

Life as a Designer: Practice-Based Development of a Lumen Smart Backpack Creative Design

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Abstract

Connected everyday products may improve convenience while simultaneously introducing weight, privacy risk, repair barriers and premature technological obsolescence. This conceptual practice-based investigation examines how a smart backpack can reduce physical and cognitive friction in mobile work without making its primary carrying function dependent on electronics, software or cloud services. A purposive literature synthesis and an adapted Double Diamond process were employed to construct provisional use contexts, derive design requirements, compare three product architectures and define a staged verification framework. The resulting LumenPack proposition separates the textile shell, service cassette and removable power module and evaluates connected features through five “graceful intelligence” criteria: passive usability, legible failure, local control, repair access and data minimization. The study contributes a traceable conceptual framework linking literature-informed concerns to design requirements, architecture decisions, verification methods and claim limits. No research involving participants, manufactured prototype or certified performance is reported; these remain future validation activities.

Keywords

Industrial Design, Smart Backpack, Human-Centred Design, Modular Product, Circular Design

1. Introduction

Design is so deeply embedded in everyday routines that the work behind it is often invisible. A commuter reaches for a transit card without looking; a student adjusts a shoulder strap while walking; a traveller removes a power bank before a security check. These actions are encounters with decisions made earlier about dimensions, access, material, interface and service. The backpack is consequently not

merely a container. It is a wearable interface between the body and the material world, and increasingly a platform for sensing, charging and communication.

The phrase life as a designer can be understood in two connected ways. It refers first to the professional activity of observing, framing, sketching, prototyping, negotiating and documenting. It also refers to the life that design enables or constrains. Products organize routines and distribute agency: they make some actions simple and others difficult; they determine what can be repaired, what information is collected and what remains useful after a company stops reinforcing it. Design research has long argued that designers use constructive representations to generate knowledge instead of merely illustrating decisions already made (Cross, 1982: pp. 221-227). Framing is consequently part of the outcome because the selected frame determines which needs, actors, and solutions receive attention (Dorst, 2011: pp. 521-532).

This responsibility is especially apparent in problems that are difficult to define completely. Buchanan describes design problems as wicked because their boundaries and acceptable solutions depend on competing values and changing stakeholder relationships (Buchanan, 1992: pp. 5-21). A smart backpack is a compact example. It can be approached as a fashion object, ergonomic carrying system, electronics enclosure, mobile interface, security product or circular product-service system. Each description creates a different brief. The question “How can more technology be added to a backpack?” encourages feature accumulation. The question adopted in this study is narrower and more demanding: How can a backpack reduce the physical and cognitive friction of mobile work while remaining dependable when technology is absent, unavailable or obsolete?

Ergonomic performance provides an essential foundation for backpack design. Load magnitude, duration, terrain, carrying position and body characteristics influence physiological demand and discomfort, while the placement of mass close to the body can reduce unnecessary movement (Knapik et al., 1996: pp. 207-216). Experimental work also indicates that loaded carriage can affect shoulder tissue conditions, reinforcing the need to examine strap width, edge pressure, curvature and foam behaviour instead of relying on visual impressions of padding (Mao et al., 2015: pp. 80-84). Modified backpack studies further indicate that harness and load-transfer decisions should be tested as systems instead of isolated details (Ramadan & Al-Shayea, 2013: pp. 462-471). These findings do not establish one universal geometry. They establish the need for fit ranges, prototypes and cautious claims.

Connectivity introduces a separate set of design risks. A battery contributes mass, heat, transport constraints and a shorter replacement cycle than the textile shell. A nearby-finding function can reduce anxiety, but persistent location history can create surveillance and ownership-transfer problems. Recent IoT privacy scholarship emphasizes that data minimization, privacy-aware requirements and explicit user control should be incorporated during product development instead of added after implementation (Kühntreiber et al., 2022; Coiduras-Sanagustín et al., 2024). A motorized lock can appear secure while creating failure modes that pre-

vent legitimate access. A permanently embedded electronics assembly can turn a serviceable bag into electronic waste. Research on modular products and reparability indicates that modular architecture, accessible service information and repair-oriented design can reinforce longer product use (Amend et al., 2022; Roskladka et al., 2025). Circular product strategies emphasize extending product life, enabling repair and maintaining material value across repeated use cycles (Bocken et al., 2016; Mesa, 2023). For the smart backpack, this implies that long-lived textile components must not be inseparably femployed to shorter-lived energy and communication modules.

Responsible design practice also depends on participation and epistemic humility. Co-creation literature challenges the assumption that designers can substitute their own empathy for the situated knowledge of users (Sanders & Stappers, 2008: pp. 5-18). A commuter in a crowded train, a traveller managing batteries, a person with limited dexterity and a repair technician each understand different failure points. Because the present manuscript does not report participant research, these perspectives are employed to formulate questions and verification tasks instead of being presented as empirical findings.

External representations are central to reflective design practice. A sketch can expose spatial conflict; a foam model can reveal pressure or reach problems; a service blueprint can show where ownership transfer fails; and a decision matrix can make disagreement visible. These artefacts are not neutral records. Their level of detail and apparent certainty influence which proposals receive investment. For that reason, the present study labels the status of each claim. Literature reinforces the problem frame, while the product priorities, concept scores and verification thresholds remain provisional design judgements. This distinction is necessary because a convincing rendering can easily be mistaken for evidence of manufacturability, safety or user value.

This article examines LumenPack, a hypothetical 24-litre modular smart backpack, as a practice-based case. Rather than presenting a finished invention, the case is intended to make the underlying design reasoning open to inspection. Three contributions are proposed. First, the article describes the designer's work as reflective and relational instead of as late-stage styling. Second, it integrates physical, digital and lifecycle requirements into a restrained product architecture. Third, it distinguishes design findings from evidence still required through a staged verification plan. The following sections present the method, the resulting design decisions and the implications for responsible smart-product development.

The term LumenPack combines lumen, a term associated with light and legibility, with pack, the product's primary carrying identity. The name is intended to express the design aim of making status, access and failure understandable without turning the backpack into a visually technology-dominant object. It is a concept name for this study, not evidence of a registered commercial brand.

Research Question and Analytical Framework

The investigation is organized around one central question: How can a modular

everyday backpack integrate only those connected functions that are justified by literature-informed carrying, privacy, repair and lifecycle requirements while preserving usefulness when digital functions fail or become obsolete? The argument proceeds through a traceability chain: literature and constructed use contexts → provisional needs and risks → design principles and requirements → alternative architectures → concept selection → graceful-intelligence review → verification methods and claim limits. The LumenPack proposition is evaluated against this chain instead of against market novelty or an assumption that connectivity is inherently desirable.

2. Background and Literature Review

The reviewed literature identifies four interdependent design challenges for a connected backpack: biomechanical carrying performance, digital privacy and control, repairable product architecture, and lifecycle stewardship. These domains cannot be optimized independently. A lighter textile structure may improve carrying comfort but provide less protection for electronics; a larger battery may increase convenience but adds mass and is a shorter-lived component; a highly integrated enclosure may look visually resolved but impede cleaning, disassembly and repair. The relevant research problem is consequently architectural: deciding which functions belong in the durable physical product, which belong in removable technical modules, and which should remain optional services.

2.1. Ergonomics and Carrying Performance

Research on backpack use consistently identifies load magnitude, load position, harness geometry and exposure duration as interacting determinants of physiological demand and discomfort. Knapik et al. (1996) synthesize physiological, biomechanical and medical effects of load carriage; Mao et al. (2015) show that shoulder-interface conditions are relevant to tissue response; and Ramadan and Al-Shayea (2013) demonstrate that backpack modifications should be assessed as integrated carrying systems. For LumenPack, this literature reinforces broad and soft strap-contact zones, avoidance of rigid electronics in pressure-bearing areas, load stabilization near the body and explicit future fit/pressure testing. It does not justify claims of posture correction or universally safe loads.

