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Engineering Design Method Using Quality Function Deployment (QFD) and the Pugh Matrix for Innovation of an Electric Clothes Drying Rack

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ABSTRACT

Air-drying laundry indoors remains a persistent household problem in tropical climates such as Malaysia, where prolonged rainy seasons and space-constrained housing limit the effectiveness of conventional clothes racks. Most commercially available racks are simple mechanical frames that offer little beyond hanging space, and they cope poorly with humidity, odour and slow drying times. This study addresses the problem by applying two complementary engineering design tools, Quality Function Deployment (QFD) and the Pugh Matrix, to systematically translate customer requirements into a functional and manufacturable clothes-rack design. A structured questionnaire survey was administered to college students at Universiti Teknikal Malaysia Melaka (UTeM) to capture the Voice of the Customer (VOC). Nineteen candidate design attributes were ranked, and seven attributes with an importance score above 40% were carried forward into a House of Quality (HOQ) matrix to derive the corresponding engineering characteristics. Three conceptual designs were generated from the HOQ outputs and evaluated against a common baseline using the Pugh Matrix. Conceptual Design 3, featuring a combined hot-and-cold air fan, UV disinfection lamp, auto-cut-off timer, stainless-steel frame, castor wheels and a double-rod hanging space, achieved the highest net score (+5) and was selected for detailed development. The selected concept was subsequently modelled in SolidWorks to produce a dimensioned 3D prototype (800 mm x 1550 mm x 500 mm). The results demonstrate that integrating QFD with the Pugh Matrix provides a transparent, data-driven pathway from customer needs to a validated product concept, and the resulting design offers a practical, higher-functionality alternative to conventional clothes racks for space-constrained, humid environments.

Keywords: Quality Function Deployment; Pugh Matrix; House of Quality; product design and development; clothes rack innovation

INTRODUCTION

Clothes racks, also known as garment or drying racks, have been used since ancient times as simple structures for drying and storing clothing. Early designs consisted of little more than wooden poles or ropes strung between fixed points; over time these evolved into foldable, wheeled and, more recently, powered structures suited to both domestic and commercial use (History of Clothing, 2025). Today, cloth racks serve a dual purpose: they provide a low-cost, fabric-friendly and energy-efficient alternative to electric dryers for air-drying laundry, and they function as storage and display fixtures in retail, fashion and laundry businesses. The market for such products is correspondingly diverse, ranging from basic budget models to mid-range racks with adjustable height and extendable arms, through to premium and increasingly smart or eco-friendly variants that use sustainable materials such as bamboo or recycled metal.

Despite this diversity, a large proportion of cloth racks sold today remain functionally simple, offering little beyond a frame and hanging rods. This creates a persistent gap between what the market offers and what users, particularly those living in humid, rain-prone climates or in space-constrained accommodation such as student housing, actually need from a drying solution.

1.1 Problem Statement

Two recurring problems motivate this study. First, Malaysia's climate is characterised by frequent and heavy rainfall (O'Brien et al., 2024), which restricts outdoor sun-drying and extends indoor drying times, creating a daily inconvenience for households and students alike. Second, the majority of cloth racks currently available lack functional features, such as heating, ventilation, disinfection or automatic control, that would meaningfully reduce drying time or improve the user experience. Together, these problems indicate a clear need for a systematically redesigned cloth rack that is grounded in actual customer requirements rather than incremental changes to existing forms.

1.2 Research Objectives

This study pursues two objectives: (1) To evaluate customer needs for an innovative cloth rack using the Quality Function Deployment (QFD) method and (2) To design and select the best conceptual cloth rack design using the Pugh Matrix method.

1.3 Scope and Limitations

The scope of this project is to design a cloth rack based on the Voice of the Customer (VOC), with data collected via a questionnaire survey among college students at Universiti Teknikal Malaysia Melaka (UTeM). Market positioning and specification analysis of existing products were used to benchmark customer preferences. The study is methodologically limited to the engineering application of QFD and the Pugh Matrix; these two tools were selected because they offer a structured, traceable route from customer requirements to a ranked concept selection, and because their combined use is well represented in recent design-engineering literature (Guler & Petrisor, 2021; Zhu et al., 2022).

