Gerontology & Geriatric Medicine
Volume 9: 1–10
© The Author(s) 2023
Article reuse guidelines:
sagepub.com/journals-permissions
DOI: 10.1177/23337214221148245
journals.sagepub.com/home/ggm
SAGE

Improving Fall Detection Devices for Older Adults Using Quality Function Deployment (QFD) Approach

Kawthar Abdul Rahman, MSc[1], Siti Anom Ahmad, PhD[1], Azura Che Soh, PhD[1], Asmidawati Ashari, PhD[1], Chikamune Wada, PhD[2], and Alpha Agape Gopalai, PhD[3]

Abstract
Engineering invention must be in tandem with public demands. Often it is difficult to identify the priorities of consumers where technological advancement is needed. In line with the global challenge of increasing fall prevalence among older adults, providing prevention solutions is the key. This study aims at developing an improved fall detection device using an approach called Quality Function Deployment (QFD). The goal is to investigate features to incorporate in existing device from consumer's perspectives. A three-phases design process is constructed; (1) Questionnaire, (2) Ishikawa Method, and (3) QFD. The proposed method begins with identifying customer needs as the requirement analysis, followed by a method to convert them to design specifications to be added in a fall detection device using QFD tool. As the top feature is monitoring balance, the new improved fall detection devices incorporating balance features will help older adults to monitor their level of risk of falling.

Keywords
falls, prevention, assisted living, technology, gerontology

Manuscript received: September 28, 2022; **final revision received:** November 30, 2022; **accepted:** December 1, 2022.

Introduction

The pace of population aging is much faster than in the past. However, with improved health and technology, people will have longer life expectancy than previous generations. Sustaining the aging population comes with several challenges. Falls among older adults has becoming global concern when it was reported that approximately 28% to 35% aged 65 years and over are estimated to fall once or more frequently each year (World Health Organization, 2007). There are several causes for older adults to fall, and frequently the contributing factors are intertwined. Similarly in Malaysia, according to studies done nationwide, the prevalence of falls are in the range of 27% to 30% (Abdul Rahman et al., 2021; Ghazi et al., 2017; Rizawati & Mas, 2008). The risk of falling is particularly significant in populations with balance impairments, such as older adults, amputees, or those with neurological conditions (Denissen et al., 2019; Miller et al., 2001; World Health Organization, 2007). Furthermore, declined physical performance specifically muscle strength and balance is identified to be one the important risk factors associated with falls (Uusi-Rasi et al., 2019).

The necessity of assistive technology in the world of aging population is undeniably a game-changer. Designed for daily activities, a cutting-edge technological advancement are indeed an increasing demand in this day and age. Fall detection device is invented for the purpose of monitoring fall events for the user and responsible as an aid for older adults in their daily lives. Enabling them to manage their long-term conditions more effectively, the device also serves as health and human services to be delivered remotely, which can be employed to increase confidence and enhance independence.

Promising better quality of life for the older adults, recent studies discovered problems with the widespread usage of fall detection devices among older adults. The

[1]Universiti Putra Malaysia, Serdang, Selangor, Malaysia
[2]Kyushu Institute of Technology, Kitakyushu, Japan
[3]Monash University Malaysia, Subang Jaya, Selangor, Malaysia

Corresponding Author:
Siti Anom Ahmad, Malaysian Research Institute on Ageing (MyAgeing™), Universiti Putra Malaysia, UPM Serdang, Selangor Darul Ehsan 43400, Malaysia.
Email: sanom@upm.edu.my

adoption of these devices is strongly influenced by their usability and reliability, which are now lacking. Despite its benefits, older adults are afraid to use technological devices, believing they are uncomfortable, complicated to use affecting their cognitive capacity, invasive that the technology would take control over their lives, affecting their health and fear of losing human contact; which causing them to stop using the purchased devices after couple of months (Abdul Rahman et al., 2021; Sundgren et al., 2020).

Other reasons are because of the reliability of the devices such as false alarm and limit to only detect falls, even though the impact following falls are of more concern rather than the occurrence of falls. There were also follow-up studies but limited by the type of data collected, which causes difficulties for proper validation on distinct populations (Bagala et al., 2012; Nyan et al., 2008). The limitations of existing devices in the market drives this study toward bridging the gap between the needs of society and the design specifications. Among the limitations discovered in a fall detection device, this study only focuses on the functionality, which aimed at acquiring added features to enhance the function of existing device. Hence, introducing a method to gather and analyze the customer needs might be of utmost importance.

All of these reported cases are classified as the needs of society. The analysis of these requirements often relates to product manufacturers which brings the designers to compete in the world of technology. Thus, this study is aimed at investigating enhanced features for a fall detection device using an approach called Quality Function Deployment (QFD). QFD is a fundamental tool for product development that consists of design, planning, and communication routines. The method has achieved significant recognition in numerous industries as a strategy to organize the tasks required to optimize the engineering design process (Bossert, 2021). It offers a methodology to directly connect customer needs with engineering characteristics, part deployment (component or module), process planning, and production planning, ensuring that the final product satisfies the original requirements. The goal of this approach is to determine and relate the costumer-based product requirements and engineering-based design parameters. It also helps to facilitate decision analysis for a certain aim of enhancement in the product. Apart from benefiting the manufacturing industry since it was first introduced, healthcare services have been capturing the enhanced technique as well. For example, applications of QFD to hospital services reveal client wants, allowing for the adjustment of essential services and achieving customer satisfaction (Kung et al., 2006; Radharamanan & Godoy, 1996). While the approach of QFD has been applied for many years in the industry to improve the product's quality when designing, to our knowledge, it has not yet been applied in fall detection devices. The advantage of applying such methodology to fall detection devices is the inclusivity of the customer voices in the development process which has not always been in the practice of designing a device. In view of that, there will be more perceptive ideas how a device should be and helps to generate more relatable improvements of the functional aspects of a product.