2.2. Privacy-by-Design and Connected-Product Governance

Research on IoT products indicates that privacy is not adequately addressed by a privacy policy added after technical development. Kühtreiber et al. (2022) identify the need for development reinforce for privacy-preserving IoT systems, while Coiduras-Sanagustín et al. (2024) synthesize recent product-design perspectives on personal-data privacy and emphasize human-centred approaches to data protection. These findings reinforce local-first operation, data minimization, explicit opt-in for remote transmission, a physical ownership-reset mechanism and exclusion of continuous precise location history from the base concept.

2.3. Repairability, Modularity and Circularity

Recent work on repairability reinforces the rationale for separating components whose failure rates and technological lifetimes differ. Amend et al. (2022) report that modular product design and repair instructions can reinforce repair behaviour and user experience. Ruiz-Pastor and Mesa (2023) treat repairability as a measurable attribute that should be considered early in product design. Mesa (2023) integrates circularity and durability through DFX guidance, and Roskladka et al. (2025) systematize design-for-repair features, practices and measures for electronic products. Together these studies reinforce non-destructive access, replaceable high-wear parts, identifiable modules, service documentation, upgrade paths and avoidance of permanently embedding short-lived electronics into a longer-lived textile shell.

2.4. Smart-Backpack and Product-Service Context

Previous smart-backpack research has framed design as a multi-criteria feature-selection problem (Lin & Chen, 2020). The present study extends that framing by treating privacy, graceful failure, service reinforce and component retirement as design criteria instead of secondary implementation issues. The product is consequently interpreted as a product-service system: value depends not only on the bag at purchase but also on replacement parts, software reinforce, ownership transfer, repair documentation and end-of-service behaviour.

2.5. Literature Gap and Contribution

Existing research provides substantial insight on ergonomics, IoT privacy, modularity and circular design, but they are commonly discussed separately. The specific gap addressed here is the lack of a compact, traceable conceptual framework for deciding when and how connected functions should be integrated into a soft-goods carrying product whose textile, electronic and energy components have different lifecycles. LumenPack is employed as a design case to connect literature-derived concerns to requirements, architecture, concept selection, graceful-intelligence criteria, verification methods and explicit claim limits.

3. Materials and Methods

3.1. Ethics and Reproducibility

The study used no human participants, animals, or personal datasets. Reproducibility is reinforced by publishing the decision criteria, weights, scores, design requirements, evidence status and proposed verification methods. Future empirical testing must obtain relevant ethics approval before participant recruitment.

3.2. Data Analysis

No participant dataset was generated in this study. Accordingly, quantitative analysis is restricted to transparent design-decision data: provisional 0 - 10 priority

markers and 1 - 5 ordinal concept scores. Descriptive comparison, weighted scoring, rank ordering and contribution-by-criterion analysis are used only to expose the consequences of author assumptions. No inferential statistics, confidence intervals or claims of population validity are appropriate at this stage.

3.3. Graceful-Intelligence Analysis

Each retained digital function was screened against five gates: passive usability, legible failure, local control, repair access and data minimization. A feature failing a gate was removed, redesigned or retained only as a future exploratory option with an explicit justification.

3.4. Concept Generation and Decision Analysis

Three alternative architectures were developed: A, technology-heavy; B, modular connected; and C, passive/minimal. Six criteria were weighted to reflect the design brief: comfort 25%, usability 20%, security 15%, repairability 20%, aesthetics 10% and cost feasibility 10%. Each concept received an ordinal score from 1 (poor) to 5 (strong). Weighted totals were calculated as $\Sigma(\text{weight} \times \text{score})$. A sensitivity check was then employed to distinguish the mathematically highest score from the concept best aligned with the connected-product research question.

3.5. Requirement Derivation and Coding

Each retained source of evidence was converted into one or more design implications and coded under five domains: physical carrying, access/usability, connected interaction/privacy, service/repair, and lifecycle/governance. Requirements were classified as absolute, target or exploratory. Absolute requirements could not be traded away (for example, access without power); targets require later engineering evidence (for example, weather resistance); exploratory items remain hypotheses for participant research.

3.6. Literature-Search and Synthesis Procedure

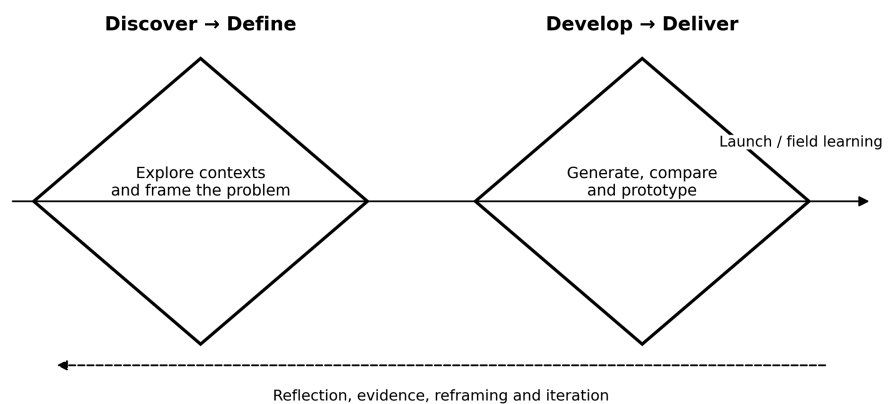
Relevant literature was identified purposively across design research, ergonomics, IoT/privacy, modularity, repairability and circular design. Search concepts included combinations of smart backpack, backpack ergonomics, load carriage, wearable electronics, Internet of Things privacy, privacy-by-design, modular product design, design for repair, repairability, circular design, product longevity and product-service systems. Foundational literature was retained where it defined enduring concepts; recent peer-reviewed studies were prioritized for privacy, repairability and electronic-product lifecycle issues. Sources were included when they directly informed a requirement, risk, architecture decision or verification question; purely promotional product claims were excluded as evidence. Because the review was purposive instead of systematic, no PRISMA completeness claim is made.

3.7. Research Design

The research adopts a conceptual, practice-based design. Its unit of analysis is the design architecture of a hypothetical 24-L everyday smart backpack. The research does not estimate population preferences; instead, it constructs an auditable chain from literature evidence to design propositions and future verification tasks.

A conceptual, practice-based design-research methodology was adopted. Practice-based design research can generate useful propositions when the assumptions, representations and decision criteria are sufficiently explicit for criticism and adaptation (Friedman, 2003: pp. 507-522). The method combines literature synthesis, context construction, requirement definition, concept comparison and verification planning. It does not replace empirical ergonomics, usability testing, certification or market research.

The design process was structured into four phases (Figure 1). Discovery examined carrying as an activity across commuting, study, mobile creative work, travel, low-light movement, separation from the bag, cleaning and repair. Definition translated these contexts into an ordered set of principles, claim boundaries and measurable requirements. Development generated three architectures and compared them against comfort, usability, security, repairability, aesthetics and cost feasibility. Delivery specified the tests and organizational evidence needed before manufacture and public claims. The process is recursive: a failed prototype, a reinforced problem or a new regulation can reopen the original problem frame. The four phases, their primary questions, key activities and expected outputs are summarized in Table 1.



Note. Adapted by the authors for this conceptual study from the Design Council's Double Diamond framework, launched in 2004. The return arrow indicates that verification and field evidence can reframe the original problem (Design Council, 2004).

Figure 1. Reflective Double Diamond framework for the conceptual design process.