LITERATURE REVIEW

2.1 New Product Design and Development

New Product Development (NPD) refers to the sequence of design, engineering and research activities that convert an idea into a marketable product. It is widely regarded as a critical success factor for organisations seeking to sustain a competitive advantage, and the effectiveness of the NPD process itself, rather than any single design decision, has repeatedly been shown to determine project outcomes (Muhammad Iqbal, 2021). Norliyana Md. Aris (2024) illustrates the value of a structured, phased NPD approach outside conventional manufacturing contexts, applying a three-phase design-and-development research model, needs exploration, module development with expert feedback, and implementation and evaluation, to a chemistry education module in Malaysia. Ball et al. (2024) similarly emphasise the organisational dimension of NPD, proposing a two-dimensional model for structuring cross-functional product-development teams based on task interdependence and individual capability. Collectively, this literature indicates that successful product innovation depends as much on a systematic process and stakeholder alignment as on the technical design activity itself, which motivates the phased, tool-supported approach adopted in the present study.

2.2 Quality Function Deployment (QFD)

QFD is an analytical method for translating the Voice of the Customer into engineering characteristics that can be acted upon at each stage of the product life cycle, from planning and design through manufacturing (Yoji Akao, 2024). Its central artefact, the House of Quality (HOQ), maps customer requirements ("Whats") against technical characteristics ("Hows"), while a roof-shaped correlation matrix captures the interactions between technical characteristics.

Recent applications illustrate the versatility of QFD across sectors. Chun and Cho (2018) combine QFD with a group communication model for construction design decision-making, showing that structured stakeholder collaboration improves the consistency and reliability of design requirements. Lombardi et al. (2020) adapt QFD into a "House of Security" to manage information and physical security risk, demonstrating that the customer-to-technical mapping structure generalises beyond physical product design. Gai et al. (2024) integrate QFD with group decision-making and social network analysis to derive design requirements from online reviews for e-commerce platforms, while Chen et al. (2024) combine online-review mining with the Kano model and QFD to prioritise service-design requirements against providers' financial constraints. Closer to the present application domain, Gu and Peng (2023) apply a Kano-QFD framework to the multichannel interaction design of a household smart clothes hanger, and Kharisma et al. (2019) use a tree-diagram and QFD approach to propose a smart clothesline suited to Indonesia's tropical weather, an application context very similar to the Malaysian setting addressed in this study. Across this body of work, QFD consistently proves effective at converting qualitative customer feedback into prioritised, actionable technical requirements, which is the basis for its adoption here.

2.3 The Pugh Matrix Selection Method

The Pugh Matrix, also known as a controlled convergence or decision matrix, is a concept-selection technique in which candidate design concepts are scored relative to a baseline (datum) concept against a common set of weighted criteria, using a simple +, S (same) or - notation (Takai & Ishii, 2004). Its main strength is that it forces an explicit, criterion-by-criterion comparison, which reduces the influence of unstructured, opinion-based decision-making in concept selection.

The method has been extended and validated across several domains. Guler and Petrisor (2021) show that a Pugh-based model increases the efficiency of small design teams operating under time and resource constraints. Zhu et al. (2022) integrate the Analytic Hierarchy Process (AHP), QFD and the Pugh Matrix to design surgical auxiliary equipment, demonstrating that pairing Pugh selection with a weighting method such as AHP or QFD strengthens the objectivity of the final decision. Sreejith and Mathirajan (2022) and S. S. (2024) adapt a modified Pugh Matrix for continuous employee performance evaluation, benchmarking it against TOPSIS, PROMETHEE and VIKOR, while Collins and Ditaunyane (2024) apply the framework to select CALL (computer-assisted language learning) software in South African schools and Singgih et al. (2024) use it to compare accident risk-control alternatives. OKUYUCU and TANIK (2023) further propose an evaluating-eliminating-updating loop built around the Pugh Decision Matrix for design-studio exercises, underscoring its pedagogical as well as industrial value. This diversity of applications confirms the Pugh Matrix as a robust, low-overhead method for narrowing multiple concepts to a single, defensible design direction, which is why it is paired with QFD in the present methodology.