Method

A design process with the aim of improving the features of the available fall detection devices in the market is represented in Figure 1. The proposed method involves requirement analysis that converts the customer needs into a technical specification with measurable ranges, followed with the implementation of the QFD approach.

Questionnaire

Referring to the study in Abdul Rahman et al. (2021), the structure of study sample, sampling technique and the results of the survey were discussed. The study was done as the first part in the phases of the design process as illustrated in Figure 1. The sample analyses for this study was restricted to older adults age 50 and above. Although the term older adults in Malaysia is defined as people aged 60 years old and above, but due to lower life expectancy compared to the Western Countries (Ashari, 2017) and referring to the National Health and Morbidity Survey (National Institutes of Health (NIH), 2018), pre-elderly aged 50 to 59 years old were included in selecting the participants. Also, early detection of health condition for this age group is considered vital as it can make a difference in their later life. The targeted sample was 400, determined using the Finite Population Correction, and the response rate was over 100% (416 respondents). The goal of the target population was to have a wide-ranging representative of older adults nationwide. The survey was conducted using a confidential self-administered questionnaire distributed to a stratified sampling of age, gender, and geographic location; representing a population estimate of 10,994,000 older adults aged over 50 years. The targeted

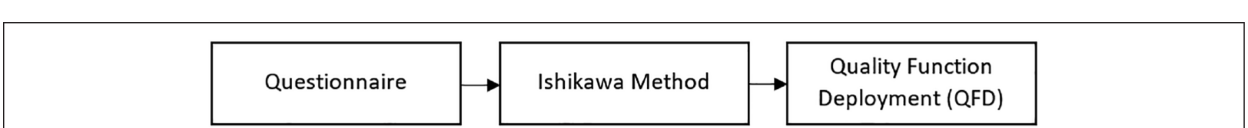

Figure 1. Phases of the design process to improve fall detection devices.

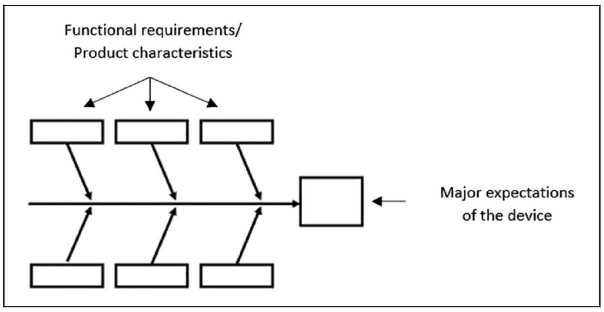

Figure 2. The development of a fishbone diagram.

participants was randomized with convenient sampling among three diverse groups of older adults which were: (1) Community-dwelling, (2) Residents of old folks' homes, and (3) The membership of an organization in Malaysia.

Ethical Considerations

The respondents were firstly informed of the research's purpose, mode of participation, benefits and confidentiality. All respondents understood the objective of this research and voluntarily signed consent forms prior to answering the questionnaire. Participation was completely voluntary, and data were conducted confidentially where names and addresses were not included in the analysis of this study. All study instruments were reviewed and approved by the Ethics Committee for Research Involving Human Subjects Review Board.

Survey Instruments

Participants were briefed earlier on the definition of a fall, which was described as an unanticipated incident in which the person comes to rest on the ground, floor, or lower level (World Health Organization, 2007). The basic mechanism of a fall detection device was described, and it was designated as a wearable device. The participants were presented a sample of an existing fall detection device and its benefit to use it on everyday basis. The questionnaire started with demography details followed by two self-administered parts on fall risk assessment: (1) Falls assessment and perceived walking stability and (2) Experience using a fall detection device, perceptions, and expectations toward the use of a fall detection device. This study only examined the second part of the survey, narrowed down to only the open-ended questions of "What is your expectation about the device in the future?" for respondents who have experience using a fall detection device" and "What is your expectation of a fall detection device if you are to use one?" for respondents who have no experience using the device. The compilation of the responses were classified as customer requirements which then will be examined to prioritize the most valued answer and were grouped into four general categories according to their aims and functions; (1) Quality, (2) Design, (3) Function, and (4) Cost. All the responses were called as the voice of customers.

Ishikawa Method

The Ishikawa Method (also called as Fishbone Diagram) named after Kaoru Ishikawa, is a tool for analysis that offers a methodical way to look at effects and the causes that lead to or influence those effects, hence referred to as cause-and-effect diagram (Watson, 2004). It serves as an assisting tool in determining the root cause of quality issues and is also used to detail the functional requirements when brainstorming a product development.

By applying this method, fishbone diagrams were developed in view of the answers from the respondents regarding their expectations of a fall detection devices (export data from the survey). These were called as the voice of customers and considered as the major expectations and were categorized according to their functions. Based on these categories, functional requirements (also referred to as voice of engineers) were derived as the product characteristics (Figure 2).

