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Abstract

The Quality Function Deployment, was born in Japan around 1965 as a method to deploy functions forming quality and measurable parameters concerning products, service or processes based on user needs. QFD is normally used in business contexts by multidisciplinary teams that, after significant training, collaborate to compile and to interpret user requirements embedded in a matrix with characteristics and attributes. However, the design discipline is changing, along with methodologies, approaches, multidisciplinary teams and working practice. The rise of recent co-designed methodologies, flexible and

holistic approaches in to design research lead to a decreased use of QFD among new designer generations. It has been noticed that when people are not adequately trained, and there is no opportunity to have face to face meetings, some methodological issues can arise while using QFD. The aim of this explorative work is to investigate the key factors that limit the use of QFD in the current multidisciplinary design research practice. A methodological literature review along with holistic experience fostered the development of a manifesto for a collaborative QFD methodology that stimulates collaborative multidisciplinary design research. This research impacts on developing a stimulating approach in to design research and practice, which shall be collaborative, inclusive, flexible, adaptable and open source, following the recent paradigms in cross-disciplines research practice.

Keywords (separated by '-') Human factors - Inclusive design - Quality Function Deployment - Design research

Collaborative Quality Function Deployment. A Methodology for Enabling Co-design Research Practice

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Keywords: Human factors · Inclusive design · Quality Function Deployment · Design research

1 Scientific Background

The cross contamination among applied methodologies in the ideation and development phases of industrial answers to human needs and requirements is fundamental in the design process.

Those under the domain of the theoretical approach of scientific research has given birth, during the last decades, to the practice of design research aiming to improve the life quality of people.

G. Di Bucchianico (Ed.): AHFE 2019, AISC 954, pp. 1–9, 2020.
https://doi.org/10.1007/978-3-030-20444-0_9

According to Archer, "Design research is systematic enquiry whose goal is knowledge of, or in, the embodiment of configuration, composition, structure, purpose, value, and meaning in man-made things and systems (…)" [1].

The concept of Design research affects the convergence of two different approaches and attitudes regarding the analysis of the actual reality and the experimentation and validation of theories with different levels of complexity. Different typologies of Design research have been developed and even more are still being proposed, within the dualism between science and industry, quality and quantity, theoretic models and prototypes.

Different research processes offer a variety of outcomes: methodologies aiming to develop shareable solution to human problems provide, generally, results like configurations, processes, and designs. When the aim of the research is to understand the causes and the contexts in which those problems are generated, Design research can provide closer results to the ones related to the scientific approach, such as theories, publications, experiments [2].

It is commonly recognized that the development of innovation in scenarios such as the Internet of Things, autonomous vehicles, assistive environments, eHealth, due to the complexity and variety of the competences required, necessarily implicates a multidisciplinary approach [3].

This exploratory work, very much focused on the Human Centered Design research and very close to industrial products and processes, can provide support for the creation of collaborative methodologies, services and other approaches that can offer new human needs-driven solutions. The term "new" recalls the concept of "innovation" referring to the major drivers in the development of contemporary industrial design research.

The design research team in these cases is composed of experts coming from Industrial Design and Engineering, Social Sciences, Ergonomics and Human Factors, Law and Policy, Economics, Computer Science, Communication and Robotics. The work of such research teams requires instruments and methods to enable them to organize and harmonize quantitative and qualitative approaches.

The analysis phase, mutual understanding, the language used to communicate ideas among different specializations have to be driven towards the direction of shared objectives derived from the real human experience.

The Quality Function Deployment (QFD) is a methodology that aims at fostering the ideation of innovative solutions based on a qualitative human-centered analysis through quantitative instruments of evaluation, like matrices and algorithms and the use of graphic [4].

It is interesting to see how the complexity and accuracy of this methodology in addressing human needs has been used for many years, since 1965.

However, the increased use of collaborative platforms along with different design approaches is nowadays overwhelming the structured, and not up-to-date QFD methodology. This research work, based on observation of design research practice in different teams, is positioning a hypothesis of applying the concept of collaborative platforms to further develop a collaborative QFD methodology able to cope to the new demand of flexible, ubiquitous design approaches for the design community.

2 The Quality Function Deployment Methodology

The Quality Function Deployment, also known as QFD, was born in Japan in 1965 as a method to deploy functions forming quality and measurable parameters concerning products, service or processes, based on user needs [4].

It was developed primarily by Yoji Akao, that described the tool as a "method to transform qualitative user demands into quantitative parameters, to deploy the functions forming quality, and to deploy methods for achieving the design quality into subsystems and component parts, and ultimately to specific elements of the manufacturing process" [5].

The Quality Function Deployment was further defined and rationalized by Yoji Akao, Shigeru Mizuno and Yasushi Furukawa, members of the JUSE (Union of Japanese Scientists and Engineers), in the early '70s after a applying the QFD for designing an oil tanker by Mitsubishi Heavy Industries [6].

