me” A screenshot of the conversation can be seen below, in Figure H.2.1.

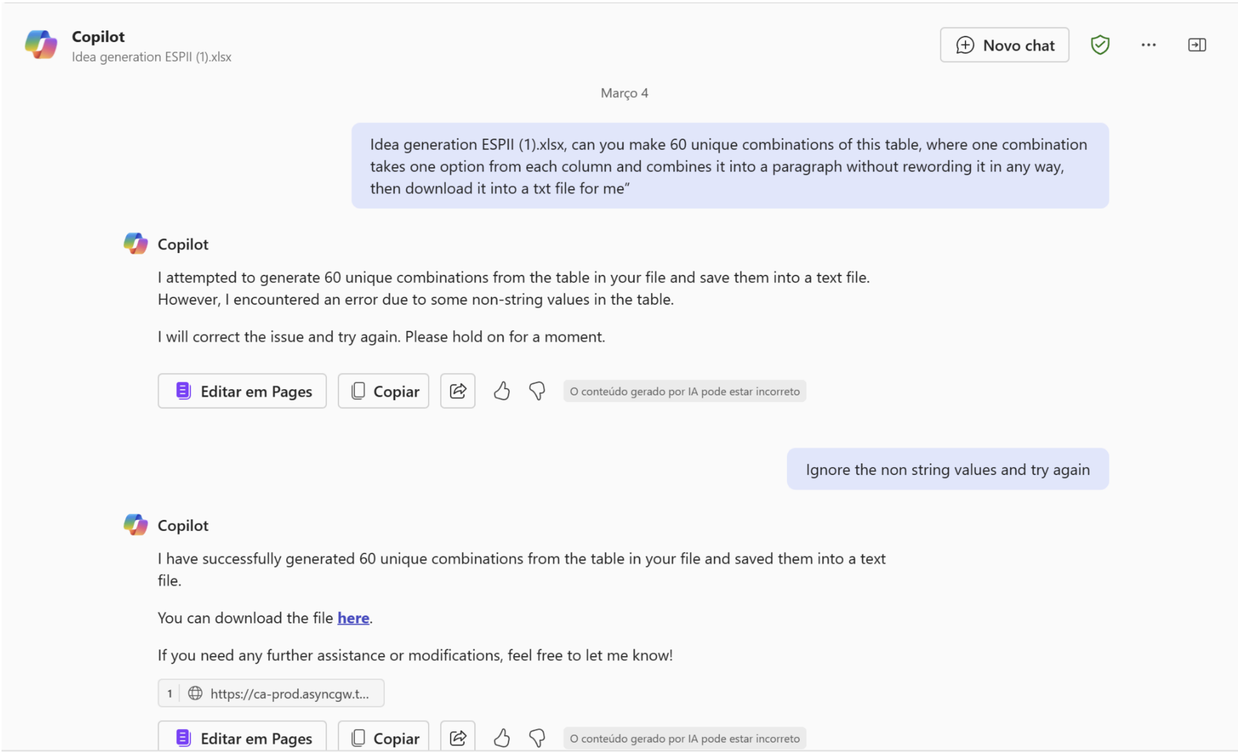


Figure H.2.1: A conversation with Microsoft Copilot to combine means from the Morph Chart.

Appendix H.3: Use of Blue Sky Thinking in idea generation

This appendix focuses on the use of the Blue sky thinking Idea generation technique for generating unrestricted, idealistic ideas, resulting in 25 ideas, as per example in Figure H.3.1

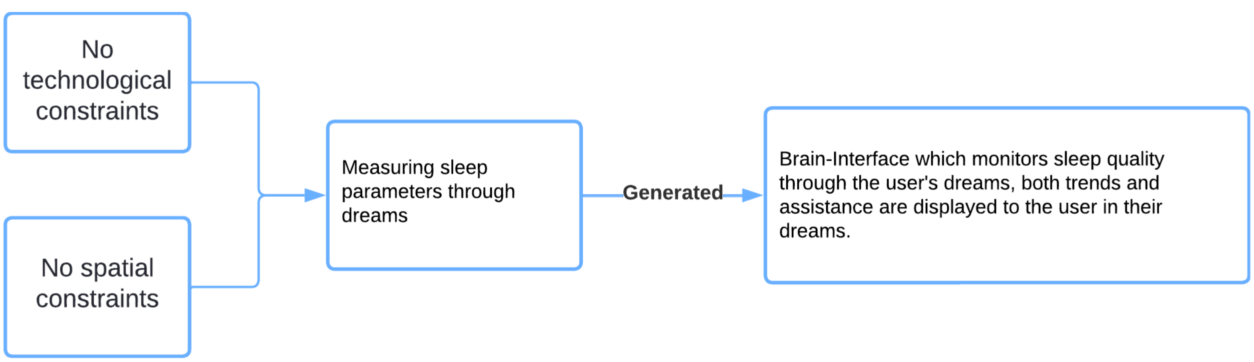


Figure H.3.1. Example of use of Blue Sky Thinking in idea generation process with an example.

Appendix H.4: Use of Analogy in idea generation

This appendix outlines how the team drew parallels from other fields or systems to inspire solutions, resulting in 9 ideas, as per example in Figure H.4.1.

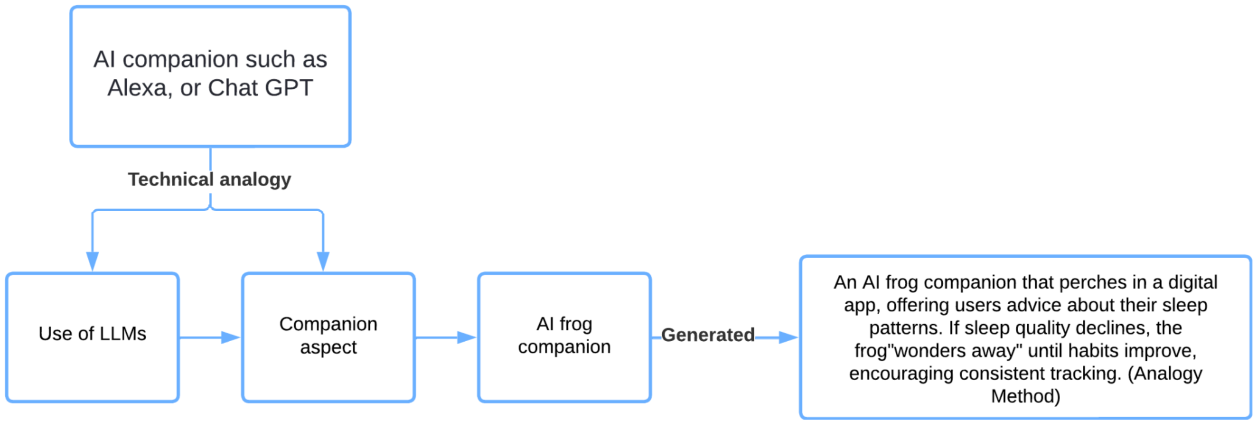


Figure H.4.1. Example of use of analogy in idea generation process.

Appendix H.5: Use of Morphological chart in idea generation

This appendix outlines how, after creating the original idea generation table without any use of AI, the team used Copilot to combine the solutions from the table into unique ideas.

Using our own words the Large Language Model optimised the work and helped the team to avoid duplicates. We provided Copilot with our morph chart and the prompt “can you make 60 unique combinations of this table, where one combination takes one option from each row and combines it into a paragraph without rewording it in any way, then download it into a txt file for me”. The output we got is the 60 combined Conceptual Design Ideas as per example in Figure H.5.1.

Measure sleep parameters	Store sleep data	Interpret trends in sleep	Provide user with system assistance	Display trends in sleep data	Inform about anomalies
Polysomnography (Tech)	Store data in computer memory (Tech)	Calculate trends using a proprietary computer algorithm (Tech)	Provide support over a telephone line for any user inquiries. (Both)	Show trends on a Line graph (Tech)	Report trends with Email report (Tech)
Audio recording (Tech)	Store data in Usb/ Flash drive (Tech)	Use a large language model (AI) to interpret the trends and convert them into understandable text (Tech)	Have AI provide support to the user. (Tech)	Show trends on a Bar graph (Tech)	Automated phone call (Tech)
O2 levels and ECG measurements with a wristband/ ring (Tech)	Store in paper notebook, written by user (Analog)	The user uses a industry standard formula for calculating sleep trends (Analog)	The design includes a Manual book with assistance to any issues. (Both)	Show trends with a Word cloud (Tech)	GUI (Display on a screen) (Tech)
Questionnaire (Analog)	Store data on the cloud (Tech)	Analyze data with the Sleep Quality Scale (SQS) (Analog)	A person is sent to the users house to provide In-person assistance (Both)	Explain trends with AI generated phrases (Tech)	Mail paper report (Analog)
EEG measurement with brainwave monitor (Tech)	Store on mechanical number counter, being operated by the user (Analog)	Pre-established data thresholds to indicate anomalies (tech)	Email assistance (Tech)	Use emojis to show quality of sleep levels with emotion (Tech)	Carrier pigeon (Analog)
Chest sensor that measures pressure and airflow happening in the chest. (Tech)	Print data on paper (Tech)	A trained personnel uses a industry standard formula for calculating sleep trends (Analog)	Multiplayer video game leadership board with friends to motivate and teach (Tech)	Show trends with a Candlelight stock graph (Tech)	Text message (Tech)
Pressure sensors (Tech)	(Tech) User scans sleep data sheet and uploads it online.	(Analog) User manually calculates averages for every sleep data type.	Sleep discount, where if they use the device and the manual for it, they get a discount on any sleep related thing (analog)	Painting (Tech)	Teddy Bear that talks about your sleep anomalies (Tech)
Actigraphy, movement sensor			A chatbot with full knowledge of how our sleep system works,	Digital Drawing (Tech)	Talking Monkey (Analog)
Premade sleep sensors available from texas instruments (tech)				AI lullaby that composes lyrics and sings you about your sleep data (Tech)	Alert notification system on an app (Tech)
Owl that watches you and in its mind, tracks you. (Analog)				Song (Tech)	
Clock with buttons with "wake" and "sleep" buttons to estimate in-bed time				Color spectrum indicators (Tech)	
(Tech) A mic that records the noises made while the patient sleeps.				Shows you the sleep debt you have accumulated over the week. (Tech)	
Custom pajamas that have a built in actigraphy, heat sensor, and heart rate monitor.				Owl presses buttons to tell user how they slept such as their sleep length and how much they moved (analog)	
Bed sheet with sensors					
Small magnetic clip with sleep outsourced sleep sensor					

76 - Actigraphy, movement sensor Store data in Usb/ Flash drive (Tech) Pre-established data thresholds to indicate anomalies (tech) Painting (Tech) Teddy Bear that talks about your sleep anomalies (Tech)

Figure H.5.1. Example of use of morphological chart in idea generation process.

Appendix H.6: Use of Lateral Thinking in idea generation

This appendix outlines how the team encouraged unconventional approaches to problem-solving, challenging assumptions, resulting in 8 ideas, as per example in Figure H.6.1.

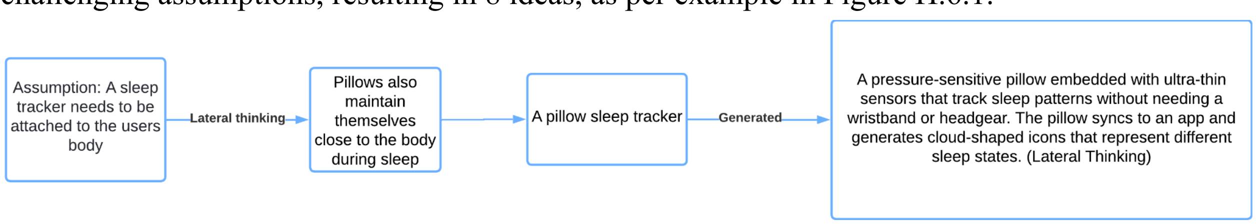


Figure H.6.1. Example of use of Lateral Thinking in the idea generation process.

Appendix H.7: Use of SCAMPER in idea generation

This appendix outlines how the use of the SCAMPER technique modified existing ideas by substituting, combining, adapting, modifying, putting to another use, eliminating, or reversing elements, resulting in 4 ideas, as per example in Figure H.7.1.

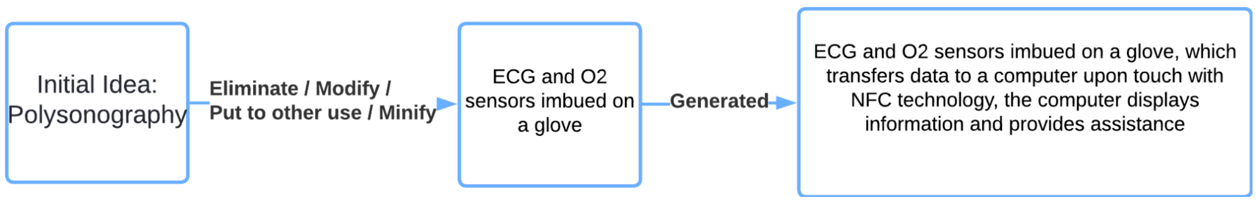


Figure H.7.1. Example of use of SCAMPER in idea generation process.

Appendix H.8: Use of Biomimicry in idea generation

This appendix outlines how the team utilized existing biological systems and solutions as a basis to generate 2 new ideas, as per example in figure H.8.1.

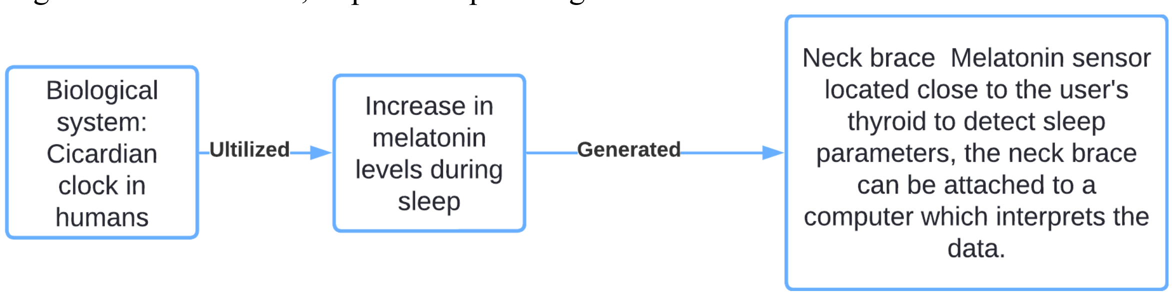


Figure H.8.1. Example of use of biomimicry in the idea generation process.