2.4 Complementary Multi-Criteria Approaches

Beyond the core QFD and Pugh Matrix literature, several studies show how these tools are increasingly combined with other multi-criteria decision-making (MCDM) methods to strengthen objectivity. Johnson et al. (2024) integrate the Analytic Hierarchy Process (AHP) with QFD in a Maintenance Quality Function Deployment (MQFD) model for the dairy sector, reporting local sensitivity ratings of 0.708 for "increased profit" and 0.472 for "reliability of decisions", and global sensitivity values of 0.351 for "quality of product" and 0.252 for "TQM tools", values that let an organisation tune its process parameters against explicit market goals. Yuzhe-Qi and Kiesu-Kim (2024) similarly combine a Kano-AHP model with Kansei Engineering for the design of health kettles, showing that pairing a requirements-prioritisation method with an affective-design technique produces designs that are both technically sound and emotionally appealing to users. These studies reinforce a broader pattern in the recent design-engineering literature: single-method approaches to concept development are increasingly being superseded by hybrid frameworks that combine a requirements-elicitation tool (QFD, Kano) with a ranking or selection tool (AHP, Pugh Matrix, TOPSIS). The present study follows this pattern in its simplest and most transparent form, QFD paired directly with the Pugh Matrix, which keeps the method accessible for an undergraduate-level design project while still delivering a defensible, criterion-based concept selection.

2.5 Synthesis and Research Gap

Table 1 summarises the reviewed studies by application domain and method combination. The literature confirms that QFD is well established for eliciting and prioritising customer requirements, and that the Pugh Matrix is a proven complement for converting those requirements into a single selected concept, whether used alone or alongside AHP, Kano or social-network analysis. However, published applications of the combined QFD-Pugh workflow to consumer clothes-drying products remain scarce, with Gu and Peng (2023) and Kharisma et al. (2019) the closest precedents, and neither is set in the specific context of Malaysian student housing. This study addresses that gap by applying the QFD-Pugh workflow end-to-end, from a localised VOC survey through to a dimensioned 3D concept, for an electric cloth-drying rack targeted at the Malaysian climate.

Table 1. Summary of reviewed QFD and Pugh Matrix applications

Study	Method(s)	Application Domain
Chun & Cho (2018)	QFD + communication model	Construction design decision-making
Lombardi et al. (2020)	QFD (House of Security)	Information & physical security management
Guler & Petrisor (2021)	Pugh Matrix	Small design-team product development
Sreejith & Mathirajan (2022); S. S. (2024)	Modified Pugh Matrix	Employee performance evaluation
Zhu et al. (2022)	AHP + QFD + Pugh Matrix	Surgical auxiliary equipment design
Gu & Peng (2023)	Kano-QFD	Smart clothes hanger interaction design
OKUYUCU & TANIK (2023)	Pugh Decision Matrix	Design-studio product exercises
Chen et al. (2024)	Kano + QFD (review-driven)	Service design
Gai et al. (2024)	QFD + GDM + social network analysis	E-commerce platform product design
Collins & Ditaunyane (2024)	Pugh Matrix	CALL software selection in education
Singgih et al. (2024)	Pugh Matrix	Accident risk-control alternatives
Yuzhe-Qi & Kiesu-Kim (2024)	Kano-AHP + Kansei Engineering	Health kettle design
This study (2025)	QFD + Pugh Matrix	Electric clothes-drying rack (Malaysia)

METHODOLOGY

This study follows a four-stage research process: (i) data collection on user needs and existing products, (ii) a user-requirements survey and data analysis, (iii) House of Quality (HOQ) development, and (iv) concept development, Pugh Matrix selection and 3D modelling. Each stage is described below.