Quality Function Deployment (QFD)

With the goal of improving fall detection devices, this study is aimed at investigating the added features that will enhance the device functionality. Generally, to establish a QFD in any product development, a House of Quality (HOQ) is built to investigate the interrelationship between the customer requirements and the design parameters. Referring to the previous phase, two inputs to construct the HOQ were established: (1) Customer-requirements-driven design (Voice of customers) and (2) Engineering-specifications-driven design (Voice of engineers). The flow diagram involving the two inputs completing the three phases of the proposed design process (Figure 1) is outlined in Figure 3.

Further evaluations were formulated by analyzing the importance rating for each customer requirements according to the responses from the respondents. The relationship matrix were recorded whether the requirements have strong, medium, or weak relationship with the functions of a fall detection device. Subsequently, the purpose of executing the relationship between the functional requirements in the triangular matrix was to show how changing any one function will affect any of the others. Finally, the output analysis of functional requirements will be ranked by technical importance which can be determined by summing the weighted interrelation values for all the functional requirements. The top ranked output will be selected as the added feature for the improvement of the proposed fall detection device.

Results

The proposed approach demonstrates effective application of QFD in identifying the most valued customer needs to

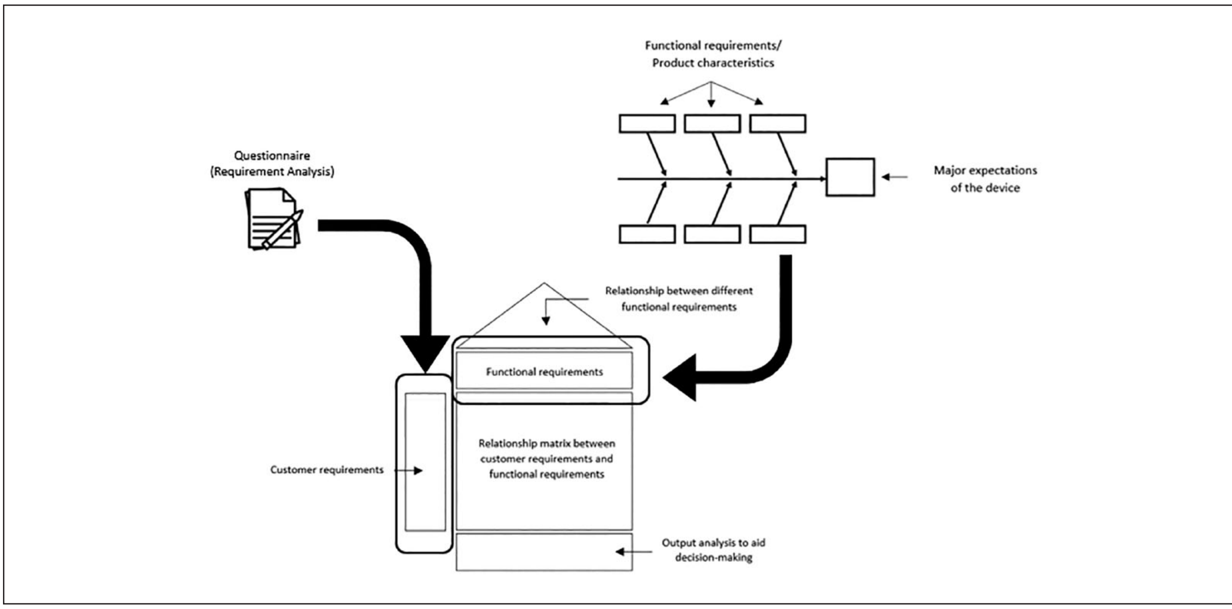

Figure 3. The flow diagram of the development of the House of Quality (HOQ).

improve the fall detection devices for older adults. Results of this study were explained in three phases in accordance with the method proposed represented in Figure 1. Firstly, the results of the survey conducted was presented in Table 1. The analysis was done by considering the demographic characteristics of the respondents.

Customer-Requirements-Driven Input

Some notable results from the survey regarding the respondents' expected features required for future fall detection devices were contributed to the development of QFD as listed in Table 2:

The responses were then grouped into four general categories of the voice of customers to accommodate the derivation of the design process, denoted as the customer-requirements-driven design for future fall detection devices: (1) Quality, (2) Design, (3) Function, and (4) Cost.

Engineering-Specifications-Driven Input

Following the proposed method, four distinct fishbone diagrams based on the four categories in Phase 1 were derived using Ishikawa Method in view of the major expectations of fall detection devices. Each fishbone diagrams were developed to obtain the functional requirements (also referred to as the voice of engineers) and denoted as the engineering-specifications-driven design (Figures 4–7).

The derivation of the fishbone diagrams were in the direction of enhancing the functional features that can add up the value of such devices. Therefore, the significance of this phase was to identify what are the functional requirements that could affect each of the customer requirements. The product characteristics of the device were selected based on the most related engineering specifications design that were derived in the fishbone diagrams and listed as follows:

1. Include emergency button
2. Size
3. Include balance features
4. Include health monitoring
5. Include GPS tracker
6. Low cost material
7. Sensor coverage
8. Use waterproof material
9. Comfortable
10. Use LED light

The Development of HOQ

As a final point, HOQ was then developed based on the two groups of distinctive inputs; customer requirements and functional requirements as shown in Figure 8.

Several calculations must be computed to generate output for the QFD. Each of these customer requirements were listed in a constructive view so that an improvement of any requirements would be considered advantageous.