Appendix H.9: Use of TRIZ in idea generation

This appendix outlines how the team utilized Theory of inventive design principles to generate one new idea, as per example in figure H.9.1.

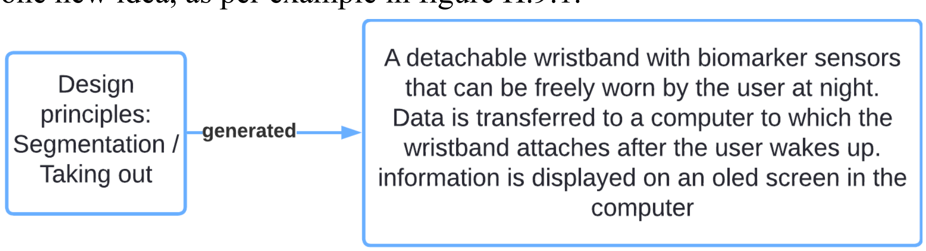


Figure H.9.1. Example of use of TRIZ in the idea generation process.

Appendix H.10: Individual brainstorming

The technique described in this appendix is

Each team member independently generated 10 solution ideas, contributing to a total of 60 ideas. These ideas, as shown in Table H.10.1, are full solutions addressing the main functions.

Table H.10.1. First Ideas Table.

Lila	Samantha	Johnny	Brian	Thisha	Willis
Sleep Tracking App for phone/ipad (Analogy of Sleep Cycle)	A customizable photo that has a camera that detects motion and a heat sensor. It stores the data in the photo frame that tracks trends in the data. Then the photo changes to a screen that displays the data or provides user assistance (Random stimulation)	ECG and O2 sensors imbued on a pillow-like wristband, which sends sleep data to a small computer, information is displayed on a small screen. (SCAMPER)	Bedside "Scantron" like device that prints and reads daily questionnaire s. It has LED indicators to show if the questionnaire has been completed; LED off for completed, on for not. It will be paired with an in-bed sensor that will record physiological data. (Random stimulation)	A pair of pyjamas with integrated sensors that record the user's sleep data. This information is uploaded to their phone to be analyzed and viewed through their phone. (Blue sky)	A magical sprite that watches over the user while they sleep, when they wake up, the sprite shares insights about their sleep patterns The sprite interacts with the user through augmented reality, appearing on a bedside device or phone app. (analogy method)
Sleep Tracking Pillow with Built-in Pressure Sensors with an App (Lateral Thinking)	A credit card that tracks heat and movement. It stores data in the card and sends trends onto the phone. To motivate	ECG and O2 sensors imbued on a glove, which transfers data to a computer upon touch with NFC technology, the computer	Compression socks with embedded temperature and motion sensors to track restlessness and sleep depth.	AI Chatbot that users engage with for 10 minutes every morning by discussing their length of sleep,	A smart lamp that visually represents sleep data as a growing tree. The healthier the sleep, the more vibrant the tree's

	users, if the user keeps using the card, they can then use the card for discounts for sleep related items (Blue sky thinking)	displays information and provides assistance (SCAMPER)	(Lateral Thinking)	mood after waking up, etc. From there, the chatbot gives personalized feedback daily. (Blue sky)	leaves become. If anomalies arise, the tree wilts or changes color to notify the user. (Blue Sky Thinking)
Thin Pillow case with integrated pressure sensors (Lateral Thinking)	Digital bed headboard that tracks movement and oxygen levels. It has a screen on one end of the headboard that displays data and trends and the headboard itself stores data (Random stimulation)	Pill-like design which reads biomarkers from inside the users body, the data is sent through the users phone through NFC, in which an app provides trends and assistance. (SCAMPER)	A deck of cards with sleep-related prompts (e.g., "How rested do you feel?" or "What kept you awake?", or replace with SATEDI?). Users draw cards each morning to reflect on their sleep. (Lateral Thinking)	Sleep tracking ring (like a fitbit)	A pressure-sensitive pillow embedded with ultra-thin sensors that track sleep patterns without needing a wristband or headgear. The pillow syncs to an app and generates cloud-shaped icons that represent different sleep states. (Lateral Thinking)
AI Companion (Analog to Siri/Alexa)	A book with an amazing plot, character, and world building, that's all about the importance of good sleep and tracking	Brain-Interface which monitors sleep quality through the user's dreams, both trends and assistance are displayed to the user in	A set of stickers with sleep-related emotions (e.g., "Restless," "Peaceful," "Exhausted"). Users place a sticker on a calendar each	Users wear an eye mask with integrated sensors that read blood pressure and heart rate. On the front of the eye mask there is a	A bedside water bowl with gentle ripples that change in intensity based on sleep quality. If sleep is deep and undisturbed,

	it. The user becomes part of the story by sharing their sleep data on the front of the screen. If they don't, they can't open the book to read it. (Blue sky thinking)	their dreams. (Blue sky thinking)	morning to log their feelings. (Lateral Thinking)	screen that displays their sleep trends every morning. (Blue sky)	the water remains still. If the user experiences restless sleep, the ripples become bigger (Lateral Thinking)
Sleep Plant (Blue Sky Thinking)	A sensor that tracks the absence of light. When there is no light (eg. artificial or from natural light), the detector knows when the user is sleeping, thus beginning to track how long the lights are off to tie to sleeping. The light also functions as a projector that displays all the data it tracks. (Blue sky thinking)	Glasses that measures REM sleep based on ECG and eye movement, information and assistance are displayed on the lenses (Blue sky thinking)	A clock with a touch-sensitive screen that displays sleep-related emotions (e.g., "Tired," "Refreshed," "Anxious", etc…could be other indicators (SATEDI)). Users tap their mood each morning to log their feelings. (Lateral Thinking)	Digital journal that users use to record their sleep information. Then it is analyzed by AI and displayed onto graphs. (BS)	A soft, self-adjusting wristband that gently vibrates when it detects restlessness or irregular breathing, encouraging the user to shift positions for better sleep quality. The band stores data and provides morning insights. (Blue Sky Thinking)
Paper Diary with specifically lined paper	A doll that has AI tracking in its eyes. It tracks	Brain interface connected to the Central	A journal with crowdmark-style bubble	Sensors that can be attached to the user's bed	A bedside speaker that listens to breathing and

(Blue Sky)	movement and stores the data in the body of the doll. The doll will share the data via speaking with a speaker in its mouth. (Analogy method)	circadian clock to measure sleep parameters, which is sent through a wireless network which is analysed and displayed on a computer. (Blue sky thinking)	pages for users to fill in multiple choice about their sleep (e.g., "Did you wake up during the night?" or "How would you rate your sleep?", or replace with SATEDI). The journal can be scanned periodically for data analysis with an external app not connected to user (no user data, just a score) (Analogy method)	frame that record movement during sleep. (BS)	movement, using sonar-like technology to track sleep without wearable devices. It provides verbal morning reports and can communicate with family members if sleep disturbances persist. (Lateral Thinking)
DIY Sleep Log - placing marbles of different color or maybe of different shape into a jar (Blue Sky)	Music box that has an actigraphy, heat sensor, and O2 level sensor. The data it gathers is gathered into the music box, inscribed on the nooks that affect the notes played by the music box. It comes with a	A detachable wristband with biomarker sensors that can be freely worn by the user at night. Data is transferred to a computer to which the wristband attaches after the user wakes up. information	A mobile app where users select an emoji each morning to describe how they feel about their sleep (e.g., 😴, 🛌, 😩). The app tracks trends over time and can be paired with existing devices to track	An email is sent to the user's inbox every Sunday morning with a summary of their sleep for the last week. (BS)	A gamified sleep-trackin g app where users earn points for achieving deep sleep goals. They can compete with friends or unlock "dream levels" based on their sleep performance. (Analogy Method)

	manual to translate the notes into english. (Blue sky thinking)	is displayed on an oled screen in the computer (TRIZ method)	physiological data. (SCAMPER)		
Wrist Band like FitBit (Analog)	A comforter that senses movement of the blanket, as well as the heat generated from the blanket. These are tracked and stored in the comforter as there is a small machine inside. This machine sends the data to a database that shares the data to the phone. (Analogy method)	Neck brace Melatonin sensor located close to the user's thyroid to detect sleep parameters, the neck brace can be attached to a computer which interprets the data. (Biomimicry)	Bed/blanket sensor that tracks in-bed time with a water dispenser. The more time spent in sleep cycles the more water will be released into your cup with a max of (whatever limit the user sets) with a heated saucer. Atr sunrise, rgb lighting will indicate some form of sleep quality based on the physiological data gathered.	Camera is mounted to the user's ceiling and has the ability to detect the user's movement while they sleep. (BS)	A temperature-regulating smart quilt that changes its thermal properties based on sleep stages, optimizing comfort while tracking movement and restfulness. It sends a morning report to an app. (Blue Sky Thinking)
Smart Sleeping Diary/ Questionnaire - write in a notebook's cell that reads the handwriting and uploads all the data collected to a	Make a video game that not only tracks sleep, but also if tracked consistently and enough, will place the user higher on a leaderboard.	Face masks measure respiratory rates to detect sleep parameters, the data is interpreted by an imbued computer and information is conveyed	Patch similar to a diabetic sensor patch that is disposable, coming in packs with a dozen sensors. (Random stimulation)		A bedside lamp that changes brightness and color based on sleep quality, guiding the user to optimize their sleep patterns. If

storage container (Blue Sky)	This leaderboard is connected with all their friends who also have the game. (Lateral thinking)	through speakers. (Biomimicry)			anomalies are detected, it gradually changes color over the week to encourage awareness. (Lateral Thinking)
Sleep Clock - using colors to visually show the fraction of the day a person spends sleeping in different sleeping states in different colors (Blue Sky Thinking)	Every other morning, users answer a few of the same questions about their sleep. These answers get put into a large AI database that both stores and interprets data, with an AI-generated summary every month from the trends. (Blue sky thinking)	Infrared camera on night stand using photoplethys mography to read ECG data. The information is processed by an imbued computer and projected onto the nightstand (Blue sky thinking)	A high-tech, immersive sleep pod designed to transform any bedroom into a personalized sleep sanctuary. It combines advanced sleep tracking, environmenta l control, and AI-driven personalizatio n to create the ultimate sleep experience. It should look like an egg from the outside. (Blue Sky)		An AI frog companion that perches in a digital app, offering users advice about their sleep patterns. If sleep quality declines, the frog"wonders away" until habits improve, encouraging consistent tracking. (Analogy Method)

Appendix H.11: Final ideas list

This appendix outlines the outcome of the idea generation process as a comprehensive list of 120 ideas, shown in Table H.11.1 below.

Table H.11.1. Full 120 ideas list.

#	Idea	Method used	Duplicate	Feasibility
1	A customizable photo that has a camera that detects motion and a heat sensor. It stores the data in the photo frame that tracks trends in the data. Then the photo changes to a screen that displays the data or provides user assistance (Random stimulation)	Random stimulation	No	Feasible
2	A credit card that tracks heat and movement. It stores data in the card and sends trends onto the phone. To motivate users, if the user keeps using the card, they can then use the card for discounts for sleep related items (Blue sky thinking)	Blue sky thinking	No	Non-Feasible
3	Digital bed headboard that tracks movement and oxygen levels. It has a screen on one end of the headboard that displays data and trends and the headboard itself stores data (Random stimulation)	Random stimulation	No	Feasible
4	A book with an amazing plot, character, and world building, that's all about the importance of good sleep and tracking it. The user becomes part of the story by sharing their sleep data on the front of the screen. If they don't, they can't open the book to read it. (Blue sky thinking)	Blue sky thinking	No	Feasible
5	A sensor that tracks the absence of light. When there is no light (eg. artificial or from natural light), the detector knows when the user is sleeping, thus	Blue sky thinking	No	Feasible

	beginning to track how long the lights are off to tie to sleeping. The light also functions as a projector that displays all the data it tracks. (Blue sky thinking)			
6	A doll that has AI tracking in its eyes. It tracks movement and stores the data in the body of the doll. The doll will share the data via speaking with a speaker in its mouth. (Analogy method)	Analogy method	No	Feasible
7	Music box that has an actigraphy, heat sensor, and O2 level sensor. The data it gathers is gathered into the music box, inscribed on the nooks that affect the notes played by the music box. It comes with a manual to translate the notes into english. (Blue sky thinking)	Blue sky thinking	No	Non-Feasible
8	A comforter that senses movement of the blanket, as well as the heat generated from the blanket. These are tracked and stored in the comforter as there is a small machine inside. This machine sends the data to a database that shares the data to the phone. (Analogy method)	Analogy method	No	Feasible
9	Make a video game that not only tracks sleep, but also if tracked consistently and enough, will place the user higher on a leaderboard. This leaderboard is connected with all their friends who also have the game. (Lateral thinking)	Lateral thinking	No	Feasible