The review followed a purposive instead of systematic synthesis strategy and was employed for requirement derivation, not for estimating population preferences. Sources were retained when they met three criteria: 1) direct relevance to one of the study domains—backpack ergonomics, connected-product privacy,

modularity, repairability, circularity/product longevity, product-service systems or design methodology; 2) peer-reviewed academic credibility, except for the Design Council source employed to document the provenance of the Double Diamond; and 3) capacity to inform a concrete design requirement, principle, risk or verification question. Established sources were retained where foundational, while recent scholarship was added for rapidly changing connected-product and circular-design issues. Each retained source was mapped to a design implication: ergonomics literature informed load distribution and harness requirements; privacy research informed data minimization, local control, consent and ownership-transfer requirements; modularity and repair research informed separable modules, service access and documentation; circular-design literature informed durability, replacement and end-of-life requirements; and smart-backpack research was employed to contextualize feature-prioritization as a design-judgement problem. Commercial smart-backpack claims were treated only as design stimuli, not as validated evidence.

Design artefacts were employed as analytical devices. A user-priority chart prevented the word smart from dominating resource allocation. A weighted concept matrix made trade-offs visible. A modular architecture diagram exposed interfaces among the textile body, electronics, battery and software. A requirements table linked each intended benefit to a verification method and claim limit. The scores are provisional author judgements on a 0 - 10 or 1 - 5 scale; they are not survey statistics and should be revised after participant research.

Figures 1-11 are design-research artefacts employed in this conceptual study. **Figure 1** adapts the Design Council Double Diamond and is cited accordingly. **Figures 2-4** are author-generated analytical graphics. **Figures 5-9** are original conceptual sketches and renderings documenting design exploration, while **Figure 10** presents the stakeholder ecosystem. None of the conceptual product images represents a manufactured or performance-validated prototype.

The project scope was restricted to an adult everyday backpack with a nominal volume of approximately 24 litres and accommodation for common laptops up to a 16-inch class, subject to verification by actual device envelopes. Expedition, military, medical, child-specific and personal-protective uses were excluded. The electronics were limited to low-power sensing, local feedback, Bluetooth-class nearby communication and power routing. Continuous wide-area location and biometric access were excluded because they add substantial privacy, energy, service and reliability burdens.

Concepts were compared using a five-point ordinal scale. Criteria weights reflected the ordered design principles: comfort received the highest weight, followed by usability and repairability, then security, aesthetics and cost feasibility. The arithmetic does not transform judgement into objective truth. Its purpose is to show where the selection depends on values and to permit alternative weightings. Requirements were also classified as absolute, target or exploratory. Absolute requirements describe boundaries that cannot be traded away, targets require later

engineering evidence, and exploratory items remain hypotheses for participant research. This evidence-status system was carried through the tables and captions so that conceptual findings would not be confused with measured performance.

Explicit scope control was also built into the method. Questions that could not be answered credibly at the conceptual stage were converted into future tests instead of resolved through invented precision. Final material specifications, radio performance, battery chemistry, ingress resistance, manufacturing yield, unit cost and environmental impact remain outside the present evidence base. This limitation is methodologically important: practice-based inquiry is strongest when it creates a coherent, testable proposition and exposes uncertainty, not when it imitates the authority of a completed engineering programme. The manuscript consequently uses terms such as proposed, intended and target whenever empirical verification is still required.

The study did not conduct interviews, surveys, experiments, clinical procedures, animal studies, or analyses of retrospective personal data. All personas, scores, risks and numerical examples are author-generated design hypotheses. Ethics committee approval was consequently not required for this conceptual stage. Any future study involving participant observation, fit testing, usability evaluation or field trials must obtain the relevant approval before recruitment, document informed consent and apply appropriate data-protection procedures.

Table 1. Research and design phases.

Phase	Primary question	Key activities	Outputs
Discover	What matters in real carrying contexts?	Literature synthesis, context mapping, stakeholder and misuse analysis	Needs hierarchy and research questions
Define	Which problem should be solved?	Principles, claim boundaries, requirements and priorities	Design brief and verification criteria
Develop	Which architecture best balances the requirements?	Concept generation, weighted comparison and prototype planning	Selected modular architecture
Deliver	What evidence is needed before launch?	Bench tests, fit studies, field pilot and service planning	Verification dossier and claim limits

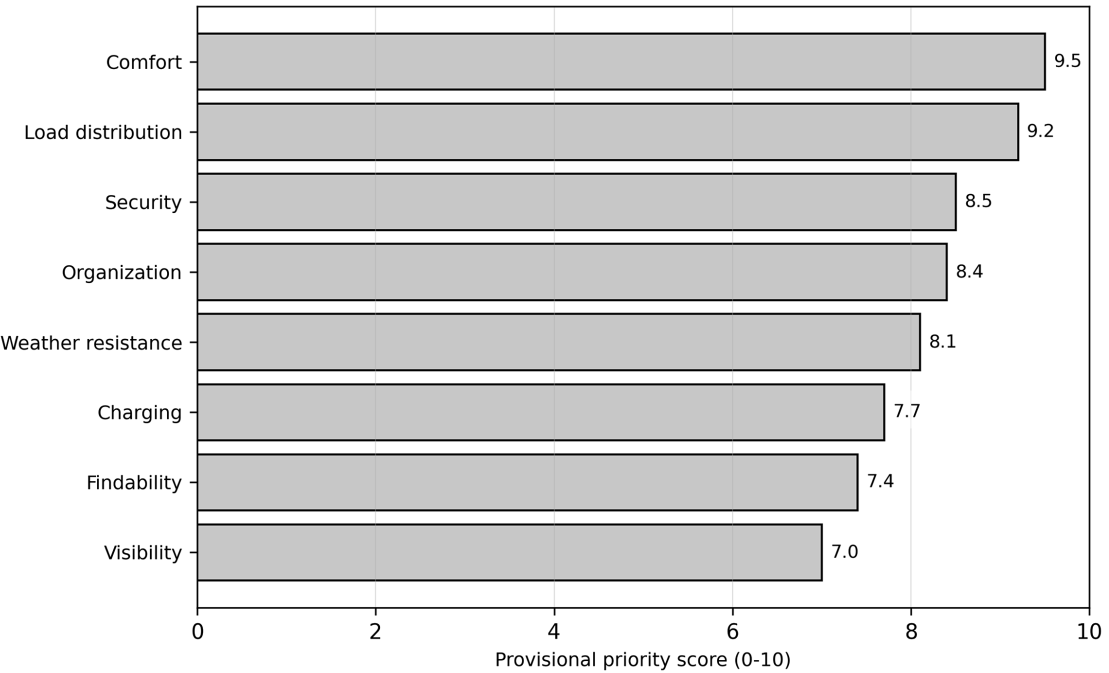
Note. The process is recursive. Evidence from any phase may trigger revision of an earlier decision.

4. Results

4.1. Framing, User Priorities and Design Principles

The literature synthesis and contextual review produced provisional design hypotheses that users may not seek isolated features. They seek more organization without losing flexible volume, more security without slower access, more visibility without an industrial appearance and more intelligence without surveillance. These tensions are more productive than a list of desired functions because they identify where synthesis is required. The provisional priority hierarchy places comfort and load distribution first, followed by security, organization and weather resistance (**Figure 2**). The ordering represents literature-derived design judge-

ment instead of measured user preference. Comfort and load distribution were prioritized because backpack ergonomics research identifies load carriage, pressure distribution and body interaction as primary determinants of carrying performance; security and organization were positioned next because they represent common functional tensions in mobile use. Charging and findability remain valuable, but they cannot override the primary carrying function.



Note. Scores are provisional author-generated priority markers, not survey results. Decimal values express only the relative ordering used for conceptual resource allocation; they do not imply measured precision. Table 2 traces each priority to its rationale and supporting literature/context.

Figure 2. Literature-informed hierarchy of design priorities.

Table 2. Literature-informed design priorities and supporting rationale.

