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# Quality Function Deployment and operational design decisions – a healthcare infrastructure development case study

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## ABSTRACT

The purpose of this paper is to demonstrate how QFD can enhance a healthcare organisation's strategic operational alignment, by synchronising the infrastructure design with the service intention. In this empirical paper, a case study of a £15 million infrastructure development has been used as the unique context to assess and test the experimental findings. QFD was utilised in order to capture and transform the requirements of decision-makers, providers, patients and local communities into both service and building design for Project K, a healthcare infrastructure, in the U.K. Two full iterations of the QFD results are presented. Using QFD generated effectiveness and efficiency by creating an information exchange platform and providing the stakeholders with a framework to optimise the decision-making. This paper makes a practical contribution by empirically testing the QFD modelling and providing evidence of its implementation within the complex, dynamic and evolving nature of the healthcare built environment sector.

## ARTICLE HISTORY

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QFD; decision-making;  
healthcare infrastructure;  
built environment

## 1. Introduction

Infrastructure development is a complex and dynamic set of operations. Its complexity often creates uncertainty and variation, which prevents the planning and design processes from being effective and efficient (Pellicer et al. 2014). Kagioglou and Tzortzopoulos (2010) identified that research has demonstrated that the current design of healthcare in the built environment does not effectively meet the users' or consumers' needs or desires. These infrastructures do not have the ability to provide and deliver efficient healthcare services. Francis (2010) and Trant (2010) explained how important the design is within healthcare infrastructures, as it impacts staff performance, patient health outcomes and users' safety.

In their publication, commissioned by The Nuffield Trust, Francis and Glanville (2002) proposed that organisations need to engage further in a stimulating and creative dialogue with different groups of stakeholders; for instance, between the design decision-makers and the external design experts, in order to foster and develop quality buildings. In the report, it is suggested that the planning and design processes must be seen as catalyst processes for change, encouraging innovative approaches. Moreover, it emphasised that a framework for the iterative exchange of information between the different stakeholders needs to be put in place to explore and trigger innovation. However, according to Francis and Glanville (2002), the reality is that the vast majority of the design provision is disengaged from the needs of the healthcare system. Barlow and Koberle-Gaiser (2008) investigated the effects of planning, finance, construction and operation on the project delivery system for new hospitals. They suggested

that new public procurement models do not automatically provide efficiency and innovation benefits. Therefore, certainly at a local level, there are inefficiencies throughout the development process, despite advice, guidance and support from the Estates and Facilities directorate in the procurement and management of healthcare infrastructures, facilities and services (DoH 2006). These issues have been directly observed by the researchers where particular healthcare organisations have experienced extremely long planning (average = 4 years) and design (average = 2.5 years) cycle time (Bamford et al. 2015). An interviewee corroborated and explained that

the main issues are around the time it takes from planning to completion. We need to find a solution to be able to reduce this cycle time; it can take up to 15 years, from the conception to the completion.

The current ad hoc methods used and the silo structure lead to inefficiencies in the planning, design, construction and management, and is illustrated by the long development cycle time, the non-fitness for purpose and the lack of innovation (Alves, Milberg, and Walsh 2012) as well as the shortcomings of many new hospital design and layout (Kagioglou and Tzortzopoulos 2010; Wood et al. 2016).

This study will demonstrate to what extent Quality Function Deployment (QFD) can be applied in the built environment, despite its complexity, to overcome issues related to (i) linking the planning and design phases, (ii) capturing and using the 'voice of the customer' (VoC) as a design input, (iii) enhancing the communication and decision-making processes for the main stakeholders and (iv) provide an alternative and robust method to complex infrastructure procurement.

## 2. Literature review

### 2.1. QFD mechanism

In order to allow capturing and meeting customer requirements through the design process, QFD uses several linked matrix diagrams to present and exchange information (Evans and Lindsay 1996; Waterworth and Eldridge 2010). These connections of matrices are often referred as the 'House of Quality' (HoQ); as they form the shape of a house when put together (Waterworth and Eldridge 2010). Kutucuoglu et al. (2001) explained that, often, a QFD activity may require several iterations of HoQ to get down to the appropriate level of detail, where, in sequence, the customer requirements will be translated into specific technical characteristics, and so on.