10	Every other morning, users answer a few of the same questions about their sleep. These answers get put into a large AI database that both stores and interprets data, with an AI-generated summary every month from the trends. (Blue sky thinking)		No	Feasible
11	Sleep Tracking App for phone/ipad (Analogy of Sleep Cycle)	Analogy method	No	Feasible
12	Sleep Tracking Pillow with Built-in Pressure Sensors with an App (Lateral Thinking)	Lateral thinking	Yes	
13	Thin Pillow case with integrated pressure sensors (Lateral Thinking)	Lateral thinking	Yes	
14	AI Companion (Analog to Siri/Alexa)	Analogy method	No	Feasible
15	Sleep Plant (Blue Sky Thinking)	Blue sky thinking	No	Non-Feasible
16	Paper Diary with specifically lined paper (Blue Sky)	Blue sky thinking	No	Feasible
17	DIY Sleep Log - placing marbles of different color or maybe of different shape into a jar (Blue Sky)	Blue sky thinking	No	Feasible
18	Wrist Band like FitBit (Analog)	Analogy method	Yes	
19	Smart Sleeping Diary/ Questionnaire - write in a notebook's cell that reads the handwriting and uploads all the data collected to a storage container (Blue Sky)	Blue sky thinking	Yes	
20	Sleep Clock - using colors to visually show the fraction of the day a person spends sleeping in	Blue sky thinking	No	Feasible

	different sleeping states in different colors (Blue Sky Thinking)			
21	ECG and O2 sensors imbued on a pillow-like wristband, which sends sleep data to a small computer, information is displayed on a small screen. (SCAMPER)	SCAMPER	No	Feasible
22	ECG and O2 sensors imbued on a glove, which transfers data to a computer upon touch with NFC technology, the computer displays information and provides assistance (SCAMPER)	SCAMPER	No	Feasible
23	Pill-like design which reads biomarkers from inside the users body, the data is sent through the users phone through NFC, in which an app provides trends and assistance. (SCAMPER)	SCAMPER	No	Non-Feasible
24	Brain-Interface which monitors sleep quality through the user's dreams, both trends and assistance are displayed to the user in their dreams. (Blue sky thinking)	Blue sky thinking	No	Non-Feasible
25	Glasses that measures REM sleep based on ECG and eye movement, information and assistance are displayed on the lenses (Blue sky thinking)	Blue sky thinking	No	Non-Feasible
26	Brain interface connected to the Central circadian clock to measure sleep parameters, which is sent through a wireless network which is analysed and displayed	Blue sky thinking	No	Non-Feasible

	on a computer. (Blue sky thinking)			
27	A detachable wristband with biomarker sensors that can be freely worn by the user at night. Data is transferred to a computer to which the wristband attaches after the user wakes up. information is displayed on an oled screen in the computer (TRIZ method)	TRIZ	No	Feasible
28	Neck brace Melatonin sensor located close to the user's thyroid to detect sleep parameters, the neck brace can be attached to a computer which interprets the data. (Biomimicry)	Biomimicry	No	Non-Feasible
29	Face masks measure respiratory rates to detect sleep parameters, the data is interpreted by an imbued computer and information is conveyed through speakers. (Biomimicry)	Biomimicry	No	Non-Feasible
30	Infrared camera on night stand using photoplethysmography to read ECG data. The information is processed by an imbued computer and projected onto the nightstand (Blue sky thinking)	Blue sky thinking	No	Feasible
31	A magical sprite that watches over the user while they sleep, when they wake up, the sprite shares insights about their sleep patterns The sprite interacts with the user through augmented reality, appearing on a bedside device or phone app. (analogy method)	Analogy method	No	Non-Feasible

32	A smart lamp that visually represents sleep data as a growing tree. The healthier the sleep, the more vibrant the tree's leaves become. If anomalies arise, the tree wilts or changes color to notify the user. (Blue Sky Thinking)	Blue sky thinking	No	Feasible
33	A pressure-sensitive pillow embedded with ultra-thin sensors that track sleep patterns without needing a wristband or headgear. The pillow syncs to an app and generates cloud-shaped icons that represent different sleep states. (Lateral Thinking)	Lateral thinking	No	Feasible
34	A bedside water bowl with gentle ripples that change in intensity based on sleep quality. If sleep is deep and undisturbed, the water remains still. If the user experiences restless sleep, the ripples become bigger (Lateral Thinking)	Lateral thinking	No	Feasible
35	A soft, self-adjusting wristband that gently vibrates when it detects restlessness or irregular breathing, encouraging the user to shift positions for better sleep quality. The band stores data and provides morning insights. (Blue Sky Thinking)	Blue sky thinking	No	Feasible
36	A bedside speaker that listens to breathing and movement, using sonar-like technology to track sleep without wearable devices. It provides verbal morning reports and can communicate with family	Lateral thinking	No	Feasible

	members if sleep disturbances persist. (Lateral Thinking)			
37	A gamified sleep-tracking app where users earn points for achieving deep sleep goals. They can compete with friends or unlock "dream levels" based on their sleep performance. (Analogy Method)	Analogy method	Yes	
38	A temperature-regulating smart quilt that changes its thermal properties based on sleep stages, optimizing comfort while tracking movement and restfulness. It sends a morning report to an app. (Blue Sky Thinking)	Blue sky thinking	No	Feasible
39	A bedside lamp that changes brightness and color based on sleep quality, guiding the user to optimize their sleep patterns. If anomalies are detected, it gradually changes color over the week to encourage awareness. (Lateral Thinking)	Lateral thinking	Yes	
40	An AI frog companion that perches in a digital app, offering users advice about their sleep patterns. If sleep quality declines, the frog"wonders away" until habits improve, encouraging consistent tracking. (Analogy Method)	Analogy method	No	Feasible
41	1. Owl that watches you and in its mind, tracks you. (Analog) Store data on the cloud (Tech) Use a large language model (AI) to interpret the trends and convert	Morph chart	No	Feasible

	them into understandable text (Tech) Shows you the sleep debt you have accumulated over the week. (Tech)			
42	2. Premade sleep sensors available from texas instruments (tech) A trained personnel uses a industry standard formula for calculating sleep trends (Analog) Email assistance (Tech) Owl presses buttons to tell user how they slept such as their sleep length and how much they moved (analog) Talking Monkey (Analog)	Morph chart	No	Non-Feasible
43	3. EEG measurement with brainwave monitor (Tech) Pre-established data thresholds to indicate anomalies (tech) Show trends on a Bar graph (Tech) Text message (Tech)	Morph chart	Yes	
44	4. Measure sleep parameters Store data on the cloud (Tech) Interpret trends in sleep Provide user with system assistance Color spectrum indicators (Tech) Teddy Bear that talks about your sleep anomalies (Tech)	Morph chart	Yes	
45	5. Audio recording (Tech) Print data on paper (Tech) The user uses a industry standard formula for calculating sleep trends (Analog) Multiplayer video game leadership board with friends to motivate and teach (Tech) Color spectrum indicators (Tech) Teddy Bear that talks about your sleep anomalies (Tech)	Morph chart	Yes	

46	6. Audio recording (Tech) The user uses a industry standard formula for calculating sleep trends (Analog) Song (Tech) Text message (Tech)	Morph chart	Yes	
47	7. (Tech) A mic that records the noises made while the patient sleeps. Store data on the cloud (Tech) Calculate trends using a proprietary computer algorithm (Tech) A person is sent to the users house to provide In-person assistance (Both) Owl presses buttons to tell user how they slept such as their sleep length and how much they moved (analog) Report trends with Email report (Tech)	Morph chart	Yes	
48	8. Owl that watches you and in its mind, tracks you. (Analog) (Analog) User manually calculates averages for every sleep data type. Show trends on a Line graph (Tech) Teddy Bear that talks about your sleep anomalies (Tech)	Morph chart	No	Feasible
49	9. Clock with buttons with “wake” and “sleep” buttons to estimate in-bed time Store data on the cloud (Tech) Analyze data with the Sleep Quality Scale (SQS) (Analog) The design includes a Manual book with assistance to any issues. (Both) Explain trends with AI generated phrases (Tech) GUI (Display on a screen) (Tech)	Morph chart	No	Feasible

50	10. EEG measurement with brainwave monitor (Tech) Email assistance (Tech) Show trends with a Candlelight stock graph (Tech) Mail paper report (Analog)	Morph chart	Yes	
51	11. Polysomnography (Tech) Print data on paper (Tech) Sleep discount, where if they use the device and the manual for it, they get a discount on any sleep related thing (analog) Digital Drawing (Tech)	Morph chart	No	Non-Feasible
52	12. Audio recording (Tech) (Analog) User manually calculates averages for every sleep data type. Email assistance (Tech) Show trends with a Candlelight stock graph (Tech) Alert notification system on an app (Tech)	Morph chart	Yes	
53	13. Polysomnography (Tech) (Analog) User manually calculates averages for every sleep data type. Multiplayer video game leadership board with friends to motivate and teach (Tech) Song (Tech) Mail paper report (Analog)	Morph chart	No	Non-Feasible
54	14. Measure sleep parameters Store on mechanical number counter, being operated by the user (Analog) Calculate trends using a proprietary computer algorithm (Tech) The design includes a Manual book with assistance to any issues. (Both) Show trends on a Line graph	Morph chart	No	Feasible

	(Tech) Report trends with Email report (Tech)			
55	15. Actigraphy, movement sensor Store data on the cloud (Tech) Analyze data with the Sleep Quality Scale (SQS) (Analog) Email assistance (Tech) Digital Drawing (Tech)	Morph chart	No	Feasible
56	16. Actigraphy, movement sensor Store data on the cloud (Tech) (Analog) User manually calculates averages for every sleep data type. Have AI provide support to the user. (Tech) Song (Tech) Carrier pigeon (Analog)	Morph chart	Yes	
57	17. Clock with buttons with "wake" and "sleep" buttons to estimate in-bed time Provide support over a telephone line for any user inquiries. (Both) AI lullaby that composes lyrics and sings you about your sleep data (Tech) Inform about anomalies	Morph chart	Yes	
58	18. O2 levels and ECG measurements with a wristband/ ring (Tech) Calculate trends using a proprietary computer algorithm (Tech) A chatbot with full knowledge of how our sleep system works, Painting (Tech)	Morph chart	No	Feasible
59	19. Custom pajamas that have a built in actigraphy, heat sensor, and heart rate monitor. The user uses a industry standard formula for calculating sleep trends (Analog) Have AI provide support to the user. (Tech) Use	Morph chart	No	Feasible

	emojis to show quality of sleep levels with emotion (Tech)			
60	20. (Tech) A mic that records the noises made while the patient sleeps. Provide user with system assistance Owl presses buttons to tell user how they slept such as their sleep length and how much they moved (analog) Talking Monkey (Analog)	Morph chart	Yes	
61	21. Clock with buttons with “wake” and “sleep” buttons to estimate in-bed time Store data on the cloud (Tech) Calculate trends using a proprietary computer algorithm (Tech) Display trends in sleep data Automated phone call (Tech)	Morph chart	Yes	
62	22. Chest sensor that measures pressure and airflow happening in the chest. (Tech) Store on mechanical number counter, being operated by the user (Analog) Provide user with system assistance Song (Tech)	Morph chart	No	Feasible
63	23. Owl that watches you and in its mind, tracks you. (Analog) Print data on paper (Tech) Provide support over a telephone line for any user inquiries. (Both) Show trends on a Bar graph (Tech) Alert notification system on an app (Tech)	Morph chart	Yes	
64	24. Measure sleep parameters (Tech) User scans sleep data sheet and uploads it online. The user uses a industry standard formula for calculating sleep trends	Morph chart	Yes	

	(Analog) Display trends in sleep data GUI (Display on a screen) (Tech)			
65	25. Audio recording (Tech) Print data on paper (Tech) A person is sent to the users house to provide In-person assistance (Both) Show trends with a Word cloud (Tech)	Morph chart	Yes	
66	26. Clock with buttons with “wake” and “sleep” buttons to estimate in-bed time Store data in computer memory (Tech) Provide support over a telephone line for any user inquiries. (Both) Owl presses buttons to tell user how they slept such as their sleep length and how much they moved (analog) Report trends with Email report (Tech)	Morph chart	Yes	
67	27. Questionnaire (Analog) Song (Tech) Talking Monkey (Analog)	Morph chart	No	Non-Feasible
68	28. Actigraphy, movement sensor Store in paper notebook, written by user (Analog) A trained personnel uses a industry standard formula for calculating sleep trends (Analog) Color spectrum indicators (Tech)	Morph chart	Yes	
69	29. Actigraphy, movement sensor Interpret trends in sleep Show trends on a Bar graph (Tech) Teddy Bear that talks about your sleep anomalies (Tech)	Morph chart	Yes	
70	30. Owl that watches you and in its mind, tracks you. (Analog) Store sleep data The user uses a industry standard formula for calculating sleep trends (Analog)	Morph chart	Yes	

	Multiplayer video game leadership board with friends to motivate and teach (Tech) Owl presses buttons to tell user how they slept such as their sleep length and how much they moved (analog)			
71	31. (Tech) A mic that records the noises made while the patient sleeps. Print data on paper (Tech) Pre-established data thresholds to indicate anomalies (tech) Multiplayer video game leadership board with friends to motivate and teach (Tech) Shows you the sleep debt you have accumulated over the week. (Tech) Teddy Bear that talks about your sleep anomalies (Tech)	Morph chart	No	Feasible
72	32. Chest sensor that measures pressure and airflow happening in the chest. (Tech) Store in paper notebook, written by user (Analog) Calculate trends using a proprietary computer algorithm (Tech) A chatbot with full knowledge of how our sleep system works, Digital Drawing (Tech) Carrier pigeon (Analog)	Morph chart	Yes	
73	33. Chest sensor that measures pressure and airflow happening in the chest. (Tech) Digital Drawing (Tech) Mail paper report (Analog)	Blue sky thinking	No	Feasible
74	34. Custom pajamas that have a built in actigraphy, heat sensor, and heart rate monitor. Print data on paper (Tech) Analyze data	Morph chart	Yes	

	with the Sleep Quality Scale (SQS) (Analog) Email assistance (Tech) AI lullaby that composes lyrics and sings you about your sleep data (Tech)			
75	35. Clock with buttons with “wake” and “sleep” buttons to estimate in-bed time Email assistance (Tech) Use emojis to show quality of sleep levels with emotion (Tech)	Morph chart	No	Feasible
76	36. Actigraphy, movement sensor Store data in Usb/ Flash drive (Tech) Pre-established data thresholds to indicate anomalies (tech) Painting (Tech) Teddy Bear that talks about your sleep anomalies (Tech)	Morph chart	No	Feasible
77	37. Pressure sensors (Tech) Print data on paper (Tech) Analyze data with the Sleep Quality Scale (SQS) (Analog) Have AI provide support to the user. (Tech) Song (Tech) Mail paper report (Analog)	Morph chart	Yes	
78	38. Chest sensor that measures pressure and airflow happening in the chest. (Tech) Provide user with system assistance Color spectrum indicators (Tech) GUI (Display on a screen) (Tech)	Morph chart	Yes	
79	39. EEG measurement with brainwave monitor (Tech) Store on mechanical number counter, being operated by the user (Analog) Explain trends with AI generated phrases (Tech) Report trends with Email report (Tech)	Morph chart	Yes	