Priority	Provisional score	Literature/context rationale
Comfort	9.5	Primary wearable-product requirement; load carriage and shoulder-interface research links pack design to discomfort and tissue loading (Knapik et al., 1996; Mao et al., 2015; Ramadan & Al-Shayea, 2013).
Load distribution	9.2	Closely coupled to carrying performance; mass placement, harness geometry and load transfer require ergonomic verification (Knapik et al., 1996; Ramadan & Al-Shayea, 2013).
Security	8.5	Important mobile-use friction, but treated as layered access control rather than an absolute “theft-proof” promise; connected security also creates privacy and failure risks (Kühtreiber et al., 2022; Coiduras-Sanagustín et al., 2024).
Organization	8.4	Supports predictable access while preserving flexible volume; treated as a constructed use-context requirement to be tested through observed packing/access tasks.

Continued

Weather resistance	8.1	Protects carried goods and electronics; retained as a target requiring defined spray testing rather than an unverified waterproof claim.
Charging	7.7	Potential convenience, but batteries add mass, service and lifecycle burdens; therefore subordinate to carrying and removability requirements (Mesa, 2023; Roskladka et al., 2025).
Findability	7.4	May reduce separation friction, but tracking creates privacy, consent and ownership-transfer risks; limited to optional, privacy-governed functions (Kühtreiber et al., 2022; Coiduras-Sanagustín et al., 2024).
Visibility	7.0	Useful in low-light constructed contexts, but auxiliary to core carrying performance and not a substitute for legally required safety equipment.

The resulting design brief was defined as follows: create a dependable everyday backpack that helps users carry, find, protect and maintain important belongings without making the bag dependent on a battery, account or cloud service. Six ordered principles govern the brief: carry well; remain legible; protect proportionately; connect selectively; fail gracefully; and age responsibly. The sequence of these principles is consequential. When an antenna location worsens shoulder pressure, carrying performance wins. When a seamless enclosure prevents non-destructive service, responsible ageing can outweigh surface purity.

These principles were operationalized as absolute requirements, performance targets and claim limits. Absolute requirements include manual access to every storage area without power, tool-free battery removal and a physical ownership-reset procedure. Targets include a competitive empty mass, stable laptop reinforce, everyday rain resistance, accessible high-wear parts and a declared software-reinforce period. Claim limits prevent the design team from using terms such as theft-proof, waterproof, posture-correcting, unlosable or lifetime without precise evidence. The acceptable language describes intended function and test conditions instead of promising universal outcomes.

Representative user profiles were employed as exploratory design prompts instead of as market evidence. A creative commuter raised questions about quick access and discreet organization. A frequent traveller emphasized battery removability, document access and under-seat handling. A student emphasized affordability and reconfigurable storage. A repair and resale specialist emphasized component identification, reset and non-destructive disassembly. The value of these provisional personas is measured by whether they change requirements and tests, not by how persuasive their biographies appear.

The resulting dimensional brief defines a product-family range instead of a single universal fit. The nominal volume is approximately 24 litres, but laptop compatibility should be defined through device envelopes instead of screen diagonal alone. Harness development should use at least two torso sizes or a validated adjustment system. Small stowable hip wings may assist longer carries, yet they should not create bulk during ordinary commuting. The load-guidance feature is

framed as an informational aid that can identify relative imbalance or unusual increases. It cannot diagnose posture, estimate injury risk or declare a universally safe load, because those outcomes depend on body size, duration, terrain, health and packing behaviour.

4.2. Data Analysis of the Conceptual Decision Model

The provisional priority hierarchy produces a mean score of 8.23/10 (range 7.0 - 9.5). The top two physical-carrying priorities—comfort and load distribution—average 9.35, whereas the three explicitly technology-associated priorities—charging, findability and visibility—average 7.37. The 1.98-point separation is not an empirical effect size; it is a transparent expression of the study’s design stance that technology must remain subordinate to primary carrying performance.

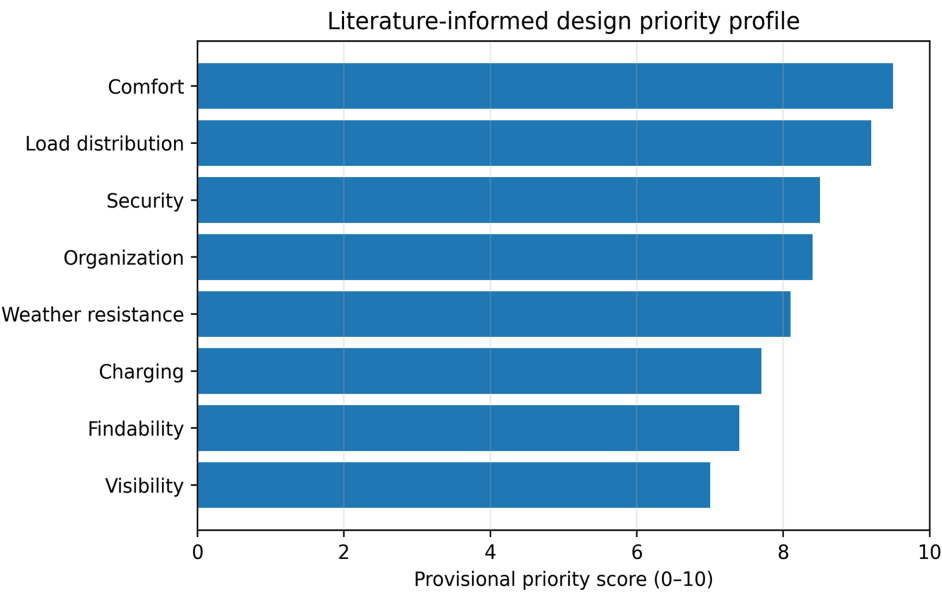


Figure 3. Literature-informed design-priority profile for conceptual resource allocation.

Figure 3 makes the hierarchy visually explicit and should be read as a design-decision profile rather than user-research data. The profile prevents connected features from receiving resources merely because they are technologically novel.

Recalculation of the reported matrix produces weighted totals of 2.40/5 for Concept A, 4.10/5 for Concept B and 4.40/5 for Concept C. Concept C is consequently the numerical leader under the base weights, while Concept B is the preferred connected architecture because it preserves the study’s explicitly required connected functions with substantially stronger repairability and graceful degradation than Concept A. This distinction is important: the decision is a constrained design choice, not an attempt to make the selected connected concept appear numerically dominant. The criterion-level contribution of each weighted score is reported in Table 3.

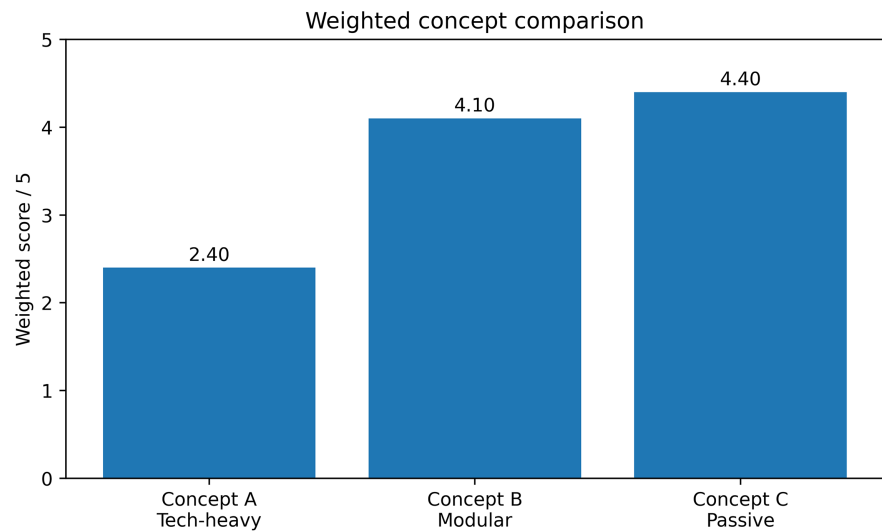


Figure 4. Weighted evaluation scores for the three conceptual architectures.

Table 3. Weighted-score decomposition for concept selection.