In the first stage, background information on the engineering method of QFD and on existing cloth-rack products was gathered from journals, articles and product benchmarking to frame the problem and inform the questionnaire design. In the second stage, the problem statement was clarified, customer demand was specified through the questionnaire survey described in Section 3.1, and the resulting data were analysed and ranked. In the third stage, the ranked customer requirements were used to construct the House of Quality (Section 3.2). In the final stage, design concepts were sketched from the HOQ output, evaluated using the Pugh Matrix (Section 3.3), and the winning concept was carried into detailed 3D modelling (Section 3.4). Throughout the process, quantitative computations, including Likert-scale aggregation, HOQ scoring and Pugh Matrix net scores, were revisited to check calculation accuracy and to confirm that the selected technical characteristics remained aligned with the prioritised customer requirements before the design was finalised.

3.1 Data Collection and Voice of the Customer

Customer requirements were captured through a structured questionnaire survey, since questionnaires remain one of the most efficient tools for gathering standardised customer feedback at the early stage of a design project (Roopa & Rani, 2012). The instrument comprised three sections. Section A recorded respondent demographics (gender, age, race, occupation and education level). Section B captured user situations and problems associated with drying laundry, such as the frequency of outdoor drying, current satisfaction with existing racks, and desired features. Section C presented nineteen candidate design criteria (for example, function, durability, weight capacity, portability, aesthetics) and asked respondents to rate the importance of each using a five-point Likert scale (strongly important to strongly unimportant). The survey was distributed to college students at UTeM, reflecting the project's target market of young adults with limited time and space for laundry management.

3.2 House of Quality (HOQ) Development

Following data collection, customer requirements with an importance rating above 40% were carried into the House of Quality matrix. The HOQ maps the prioritised “Whats” (customer needs) against candidate “Hows” (technical/engineering characteristics), records the degree of relationship between each pair, benchmarks the design against a competitor product, and uses a roof-shaped correlation matrix to flag positive or negative interactions between technical characteristics (Larisang, 2023). The output of the HOQ is a ranked set of technical characteristics, expressed here as the degree of importance, degree of difficulty and estimated cost for each characteristic, which directly informed the conceptual design criteria.

3.3 Concept Generation and the Pugh Matrix

Three conceptual designs were generated by hand and digital sketching based on the HOQ output, incorporating combinations of the top technical characteristics identified (heating, ventilation, timer control, stainless-steel construction, mobility and hanging capacity). Conceptual Design 1 was designated the baseline (datum). Each of the remaining concepts was then compared against the baseline, criterion by criterion, and scored as better (+), the same (S) or worse (-) than the baseline, following the standard Pugh Matrix protocol (Takai & Ishii, 2004). The net score (sum of positives minus sum of negatives) for each concept determined its rank, and the highest-ranked concept was carried forward to detailed design.

3.4 Detailed 3D Modelling

The selected concept was developed into a dimensioned, detailed 3D model using SolidWorks computer-aided design (CAD) software. This step converts the winning concept sketch into an assembly-accurate model, allowing the structural layout, component placement and overall dimensions of the cloth rack to be verified before any physical prototyping.

3.5 Project Planning

The overall project timeline was planned and tracked using a Gantt chart, spanning topic selection, literature and product benchmarking, questionnaire design and distribution, data analysis, HOQ and Pugh Matrix development, and final 3D modelling and reporting, consistent with standard project-management practice for time-boxed, deliverable-driven engineering design projects.

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RESULTS AND DISCUSSION

4.1 Respondent Profile and Voice of the Customer

The majority of survey respondents were female students, with 50% of respondents identifying as students, consistent with the project's target market of young adults aged below 30 (89.7% of respondents fell in the 20-29 age bracket). Most respondents were Malay (88.5%) and held or were pursuing a Bachelor's degree. In terms of laundry behaviour, most respondents reported drying clothes outdoors and identified unpredictable weather as their primary problem, directly supporting the problem statement in Section 1.1. Respondents were, on balance, neutral on the functionality of their current cloth racks, indicating clear room for improvement. Table 2 presents the ranked results of the nineteen candidate design criteria collected in Section C of the survey, expressed as the percentage of respondents rating each criterion “strongly important”.