Identifying the relative weight of customer importance for each customer requirements. The importance ratings was set up based on the responses from the survey, by computing in the range of 1 to 10 with the highest response as 9 and the lowest as 3 such that the total of all relative weight for each requirement was to be 100%. This step was intended to prioritize the customer requirements. For example, using this rating scale, if two requirements had equal importance, and the other requirements were

Table 1. The Association Between Falls and Instability With Demographic, Perceived Gait Problems and Interest in Fall Detection Devices.

		Falls in 6 months			Instability	
	Total (*n*, %)	1–2	3 or more	None	Yes	No
Total respondents (*n*, %)	416 (100)	106 (25.4)	36 (8.7)	274 (65.9)	115 (27.6)	301 (72.4)
Demographic						
Gender (*n*, %)						
Male	81 (19.5)	20 (24.7)	10 (12.3)	51 (63)	25 (30.9)	56 (69.1)
Female	335 (80.5)	86 (25.7)	26 (7.7)	223 (66.6)	90 (26.9)	245 (73.1)
Age (years) (*n*, %)						
50–59	89 (21.4)	20 (22.5)	6 (6.7)	63 (70.8)	21 (23.6)	68 (76.4)
60–69	205 (49.3)	45 (21.9)	11 (5.4)	149 (72.7)	39 (19)	166 (81)
70–79	102 (24.5)	35 (34.3)	12 (11.8)	55 (53.9)	40 (39.2)	62 (60.8)
>80	20 (4.8)	6 (30)	7 (35)	7 (35)	15 (75)	5 (25)
Gait problem (*n*, %)						
Walking with a bit stooped	44 (10.6)	9 (20.5)	10 (22.7)	25 (56.8)	26 (59.1)	18 (40.9)
Walking with shuffle foot	43 (10.3)	22 (51.2)	11 (25.6)	10 (23.3)	36 (83.7)	7 (16.3)
Difficulty rising from a chair	81 (19.5)	28 (34.6)	12 (14.8)	41 (50.6)	46 (56.8)	35 (43.2)
Cannot walk without assistance	31 (7.5)	12 (38.7)	11 (35.5)	8 (25.8)	27 (87.1)	4 (12.9)
Not having such problems	266 (63.9)	54 (20.3)	11 (4.1)	201 (75.6)	22 (8.3)	244 (91.7)
Interest in fall detection device (*n*, %)						
Yes	266 (63.9)	76 (18.3)	26 (6.3)	164 (39.4)	88 (21.2)	178 (42.8)
Maybe	130 (31.3)	28 (6.7)	10 (2.4)	92 (22.1)	22 (5.3)	108 (26.0)
No	20 (4.8)	2 (0.5)		18 (4.3)	5 (1.2)	15 (3.6)

Table 2. Expected Features for Future Fall Detection Devices by the Respondents.

	%
Expected features for fall detection devices	Total sample (*N*=416)
Easy to use/ User-friendly	45.7
Affordable price	34.9
Accurate	12.5
Effective in terms of fast response	10.8
Easy to wear	4.3
Fall prevention device	4.1
Lightweight	3.8
Portable and offers freedom of movement	1.9
Small	1.7
Durable	0.5
Waterproof	0.5
Able to detect which part of the body affected when fall occur	0.2
Include date and time, and next-to-kin contact	0.2
Accessible to more than one person (child, caretaker/next-to-kin)	0.2

of no importance, the two would both be scored 50, and the others 0. In this study, there were 16 requirements and if all requirements were rated equally important, each would be given a score of 100/16=6.25.

Identifying the relationship matrix between customer requirements and functional requirements. The interrelationships between each customer and functional requirements were evaluated and categorized as either having strong (9), medium (3), and weak (1). Each functional requirements were bind by the direction of improvements beforehand to have better guidance in determining the relationship. For example, the relationship between the Customer Requirement Efficiency and the Functional Requirement Include emergency button is strong thereby scoring 9. This means by having the emergency button in the device, the efficiency would increase.

Identifying the correlations between each of functional requirements and their direction of improvement. The correlations is presented in the triangular matrix ("roof" of the house). The matrix will show how each functional requirements would influence the other positively or negatively depending on the directions of improvements. By doing so, when the output analysis was done, this matrix will be useful to get the information of the product characteristics and as a guidance on what to include or exclude in the design parameters. For example, minimizing the size of the device will have positive relation to low cost material and comfortable design.

Generating the ranking among the functional requirements. Finally, the relationship matrix in II resulted in a weighted score relating how changing an engineering specification will affect the overall functional performance of the device. The technical importance for each functional requirements was determined by summing the product of the relationship value and the relative weight by the customer's importance. Hence, the

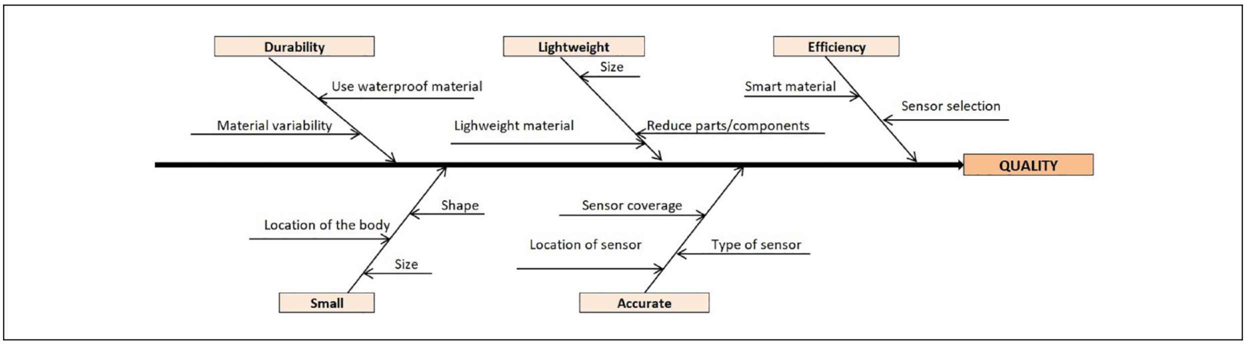

Figure 4. Fishbone diagram of customer-requirement-driven of quality.