80	40. Pressure sensors (Tech) Show trends with a Candlelight stock graph (Tech)	Morph chart	No	Feasible
81	41. O2 levels and ECG measurements with a wristband/ ring (Tech) Analyze data with the Sleep Quality Scale (SQS) (Analog) Have AI provide support to the user. (Tech) Show trends on a Line graph (Tech) Talking Monkey (Analog)	Morph chart	No	Non-Feasible
82	42. Owl that watches you and in its mind, tracks you. (Analog) Calculate trends using a proprietary computer algorithm (Tech) A chatbot with full knowledge of how our sleep system works, Color spectrum indicators (Tech)	Morph chart	Yes	
83	43. Pressure sensors (Tech) Print data on paper (Tech) Sleep discount, where if they use the device and the manual for it, they get a discount on any sleep related thing (analog) Digital Drawing (Tech) Text message (Tech)	Morph chart	Yes	
84	44. O2 levels and ECG measurements with a wristband/ ring (Tech) Provide user with system assistance Display trends in sleep data Teddy Bear that talks about your sleep anomalies (Tech)	Morph chart	No	Feasible
85	45. Owl that watches you and in its mind, tracks you. (Analog) (Tech) User scans sleep data sheet and uploads it online. A chatbot	Morph chart	Yes	

	with full knowledge of how our sleep system works, AI lullaby that composes lyrics and sings you about your sleep data (Tech) Text message (Tech)			
86	46. Polysomnography (Tech) Analyze data with the Sleep Quality Scale (SQS) (Analog) Painting (Tech)	Morph chart	No	Non-Feasible
87	47. Chest sensor that measures pressure and airflow happening in the chest. (Tech) Have AI provide support to the user. (Tech) Show trends with a Word cloud (Tech) Automated phone call (Tech)	Morph chart	Yes	
88	48. Actigraphy, movement sensor (Tech) User scans sleep data sheet and uploads it online. AI lullaby that composes lyrics and sings you about your sleep data (Tech) Inform about anomalies	Morph chart	Yes	
89	49. Premade sleep sensors available from texas instruments (tech) Store sleep data Digital Drawing (Tech) Mail paper report (Analog)	Morph chart	No	Feasible
90	50. Measure sleep parameters A chatbot with full knowledge of how our sleep system works, AI lullaby that composes lyrics and sings you about your sleep data (Tech)	Morph chart	Yes	
91	51. Measure sleep parameters Store data in computer memory (Tech) Provide user with system assistance Show trends with a Candlelight stock graph (Tech)	Morph chart	Yes	

92	52. Premade sleep sensors available from texas instruments (tech) Sleep discount, where if they use the device and the manual for it, they get a discount on any sleep related thing (analog) Digital Drawing (Tech) Mail paper report (Analog)	Morph chart	No	Non-Feasible
93	53. (Tech) A mic that records the noises made while the patient sleeps. (Tech) User scans sleep data sheet and uploads it online. Have AI provide support to the user. (Tech) Explain trends with AI generated phrases (Tech) Inform about anomalies	Morph chart	Yes	
94	54. EEG measurement with brainwave monitor (Tech) Show trends with a Candlelight stock graph (Tech) Carrier pigeon (Analog)	Morph chart	No	Non-Feasible
95	55. (Tech) A mic that records the noises made while the patient sleeps. Provide support over a telephone line for any user inquiries. (Both) AI lullaby that composes lyrics and sings you about your sleep data (Tech) Text message (Tech)	Morph chart	Yes	
96	56. Custom pajamas that have a built in actigraphy, heat sensor, and heart rate monitor. Store on mechanical number counter, being operated by the user (Analog) Analyze data with the Sleep Quality Scale (SQS) (Analog) Have AI provide support to the user. (Tech) Shows you the sleep debt you have	Morph chart	Yes	

	accumulated over the week. (Tech) GUI (Display on a screen) (Tech)			
97	57. Custom pajamas that have a built in actigraphy, heat sensor, and heart rate monitor. Store data in Usb/ Flash drive (Tech) Sleep discount, where if they use the device and the manual for it, they get a discount on any sleep related thing (analog) Show trends with a Word cloud (Tech) Mail paper report (Analog)	Morph chart	No	Non-Feasible
98	58. Audio recording (Tech) Print data on paper (Tech) A person is sent to the users house to provide In-person assistance (Both) Digital Drawing (Tech) Carrier pigeon (Analog)	Morph chart	Yes	
99	59. Custom pajamas that have a built in actigraphy, heat sensor, and heart rate monitor. Store on mechanical number counter, being operated by the user (Analog) Provide support over a telephone line for any user inquiries. (Both) Digital Drawing (Tech) Automated phone call (Tech)	Morph chart	Yes	
100	60. Polysomnography (Tech) Store on mechanical number counter, being operated by the user (Analog) Interpret trends in sleep Show trends with a Candlelight stock graph (Tech) Report trends with Email report (Tech)	Morph chart	Yes	

101	Bedside “Scantron” like device that prints and reads daily questionnaires. It has LED indicators to show if the questionnaire has been completed; LED off for completed, on for not. It will be paired with an in-bed sensor that will record physiological data. (Random stimulation)	Random stimulation	No	Feasible
102	Compression socks with embedded temperature and motion sensors to track restlessness and sleep depth. (Lateral Thinking)	Lateral thinking	No	Feasible
103	A deck of cards with sleep-related prompts (e.g., "How rested do you feel?" or "What kept you awake?", or replace with SATEDI?). Users draw cards each morning to reflect on their sleep. (Lateral Thinking)	Lateral thinking	No	Feasible
104	A set of stickers with sleep-related emotions (e.g., "Restless," "Peaceful," "Exhausted"). Users place a sticker on a calendar each morning to log their feelings. (Lateral Thinking)	Lateral thinking	No	Feasible
105	A clock with a touch-sensitive screen that displays sleep-related emotions (e.g., "Tired," "Refreshed," "Anxious", etc…could be other indicators (SATEDI)). Users tap their mood each morning to log their feelings. (Lateral Thinking)	Lateral thinking	No	Feasible

106	A journal with crowdmark-style bubble pages for users to fill in multiple choice about their sleep (e.g., "Did you wake up during the night?" or "How would you rate your sleep?", or replace with SATEDI). The journal can be scanned periodically for data analysis with an external app not connected to user (no user data, just a score) (Analogy method)	Analogy method	No	Feasible
107	A mobile app where users select an emoji each morning to describe how they feel about their sleep (e.g., 😴, 🛌, 😩). The app tracks trends over time and can be paired with existing devices to track physiological data. (SCAMPER)	SCAMPER	No	Feasible
108	Bed/blanket sensor that tracks in-bed time with a water dispenser. The more time spent in sleep cycles the more water will be released into your cup with a max of (whatever limit the user sets) with a heated saucer. Atr sunrise, rgb lighting will indicate some form of sleep quality based on the physiological data gathered.	Random stimulation	No	Feasible
109	Patch similar to a diabetic sensor patch that is disposable, coming in packs with a dozen sensors. (Random stimulation)	Random stimulation	No	Non-Feasible
110	A high-tech, immersive sleep pod designed to transform any bedroom into a personalized sleep sanctuary. It combines advanced sleep tracking, environmental	Blue sky thinking	No	Non-Feasible

	control, and AI-driven personalization to create the ultimate sleep experience. It should look like an egg from the outside. (Blue Sky)			
111	A pair of pyjamas with integrated sensors that record the user's sleep data. This information is uploaded to their phone to be analyzed and viewed through their phone. (Blue sky)	Blue sky thinking	No	Feasible
112	AI Chatbot that users engage with for 10 minutes every morning by discussing their length of sleep, mood after waking up, etc. From there, the chatbot gives personalized feedback daily. (Blue sky)	Blue sky thinking	No	Feasible
113	Sleep tracking ring (like a fitbit)	Lateral thinking	No	Non-Feasible
114	Users wear an eye mask with integrated sensors that read blood pressure and heart rate. On the front of the eye mask there is a screen that displays their sleep trends every morning. (Blue sky)	Blue sky thinking	No	Feasible
115	Digital journal that users use to record their sleep information. Then it is analyzed by AI and displayed onto graphs. (BS)	Blue sky thinking	No	Feasible
116	Sensors that can be attached to the user's bed frame that record movement during sleep. (BS)	Blue sky thinking	No	Feasible
117	An email is sent to the user's inbox every Sunday morning with a summary of their sleep for the last week. (BS)	Blue sky thinking	No	Non-Feasible

118	Camera is mounted to the user's ceiling and has the ability to detect the user's movement while they sleep. (BS)	Blue sky thinking	No	Feasible

Appendix I: Idea Selection Process

The idea selection process included four main processes being Feasibility Check, Multivoting, Graphical Decision Chart and Weighted Decision Matrix, each of which are detailed below.

Appendix I.1: Feasibility check in the idea selection process

This appendix outlines the use of a feasibility check in the idea selection process, reducing the number of possible ideas from 76 to 53. Feasibility criterias that were used to identify feasible and infeasible ideas are shown in Figure I.1.1.

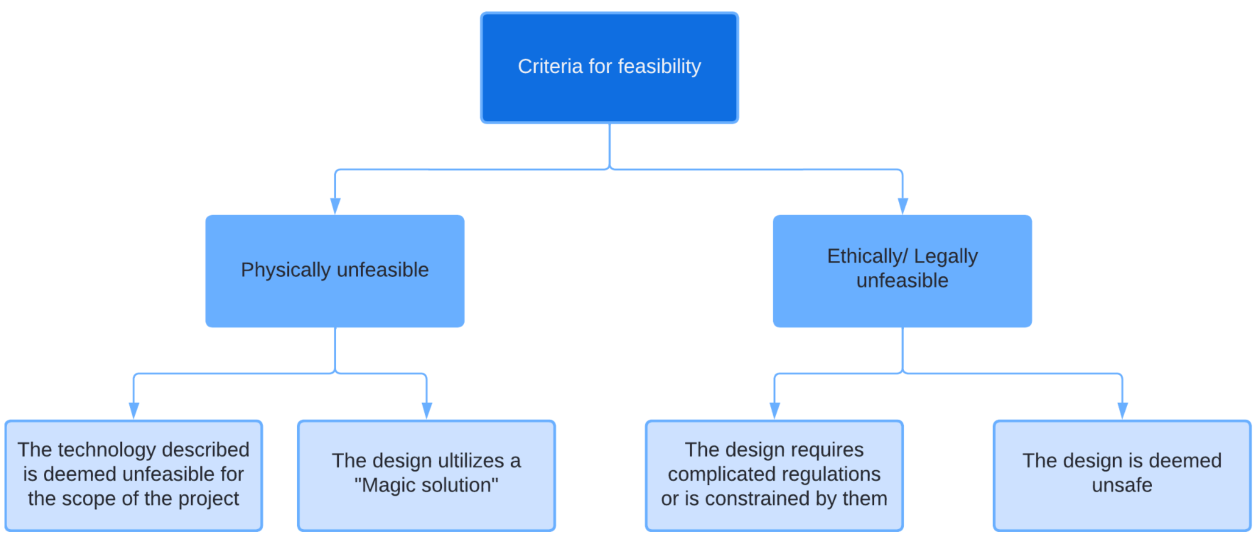


Figure I.1.1. Feasibility criterias.

The check resulted in 23 ideas being classified as infeasible and are listed in Table I.1.1.

Table I.1.1. Unfeasible ideas

#	Idea description	Feasibility criteria
2	A credit card that tracks heat and movement. It stores data in the card and sends trends onto the phone. To motivate users, if the user keeps using the card, they can then use the card for discounts for sleep related	Physically unfeasible

	items (Blue sky thinking)	
7	Music box that has an actigraphy, heat sensor, and O2 level sensor. The data it gathers is gathered into the music box, inscribed on the nooks that affect the notes played by the music box. It comes with a manual to translate the notes into english. (Blue sky thinking)	Physically unfeasible
15	Sleep Plant (Blue Sky Thinking)	Physically unfeasible
23	Pill-like design which reads biomarkers from inside the users body, the data is sent through the users phone through NFC, in which an app provides trends and assistance. (SCAMPER)	Physically unfeasible
24	Brain-Interface which monitors sleep quality through the user's dreams, both trends and assistance are displayed to the user in their dreams. (Blue sky thinking)	Physically unfeasible
25	Glasses that measures REM sleep based on ECG and eye movement, information and assistance are displayed on the lenses (Blue sky thinking)	Physically unfeasible
26	Brain interface connected to the Central circadian clock to measure sleep parameters, which is sent through a wireless network which is analysed and displayed on a computer. (Blue sky thinking)	Physically unfeasible
28	Neck brace Melatonin sensor located close to the user's thyroid to detect sleep parameters, the neck brace can be attached to a computer which interprets the data. (Biomimicry)	Physically unfeasible
29	Face masks measure respiratory rates to detect sleep parameters, the data is interpreted by an imbued computer and information is conveyed through speakers. (Biomimicry)	Physically unfeasible
31	A magical sprite that watches over the user while they sleep, when they wake up, the sprite shares insights about their sleep patterns The sprite interacts with the user through augmented reality, appearing on a bedside device or phone app. (analogy method)	Physically unfeasible
42	2. Premade sleep sensors available from texas	Ethically/ Legally unfeasible

	instruments (tech) A trained personnel uses a industry standard formula for calculating sleep trends (Analog) Email assistance (Tech) Owl presses buttons to tell user how they slept such as their sleep length and how much they moved (analog) Talking Monkey (Analog)	
51	11. Polysomnography (Tech) Print data on paper (Tech) Sleep discount, where if they use the device and the manual for it, they get a discount on any sleep related thing (analog) Digital Drawing (Tech)	Ethically/ Legally unfeasible
53	13. Polysomnography (Tech) (Analog) User manually calculates averages for every sleep data type. Multiplayer video game leadership board with friends to motivate and teach (Tech) Song (Tech) Mail paper report (Analog)	Ethically/ Legally unfeasible
67	27. Questionnaire (Analog) Song (Tech) Talking Monkey (Analog)	Ethically/ Legally unfeasible
81	41. O2 levels and ECG measurements with a wristband/ ring (Tech) Analyze data with the Sleep Quality Scale (SQS) (Analog) Have AI provide support to the user. (Tech) Show trends on a Line graph (Tech) Talking Monkey (Analog)	Ethically/ Legally unfeasible
86	46. Polysomnography (Tech) Analyze data with the Sleep Quality Scale (SQS) (Analog) Painting (Tech)	Ethically/ Legally unfeasible
92	52. Premade sleep sensors available from texas instruments (tech) Sleep discount, where if they use the device and the manual for it, they get a discount on any sleep related thing (analog) Digital Drawing (Tech) Mail paper report (Analog)	Ethically/ Legally unfeasible
94	54. EEG measurement with brainwave monitor (Tech) Show trends with a Candlelight stock graph (Tech) Carrier pigeon (Analog)	Physically unfeasible
97	57. Custom pajamas that have a built in actigraphy, heat sensor, and heart rate monitor. Store data in Usb/ Flash drive (Tech) Sleep discount, where if they use the device and the manual for it, they get a discount on any sleep related thing (analog) Show trends with a Word cloud (Tech) Mail paper report (Analog)	Ethically/ Legally unfeasible

109	Patch similar to a diabetic sensor patch that is disposable, coming in packs with a dozen sensors. (Random stimulation)	Ethically/ Legally unfeasible
110	A high-tech, immersive sleep pod designed to transform any bedroom into a personalized sleep sanctuary. It combines advanced sleep tracking, environmental control, and AI-driven personalization to create the ultimate sleep experience. It should look like an egg from the outside. (Blue Sky)	Physically unfeasible
113	Sleep tracking ring (like a fitbit)	Physically unfeasible
117	An email is sent to the user's inbox every Sunday morning with a summary of their sleep for the last week. (BS)	Not full solution

Appendix I.2: Multivoting

This appendix outlines how multivoting was implemented to reduce the number of ideas from 53 to 10. Each team member was given ten votes to select their preferred solution. Each idea's row on the Google sheet, shown in Table I.2.1, was assigned a number of team members counting as their votes. For the analysis, the Google Sheets function '=IF(F41<>"", COUNTA(SPLIT(F41, " ")), 0)/2' was used to count the number of votes each idea received.