Table 2. Ranked customer requirements from the questionnaire survey

Criteria	% Strongly Important	Rank
Function	49%	1
Quality (quality of wardrobe)	48%	2
Space (space for the hanger)	46%	3
Durability	44%	4
Easy to use (operation of the motor)	43%	5
Easy to maintain (motor/heater)	42%	6
Weight capacity	41%	7
Material	38%	8
Easy to assemble	36%	9
Size (total size of product)	35%	10
Adjustable (height of the hanger)	33%	11
Ergonomic (hanging height)	31%	12
Timer (auto cut-off on the motor)	31%	13
UV disinfection (bacteria inactivation)	30%	14
Foldable	23%	15
Portability	22%	16
Design	10%	17
Aesthetic	7%	18

Functionality (49%) was the highest-ranked criterion, followed by quality (48%), space for hangers (46%), durability (44%), ease of use (43%), ease of maintenance (42%) and weight capacity (41%). These seven criteria, all rated above the 40% importance threshold, were selected as the primary customer requirements carried forward into the House of Quality, summarised in Table 3. By contrast, design and aesthetic considerations ranked lowest (10% and 7% respectively), indicating that, for this target market, functional performance takes clear priority over visual styling.

Table 3. Main criteria selected for HOQ development (>40% importance)

No.	Criteria	% Strongly Important
1	Function	49%
2	Quality (quality of wardrobe)	48%
3	Space (space for the hanger)	46%
4	Durability	44%
5	Easy to use (operation of the motor)	43%
6	Easy to maintain (motor heater)	42%
7	Weight capacity	41%

4.2 House of Quality (HOQ) Analysis

Figure 1 presents the completed House of Quality matrix, mapping the seven prioritised customer requirements against candidate technical characteristics: portability, presence of a heater and exhaust fan, heat- and water-resistant construction, use of stainless steel, castor wheels, an auto-cut-off timer, fast drying and large hanging capacity. Every customer requirement received the maximum importance weighting of 5, reflecting the tightly clustered 41-49% importance scores from the survey. The roof of the matrix identifies predominantly positive or neutral correlations between the technical characteristics, with one negative correlation and no strongly negative interactions, indicating that the selected characteristics are largely compatible and can be pursued jointly without major engineering trade-offs.