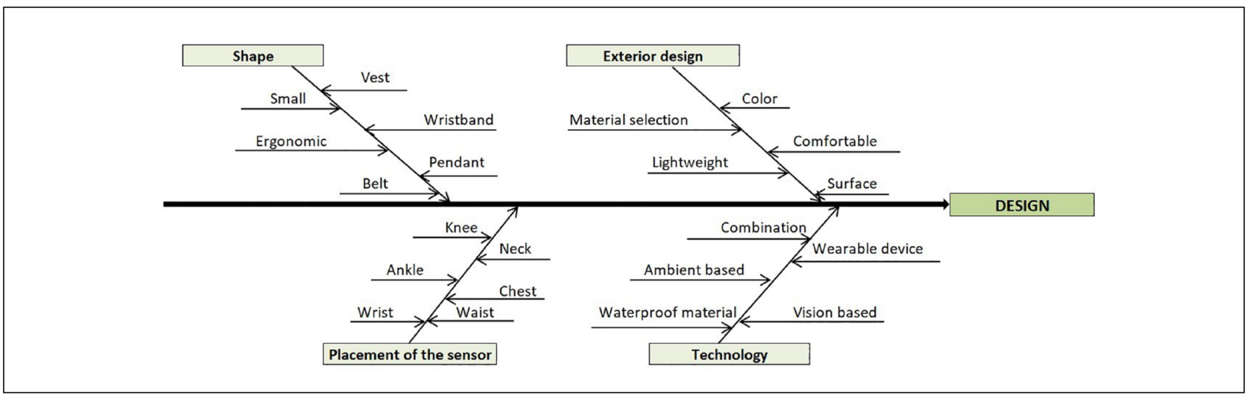

Figure 5. Fishbone diagram of customer-requirement-driven of design.

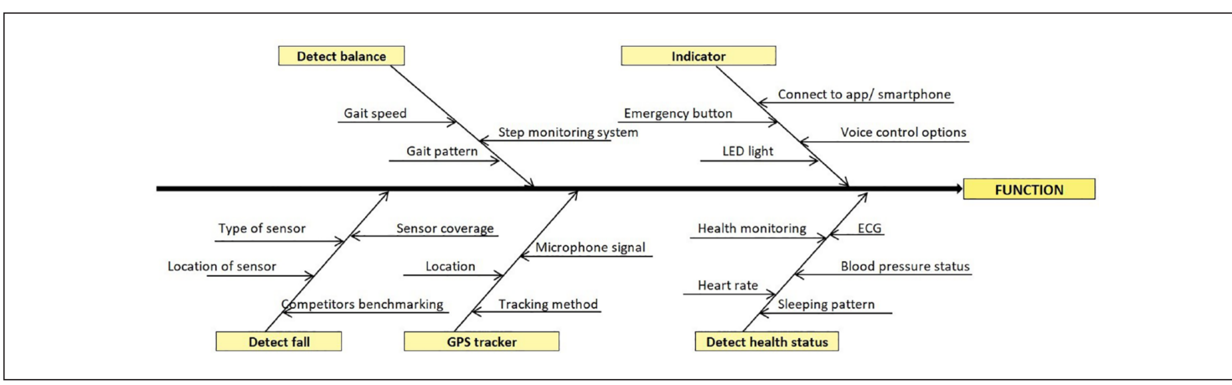

Figure 6. Fishbone diagram of customer-requirement-driven function.

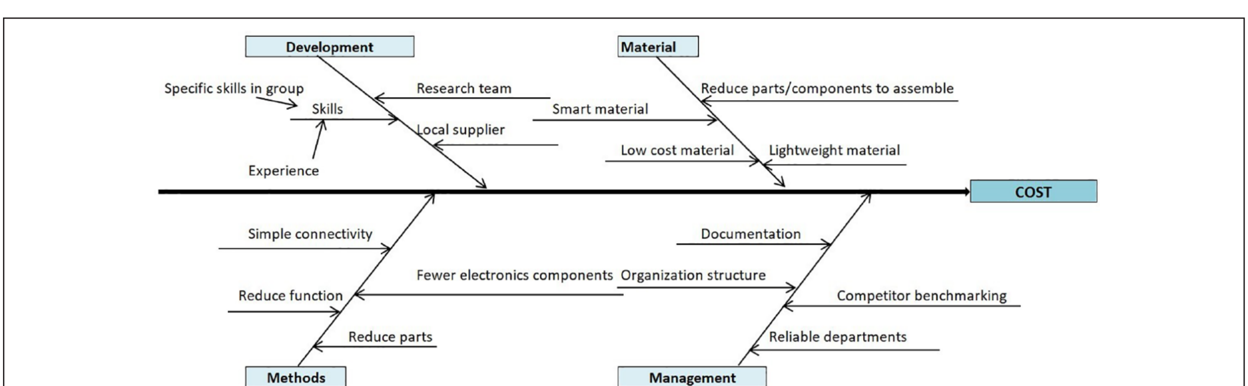

Figure 7. Fishbone diagram of customer-requirement-driven cost.