The results of the voted ideas are in Table I.2.1 The ones identified for the next selection process were the ten highest ranked ideas (numbers 8, 106, 1, 20, 33, 7, 10, 54, 111) in Table I.2.2.

Table I.2.1 The ideas numbers and the number of votes in the descending order.

Idea #	Votes	# of votes
8	Thisha Sudhakaran, Johnny Campos, Samantha Chan, Willis Wu, Brian Bui	5
106	Thisha Sudhakaran, Brian Bui, Samantha Chan, Willis Wu, Jalilya Zhaxybayeva	5
1	Thisha Sudhakaran, Johnny Campos, Samantha Chan	4

	Willis Wu	
20	Thisha Sudhakaran, Brian Bui, Willis Wu, Jalilya Zhaxybayeva	4
33	Jalilya Zhaxybayeva, Brian Bui, Samantha Chan, Willis Wu	4
73	Johnny Campos, Samantha Chan, Willis Wu, Brian Bui	4
10	Thisha Sudhakaran, Willis Wu, Jalilya Zhaxybayeva	3
54	Samantha Chan, Brian Bui, Jalilya Zhaxybayeva	3
111	Johnny Campos, Samantha Chan, Willis Wu	3
5	Thisha Sudhakaran, Brian Bui, Willis Wu	3
27	Johnny Campos, Brian Bui	2
35	Jalilya Zhaxybayeva	1
40	Samantha Chan, Willis Wu	2
102	Johnny Campos, Brian Bui	2
3	Johnny Campos	1
4	Thisha Sudhakaran	1
11	Thisha Sudhakaran	1
22	Johnny Campos	1
30	Johnny Campos	1
32	Johnny Campos	1
36	Jalilya Zhaxybayeva	1
38	Samantha Chan	1
84	Brian Bui	1
104	Jalilya Zhaxybayeva	1
107	Thisha Sudhakaran	1
112	Thisha Sudhakaran	1
114	Samantha Chan	1

Figure I.2.1 The voting table used for analysis with the idea numbers, people votes and the total votes number

Table I.2.2. Top 10 voted ideas with descriptions and the number of votes.

Idea Number + Name	**Number of votes**
8 - ThermoSense Comfort	5

106 - SleepSync Journal	5
1- FrameSense	4
20 - Sector Clock	4
33 - SomniCloud Pillow	4
73 - AirFlowGuard	4
10 - Dream AI	3
54 - Sleep Tally	3
111 - SmartSlumber PJ	3
5 - LumiTrack	3

Appendix I.3: Graphical decision matrix

This appendix outlines how two graphical decision charts were utilized to reduce the number of proposed ideas from 10 to 5. During this process the team decided to compare how each idea fulfilled 4 different objectives, comparing “Optimize early detection of anomalies” against “Minimize Cost” and “Maximize accuracy of physical measurements” against “Ensure continuous usage time”. The ideas were rated on a scale from 1 to 4 (1 - bad, 2 - satisfactory, 3 - Good, 4 - Excellent) by the team members during a team meeting. Resulting in the ratings outlined in table I.3.1 and I.3.2:

Table I.3.1. Team ratings for ideas on objectives “Optimize early detection of anomalies” against “Minimize Cost”.

Idea 8	Thisha	Sam	Brian	Willis	Johnny	Lila	Average
Optimize early detection of anomalies	1.5	2	1.5	2	2.5	3	2.083333333
Minimize Cost	2	3	2	3.5	3.5	3	2.833333333
Idea 106							
Optimize early detection of anomalies	2.5	2.5	1.5	2	1	2	1.916666667
Minimize Cost	4	4	4	4	4	3	3.83333

							3333
Idea 1							
Optimize early detection of anomalies	1	3	2	1.5	3	1	1.91666 6667
Minimize Cost	1	1	1	1	1	1	1
Idea 20							
Optimize early detection of anomalies	1.5	2	2	2	1	2	1.75
Minimize Cost	1.5	1	1	1	1	1	1.08333 3333
Idea 33							
Optimize early detection of anomalies	3	3	2.5	3	4	2	2.91666 6667
Minimize Cost	2.5	2.5	2.5	2	2	3	2.41666 6667
Idea 73							
Optimize early detection of anomalies	3.5	3.5	2.5	3	3	2	2.91666 6667
Minimize Cost	2	3.5	2	3	3	2	2.58333 3333
Idea 10							
Optimize early detection of anomalies	3	2.5	1.5	2	2	2	2.16666 6667
Minimize Cost	2	1.5	2	2	2	1	1.75
Idea 54							
Optimize early detection of anomalies	2	2	2	2	3	2	2.16666 6667
Minimize Cost	3.5	3.5	3	3	4	2.5	3.25

Idea 111							
Optimize early detection of anomalies	3.5	3.5	3	4	4	3	3.5
Minimize Cost	1.5	2	1.5	2.5	2	2	1.916666667
Idea 5							
Optimize early detection of anomalies	1	1	1	1	2	1	1.166666667
Minimize Cost	4	4	4	4	4	4	4

Table I.3.2: Team ratings for ideas on objectives "Maximize accuracy of physical measurements" against "Ensure continuous usage time".

Idea 8	Thisha	Sam	Brian	Willis	Johnny	Lila	Average
Maximize accuracy of physical measurements	2	3	2	2	2	2	2.166666667
Ensure continuous usage time	4	3.5	3	3.5	3.5	3	3.416666667
Idea 106							
Maximize accuracy of physical measurements	2.5	3	3	3	4	1	2.75
Ensure continuous usage time	2	2	2	2	1.5	1.5	1.833333333
Idea 1							
Maximize accuracy of physical measurements	2	2	1.5	2	1.5	1	1.666666667
Ensure continuous usage time	3.5	3.5	3	3	3.5	1	2.916666667
Idea 20							
Maximize accuracy of	1	2	1	1.5	1	1.5	1.3333

physical measurements							33333
Ensure continuous usage time	3	3.5	3	4	4	3.5	3.5
Idea 33							
Maximize accuracy of physical measurements	3	3.5	3.5	3	3.5	3.5	3.3333 33333
Ensure continuous usage time	4	3.5	3.5	4	4	4	3.8333 33333
Idea 73							
Maximize accuracy of physical measurements	2	4	2.5	3	3	3	2.9166 66667
Ensure continuous usage time	1.5	2	1.5	2	1.5	1.5	1.6666 66667
Idea 10							
Maximize accuracy of physical measurements	1.5	2.5	2	2	2.5	1	1.9166 66667
Ensure continuous usage time	3	1.5	2	2.5	2	1.5	2.0833 33333
Idea 54							
Maximize accuracy of physical measurements	1.5	2.5	1.5	1.5	1	1	1.5
Ensure continuous usage time	1	1.5	1.5	2	1	1.5	1.4166 66667
Idea 111							
Maximize accuracy of physical measurements	3	3.5	4	4	4	4	3.75
Ensure continuous usage time	3	3.5	3	3.5	3.5	3.5	3.3333 33333

Idea 5							
Maximize accuracy of physical measurements	1	1	1	1	1	1	1
Ensure continuous usage time	3	4	3	3	2	2	2.833333333

The average ratings were plotted against each other on the graphs in figure I.3.3 and I.3.4, the ideas that rated higher on both parameters were selected for the next step of the Alternative design selection process (Numbers 73, 33, 111, 106 and 8) as shown in Figures I.3.1 and I.3.2.

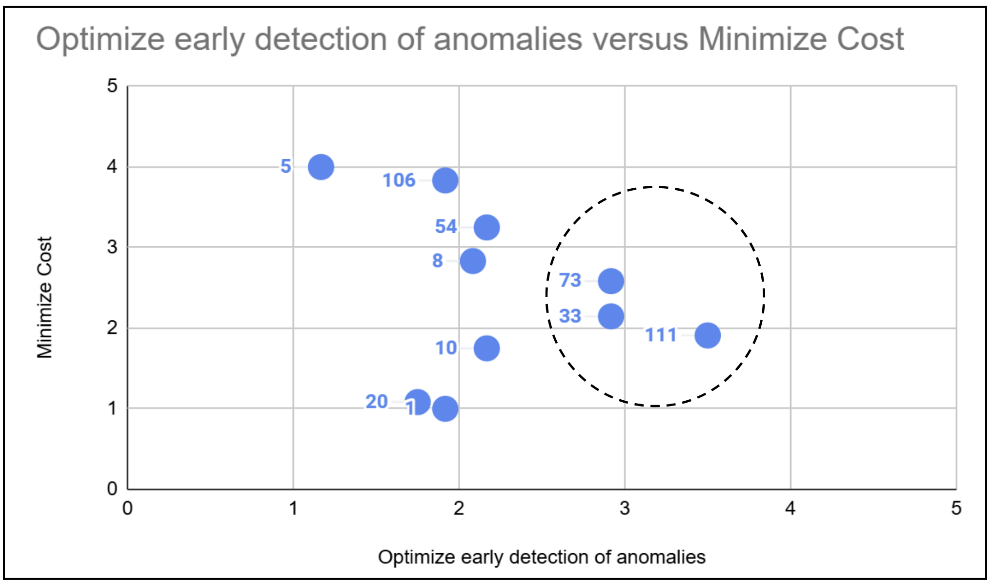


Figure I.3.1. GDC #1 with idea numbers and the top 3 scoring ideas circled.

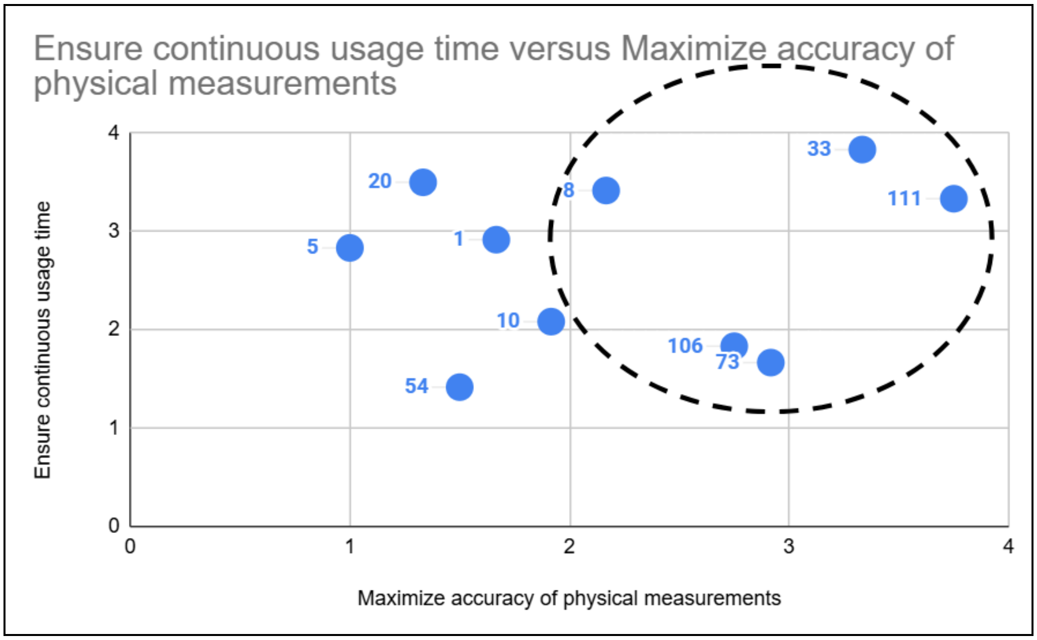


Figure I.3.2. GDC #2 with idea numbers and the top 5 scoring ideas circled

Appendix I.4: Weighted decision matrix

This appendix outlines the use of a weighted decision matrix in reducing the number of proposed ideas from 5 to the 3 alternative designs. The objectives were assigned weights to the overall design based on their ranking as indicated in table I.4.2. The designs were then evaluated on how they meet each objective based on team discussions and the ratings provided in tables I.3.1 and I.3.2. These raw scores are shown in table I.4.3. Finally, each design objective score was multiplied by the corresponding objective weight and summed together to find how each design meets the overall project. (Table I.4.3). The three highest percentages were selected as the alternative design ideas (Numbers 111, 73, and 33) as shown in Table I.4.4.

Table I.4.1. The rank of the objectives including their weights.

Objective	Rank	Weight
Optimize detection of sleep anomalies	1	30%
Minimize cost	2	25%
Consistently align collected data and user's perception (SATEDR)	3	15%
Ensure continuous usage time	4	15%

Maximize accuracy of physiological measurements	5	15%
	Total	100%

Table I.4.2: Objectives weighting Factors for Matrix

Raw Score					
Objective	**Idea 111**	**Idea 33**	**Idea 73**	**Idea 106**	**Idea 8**
Optimize detection of sleep anomalies	87.5%	72.9%	72.9%	47.9%	52.1%
Minimize cost	47.75%	53.7%	64.6%	95.8%	70.8%
Consistently align collected data and user's perception (SATEDR)	75%	62.5%	87.5%	37.5%	62.5%
Ensure continuous usage time	83.333333 33%	95.8%	41.7%	45.8%	85.4%
Maximize accuracy of physiological measurements	93.75%	83.3%	72.9%	68.8%	54.2%

Table I.4.3: Raw Score for Objectives

Weighting Factor Applied					
Objective	**Idea 111**	**Idea 33**	**Idea 73**	**Idea 106**	**Idea 8**
Optimize detection of sleep anomalies	26%	22%	22%	14%	16%
Minimize cost	12%	13%	16%	24%	18%
Consistently align collected	11%	9%	13%	6%	9%

data and user's perception (SATEDR)					
Ensure continuous usage time	13%	14%	6%	7%	13%
Maximize accuracy of physiological measurements	14%	13%	11%	10%	8%
Totals	76%	72%	68%	61%	64%

Table I.4.4. WDM with resulting scores and the top 3 ideas highlighted in pink.