Criterion	Weight	A contribution	B contribution	C contribution
Comfort	25%	0.50	1.00	1.25
Usability	20%	0.60	0.80	0.80
Security	15%	0.60	0.60	0.45
Repairability	20%	0.20	1.00	1.00
Aesthetics	10%	0.30	0.40	0.40
Cost feasibility	10%	0.20	0.30	0.50
Total	100%	2.40	4.10	4.40

4.3. Concept Comparison and Modular Architecture

Technology was not assumed to be the starting point of the design. The literature-informed brief first established the physical, privacy, service and lifecycle requirements; connected functions were then retained only where they plausibly addressed a defined friction without violating higher-order requirements. Three architectures were compared to make this choice explicit. Concept A integrated a large battery, rigid shell, motorized lock and prominent interface. It offered high feature visibility but performed poorly in weight, service access and graceful degradation. Concept C used a strong passive backpack with only a removable tracker pocket. It performed well in cost, longevity and simplicity but provided limited local sensing and load feedback. Concept B separated the physical, electronic and energy layers while keeping local controls and optional software. The weighted matrix selected Concept B for the connected proposition because it offered the strongest balance among the specified requirements; Concept C remains a credible passive product-family variant. The complete criterion scores, weights and design interpretations for the three architectures are presented in **Table 4**.

Table 4. Weighted comparison of the three concept architectures.

Criterion (weight)	Concept A: tech-heavy	Concept B: modular	Concept C: passive	Interpretation
Comfort (25%)	2	4	5	Rigid integration penalizes A
Usability (20%)	3	4	4	B retains local control and optional software
Security (15%)	4	4	3	A appears strong but has lock-failure risk
Repairability (20%)	1	5	5	B and C preserve service access
Aesthetics (10%)	3	4	4	Quiet technology supports B
Cost feasibility (10%)	2	3	5	C is simplest; B remains feasible
Weighted score/5	2.35	4.15	4.45	B selected for connected range; C retained as passive variant

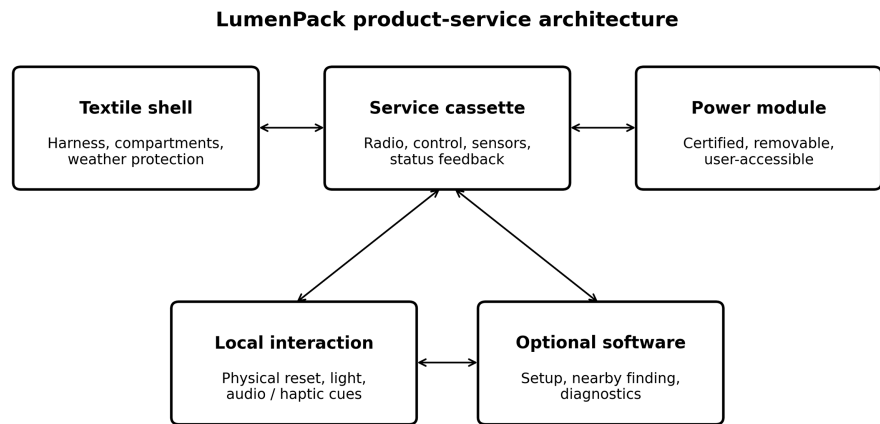
Note. Scores are analytical design judgements. The passive concept scores highest numerically on simplicity, but the modular concept is selected because the project brief requires restrained connected functions.

The chosen architecture is organized into three principal layers. The textile shell contains the harness, laptop zone, main volume, protected valuables zone, weather-management details and removable organizer panels. The service cassette contains the micro-controller, short-range radio, sensor interface and status controls. The power module is separately removable and should undergo appropriate third-party certification before any commercial release. The bag remains a complete passive product when both electronic modules are removed. This boundary reflects different expected lifecycles: textile, battery and communication hardware do not wear or become obsolete at the same rate.



Note. Conceptual visual design asset produced for this study. The images represent proposed form and feature relationships, not a manufactured or performance-validated prototype.

Figure 5. LumenPack conceptual sketch and annotated feature sheet: front, back, and side views.

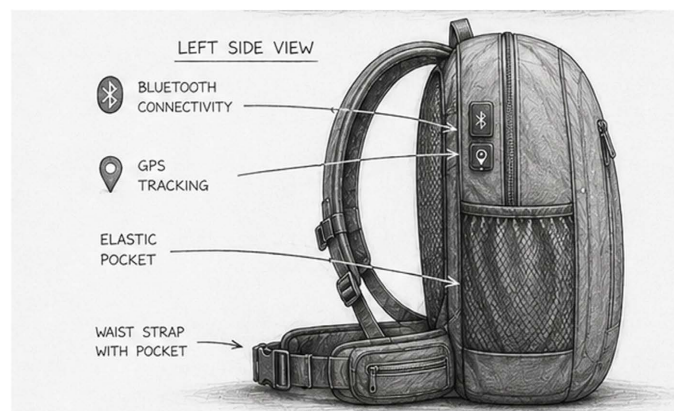


Primary carrying function remains usable when the electronics and battery are removed.

Note. The diagram is author-generated. Module boundaries correspond to different lifecycles, cleaning needs and service responsibilities.

Figure 6. Modular LumenPack product-service architecture.

The physical configuration deliberately avoids a technology-dominant appearance. A semi-rigid frame sheet stabilizes the laptop area and reinforces load transfer without producing a full hard shell. Shoulder straps use broad contact zones, curved geometry and soft edges. Electronics are excluded from direct strap-contact areas because rigid components can create local pressure and obstruct cleaning. The internal organization combines a stable laptop/document zone, an open central volume and low-profile attachment points for removable panels. Users can retain structure or remove the organizers to recover a conventional open bag. The visual design assets in **Figures 5-9** make the proposed form, harness, pocket arrangement and technology-control locations inspectable; they should be treated as conceptual renderings/mock-ups instead of evidence of manufacturability or ergonomic performance.



Note. Conceptual visual design asset produced for this study. The images represent proposed form and feature relationships, not a manufactured or performance-validated prototype.

Figure 7. LumenPack left-side conceptual rendering with proposed connectivity controls and side pocket.



Note. Conceptual visual design asset produced for this study. The images represent proposed form and feature relationships, not a manufactured or performance-validated prototype.

Figure 8. LumenPack conceptual back-view rendering.



Note. Conceptual visual design asset produced for this study. The images represent proposed form and feature relationships, not a manufactured or performance-validated prototype.

Figure 9. LumenPack conceptual front-view rendering.

Access and organization were evaluated as dynamic activities instead of as a simple count of compartments. Frequently used objects require predictable locations that can be reached without exposing the entire main volume, while irregular equipment requires flexible space. The proposed internal rail is deliberately mechanical and low profile. It can accept removable panels and pouches without be-

coming a proprietary electronic ecosystem. A light-coloured lining improves visual search and contamination inspection, while tactile differences between pulls reinforce use with limited visual attention. Side access is restricted to selected zones because every additional opening creates seam, water and security consequences. These decisions require observed packing and walking trials, since preferences stated in a questionnaire may not predict actual movement or reach.

Security is structured through differentiated access zones instead of a single anti-theft proposition. A back-adjacent valuables pocket is protected while the backpack is worn. Main zipper ends can be covered and joined with a conventional lock. Frequently used pockets remain deliberately accessible and are not marketed as high-security storage. An optional opening sensor can provide a local or phone alert, but the user can disable it, and the mechanism never physically traps contents. This arrangement places passive geometry before electronics and avoids treating a notification as proof of protection.

Visibility follows the same layered logic. Passive retroreflective piping can remain visually quiet in daylight while responding to external light at night. Optional low-power rear-facing light guides can add conspicuity, but they are auxiliary and cannot be presented as a replacement for legally required bicycle lighting or user attention. Technology is consequently expressed through subtle cues and service logic instead of a gadget-like exterior.