The primary difference between QFD and other conventional quality management tools is that quality is being built into a product, and not inspected out of it (Lochner and Matar 1990). It is emphasised that the main feature of QFD is to collect the VoC, in order to provide the starting point for the identification of the technical requirements during and throughout a new product or service development, in a systematic manner (Murali, Pugazhendhi, and Muralidharan 2016; Sharifi, Ismail, and Reid 2006). QFD is powerful as it provides a framework to break down the objectives and to optimise the trade-offs throughout all stages of the development, from design to productions (Abdul-Rahman, Kwan, and Woods 1999). To work effectively, QFD needs to be developed by a cross-functional team, including research and development, design engineering and production, as well as finance and marketing. When QFD is well implemented, it provides an excellent interdepartmental means of communication that creates a common quality focus across all functions/operations in an organisation (Andronikidis et al. 2009). Communication and teamwork, within an organisation, must be greatly enhanced in order to make QFD work successfully (Dube, Johnson, and Renaghan 1999; Gerst 2004; Griffin 1992). By integrating the customer demands with the technical aspects, and aligning these with the resources and capability of the organisation, a firm can optimise its products and services as well as its own structure. Hence, QFD is not only a methodological tool, but a universal concept that provides a means of translating customer requirements during each stage of the service development (Chan and Wu 2002).

### 2.2. QFD benefits and drawbacks

Andronikidis et al. (2009) and Murali, Pugazhendhi, and Muralidharan (2016) reviewed the benefits of implementing QFD. They explained that it supports the cost reductions of new product development, reduces the rework and design changes, and reduces the risk of failure (Bouchereau and Rowlands 2000; Gonzalez et al. 2004; Griffin and Hauser 1993). It was identified that QFD supports the process to speed up the design and lowers cycle times substantially (Griffin 1992; Xie, Tan, and Goh 2003), as well as bringing stability into the quality assurance planning and increasing the possibility for breakthrough innovation (Vinodh, Devadasan, and Rajanayagam 2008; Xie, Tan, and Goh 2003) notably by enhancing cross-functional team communication (Chan and Wu 2002; Griffin and Hauser 1993). Ultimately, it improves the firm's overall operational

performances by meeting, or exceeding, customer demand and requirements by increasing customer satisfaction (Bouchereau and Rowlands 2000; Chan and Wu 2002; Gonzalez et al. 2004).

However, there are issues which have also been reported and summarised by Andronikidis et al. (2009). They explained that, firstly, QFD can be a long, onerous and cumbersome process (Bouchereau and Rowlands 2000; Chan and Wu 2002). A large amount of data must be gathered from customers, competitors and decision-makers, and processed to fit the QFD format. Sometimes, the relationships are difficult to establish and can depend upon the decision-makers' perspectives and subjectivities. It is possible that bias is injected at some stage of the QFD, the correlation amongst the various characteristics can lead to confusion, and the targets can be set imprecisely (Bouchereau and Rowlands 2000). Moreover, it is extremely important to note that QFD should be undertaken as an ongoing process, but that a saturation of data and information needs to be achieved for optimum results and conclusion. More specifically, QFD assumes that there are linear relationships between the customer requirements and the product or service characteristics, which is a simplified version of the reality (Karsak, Sozer, and Alpteki 2002). In other words, QFD assumes that the customer requirements are deterministic, belonging to the known domain and do not change substantially over time (Xie, Tan, and Goh 2003). QFD is a technique that aggregates both qualitative and quantitative data, but remains overall an interpretative structure (Andronikidis et al. 2009; Bouchereau and Rowlands 2000; Dagersten, Heywood, and Chatwin 1998). Therefore, some authors explained that QFD could be improved using more quantitative techniques, such as Analytical Hierarchy Process (AHP), to compensate for some of its subjective weaknesses (Dai and Blackhurst 2012; Kwong and Bai 2003). Integrating pairwise comparison would bring in a systematic process to overcome some of the disadvantages and reduce the decision-makers' subjectivity, for instance by controlling the decision-makers' bias, and improving the imprecise customers' ranking requirements (Kwong and Bai 2003). Ho, Dey, and Lockström (2011) combined QFD and AHP to enhance strategic sourcing decisions, where QFD enabled translating the requirement into the selection criteria and AHP allowed the weighting and the evaluation of those criteria. Karsak, Sozer, and Alpteki (2002) merged both to determine the intensity of the relationship between the requirements and the characteristics and Dai and Blackhurst (2012) combined both to measure the voice of stakeholder in the process.