QFD has largely been applied over half a century as a tool to literally capture the "voice of the customer". The voice of the customer is collected and analyzed in a variety of different ways: direct discussion or interviews, surveys, focus groups, customer specifications, observation, field reports. QFD is normally used in business contexts by multidisciplinary teams that, after significant training, collaborate to compile and to interpret user requirements embedded in a matrix with characteristics and attributes [7] (Fig. 1). AQ3

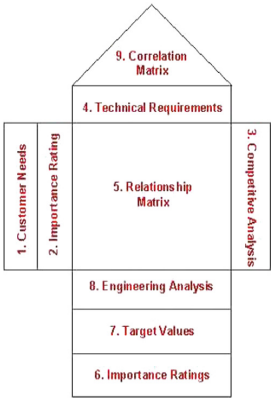

Fig. 1. Graphical representation of the traditional matrix of the Quality Function Deployment.

These parameters are embedded in a structure called the "House of Quality" that allows teams to envision solutions as an output to measure the relevance of the features for the satisfactions of the identified needs by using a graphical approach and predefined algorithms. Matrices are used as a communication tool at each step of the procedure, and the added value is within the process of communication and decision-making [8].

At the end of the 90s, when QFD has been largely diffused across the world, Professor Yoshizawa during the sixth symposium on QFD pointed out two fundamental observations on the significance of QFD in industry [9].

"QFD has changed what we have known as quality control in manufacturing processes, and established quality control for development and design. In other words, QFD has established quality management in product development and design. QFD has played a significant role when the focus of TQC shifted from process-oriented QA (Quality Assurance) to design-oriented QA and creation of a new product development system".

"QFD has provided a communication tool to designers. Engineers, positioned midway between the market and production, need to lead new product development. QFD renders a powerful arm to engineers as they build a system for product development".

After Akao, many other researchers contributed to the evolution of the QFD methodology that is currently in use. Different practitioners across the world took inspiration from different approaches such as: Conjoint Analysis, Theory of the Resolution of Invention-related Tasks (TRIZ), Conflict Management, Taguchi methods and different others [10]. A relevant fact is also shown in the application of QFD to software design other than product design [11]. Considering the perception of the design discipline among practitioners and researchers, it is easily recognizable a paradigm change that rapidly brought innovation across the years.

Methodologies, approaches and working practice are getting contaminated by cross discipline collaboration of teams. The rise of recent co-designed methodologies, flexible and holistic approaches in to design research lead to a decreased use of the originally deployed QFD methodology among new generations of designers. During the past years the authors have been using the QFD in several design research projects, with the aim of bringing innovation with support of Human Centered Design approach, including researchers from different fields and professionals from related markets [12].

It has been noticed that scarcity of awareness for designers and researchers, associated with communication difficulties, such as lack of face-to-face meetings and information exchange, developed instrumental methodological issues while using the QFD methodology.

One of the major issues is related to a lack of knowledge in interpreting matrices, not easily readable by subjects who are not proficient with QFD. An interesting research question that arises from this premise is: how to improve and update the use of the QFD methodology according to the current design practice and envision a further sustainable development for the future?

How collaborative models, platforms and technologies can foster the use and revitalize the application of the QFD tool across disciplines, countries and practitioners?

3 The Rise of Collaborative Platforms

Collaborative design has become a predominant approach in different research and working fields [13].

Collaborative design is an approach that allows a group of people to design a solution together. It helps teams to build a shared understanding of both design problem and solution [14]. It provides the means for people to work together to decide which functionality and interface elements best implement the feature they want to create [14]. Collaborative design is also described by Wang et al., as "a design process where a product is designed through the collective and joint efforts of many designers" [15].

It helps to think out of the box, brainstorms ideas with multidisciplinary teams and engages various stakeholders with different perspectives in the creative process. One of the most direct examples of how collaborative design is becoming popular among different fields is in the use of collaborative software, groupware or online platforms.

A collaborative groupware is an application software designed to support team members involved in pursuing a common task that enables them to achieve a particular goal [16]. During the process, team members use different tools and software to easier the decision making, management and creative thinking procedure.

Collaborative platforms gained popularity around 1990 when the US Government began to use them for different purposes [17]. One of the first robust applications was the Navy's Common Operational Modeling, Planning and Simulation Strategy (COMPASS), allowing up to six users to create connections with each other [18].

As the potential of Internet connection grew up, the number of users increased, the cost diminished and the continuous demand improved. Nowadays we are pervaded by an increased number of software, offering online collaborative services across the world. A short list of examples includes: electronic calendars/time management software, project management (CRM) solutions, workflow systems, knowledge management systems, enterprise bookmarking, online spreadsheets and collaborative documents, client portals, only to mention some of them.

Collaborative platforms, have been successful and used across different fields such as: Urban Planning (facilitated workshops with various communities), Community Building (such as the Detroit Collaborative Design Center (DCDC) [19]), Architecture (with different participatory methods called EDP "Equal Design Partners" and IDP "Integrated Project Delivery").

The success of these platforms is consistently described by Shea et al. in three main tasks: task interdependence (how closely group members work together), outcome interdependence (whether, and how, group performance is rewarded), and potency (members' belief that the group can be effective) [20].