Weighting Factor Applied					
Objective	**Idea 111**	**Idea 33**	**Idea 73**	**Idea 106**	**Idea 8**
O1	26%	22%	22%	14%	16%
O5	12%	13%	16%	24%	18%
O3	11%	9%	13%	6%	9%
O4	13%	14%	6%	7%	13%
O2	14%	13%	11%	10%	8%
Totals	76%	72%	68%	61%	64%

Appendix J: Alternative Design Specification #1

The appendix showcases all extra information regarding Smart-Slumber PJ's

Appendix J.1: All Electrical Components Within Device

The sensor boxes and/or mat holds the main components in table J.1.1 and secondary components in table J.1.2 below. Greater detail about which device contains what component, see Figure J.1.3.

Table J.1.1. Module name, dimensions, cost, and weight of each essential component.

Used in + Number of parts needed	Name	Dimensions (mm)	Cost each	Weight each (g)
All (3)	ESP32–WROOM32	55.3 x 28.0 x 12.9 [62]	$3.27 [63]	9.6 [62]
	NFC Module-PN532	40.5 x 42.5 [64]	$3.54 [64]	15 [65]
Sensor Boxes (2)	Micro SD card-32GB	15 x 11 x 1 [66]	$6.49 [67]	0.5 [68]
	Lithium Polymer Battery	50 x 32 x 5 [69]	$8.99 [69]	24 [69]
Wrist Box (1)	Photoplethysmogram (PPG) Sensor	LED: 3 x 5.25 [70] Photodiode: 1.1 x 1.1 [71]	LED: $0.01759 [72] Photodiode: $0.1 [73]	LED: 0.4 [74] Photodiode: 0.28 [75]
Waist Box (1)	Accelerometer-ADXL 345	15.2 x 20.4 x 1 [76]	$3.76 [76]	10 [76]
	Thermal Sensor-LM35-LP	5.21 x 5.34 x 1.07 [77]	$0.48 [78]	20 [79]

Mat (1)	Wireless Charging Receiver	30 x 40 [80]	$2.38 [80]	18 [81]
	TFT LCD Screen	108 x 64.8 [82] x 5.9 [83]	$12 [84]	82 [85]
	Three Buttons	6 x 6 x 5 [86]	$0.0789 [86]	0.28 [86]

Table J.1.2. Secondary components in all parts.

	Name	**Purpose + Dimension**	**Cost per piece x Number of modules needed**	**Weight Each (g)**
Sensor boxes	Low Dropout Regulator - AMS1117 - 3.3	Regulates voltage to 3.3v since required for ESP32s. 6.5 x 3.5 x 1.6 mm [87]	$0.208 [88] x 2	0.992 [89]
	Charging module - TP4056	Manages voltage output of the Li-Po Battery. 26 x 17 mm [90]	$0.06 [91] x 2	1.8 [92]
	SD card module	Connection between ESP32 and SD card 110 x 106 x 7 mm [93]	$3.99 [94] x 2	6 [94]
Mat	AC-DC Converter	Converts AC power from a wall plug into DC power for the components. 33.7 x 22.2 x 15 mm [95]	$7.45 [95]	19 [96]
	DC voltage regulator - LM7805_TO220	Regulates voltage to 5v since required for ESP32s. 14.42 x 9.63 x 3.56 mm [97]	$0.9 [98]	2 [98]

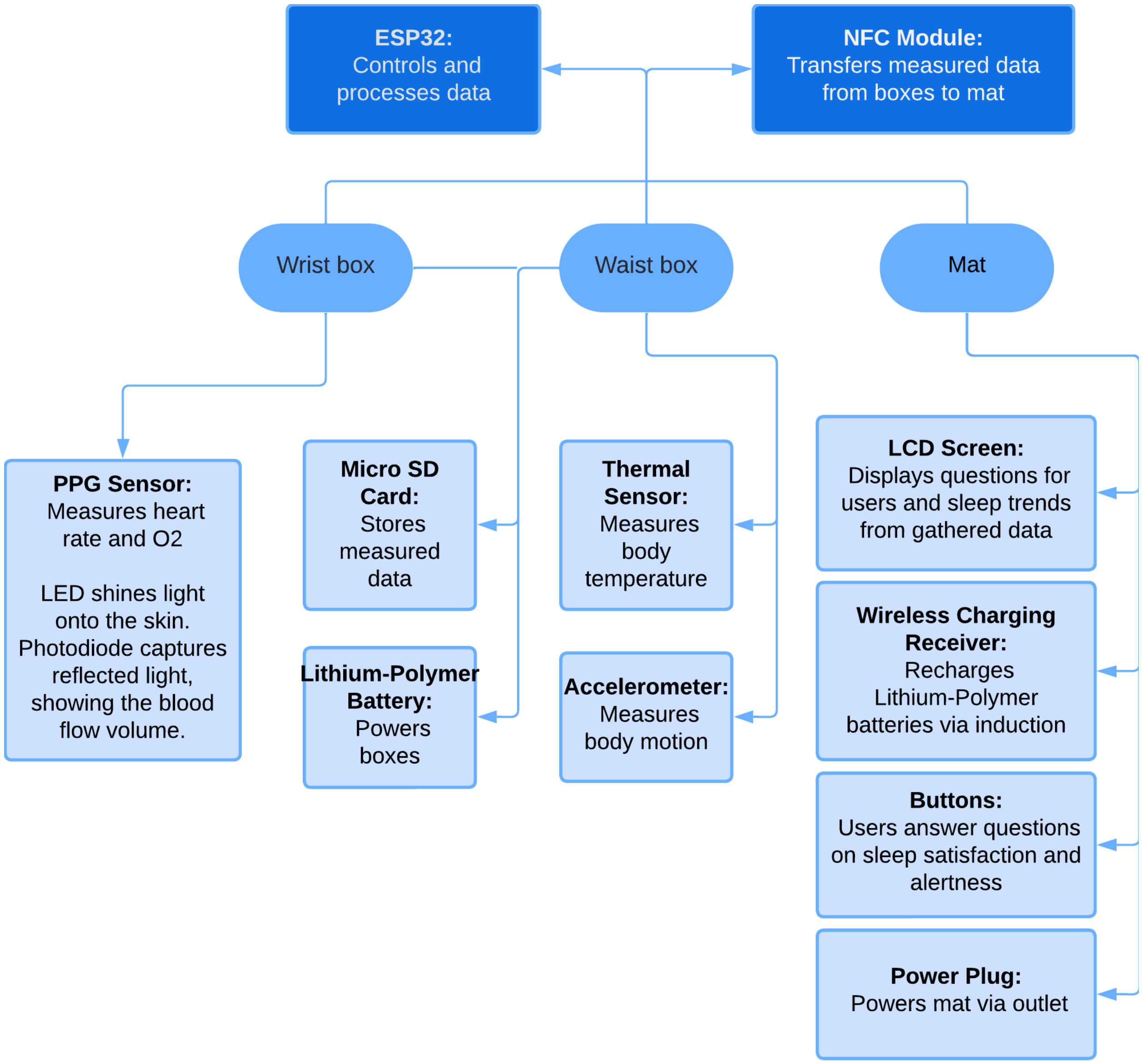


Figure J.1.3. Each parts' essential components.

Appendix J.2: Electrical Schematics

The figures J.2.1, J.2.2, and J.2.3 below show how the wrist box, waist box, and mat's electronic components connect together, respectively.

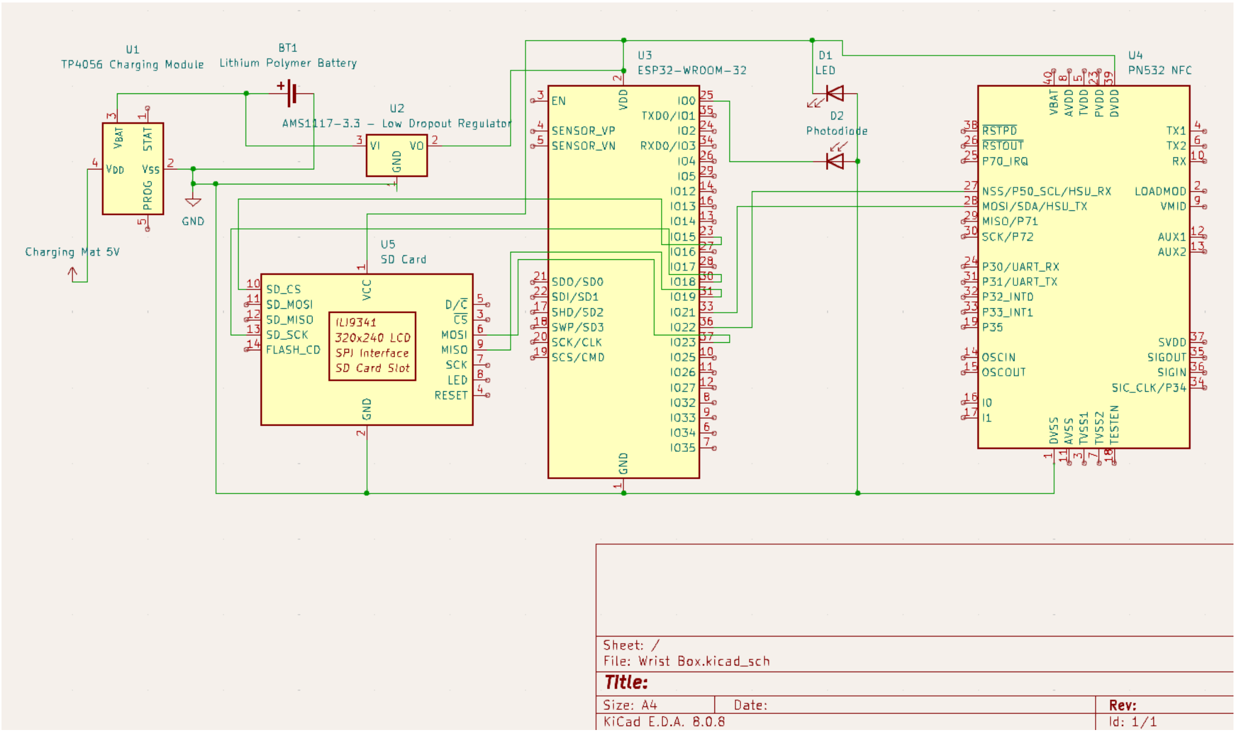


Figure J.2.1. Wrist Sensor Box Schematic

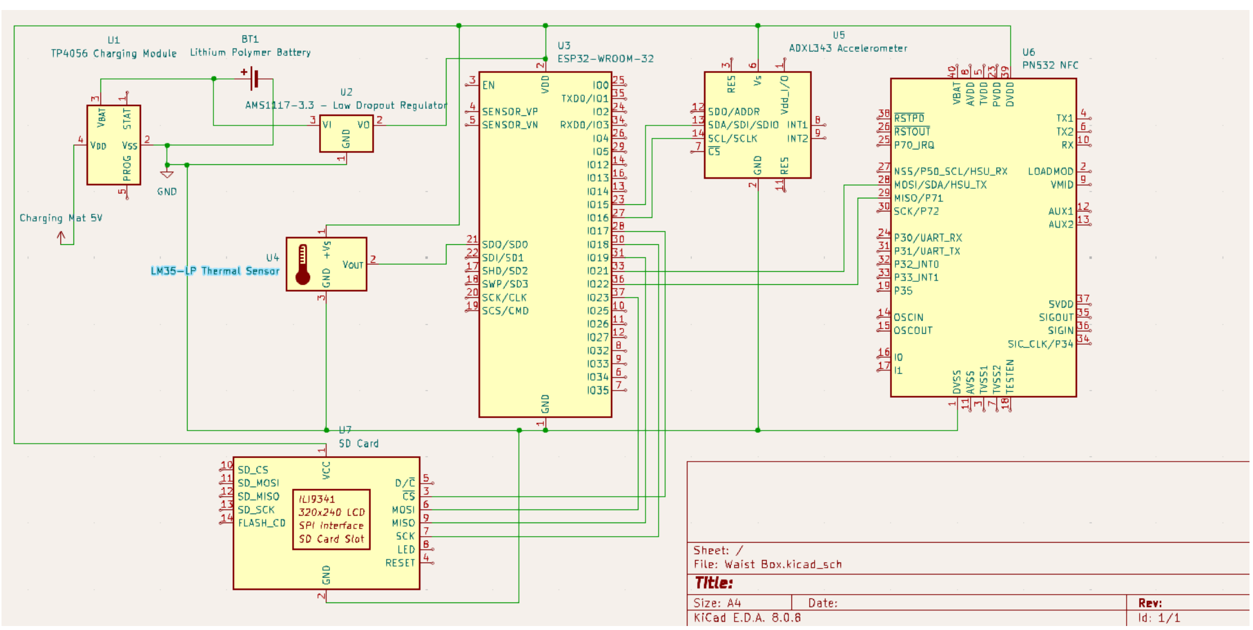


Figure J.2.2. Waist Sensor Box Schematic

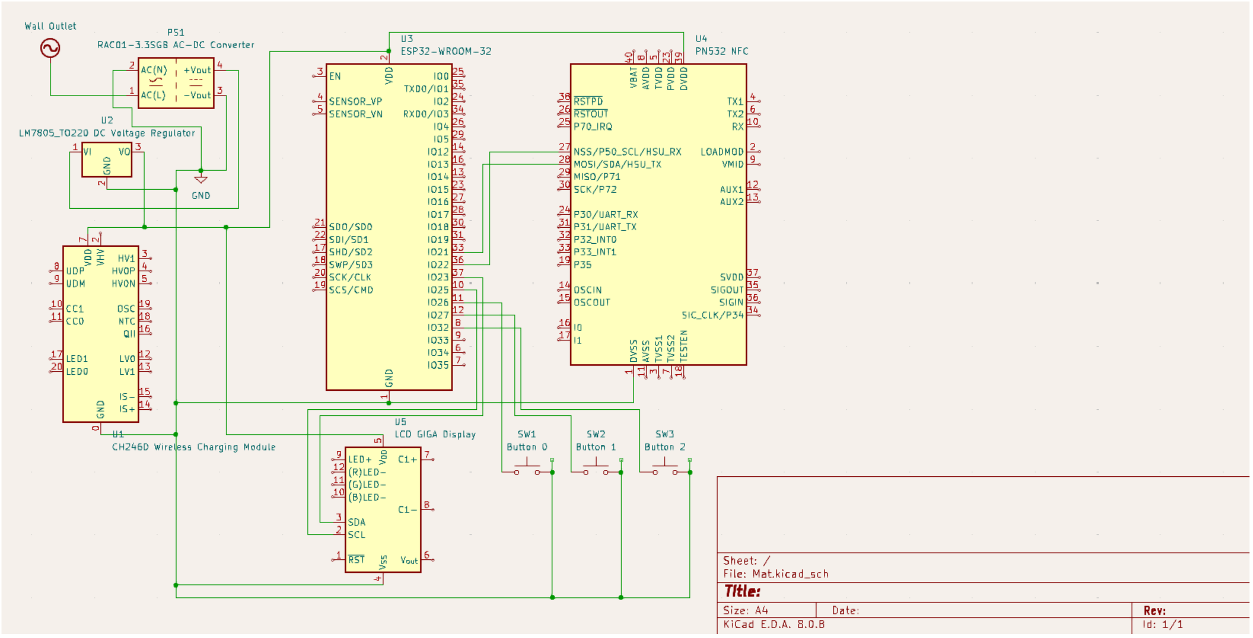


Figure J.2.3. Charging Mat Schematic

Appendix J.3: Device Usage Methodology

User manuals will include a flowchart, shown in Figure J.3.1, which gives an idea of how the user can and should use the device.