Energy planning applies the same principle of proportionality. The base electronics should spend most of their time in low-power states and should not assume that the backpack is a general-purpose charging station. Device charging is provided through the removable power module instead of a permanently sewn battery. The module pocket should be inspectable, protected from crushing and accessible without opening the clothing compartment. The bag should remain washable after the electronic layers are removed. These requirements increase connector and enclosure complexity, but they reinforce travel, battery replacement, thermal inspection and end-of-life separation. A higher-capacity module should be offered only when the added weight and transport implications are stated clearly.

4.4. Interaction, Privacy, Repair and Product Longevity

The interaction strategy prioritizes local comprehensibility. Essential status is communicated through a small physical control and restrained light, sound or haptic patterns. Basic actions—checking power, disabling alerts, resetting ownership and accessing contents—do not require an application. Optional software reinforces setup, nearby finding, diagnostics and firmware updates. This separation limits the damage caused by operating-system changes, account loss or service termination. This directly operationalizes passive usability, legible failure and local control.

Findability is approached conservatively. A temporary short-range connection can reinforce a separation reminder, but radio interruption is common in crowded environments. The interface must distinguish connection loss from confirmed aban-

donment and permit adjustable delay or suppression. Any wider crowd-assisted service would require explicit opt-in, rotating identifiers, anti-stalking measures and clear retention rules. Continuous precise location history is outside the base concept. The design principle is data minimization: collect only what is necessary for the selected function and keep basic use available without an account. These constraints operationalize local control and data minimization.

Privacy-governance requirement. The optional software layer is limited to device status, user-authorized setup data, short-range finding events and diagnostics necessary for reinforce. Continuous precise location history is excluded from the base concept. Status and finding data should remain local by default. Transmission beyond the paired device should occur only after explicit opt-in, through protected communication, and only for the selected service. Routine diagnostic logs should be retained no longer than 30 days unless the user deliberately submits them for an active reinforce case; reinforce-case records should be deleted or de-identified when the case closes, subject to applicable legal obligations. A physical ownership-reset process must erase locally stored personal data, pairing credentials and previous account associations before transfer or resale. These periods are design requirements for future implementation, not descriptions of an operating service.

Repairability is embedded in the boundaries between modules and in the treatment of high-wear components. The battery, electronics cassette, zipper pulls, sternum strap, organizer panels and abrasion base are intended to be replaceable. Structural textile repair may still require specialist equipment, but access should not depend on destructive adhesives at foreseeable service points. Components receive identifiers linked to a product record describing materials, compatibility and service history without storing personal data by default. The objective is not decorative modularity; each boundary corresponds to a real difference in failure rate, cleaning need, technology cycle or service responsibility. This operationalizes the repair-access criterion.

Circularity consequently reshapes both the aesthetic and commercial brief. A clean surface can still include discreet service access. A durable shell can be sold in passive and connected configurations, reducing forced electronics consumption. A user can replace a failed cassette without discarding the fabric body, and a second-hand owner can perform a documented reset. Product longevity also requires software commitments. A removable module does not solve digital obsolescence when the manufacturer does not declare update duration, compatibility and end-of-service behaviour. This direction is also consistent with systems-oriented repair research, design-for-circular-disassembly methods, and work on spare-part harvesting for repair and refurbishment (Parajuly et al., 2024; Formentini & Ramanujan, 2023; Richter et al., 2023).

The resulting concept is assessed using five graceful-intelligence criteria used consistently across the findings: 1) passive usability—essential carrying and access functions remain available without software or power; 2) legible failure—loss of a

digital function is visible and does not block legitimate physical use; 3) local control—essential settings, disablement and ownership reset do not require mandatory cloud dependence; 4) repair access—shorter-lived or high-wear components can be removed or serviced without discarding the whole product; and 5) data minimization—only data necessary for an explicitly selected function are collected and retained. These criteria operate as design gates: a proposed connected feature should be removed, redesigned or deferred when it fails one of the five gates without a documented justification. The feature-level outcomes of this screening are summarized in **Table 5**.

Service governance is consequently treated as part of the designed experience. The manufacturer should declare a minimum security-update period, identify compatible replacement modules and describe what happens when an online service ends. Users should receive advance notice of material changes and retain local access to the bag after cloud functions are discontinued. Diagnostic records should avoid unnecessary personal information, and the second-hand transfer process should erase prior ownership securely. These commitments require coordination among design, engineering, legal, customer reinforce and commercial teams. Without such coordination, physical modularity can become an empty promise because the replacement part, reset procedure or software reinforce may not exist when it is needed.

Table 5. Graceful-intelligence design-gate assessment of selected functions.

Feature	Passive usability	Legible failure	Local control	Repair access	Data minimization	Decision
Mechanical access	Pass	Pass	Pass	Pass	N/A	Retain as core
Removable power module	Pass	Pass	Pass	Pass	N/A	Retain; certification required
Nearby finding	Pass	Pass	Pass	Pass	Pass with local-first data	Retain as optional
Continuous location history	Pass	Conditional	Weak	Conditional	Fail	Exclude from base concept
Motorized lock	Fail if power lost	Weak	Conditional	Conditional	N/A	Exclude
Opening sensor alert	Pass	Pass	Pass	Pass	Pass if event-only	Optional
Load guidance sensor	Pass	Pass	Pass	Pass	Pass if local	Exploratory; no medical claim

The gate assessment demonstrates that removing features is a substantive design outcome instead of merely an aesthetic choice. Continuous location history conflicts with data minimization and local control, while a motorized lock creates unacceptable dependence on power for legitimate access. By contrast, nearby finding and opening alerts can remain optional because their failure does not disable the backpack's physical function.

4.5. Verification Priorities and Implications for Practice

The findings should remain design propositions until empirical verification is completed. Testing should begin with structural and electrical bench work before large user studies. Early prototypes must examine seam strength, strap attachment, drop behaviour, water paths, connector retention, thermal conditions and safe battery removal. Fit and usability work should then compare torso ranges, pressure distribution, dynamic pocket access, organizer comprehension, alert interpretation and ownership reset. A field pilot should examine false alarms, charging habits, feature disablement, maintenance and nonuse over time.

This sequence is important because a polished application cannot compensate for a failing harness or unsafe energy architecture. Requirements should be traceable from need to design response, verification method and claim boundary (**Table 6**). For example, the need for everyday rain protection leads to seam orientation, protected zipper paths and drainage; verification requires a defined spray procedure and internal moisture inspection; the public claim remains weather resistant unless a stronger standard is passed. Traceability prevents marketing language from outrunning evidence.

Table 6. Selected requirements, verification methods, and claim limits.

Requirement	Design response	Verification	Claim limit
Access without power	Mechanical zippers and physical controls	Power-off task inspection	No claim of automated access
Battery removability	Separate user-accessible module	Timed removal and retention test	Compatible module only
Everyday rain protection	Protected zipper paths, seam orientation and drainage	Defined spray test and internal moisture inspection	Weather resistant, not waterproof
Balanced carrying support	Frame sheet, adjustable harness and packing guidance	Fit, pressure and movement studies	No medical or universally safe-load claim
Ownership transfer	Physical reset and documented re-pairing	Second-hand transfer scenario	No recovery guarantee
Repairability	Replaceable high-wear parts and service cassette	Disassembly and reassembly trial	Availability subject to declared service period

Note. Final thresholds and public claims must be established through completed engineering, testing and certification.