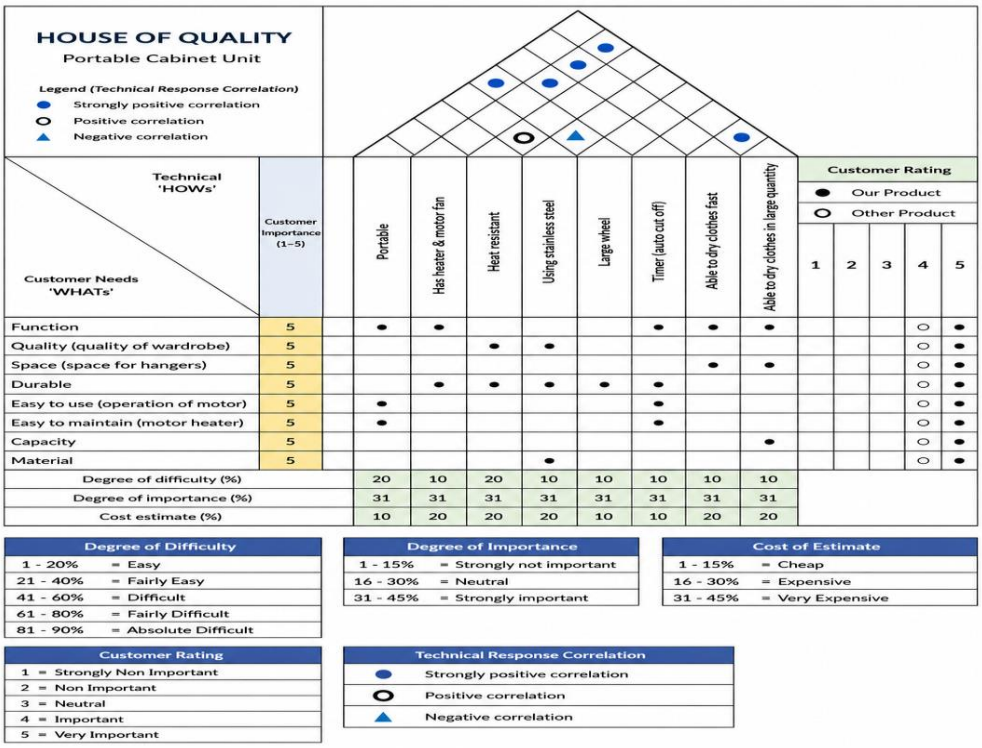

Figure 1. House of Quality (HOQ) matrix for the cloth-rack requirements

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Based on the degree of importance and degree of difficulty scores derived from the HOQ, six technical design criteria were carried into concept generation: (a) an integrated heater, (b) an exhaust fan, (c) an auto-cut-off timer, (d) stainless-steel construction, (e) castor wheels, and (f) a large hanging capacity (space for hangers).

4.3 Conceptual Design Generation

Three conceptual designs were generated from the HOQ output, illustrated in Figures 2. Conceptual Design 1uses a stainless-steel frame and hanger rod, a 220V/110V dryer unit with a 110 W LED light, and a model 15TGQZ exhaust fan (1330 RPM, 220-240V motor rating, 35 dB). While, Conceptual Design 2 introduces castor wheels for mobility, a PU-Oxford cloth cover over an aluminium tube frame, and a model APJ-150 heater-timer unit (1500 W, AC220V/50Hz) with a two-layer rod for greater hanging capacity than Design 1. Conceptual Design 3 combines castor wheels with a 20 W cold-air fan, an 820 W hot-air fan, a 7 W UV disinfection lamp, a 50 W LED desk lamp and a 130 W motor (220V, 50Hz), together with a double-rod hanging space and a model DEWW-09A exhaust fan (220-240V/50Hz, 12 W, 34 dB).

Figure 2. Comparison of three conceptual designs for the proposed portable clothes drying cabinet. Concept 1 features a compact stainless-steel cabinet with an integrated drying unit and LED lighting. Concept 2 adopts a dual-zone drying configuration with a fabric enclosure, aluminium frame, heater, and caster wheels to maximize drying capacity and portability. Concept 3 incorporates a stainless-steel cabinet with a double-rod hanger, timer-controlled heating system, UV sterilization, and mobility features, providing an enhanced solution for efficient, hygienic, and user-friendly clothes drying.

4.4 Pugh Matrix Concept Selection

Conceptual Design 1 was set as the baseline (datum) and scored "S" against every criterion. Concepts 2 and 3 were then scored relative to the baseline across eight criteria derived from the HOQ output and the customer requirements in Table 2. The results are summarised in Table 3.

Table 3. Pugh Matrix evaluation of the three conceptual designs

Selection Criteria	Concept 1 (Baseline)	Concept 2	Concept 3
Lot of function	S	S	+
Space (space for hangers)	S	-	+
Durable	S	-	+

Easy to use (operation of motor)	S	S	+
Easy to maintain (motor heater & exhaust fan)	S	S	+
Capacity	S	+	+
Material	S	-	S
Cost	S	+	-
Sum of Positives (+)	**0**	**2**	**6**
Sum of Negatives (-)	**0**	**3**	**1**
Net Score	**0**	**-1**	**5**
Rank	**2**	**3**	**1**

Conceptual Design 3 achieved six positive scores against only one negative score (cost), yielding a net score of +5 and the top rank. Conceptual Design 2 recorded a negative net score (-1), driven by weaker durability, space and material performance relative to the baseline, despite a cost and capacity advantage. Conceptual Design 1, as the unscored baseline, ranked second by definition. On this basis, Conceptual Design 3 was selected for detailed development, as it most comprehensively satisfies the prioritised customer requirements of functionality, space, durability, ease of use and ease of maintenance, at the acceptable trade-off of a higher relative cost.

4.5 Detailed 3D Design

The selected concept (Design 3) was developed into a dimensioned 3D model in SolidWorks, shown in Figures 5. The final assembly measures 800 mm (width) x 1550 mm (height) x 500 mm (length), constructed primarily from stainless steel for durability, corrosion resistance and aesthetic finish. The design integrates a heater module for controllable, steady heat; a cold-air fan for operation under varied ambient conditions; a UV disinfection lamp to reduce surface pathogens; an LED desk lamp for task lighting; and castor wheels for portability.