To be successful, a collaborative project must establish a definition of the team, identify their outcomes, ensure there is a purpose of the collaboration and clarify the interdependencies of the members [21]. It is possible to interpret an overlap of the topics already part of the QFD methodology.

On the other hand, there are different design and implementation issues. Workers that collaborate through such groupware do not only have to address technical issues, but also carefully consider organizational aspects [22] and team processes that should be supported with the software application.

Some of the identified issues are: persistence is needed in different cases; online voice and video meetings disappears after the session, leaving behind a lack of information that cannot be stored, if not by accurately recording the sessions. Multiple input and output streams can improve concurrency issues into the shared software

applications. Motivational issues are important, especially in settings where no pre-defined group process was in place. Design patterns in the methodological process can drive design issues and choices in a way that all team members can participate in the development process.

While the QFD has been largely used over decades, the lack of a fresh, innovative and collaborative information sharing among multidisciplinary teams working on solution development represents one consistent issue in the current spreading of QFD to a wider audience.

4 The Case Study: A Methodology for Enabling Co-design Research Practice

The research team during various years of design and research practice, highlighted the majority of constraints while using the QFD methodology, particularly when the communication among teams was weak and inconsistent.

In details, during the research project "Habitat", aiming to design inclusive IoT-based solutions for older people, it has been noticed how the use of QFD methodology was not performing well across different multidisciplinary teams working from remote.

One of the major aims of the preliminary work of analysis of user needs and definition of design requirements, was to combine available technologies on the market with the design requirements expressed by the users by using the QFD methodology [23].

The Habitat research was developed around a User Centred Design approach [24] to design smart objects and systems that control them.

The applied methodology was aimed at optimizing the combination between constraints deriving from the technological choices and requirements derived from the analysis of the needs carried out with users.

During this research the inputs are the "Needs," and are defined to reflect users' necessities and the "Features", as measurable performances of the object to be designed. Both needs and features have been indexed in correlation through a matrix chart, which supported designers to evaluate the degree of relationship.

Starting from hierarchy resulting from expressed evaluations, designers developed through brainstorming the feasible solutions for answering user needs. One of the major issues encountered during this ideation process was related to the lack of communication when combining topics related to quality (emotions and necessities of selected categories of users), with others related to quantity (measurable features of the smart objects to be designed regarding both design and technologies).

As a result, the iteration among teams of designers, engineers and caregivers was not optimized, despite the rigid, functional structure of the QFD. In practice the methodology was performing well, but the connection among teams was not strong enough. This means unclear communication, time not optimized and the most important aspect, inefficiency during the design and optimization stages.

This helped to change the strategy behind the QFD, by organizing different meetings among designers, engineers and caregivers, by using online platforms as well as in person communication strategy.

In a further stage, when the prototypes were defined, a test phase was performed in order to collect feedback for mainly evaluating the usability.

At the end of the test phases, information gathered through observation, questionnaires and focus groups were further elaborated through collaborative platforms and online database.

As a result, since the process of design, implementation, prototyping and test was implemented with collaborative platforms and online database, the team performance as well as the efficacy of the design was perceivable among the team members.

The implementation of the QFD methodology with collaborative platforms available online and data sharing options fostered the inner collaboration between designers of different disciplines by improving their sense of responsibility as well as the group challenge in performing better.

5 Envisioning the Future of Collaborative QFD Platforms

The design process is evolving with a pace which is proportional to the technology development. The rise of recent co-designed methodologies, flexible and holistic approaches in design research may lead to a further decreased use of QFD methodology. This would translate in a big lost in terms of scientifically proven design methodology used in the research and development scenario.

Knowledge and training are also important in order to spread out the concept of QFD and the case study of the Habitat project proved how those topics are extremely relevant in current design research.

As a preliminary result, it is possible to state that the benefit of a ollaborative QFD platform are boosting the design outcomes.

The collaborative QFD platform could support practitioners but also researchers in interpreting matrices, analyzing workflows and foster the mutual understanding process among multidisciplinary teams, who are not physically connected.

As a preliminary statement of the Collaborative QFD platform manifesto, some of the inputs might be taken in to account:

- Allow multidisciplinary teams to foster understating of user needs;
- Enable team players to make meaningful brainstorming;
- Unobtrusively improve the quality of working practice;
- Foster a long-lasting Human Centered Design approach during different stages of the project;
- Connect mindsets, strategies and approaches with as less as possible constraints;
- Allow data sharing, information sharing, idea sharing in an accessible way;
- Increase awareness by allowing practitioners to adjust the system according to their needs.

A future impact of this work will lead towards the creation of a collaborative web-based platform that uses the QFD methodology to enable new generations of designers and engineers to intuitively understand customer needs, translate in to meaningful requirements and foster innovative designs.

This research will impact on developing a stimulating collaborative approach in to design research and practice, which shall be collaborative, inclusive, flexible, adaptable and open source, following the recent paradigms in cross-disciplines research practice.

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