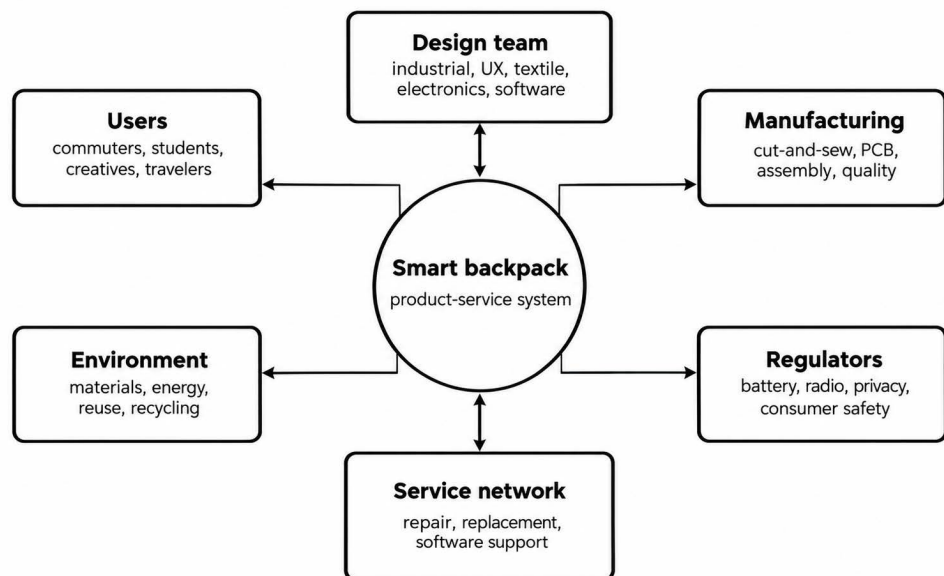
The case further clarifies the professional responsibilities of the designer. Design artefacts are not neutral. A rendering can conceal inaccessible fasteners; a matrix can make subjective priorities appear objective; a prototype can turn a temporary workaround into an implied capability. Responsible practice labels evidence status and preserves uncertainty. It also creates forums in which engineering, service, marketing, privacy and manufacturing can compare consequences against agreed principles.

Risk assessment should proceed alongside concept development instead of being deferred until later. Foreseeable hazards include local pressure from rigid parts, overheating or damage to the power module, water reaching connectors, false sep-

aration alerts, unauthorized ownership transfer and ambiguous lighting that creates false confidence. Each risk requires a prevention or mitigation strategy, a responsible discipline and a residual-risk statement. The same approach applies to misuse. A finding function intended for a lost bag can be repurposed to follow a person, and a load indicator can be misread as a medical limit. Threat and misuse scenarios should consequently influence defaults, interface language and reinforce procedures before the product reaches visual refinement.

Several of LumenPack's strongest design decisions arise from deliberate subtraction: no permanently embedded battery, no motorized lock, no mandatory account, no continuous location history and no claim that a sensor determines a universally safe load. Restraint is not a lack of ambition. It is a method for protecting the coherence of the product and directing resources toward the functions that matter most. The backpack project makes the social structure of design unusually visible. A soft-goods product may appear self-contained, but its success depends on relationships among users, design specialists, manufacturers, regulators, service teams, and environmental systems. Each group defines quality differently. Users may emphasize comfort, access, appearance, and trust. Manufacturing teams emphasize repeatability, yield, takt time, and supplier capability. Regulators emphasize safety and truthful claims. Service teams need diagnostic access and replaceable parts. Environmental systems do not speak through meetings, so lifecycle assessment, material data, and policy must represent impacts that market feedback may ignore.

Stakeholder ecosystem surrounding the backpack



Note. The ecosystem treats the backpack as a product-service system whose value and risks are distributed across multiple actors. Arrows indicate reciprocal influence rather than a linear supply chain. The diagram is author-generated.

Figure 10. Stakeholder ecosystem surrounding the smart backpack.

A stakeholder-ecosystem perspective prevents the purchaser from being treated as the only relevant actor. The person who assembles a battery connector, the courier who handles the package, the technician who replaces a zipper slider, the secondhand owner who resets the tracker, and the recycler who separates the electronic cassette all encounter the design. Their interactions may occur years apart, but they are linked by architecture. **Figure 10** positions the backpack at the center of reciprocal relationships instead of as the endpoint of a one-way pipeline.

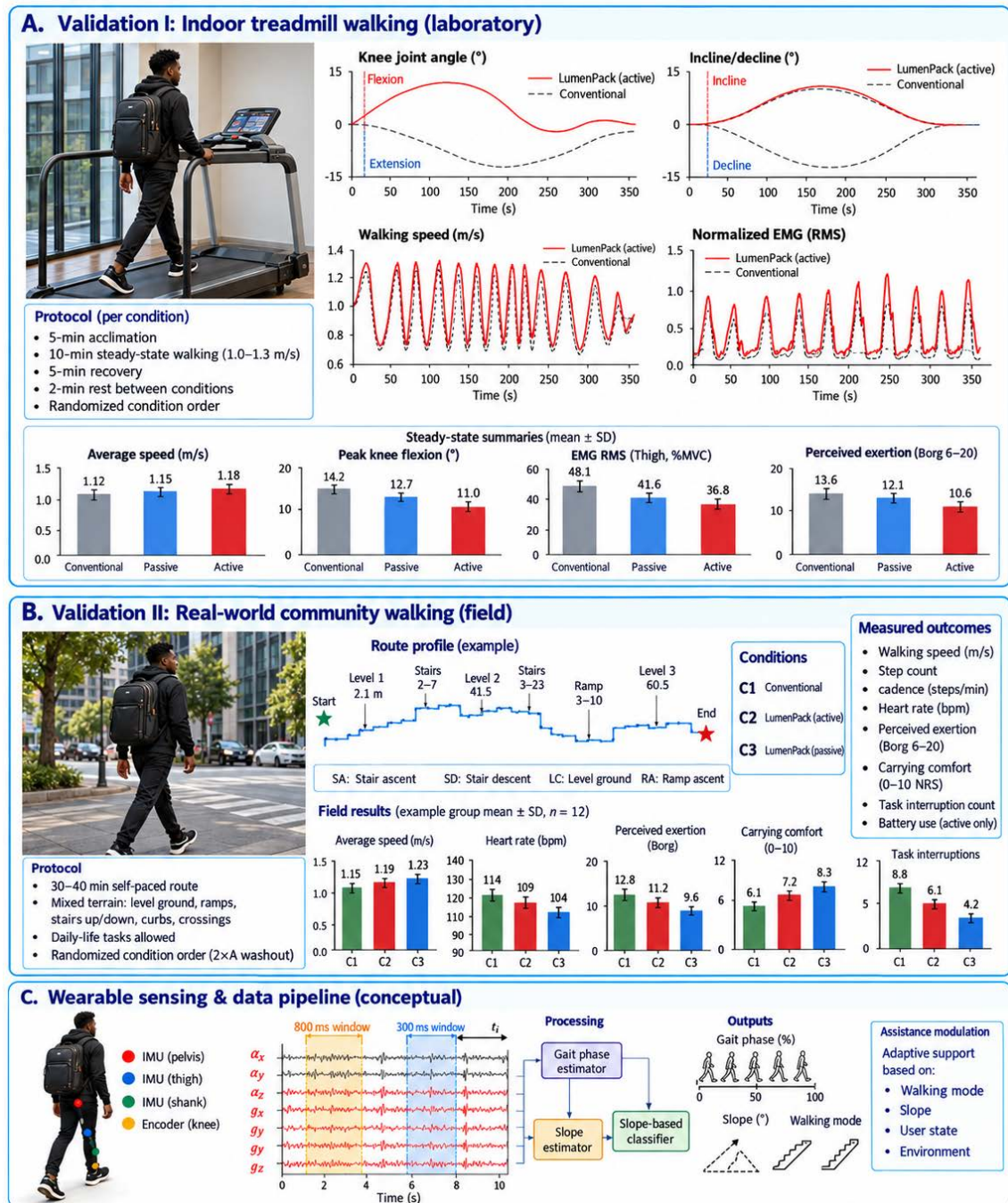


Figure 11. Conceptual user experiment for LumenPack.

Finally, empathy becomes operational only when it materially changes architecture or the allocation of resources. Travel routines produce the removable power module. Variation in comfort produces fit studies instead of a universal ergonomic claim. Repair needs produce accessible modules and documentation. Anxiety about tracking produces local control and minimized data. The designer's accountability is visible when a concern can be traced to a requirement and later tested.