Figure 5. Orthographic views of the developed portable cabinet system showing the front, side, and top configurations. The design incorporates a compact enclosure with an integrated ventilation fan, lockable access panel, caster wheels for mobility, and an external power connection, providing a practical, portable, and user-friendly solution for laboratory and industrial applications.

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DISCUSSION

The results confirm that functionality, durability and motor/heater performance are the design attributes that most strongly determine customer acceptance of an innovative cloth rack, consistent with the survey ranking in Table 1 and the criteria retained in the HOQ. The systematic QFD-Pugh workflow adopted here offers three practical advantages over an unstructured design process. First, it anchors design decisions in quantified customer data rather than designer intuition, reducing the risk of over-investing in low-priority attributes such as aesthetics (ranked 17th) at the expense of high-priority attributes such as function (ranked 1st). Second, the HOQ's correlation roof surfaces interactions between technical characteristics before they are locked into a concept, allowing conflicting characteristics to be identified and reconciled early. Third, the Pugh Matrix provides a transparent, auditable basis for concept selection, expressed as a simple net score, that non-specialist stakeholders such as project supervisors or panel assessors can readily interpret.

These findings are consistent with prior applications of QFD and the Pugh Matrix in related domains, including Gu and Peng's (2023) Kano-QFD design of a smart clothes hanger and Zhu et al.'s (2022) combined AHP-QFD-Pugh selection of surgical auxiliary equipment, both of which found that pairing a requirements-prioritisation tool with a concept-scoring matrix produced a design outcome that was both customer-aligned and technically defensible. The present study extends this evidence base to the specific context of humid-climate, space-constrained student housing in Malaysia, an application setting that has received limited attention in the QFD-Pugh literature to date.

The main limitation of the study is that the VOC data were collected from a single, relatively homogeneous respondent population (UTeM college students), which constrains the generalisability of the ranked requirements in Table 1 to other demographic segments, such as households with young children or commercial laundromats. In addition, the evaluation to date is limited to a virtual 3D concept; physical prototyping and durability, thermal and energy-consumption testing were outside the scope of this study and are necessary before the design can be validated for manufacture.

CONCLUSION AND RECOMMENDATIONS

This study applied Quality Function Deployment and the Pugh Matrix to systematically design and select an innovative electric cloth-drying rack based on documented customer needs. The QFD process, anchored in a structured questionnaire survey, identified function, quality, space, durability, ease of use, ease of maintenance and weight capacity as the seven customer requirements of highest importance, and translated them into a set of prioritised technical characteristics via the House of Quality. The Pugh Matrix subsequently provided an objective basis for comparing three concepts derived from the HOQ output, resulting in the selection of Conceptual Design 3, a stainless-steel, castor-mounted rack with integrated heating, dual-fan ventilation, UV disinfection and timer control, as the design offering the best fit to customer requirements. The selected concept was further developed into a dimensioned 3D CAD model, confirming its technical feasibility.

Both research objectives were therefore achieved: customer needs were evaluated using QFD, and the best design concept was selected and developed using the Pugh Matrix. The study demonstrates that this two-tool workflow is an effective, transparent and replicable method for new product design and development in the small-appliance and household-product sector.

Two directions are recommended for future work. First, smart-technology integration, such as IoT connectivity, app-based or Bluetooth control, and automated humidity sensing, should be investigated to extend the product's functionality in line with broader market trends toward connected home appliances. Second, given that 49% of respondents identified functionality as their primary concern, further refinement of the heating and control interface, for example, a touchscreen controller for the drying cycle, is recommended to strengthen the product's competitive position. Physical prototyping and performance testing (drying time, energy consumption, structural durability) are also recommended as the immediate next step to validate the 3D concept developed in this study.

Author Contributions

W.D.W.Z. conducted the literature review, questionnaire design and administration, QFD/HOQ analysis, CAD modelling, prototype fabrication, and drafted the manuscript. M.N.A. supervised the research, provided methodological guidance, and reviewed and edited the manuscript. I. reviewed the manuscript. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement

The questionnaire data supporting the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare no conflict of interest.

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