### 2.3. QFD applications

Despite their manufacturing grounded origins, QFD has been successfully implemented within other sectors. Deszca, Munro, and Noori (1999), Chang and Chen (2011) and Zawati and Dweiri (2016) explored its application to the service sector, such as hotels and airline, for improving service and process design. It has also been implemented in the e-commerce sector (Tan, Tang, and Forrester 2004; Waterworth and Eldridge 2010), education (Koksai and Egitman 1998; Lam and Zhao 1998), (e)banking (Gonzalez et al. 2004; Shahin, Bagheri Iraj, and Vaez Shahrestani 2016), hospitality and tourism (Das and Mukherjee 2008; Dube, Johnson, and Renaghan 1999), public sector (Gerst 2004), retail (Sher 2006), information services (Chin et al. 2001)

and web interface (Hamilton and Selen 2004). Furthermore, some applications of QFD can be found within the healthcare sector (Chang 2006; George 2003; Lim and Tang 2000; Lim, Tang, and Jackson 1999) and the construction sector (Abdul-Rahman, Kwan, and Woods 1999; Dijkstra and Van der Bij 2001; Dikmen, Birgonul, and Kiziltas 2005; Gilbert III, Omar, and Farid 2016; Kassela, Papalexi, and Bamford 2017; Moghimi et al. 2017; Rahman and Qureshi 2008; Wang 2014). However, despite these construction-related studies, the application remains limited in depth, scale and scope, and implementations are scarce and embryonic compared to other sectors (Dikmen, Birgonul, and Kiziltas 2005). This is evidenced and supported by Cudney and Gillis (2016) who are aiming to propel further research of QFD in construction after their systematic literature review. Abdul-Rahman, Kwan, and Woods (1999) published a paper describing the concepts and techniques of QFD, applied to a low-cost housing scheme, which was the first example within the construction industry. John et al. (2014) undertook a study to understand the level of awareness of QFD in construction in Nigeria, finding very little evidence. Other applications of QFD in the built environment can be found in Ahmed, Sang, and Torbica (2003) who showed that QFD can be successfully used in the planning phase of civil engineering project. Delgado-Hernandez et al. (2007) applied QFD to plan and design a nursery, while explaining that the QFD benefits have not been fully realised in construction. Finally, Eldin and Hikle (2003) used it to design large size classroom and Wood et al. (2016) applied it to design a 'green' hospital in Malaysia. Although academics and practitioners seem to slowly be moving more towards aspect of its application in the construction, this remains infrequent, supporting the contribution of this study both at the practical and theoretical level (Cudney and Gillis 2016 and Dikmen, Birgonul, and Kiziltas 2005).

#### 2.4. QFD process

Adapted from Kathiravan et al. (2008), Rahman and Qureshi (2008) and Dale, Dehe, and Bamford (2016), a nine-stage framework illustrating the QFD process was developed, as per Figure 1. It enables a cross-functional team of decision-makers to capture the VoC and derivate the product and service design.

This framework is designed to populate the different component of QFD via the HoQ. First the 'voice of the customer' has to be captured, and then each item's importance is rated. The decision-makers will brainstorm to establish the technical characteristics of the products and services in relation to these requirements. Once these components have been agreed upon, their relationships are analysed. Afterwards, reviewing and modifying the requirements is often considered appropriate. Then, the decision-makers will study and analyse the foreseen trade-offs between each characteristic. At this stage, it is current practice to undertake a benchmarking assessment, where the decision-makers can record the performance of each requirement for a selection of benchmarks (here different healthcare infrastructure). Once the model is populated, the target values are computed and analysed, which will lead the decision-makers to derivate the initial service requirement specifications.

The following two sections introduce the generic issues and decision-making that tends to create inefficiencies and reworks

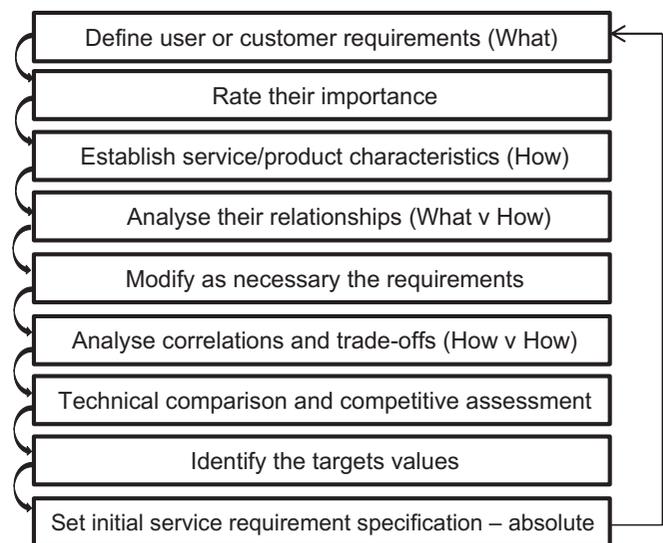


Figure 1. QFD – Nine stage framework. Adapted from: Dale, Dehe, and Bamford (2016).

within the planning and design processes. Moreover, they will set the foundation establishing to what extent QFD has a potential role to play in overcoming these difficulties.