Manufacturing and commercial decisions must preserve this same logic. The passive shell, connected cassette and power module can be offered as a product family, allowing users to pay only for the functions they value. However, product-family complexity should not produce incompatible generations or excessive stock. Interface dimensions, connectors and reset procedures require controlled documentation. Pilot production should track seam variation, connector installation, water paths and service time. Commercial review should include the cost of updates, replacement parts, returns and responsible retirement instead of evaluating only the initial bill of materials. This broader cost architecture makes lifecycle responsibility visible before launch.

5. Discussion

The findings reinforce moving from feature-led smart-product development toward lifecycle-aware system architecture. The most important outcome is not the presence of Bluetooth, sensing or charging; it is the decision to make these capabilities removable and subordinate to the backpack's passive function. This interpretation is consistent with recent repairability research showing that architecture, access, documentation and service conditions influence whether products can actually be repaired and retained in use (Amend et al., 2022; Ruiz-Pastor & Mesa, 2023; Roskladka et al., 2025).

The concept-selection analysis also reveals an important tension. The passive Concept C obtains the highest base weighted score because simplicity improves comfort, repairability and cost feasibility. Selecting Concept B for the connected research proposition is consequently justified only as a constrained choice: if connected functions are required, modular separation is preferable to technology-heavy integration. This is a stronger conclusion than claiming that the smart version is universally superior. It allows a future product family to include both passive and connected variants and makes the cost of connectivity visible.

The graceful-intelligence framework broadens privacy-by-design into a more comprehensive product-governance test. Privacy research emphasizes data minimization, user control and early integration of privacy requirements (Kühtreiber et al., 2022; Coiduras-Sanagustín et al., 2024). LumenPack adds passive usability, legible failure and repair access because a connected physical product can harm users even without a conventional data breach: a dead battery can block access, obsolete software can strand hardware, and inaccessible modules can convert a repairable textile product into electronic waste.

From the perspective of circular design, the three-layer architecture operation-

alizes the principle that module boundaries should follow lifecycle differences. The textile shell is expected to have a different wear and obsolescence profile from batteries and communication electronics. Separating them may reinforce replacement, cleaning, upgrading and end-of-life sorting, but modularity alone does not prove lower environmental impact. Additional connectors, enclosures and duplicated interfaces can increase material use. A comparative lifecycle assessment is consequently required before any environmental superiority claim is made.

Methodologically, the principal strength of the study lies in traceability instead of empirical generalizability. The matrices, priority profile, design-gate table and verification plan expose how literature and author judgement were converted into architecture. Their weakness is equally clear: author-generated scores can structure reasoning but cannot establish what users actually prefer or how the product performs. The next research phase should replace assumptions with observed packing/access behaviour, pressure and fit measurements, failure-recovery tasks, privacy comprehension tests and longitudinal repair/service evidence.

5.1. Implications for Design Practice

For connected soft-goods products, design teams should first define the complete passive product, then justify each digital feature against a documented friction and lifecycle cost. Service planning should begin during architecture development, including replacement-module availability, software-reinforce duration, ownership transfer, security updates and end-of-service behaviour. Marketing claims should be tied to verification evidence so that terms such as waterproof, theft-proof, ergonomic or sustainable are not used beyond the tested conditions.

5.2. Limitations and Future Research

The principal limitations arise from the absence of participant research, manufactured prototypes, laboratory measurements, supplier quotations, certification evidence and comparative lifecycle assessment. The numerical priorities and scores are decision-reinforce assumptions instead of observations. Future work should use a mixed-method validation programme: 1) anthropometric fit and pressure-distribution testing across torso ranges; 2) timed access and packing tasks; 3) rain, drop, connector-retention and thermal bench tests; 4) privacy and ownership-transfer usability studies; 5) repair-time and disassembly scoring; 6) field trials measuring false alerts, charging behaviour and feature non-use; and 7) cradle-to-grave or cradle-to-circularity lifecycle assessment comparing passive, modular-connected and integrated alternatives. These studies would allow the current conceptual requirements to be converted into validated specifications and defensible product claims.

6. Conclusion

Life as a designer must not be understood as a linear progression from inspiration to styling. It is a disciplined cycle of framing, making, comparing, testing and ne-

gotiating. The LumenPack case demonstrates that connected-product design becomes credible only when the physical product remains strong and the digital layer is proportionate to the problem. Comfort, load distribution, access and durability should be resolved before connectivity is allowed to define value.

The proposed concept addresses these concerns through a separable textile shell, service cassette and power module; legible organization; passive-first security; optional nearby communication; local controls; repair pathways; and declared claim boundaries. Its defining quality is restraint. Technology is retained when it reduces meaningful physical or cognitive friction and removed when it produces disproportionate weight, surveillance, fragility or dependency.

The conceptual status of the study imposes clear limitations. It does not report participant data, certified performance, supplier quotations, lifecycle assessment, penetration testing or a manufactured product. The priority scores and concept ratings are analytical devices, not population estimates. Future work must include diverse-body fit trials, observed packing and access tasks, interpretation of alerts, privacy-comprehension testing, disassembly trials, environmental assessment and longitudinal field use.

Future investigations should compare passive and connected prototypes with participants representing different torso dimensions, carrying routines, abilities and technology preferences. Studies should measure not only first-use satisfaction but also packing behaviour, false alerts, feature abandonment, cleaning, repair and ownership transfer over time. Environmental work should test whether the added electronics are justified by longer textile use and module replacement. Organisational case studies could also examine how multidisciplinary teams negotiate conflicts among appearance, privacy, service cost and manufacturability, because the quality of the final object depends on governance as well as individual skill.

The practical contribution of the case lies in the structure it provides for review. A team can ask whether the physical function remains complete without software, whether every collected datum is necessary, whether a failed module can be removed safely, whether a second owner can reset the product, and whether each public claim has a defined verification route. These questions are more transferable than the particular form of the backpack and can be employed as practical gates during briefing, concept review, prototyping, pilot production and post-launch evaluation across connected-product development programmes and design education studios.

For design researchers and practitioners, the principal contribution is a traceable evaluation framework for conceptual connected-product development. Literature-informed concerns are converted into provisional requirements; requirements govern architecture; the five graceful-intelligence criteria screen connected functions; and verification plans govern the limits of future claims. The LumenPack case demonstrates this sequence without presenting author assumptions as user evidence. Its value consequently lies less in asserting a finished smart backpack than in showing how physical utility, privacy, repairability and lifecycle stew-

ardship can be made explicit and reviewable before empirical validation and commercialization.

Research and Publication Ethics

This manuscript presents a conceptual design investigation and does not involve human participants, animals, clinical procedures, surveys, interviews, observation, experiments or retrospective personal data. Ethics committee approval was consequently not required. Any future human-factors, usability or field study arising from the proposed validation plan must receive appropriate approval before data collection, and the committee name, approval date and approval number should be reported in the Method section and on the first or last page of the submitted article.

Data Availability

No empirical dataset was generated; the figures, tables and numerical ratings are author-generated design artefacts contained in the article.

Ethics Status

No human participants, animals or personal datasets were used; ethics committee approval was not required.

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Author Contributions

Conceptualization, Abraham K. Kromah and Xu Guiping; Methodology, Abraham K. Kromah; Software, Abraham K. Kromah; Validation, Abraham K. Kromah and Xu Guiping; Formal Analysis, Abraham K. Kromah; Investigation, Abraham K. Kromah; Resources, Abraham K. Kromah; Data Curation, Abraham K. Kromah; Writing original draft preparation, Abraham K. Kromah; Writing review and editing, Abraham K. Kromah and Xu Guiping; Visualization, Abraham K. Kromah; Supervision, Xu Guiping; Project administration, Abraham K. Kromah; Funding acquisition, Abraham K. Kromah.

Conflicts of Interest

The authors declare no conflict of interest.

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