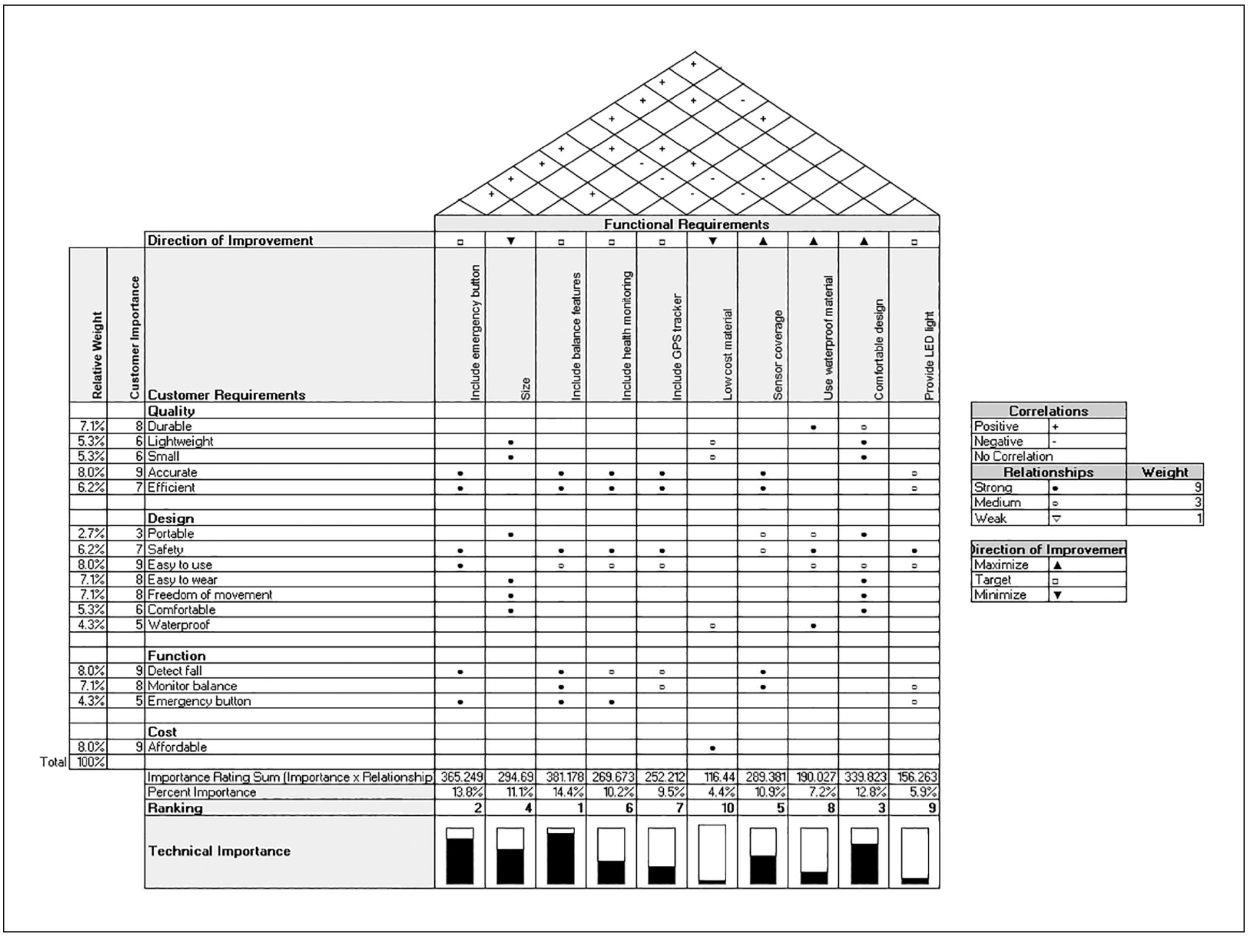

Figure 8. House of Quality to improve fall detection device.

percentage importance that build up the ranking among the functional requirements reveals the design parameter of which engineering effort can most affect the overall satisfaction of the customer.

The output analysis can be concluded by following the ranking of the technical importance. QFD approach confirms that the most important function was to include balance features. The results were aligned with the target of direction of improvement. Even though the function to monitor balance was not the highest rating by the customer, but when assessing with other functional requirements, the characteristic of including balance features have strong relationships with the top rated customer requirements. The next three highest ranked functional requirements were to include emergency button, comfortable design, and minimizing the size.

Discussion

In view of the survey analysis, where respondents reported high prevalence of falls and balance instability, it is relevant to proceed with the proposed design process in regards to improve fall detection devices for older adults (Abdul Rahman et al., 2021). Also, majority of the respondents were interested to use such devices.

Several design characteristics had been proposed as having a potential impact on the functionality of a fall detection device prior the application of QFD in this study. QFD established a technique for prioritizing these criteria in order to meet the customer's functional requirements. Started with a fundamental step which was the requirement analysis, it involves three types of activities which were:

(1) Eliciting requirements—Gathering information from a survey to construct the requirements
(2) Analyzing requirements—Translating the gathered information into meaningful design parameters to be focused on (how they can affect the requirements)
(3) Documenting—Documentation of the requirements and its related design parameters using an assisting tool called Ishikawa Method.