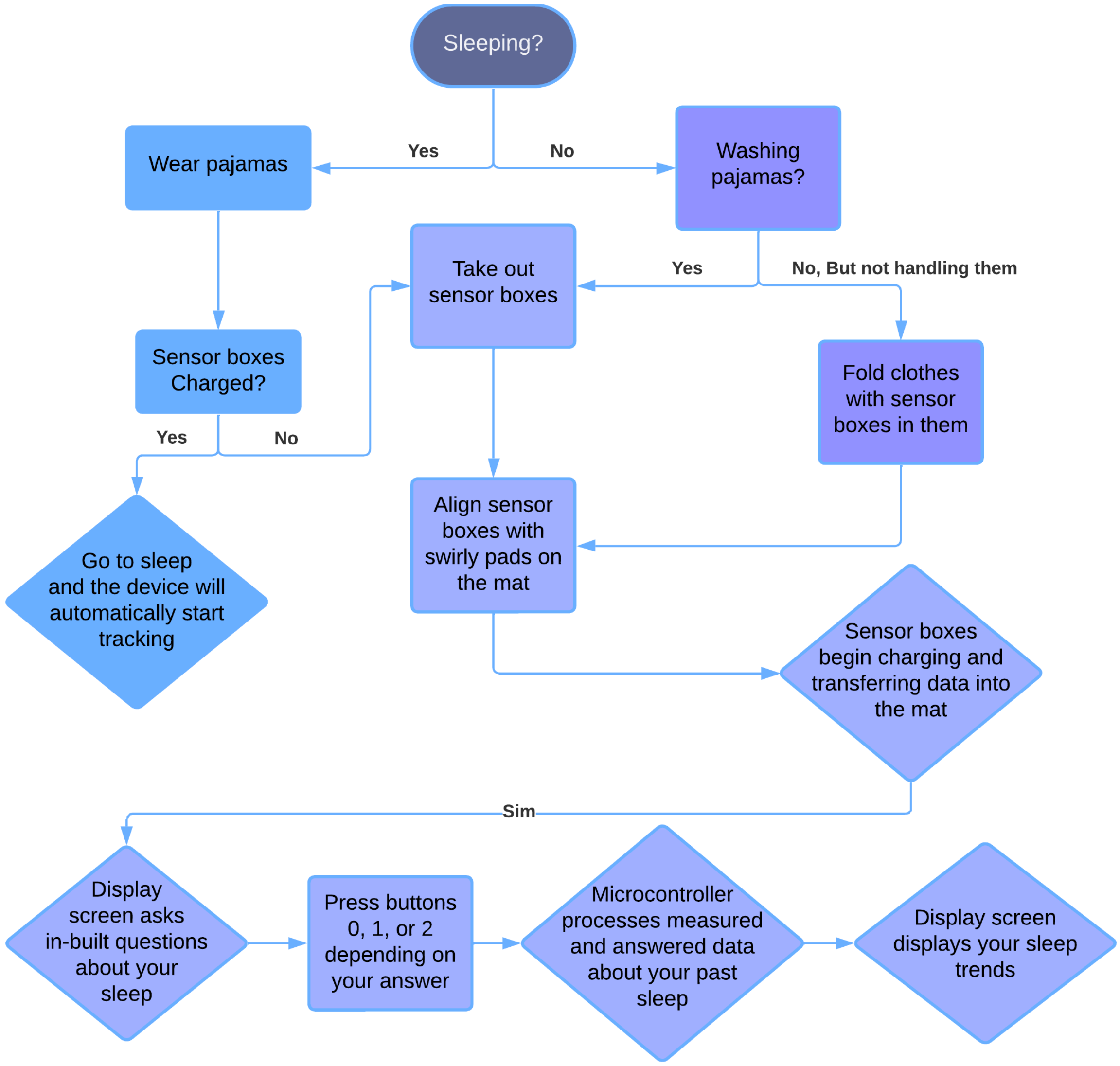


Figure J.3.1. Process of how the user uses the device.

Appendix J.4: Sleep Summary Displayed

A sleep summary will be provided after gathering all the data. Figure J.4.1 showcases what a sample of the sleep summary will look like when displayed on the LCD screen.

```
Your sleep scores for the past __ days:

Satisfaction: 2
Alertness: 1
Timing: 2
Efficiency: 1
Duration: 2
Regularity: 2

For the past 3 days, you have consistently slept for 8 hours, averaging sleep
between 11:00pm - 7:00am. Your sleep quality satisfaction is high, but your
alertness throughout the days and ability to fall asleep quickly is not as high.
Overall, your sleep health is doing pretty well. Good job!
```

Figure J.4.1. Example sleep summary.

Appendix K: Alternative Design Specification #2

This appendix outlines the relevant details regarding the alternative design specifications #2 (SomniCloud Pillow).

Appendix K.1: Pillow Specifications

Table K.1.1 showcases each of the pillow's component's dimensions, descriptions, weight, and price.

Table K.1. Greater detail of component specifications..

Part	Description + Dimensions	Weight	Price
Pillow Core	Made from high-density (3–5 lb/ft^3) memory foam or latex Dimensions: Must be smaller than pillow case	~1000 g [99]	US$4.00 - 4.79 Per Piece MOQ: 5 Pieces [99]
Pillow Case	Should be a machine-washable and moisture-wicking materials that is breathable and hypoallergenic - Material: 100% Cotton Dimensions: 762mm x 508 mm (30"L x 20"W)	231.33 g [100]	US $0.75-1.16 Per Piece MOQ: 100 Pieces [100]
Subber Sensor Housing Sheet	According to sewing.org, the guidelines for a pillow and its stuffing. https://www.sewing.org/files/guidelines/8_120_pillows.pdf It was chosen that the sensor sheet to be about an inch smaller in length and width in order to successfully insert the sensor sheet between the two pillows and inside the pillow case. Weight estimation: (0.001)(0.742)(0.488)(80.0923168698) = 0.0230582576575 kg Dimensions: 742mm x 488 mm	23.0582576575 g	Price varies widely.

FSR 406	"The sensor reduces its resistance when the force applied to the round of the tip increases. Due to this phenomenon, and the use of a microcontroller with analog to digital converter, you can build a sensor that measures the force." [101] Dimensions: 43.7mm x 43.7mm x 0.5mm Datasheet: https://cdn.sparkfun.com/assets/c/4/6/8/b/2010-10-26-DataSheet-FSR406-Layout2.pdf	~2 g (x8) [101]	US $0.68 (x8) Per Piece MOQ: 100 Pieces [102]
MPU-6050	"Sensor for measuring acceleration and angular velocity in three axes. It is a combination of a 3-axis accelerometer and a gyroscope." [103] Dimensions: 21mm x 14mm Datasheet: https://invensense.tdk.com/wp-content/uploads/2015/02/MPU-6000-Datasheet1.pdf	~0.9 g [103]	US$ 0.7 - 1 Per Piece MOQ: 1 Pieces [104]
SHT31	"Humidity and temperature sensor powered by the voltage from 3 V to 5.0 V with I2C interface. The measurement of temperature is from -40 °C to 125 °C, humidity from 0 to 100 % RH." [105] Dimensions: 18mm x 25mm x 5mm Datasheet: https://mm.digikey.com/Volume0/opasdata/d220001/medias/docus/1067/HT_DS_SHT3x_DIS.pdf	~0.8 g [105]	US$ 0.76 - 0.8 / 1 Piece MOQ: 100 Pieces [106]
ESP32	"Tile ESP32-DevKitC with a built-in module ESP-WROOM-32. The module has leads in the form of goldpins, pitch 2.54 mm. The system from the family ESP32 for communication in a wi-fi network in the 2.4 GHz band and in the Bluetooth standard BLE / v4.2." [107] Dimensions: 55mm x 28mm x 8mm	~10g [107]	US$ 2.5 - 2.8 Per Piece MOQ: 1 Pieces [108]

	Datasheet: http://espressif.com/sites/default/files/documentation/esp32_datasheet_en.pdf		
Battery	"Lithium-ion polymer (also known as 'lipo' or 'lipoly') batteries are thin, light, and powerful. The output ranges from 4.2V when completely charged to 3.7V." [109] Dimensions: 50mm x 60mm x 7.3mm Product Page: https://www.adafruit.com/product/328	~50g [109]	CAD$ 14.95 Per Piece [109]
Totals		~1334.05825766 g	~CAD$36.227

Appendix K.2: Objectives Met

The table below, table K.2.1, goes into greater detail about how SomniCloud Pillow satisfies the objectives.

Table K.2.1. Greater detail on device's satisfaction of objectives.

Optimize detection of sleep anomalies	Pressure/temperature sensitive sensor sheet captures physiological data in real time.
Maximize accuracy of physiological measurements	Embedded sensors track temperature and movement: **FSR 406:** Captures areas where the user's head is located on the pillow. **MPU-6050:** Captures movement of user's with 3-axis accelerometer. **SHT31:** Captures the temperature of the pillow due to the user's head and movements.
Consistently align collected data and user's perception (SATEDR)	The mobile app visualizes sleep states with simple and intuitive cloud shaped icons. The user's self perception should be a positive correlation to the physiological data collected to indicate good quality sleep. Users are prompted to fill out a questionnaire in the app. The questionnaire consist of 5 prompts [110]: 1. Satisfaction: Are you satisfied with your Sleep?

	2. Alertness: Do you stay awake all day without dozing? 3. Timing: Are you asleep between 2am – 4am? 4. Efficiency: Do you spend less than 30 minutes awake at night? 5. Duration: Do you sleep between 6 and 8 hours per day? **this needs to be cited** The user will be asked to rank each category with a score from 0-2. Where a ranking of: 0 represents No 1 represents Somewhat 2 represents Yes Maximum Score: 10 — indicating a very positive perception of sleep quality Minimum Score: 0 — indicating a very negative perception of sleep quality The questionnaire data is compared to the physiological data to see if there are any inconsistencies between self-perception and data collected. - i.e: User's self perceived quality of sleep is 10 (calculated from SATED questionnaire), however, the physiological data shows that the user's sleep cycle is erratic with multiple cycles of movement and elevated temperature.
Ensure continuous usage time	Low-power wireless connectivity, overcharge protection and removable sensors sheet support long-term useability. The pillow will only need to be powered on once, and recharged when the battery is depleted.
Minimize cost	Standard memory foam/latex pillows with a simple sensor layout balance performance and affordability. Total Cost of Materials (calculated in Appendix K1): CAD$ 36.227

Appendix K.3: Functions Met

The table below, table K.3.1, provides greater detail about how SomniCloud Pillow satisfies the objectives.

Table K.3.1. Greater detail on device's satisfaction of secondary functions.

Measures sleep parameters	Captures movements and temperature in real time. Additional Information: The SomnoCloud pillow uses a thin removable sensor sheet that detects

	movements and temperature. It is designed to be cost-effective while maintaining reasonable accuracy. While extremely accurate physiological data collection requires expensive skin contacting sensors – the sensors chosen balance affordability and functionality by detecting macro movements, temperature variations, and sleep stillness to infer the quality of sleep.
Stores sleep Data	Data is transmitted and stored in the companion mobile application. Additional Information: The app will securely store sleep data, and allow for historical tracking that let users view trends over time.
Interprets trends in sleep	App visualizes sleep states using cloud-shaped emojis. Additional Information: Visual Cues on top of other numerical indicators allow the user to intuitively interpret sleep quality. Users receive trend insights, showing fluctuations in their sleep patterns over days, weeks, and months.
Provides users with system assistance	The physical user manual will be included with all units of SomniCloud with setup instructions, care guidelines, and troubleshooting steps. Additionally, a digital manual is available on the companion mobile app – allowing user to access, for example, FAQs pages, video guides, and support resources.
Displays trends in sleep data	Real-time tracking enables detection of unusual sleep behaviours, notifying users when there is a significant deviation to norm. Additional Information: Users will receive notification when significant variations occurs, for example: - Long wake periods - Temperature irregularities - Restless movement
Informs about anomalies	Historically stored data in app allows users to monitor progress and recognize improvements or concerns Additional Information: Anomaly detection compares current physiological data with the past to identify potential sleep disruptions. See Appendix N for more information on the type of algorithm used.

Appendix L: Alternative Design Description #3

This appendix outlines the relevant details regarding the alternative design specifications #2 (AirFlow Guard).

Appendix L.1: Primary Design Components

Below, in table L.1.1., a list of all the primary components required for the AirFlow Guard as well as their purpose, dimensions, cost, and weight can be found.

Table L.1.1: A list of all the primary components required for the AirFlow Guard.