The motive to apply the Ishikawa Method was to derive functional aspects in the direction of improving fall detection devices in terms of quality, design, function, and cost, and to be used in QFD development. Each features that customers want were recapitulated as voice of customers and being matched to engineering specifications. Translating the voice from customers to engineers were crucial because it helps both sides of the parties to work together to produce the device that includes their expectations.

The constructed QFD drawn several conclusions about the proposed improvements. The relationship matrix described the customer interests' effects to one or more technical parameters or vice versa. The relationships of the customer importance were examined across each functional requirements in regards with three levels; strong, medium, and weak. Meanwhile, the roof of the HOQ contained information about the correlation between functional requirements whether there is a strong relationship (positive) or there is a contradiction (negative) between them.

It can therefore be stated that QFD approach indicates that including balance features in a fall detection device can improve its functionality for older adults. The enhanced device would be beneficial to their population as previous studies revealed that poor balance were associated with falls in older adults (Belgen et al., 2006; Berg et al., 1989; Campbell et al., 1989; Harris et al., 2005; Hatch et al., 2003; Lipsitz et al., 1991; Maki & McIlroy, 1996; Tinetti et al., 1988).

The highlight of the present study was how a new approach can facilitate a journey of a product development. From the design aspect, clear objective of the design specifications were obtained using QFD. In this study, findings can improve the understanding of fall events of older adults by capturing balance instability when using the device. The idea of incorporating balance features into the existing fall detection devices would assist older adults in monitoring their daily movements. While the existing fall detection devices monitor fall events, the proposed solution will simultaneously monitoring balance instability of older adults. This means if there is instability detected, the device will alert the user of fall risk so that precaution steps can be taken to avoid fall. As past studies have verified that instability is one of the risk of falls, the scenario will help prevent future falls because the device can now anticipate their level of stability. Older adults become more aware of their conditions which can abridge family members and health professionals to provide better solutions if needed. The enhanced feature would increase their safety measure, boosting the confidence to practice active aging.

Limitations and Future Directions of the Study

In terms of respondents' demography, this study did not consider individual differences among older adults (such as education level, technology literacy level). Model verification can be implemented on future respondents. Although input from a large number of older adults would provide more representative data from a user perspective, an additional survey among clinicians and physical therapists who have experienced attending patients using fall detection devices would deliver more meaningful results for the study. Application of QFD open the door to other horizons in improving fall detection devices as many design parameters derived in Fishbone Diagram would have impacted other research objectives in the context of assisting older adults.

Next step of the study is to implement the QFD results which is to include balance features in future fall detection devices in designing an enhanced fall detection device incorporating balance monitoring system. A fall detection device with balance monitoring will be advantageous to the field of assistive devices as the design is advancing the state of the art. The process was validated by the society needs which provides the motivation to make an improvement in the existing devices. Future studies involving balance monitoring offers wide range of methods as the term balance itself has various techniques to regulate the assessment.

Conclusion

The objective of constructing QFD in any field is to translate customer requirements into the engineering specifications of a product. Developing the best design is always have been the goal of a designer in production line. A product's design maturity can still be improved by the use of new design techniques and technological development.

In the field of designing assistive devices, designers should always ponder upon designing with the consumer rather than for them; which also means that they are highly dependent upon consumer's input. The approach that have been implemented helps in decision making of the analysis in ways that improving the existing devices to satisfy the desired customer needs using the latest state-of-the-art technology. Furthermore, QFD creates opportunities for innovation and possibilities for creativity in one direction, reducing implementation time and energy. The process is also beneficial for repeated cycles of product development.

The effort in combating the rising numbers of falls accidents among older adults could be one of the ways forward to produce fall prevention programs in promoting quality healthy wellbeing and minimizing social burden associated with fall-related consequences. The phrase "prevention is better than cure" really is important when it associates to this population where risk factors for falls must be addressed early to maximize potential treatment if needed.

Acknowledgment

The authors would like to specially acknowledge Universiti Putra Malaysia and Kyushu Institute of Technology Japan, for funding this study. We also thank all the participants for the time, ideas, and views contributed to this study.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This work was supported by the Matching Grant Universiti Putra Malaysia-Kyushu Institute of Technology (UPM-KYUTECH), titled “Fall and Balance Monitoring for Older Persons” (9300464). Also, the support provided by the School of Graduate Studies during the study at the Universiti Putra Malaysia is also acknowledged.

Ethics Statement

Institutional Review Board approval was received from the Ethics Committee for Research Involving Human Subjects Review Board (JKEUPM-2017-251), Universiti Putra Malaysia for the questionnaire distribution. The questionnaire comprised of two self-administered parts on fall risk assessment following completion of demography details; (1) Falls assessment and perceived walking stability and (2) Experience using a fall detection device, perceptions, and expectations toward the use of a fall detection device. Details included in this study regarding their expectations are presented in Table 1.

ORCID iD

Kawthar Abdul Rahman https://orcid.org/0000-0003-2608-1657

References

Abdul Rahman, K., Ahmad, S. A., Che Soh, A., Ashari, A., Wada, C., & Gopalai, A. A. (2021). The association of falls with instability: An analysis of perceptions and expectations toward the use of fall detection devices among older adults in Malaysia. *Public Health Frontier*, *9*, 1–11. https://doi.org/10.3389/fpubh.2021.612538

Ashari, A. (2017). *Fall risk assessment and effectiveness of home based exercise on balance and functional mobility among Malaysian adult aged 50 years and above*. [Doctoral dissertation]. Curtin University.