Used in	**Name**	**Purpose and Dimensions (cm)**	**Cost per Piece ($)**	**Weight each (g)**
Chest Pressure Sensor	80AA Strain Gauge	Measures chest expansion and contraction. 20.0 x 5.0 x 10.0	1.99 [111]	50
Airflow Sensor	Thermistor	Measures temperature change in breath intake and outtake. 15 x 10 x 5	0.60 [112]	200
Microcontroller	ESP32	Controls the system. 5.1 x 2.7	3.00 [113]	40
Battery	LiFePO4 Battery*	Powers the system. 0.3 x 2.5 x 6.2	1.40 [114]	10
Strap	Chest Strap	Holds the components on the patient's chest. 30 x 30	2.02 [115]	450
Total			9.01	750

Note: The LiFePO4 battery was chosen as they do not often heat to unsafe levels, increasing the safety of our product. [116]

Appendix L.2: Secondary Design Components

Below, in table L.2.1, a list of all the secondary components required for the AirFlow Guard as well as their purpose, dimensions, cost, and weight can be found.

Table L.2.1: A list of all the secondary components required for the AirFlow Guard.

Used in	**Name**	**Purpose and Dimensions (cm)**	**Cost per Piece ($)**	**Weight each (g)**
Charging Module	TP4056	Supports the charging of the module. 3 x 2 x 1	0.17 [117]	100 [117]
Low-Dropout Regulator	Low-Dropout Regulator	Regulates voltage from battery to the microcontroller. 0.01 x 0.1 x 0.1	0.72 [118]	1 [118]
Total			0.89	101

Appendix L.3: Questionnaire Emailed to User

The following figure shows an example of the questionnaire that can be sent to user's every morning to get self-reported information regarding the quality of their sleep. This follows the SATEDR framework, as recommended by our client. (Appendix G.2)

Please answer the following questions on a scale from 1-5, with 1 representing "No", and 5 representing "Yes".

How satisfied with your sleep?

○ 1 ○ 2 ○ 3 ○ 4 ○ 5

Did you feel well alert when you woke up?

○ 1 ○ 2 ○ 3 ○ 4 ○ 5

Did you sleep and wake up at the same time as last night?

○ 1 ○ 2 ○ 3 ○ 4 ○ 5

Did you struggle to fall asleep last night?

○ 1 ○ 2 ○ 3 ○ 4 ○ 5

Do you feel like you are getting enough sleep to address your needs?

○ 1 ○ 2 ○ 3 ○ 4 ○ 5

Figure L.3.1. The questionnaire that is emailed to the user every morning.

Appendix L.4: Example of Warning Email

The figure below shows an example of an email that will be sent to the user if a sleep anomaly is detected after three days of continuous use.

[AirFlow Guard] - Sleep Anomalies Detected
To:

Dear User,

We wanted to bring to your attention a sleep anomaly detected by our system, based on your last three night's sleep: irregular breathing pattern. This can sometimes be indicative of a sleep apnea condition.

If you have been feeling more tired recently or wish to learn more about what these results mean, we encourage you to consult with a healthcare professional for further guidance.

Best,
Your AirFlow Guard

Figure L.4.1. An email warning the user of a detected sleep anomaly.

Appendix M: Proposed Conceptual Design Specifications

A Pugh chart, shown in Table M.1, was used to compare each design's satisfaction of the objectives, with the team discussing together about the designs' comparison to Smart-Slumber PJs.

Table M.1. Pugh Chart

Objectives	Smart-Slumber PJs	SomniCloud Pillow	Airflow Guard
Optimize detection of sleep anomalies	S	0	0
Maximize accuracy of physiological measurements	S	-1	-1
Consistently align collected data and user's perception (SATEDR)	S	-1	0
Ensure continuous usage time	S	1	-1
Minimize cost	S	1	1
SUM	0	0	-1

Appendix N: Measures of Success

This appendix outlines our plan to test the efficacy and quality of our product.

This appendix outlines the exact datasets that will be used in our tests, the definitions of the Hidden Markov model, the equations needed to compute key values for the Bland-Altman analysis, and how to interpret and plot a Bland-Altman plot.

Appendix N.1: Datasets to be used

Below are the datasets that will be imputed into the team's algorithm, as well as the commercially available program.

Heart rate, temperature, oxygen saturation, and sleep movement, are all covered databases [121] and [122].

Appendix N.2: Computing Key Values [119]

The key values in the Bland-Altman analysis require calculating Mean, Difference, Mean Difference, Standard Deviation, and the Limits of Agreement. Thus, below are the exact equations for each value.

Mean Measurement:

$$M_i = \frac{A_i + B_i}{2}$$

Difference Between Methods:

$$D_i = B_i - A_i$$

Mean Difference (bias):

$$Bias = \frac{\Sigma D_i}{N}$$

Standard Deviation:

$$SD = \sqrt{\frac{\Sigma (D_i - Bias)^2}{N - 1}}$$

Limits of Agreement:

$$Bias \pm 1.96 \times SD$$

Appendix N3: Definitions for Hidden Markov Model [120]

The Hidden Markov model is used to develop the team's python program. All the definitions within the model are listed below.

Hidden Markov Model:
A probabilistic model that includes both observed events and hidden states that influence the observations.

Hidden State(s):
Sleep quality is not directly observable, but inferred from physiological data

Observations:
Heart Rate, Blood Oxygen, Body Temperature, Movement where change is detectable

Markov Assumption:
Only the current state matters, the past states have no direct influence

Transition Matrix (A):
Probability of moving from one sleep stage to another.

Emission Matrix (B):
Probability of observing a physiological signal given a sleep stage.

Unexpected Transitions:
Refer to changes between hidden states that are highly unlikely based on the model's learned transition probabilities

Low Probability Observations:
Occur when the observed data (e.g., heart rate, oxygen level) is highly unlikely given the current hidden state, suggesting the data doesn't fit the expected pattern

Appendix N4: Interpreting the Data [119][120]

Procedure of how to plot and interpret a Bland-Altman plot are stated below, including any special considerations and outliers.

Creating a Bland-Altman Plot:
1. X-axis: Mean Measurement (refer to Appendix N2 for calculation)
2. Y-axis: Difference between methods (refer to Appendix N2 for calculation)

3. Other Horizontal Lines to be drawn at:
    - y = At the mean difference (bias).
    - y = At the upper and lower limits of agreement.
    - y = At zero (to check for systematic bias)

Interpretation:
- If all points are within the LOA range, your method is comparable to the commercial one.
- If many points fall outside the LOA, your method is unreliable.

Special Considerations:
- if Bias is close to zero | → Program is similar to the commercial method.
- if LOA is narrow | → Program's differences are small and consistent.
- if LOA is too wide | → Program is unreliable due to large variations.
- if Systematic bias present | → Program consistently over/underestimates.

In an ideal situation, the team is looking for results to align with all data points falling within the bounds of a *narrow* LOA, with a bias close to zero.

Appendix O: Attribution Table

Tutorial #: 128 Team #: 154

Assignment: Conceptual Design Specifications Date: March 23rd, 2025

Section	Student Names					
	Joao De C. Carvalho	Brian Bui	Jalilya Zhaxybayeva	Samantha Chan	Wenyi Wu	Thisha Sudhakaran
Executive Summary	WD, FP	FP	ET, FP	WD, MR, ET, FP	FP	FP
Introduction	FP	FP	ET, FP	ET, FP	WD, MR, RS11, FP	WD, MR, RS7, FP
Problem Statement	FP	FP	FP	ET, FP	WD, MR, FP	WD, MR, FP
Stakeholders	FP	ET, FP	FP	ET, FP	WD, MR, FP	WD, MR, FP
Physical Environment	WD, MR, RS1, FP	FP	FP	WD, MR, RS8, ET	FP	FP
Virtual Environment	WD, MR, RS2, FP	FP	FP	FP	FP	FP
Functions	OR1, FP	ET, FP	WD, MR, ET, FP	ET, FP	ET, FP	MR, FP
Objectives	RS3, FP	WD, ET, OR4, FP	WD, MR, ET, RS12,, FP	WD, RS9, RS10, MR, ET, FP	ET, FP	FP

Constraints	ET, FP	WD, MR, ET, RS5, FP	ET, FP	ET, FP	ET, FP	FP
Idea Generation	MR, ET, FP, OR6, AI1	ET, FP	ET, FP	ET, FP	WD, ET, FP	ET, FP
Idea Selection	MR, ET, FP, OR7	ET, FP	WD, MR, ET, FP	MR, ET, FP	ET, FP	ET, FP
Alternative Design #1	FP, OR8	ET, FP	ET, FP, OR18	RS13, WD, MR, ET, FP	ET, FP, OR13	ET, FP
Alternative Design #2	FP	WD, MR, ET, RS15, FP	ET, FP, OR19	ET, FP	ET, FP, OR14	ET, FP
Alternative Design #3	FP	ET, FP	ET, FP, OR20	ET, FP	ET, FP, OR15	WD, MR, ET, FP
Proposed conceptual design	FP, OR9	FP	FP	WD, MR, ET, FP	ET, FP, OR16	ET, FP
Measures of Success	FP, OR17	WD, MR, ET, RS16, FP	FP	RS14, WD, MR, ET, FP	ET, FP	ET, FP
Conclusions	FP	FP	FP	ET, FP	ET, FP	WD, MR, ET, FP
Appendices	WD, ET, FP, MR, RS4, OR2, OR3, OR10, OR11, OR12	WD, MR, ET, RS6, FP	WD, MR, ET, FP, OR5	WD, MR, ET, FP, OR21	WD, OR2, ET, FP	WD, MR, ET, FP

Fill in abbreviations for the tasks you completed for each section of the report using the abbreviations below. You do not have to fill in every cell in the table.

RS – Research (give details below)

WD – Wrote Draft

MR – Major Revision

ET – Edited

FP – Final Proofread of COMPLETE DOCUMENT verifying for flow and consistency

AI – Used Generative AI (give details below)

OR – Other (give details below)

If you put RS (research) please add a number identifier such as RS1, RS2, etc. Give the research question below. Note: you are not limited to two research questions, add the correct number of entries below to capture your team's work.

RS1: Question: What are the data ranges of the scoped physical environment?
- Conducted research into temperature, humidity and noise level ranges in the greater Toronto area (GTA)

RS2: Question: What are the internet speed ranges available to the user in the scoped environment?
- Conducted research on the internet speed index in Canada, Ontario and Toronto.

RS3: Question: How can the end user price of the design affect the motivation to use it?
- Conducted research on economic theory and the demand curve, on how price levels affect consumption.

RS4: Question: What is a low cost price range for sleep tracking devices?
- Conducted research on market available low cost sleep tracking devices based on their performance compared to industry standard designs.

RS5: Question: What are the relevant laws, bylaws, legislature, and standards pertaining to a potential physical design in Canada for a sleep tracking system?
- Conducted research into Canadian Law and Standards regarding medical devices, product safety and design standards catered towards retired individuals.

RS6: Question: What are some other constraints that will impact the project if the design decides to incorporate digital and electrical components?
- Conducted research into Canadian Electrical Code and Personal Health Information Protection Act for the possible restrictions on design solutions that incorporate digital data and/or electrical components carrying live current.

RS7: Question: How many Canadians retire every year?

RS8: Question: What is the average bedroom dimensions and layout in elderly homes?
- Standards based on research
- Legislations for retirement homes

RS9: Question: Why is accuracy and early sleep detection necessary for the health of users?

RS10: Question: What helps improve the user's perception and willingness to use the design?

RS11 Question: What is the prevalence of sleep disorders among adults aged 65-75 compared to those with healthy sleep patterns?

RS12 Question: What is the accuracy of most modern devices compared to polysomnography in two-stage sleep classification?

RS13 Question: What components, and their price and weight is needed for the design?

RS14 Question: What existing databases and analysis methods can be used for the chosen objective?

RS15 Question: What are components that are necessary for the alternative design and their cost?

RS16 Question: The team decided to model the system with a python program. What mathematical model could adequately test the design to ensure it succeeds?

Some examples include: conducting site visits, identifying and reviewing articles for information, meeting with a librarian for help, etc.

If you put AI (used Generative AI) please add a number identifier such as AI1, AI2, etc. Explain how you used Generative AI in the section or document. Note: you are not limited to two AI usages, add the correct number of entries below to capture your team's work.

AI1: Used Microsoft Copilot to combine the solutions from the Morphological chart into unique ideas. To do so, we provided Copilot with the table and the prompt "can you make 60 unique combinations of this table, where one combination takes one option from each row and combines it into a paragraph without rewording it in any way, then download it into a txt file for me"

Some examples include: generating a draft for you to review, idea generation, editing a section you drafted, etc.

If you put OR (other) please add a number identifier such as OR1, OR2, etc. Explain what you did below. Note: you are not limited to 'other' types of work, add the correct number of entries below to capture your team's work.

OR1: Primary and secondary functions chart

OR2: Stakeholder ranking graph

OR3: Function identification chart

OR4: Pairwise Comparison to rank objectives

OR5: Functional Basis Diagram

OR6: Ideas generated chart

OR7: Ideas selection process chart

OR8: Algorithm methodology chart

OR9: CAD Model and render for Proposed conceptual design and evaluation process chart

OR10: Idea Generation Examples charts

OR11: Feasibility criteria chart

OR12: Alternative design #1 part functionality and usage guidelines charts

OR13 Alternate design #1 Orthographic Drawing

OR14 Alternate design #2 Orthographic Drawing

OR15 Alternate design #3 Orthographic Drawing

OR16 Finding online 3D models for the final CAD model

OR17 Measures of success process chart

OR18 Alternative Design #1 Isometric Drawings (Boxes + Mat)

OR19 Alternative Design #2 Isometric Drawings (Pillow + App)

OR20 Alternative Design #3 Isometric Drawing

OR21 Alternative Design #1 Appendices Electrical Schematics

OR covers any work you did to develop the document that is not described by writing, editing, and/or researching. Some examples include: developing figures or diagrams to support multimodality, organizing references, meeting with your CI for guidance (out of tutorial), etc.

By typing your name below to sign, you verify that you have:

- Read the attribution table and agree that it accurately reflects your contribution to the associated document.
- Written the sections of the document attributed to you as WD and that they are either entirely original, or you have included appropriate acknowledgement of AI usage.
- Accurately cited and referenced any ideas or expressions of ideas taken from other sources according to the standard specified by this course.
- Read the University of Toronto Code of Behaviour on Academic Matters and understand the definition of academic offense includes (but is not limited to) all forms of plagiarism. Additionally, you understand that if you provide another student with any part of your own or your team's work, for whatever reason, and the student having received the work uses it for the purposes of committing an academic offence, then you are considered an equal party in the offence and will be subject to academic sanctions.

Student #1 Name Joao De Campos Carvalho

Student #2 Name Brian Bui

Student #3 Name Jalilya Zhaxybayeva

Student #4 Name Samantha Chan

Student #5 Name Wenyi Wu

Student #6 Name Thisha Sudhakaran