Bagalà, F., Becker, C., Cappello, A., Chiari, L., Aminian, K., Hausdorff, J. M., Zijlstra, W., & Klenk, J. (2012). Evaluation of accelerometer-based fall detection algorithms on real-world falls. *PLoS One*, *7*(5), e37062–e37069. https://doi.org/10.1371/journal.pone.0037062

Belgen, B., Beninato, M., Sullivan, P. E., & Narielwalla, K. (2006). The association of balance capacity and falls self-efficacy with history of falling in community-dwelling people with chronic stroke. *Archives of Physical Medicine and Rehabilitation*, *87*, 554–561. https://doi.org/10.1016/j.apmr.2005.12.027

Berg, K., Wood-Dauphinee, S., Williams, J. I., & Gayton, D. (1989). Measuring balance in the elderly: Preliminary development of an instrument. *Physiotherapy Canada*, *41*, 304–311. https://doi.org/10.3138/ptc.41.6.304

Bossert, J. L. (2021). *Quality function deployment: A practitioner’s approach*. CRC Press.

Campbell, A. J., Borrie, M. J., & Spears, G. F. (1989). Risk factors for falls in a community-based prospective study of people 70 years and older. *Journal of Gerontology*, *44*(4), M112–M117. https://doi.org/10.1093/geronj/44.4.m112

Denissen, S., Staring, W., Kunkel, D., Pickering, R. M., Lennon, S., Geurts, A. C., Weerdesteyn, V., & Verheyden, G. S. (2019). Interventions for preventing falls in people after stroke. *Cochrane Database of Systematic Reviews Interventions*, *10*, 1–66. https://doi.org/10.1002/14651858.cd008728.pub3

Ghazi, H. F., Elnajeh, M., Abdalqader, M. A., Baobaid, M. F., Rahimah Rosli, N. S., & Syahiman, N. (2017). The prevalence of falls and its associated factors among elderly living in old folks home in Kuala Lumpur, Malaysia. *International Journal of Community Medicine and Public Health*, *4*(10), 3524–3529. https://doi.org/10.18203/2394-6040.ijcmph20174214

Harris, J. E., Eng, J. J., Marigold, D. S., Tokuno, C. D., & Louis, C. L. (2005). Relationship of balance and mobility to fall incidence in people with chronic stroke. *Physical Therapy*, *85*(2), 150–158. https://doi.org/10.1093/ptj/85.2.150

Hatch, J., Gill-Body, K. M., & Portney, L. G. (2003). Determinants of balance confidence in community-dwelling elderly people. *Physical Therapy*, *83*(12), 1072–1079. https://doi.org/10.1093/ptj/83.12.1072

Kung, C. Y., Yang, P. Y., & Yan, T. M. (2006). *Applying grey relational method to analyze the QFD process of medical service quality* [Conference session]. Conference Proceedings-IEEE International Conference on Systems, Man and Cybernetics, Taipei, Taiwan, *1*, 780–785. https://doi.org/10.1109/ICSMC.2006.384482

Lipsitz, L. A., Jonsson, P. V., Kelley, M. M., & Koestner, J. S. (1991). Causes and correlates of recurrent falls in ambulatory frail elderly. *Journal of Gerontology*, *46*(4), M114–M122.

Maki, B. E., & McIlroy, W. E. (1996). Postural control in the older adult. *Clinics in Geriatric Medicine*, *12*, 635–658.

Miller, W. C., Speechley, M., & Deathe, B. (2001). The prevalence and risk factors of falling and fear of falling among lower extremity amputees. *Archives of Physical Medicine and Rehabilitation*, *82*(8), 1031–1037.

National Institutes of Health (NIH). (2018). *National health and morbidity survey 2018: Elderly health. volume two: Elderly health findings (Vol. 2)*. Institute for Public Health, National Institutes of Health (NIH), Ministry of Health. https://doi.org/10.1017/CBO9781107415324.004

Nyan, M. N., Tay, F. E., & Murugasu, E. (2008). A wearable system for pre-impact fall detection. *Journal of Biomechanics*, *41*(16), 3475–3481. https://doi.org/10.1016/j.jbiomech.2008.08.009

Radharamanan, R., & Godoy, L. P. (1996). Quality function deployment as applied to a health care system. *Computers & Industrial Engineering*, *31*(1-2), 443–446. https://doi.org/10.1016/0360-8352(96)00171-4

Rizawati, M., & Mas, A. S. (2008). Home environment and fall at home among the elderly in masjid tanah province. *Journal of Health and Translational Medicine (Jummec)*, *11*(2), 72–82.

Sundgren, S., Stolt, M., & Suhonen, R. (2020). Ethical issues related to the use of gerontechnology in older people care: A scoping review. *Nursing Ethics*, *27*(1), 88–103. https://doi.org/10.1177/0969733019845132

Tinetti, M. E., Speechley, M., & Ginter, S. F. (1988). Risk factors for falls among elderly persons living in the community. *New England Journal of Medicine*, *319*, 1701–1707. https://doi.org/10.1056/nejm198812293192604

Uusi-Rasi, K., Karinkanta, S., Tokola, K., Kannus, P., & Sievänen, H. (2019). Bone mass and strength and fall-related fractures in older age. *Journal of Osteoporosis*, *2019*, 1–6. https://doi.org/10.1155/2019/5134690

Watson, G. (2004). *The legacy of Ishikawa*. Quality Progress.

World Health Organization. (2007). *WHO global report on falls prevention in older age*. WHO Press, World Health Organization.