#### 2.5. Built environment issues and key decision-making within planning and design

Schraven, Hartmann, and Dewulf (2011) reported that the key challenges to achieving effective infrastructure management are to: (i) align the infrastructure objectives with the context and the intervention; (ii) formulate coherent strategies between the different functions/departments or group of stakeholders, which still have a strong silo culture; and (iii) manage accordingly the multiple actors with different interests.

Therefore, collaborative work, certainly at the planning and design stage, must be undertaken between the healthcare and construction industries to achieve the objectives. According to Francis and Glanville (2002), there are four strategic directions to follow: (i) development of new forms of procurement based on partnering and long-term relationships; (ii) agreement on the mechanisms with which to achieve a greater integration of design and construction; (iii) agreement on how to manage and measure the increased levels of performance and; (iv) development of information frameworks and systems to support the strategic planning and design programme for the healthcare environment, as well as mechanisms with which to effectively pass on the lessons (Kagioglou and Tzortzopoulos 2010). Therefore, can QFD be the systematic platform used to address these key challenges?

During the planning and design processes, senior managers will have a set of decision-making critical in the success or failure of any project. Considering the complexity perceived, the decision-makers have substantial responsibilities regarding the design philosophy, impacting the size and layout, the operations and services integration, the site location, and the service quality aimed for. All of these decisions must be transparent, rational and inclusive for the large range of stakeholders.

Francis (2010) pointed out that effective design will provide efficient layout, supporting productive workflow, making best use of staff and technology, and will naturally impact on the reduction of waiting times and improve user experience by making pathways clear. Moreover, Trant (2010) identified eight key attributes that make a good design: (i) the building needs to make a contribution to its local environment by being suitably integrated; (ii) the design should take advantage of open space; (iii) logical and clear pathways with one main reception is essential; (iv) the building needs to take advantage of the natural environment to create a sustainable infrastructure and utilise environmentally sensitive material and technology; (v) the design needs to consider a well-planned waiting area with fit for purpose finishes and furniture; (vi) the building should take advantage of natural light and have appropriate ventilation systems; (vii) the building needs to have effective, well-located storage space; and, finally (viii) the design should have the potential to be adapted easily for future changes and modifications. Hence, can QFD be the systematic platform used to capture and integrate these design attributes?

## 2.6. Evidence-based design (EBD), an emerging solution

Codinhoto et al. (2010) explained that evidence-based design (EBD) is a tool that supports sharing vast amounts of information in order to optimise design decisions between the architects, engineers and healthcare planners. Malkin (2008) pointed out that EBD is an approach to assist decision-makers in making design decisions regarding the size design of the room, and the equipment within it, based on the available knowledge and information. Although Codinhoto et al. (2010) recognised its potential, they also acknowledged that the use of EBD for all decisions would be considerably challenging, given the timescales and variety of decisions required. Therefore, it should only be used to support critical decisions (Codinhoto et al. 2010). Many of the EBD's general features and objectives are similar to QFD; however, QFD mechanics are more detailed and prescriptive, as per the nine steps framework described in Section 2.4. It has been pointed out that EBD is relatively recent and lacks descriptive and practical evidence. Similarly to QFD, only a few applications are available in the context of new infrastructure development, and practitioners will need to develop their own models until EBD has been implemented within an effective interface, such as the Cochrane Collaboration. This emphasises the rationale for testing empirically QFD in a complex built environment in order to understand its potential and usefulness in this dynamic context of healthcare infrastructure development. To frame the research further, the following research questions have been posited: *RQ1: to what extent is QFD a relevant and reliable solution to optimise new infrastructure design decisions?* And *RQ2: how can QFD be applied to support to capture the service needs, contribute towards the design decisions, and enable the alignment of the firm's departments strategies?*

## 3. Methodology

### 3.1. Research method

In order to address the two research questions, an embedded single-case study approach was derived from a wider action

research project, investigating the built environment practices of a healthcare organisation from a planning, design, construction and management perspective. The researcher had an active role and unlimited access to the organisation over an extended time period of two years, and participated to some of the public consultation events.

Ryan, Scapens, and Theobald (2002) defined 'a case study' as a research method on its own. It can be used as an effective mechanism by which to study, analyse and report on a phenomenon. Similarly, Yin (2009) explained that a case study can be selected by researchers who are interested in empirically exploring, explaining and illustrating a phenomenon in depth (i.e. the application of QFD within the healthcare built environment), by capturing a rich understanding of the phenomenon in a real-life context.

In this paper, the case study (referred to as Project K) was used as a vehicle, both to expose and test the experimental findings. QFD was led and deployed by one of the author to optimise the decision-making process behind the design of Project K, a £15 million infrastructure. The researcher proposed QFD, provided the expertise and facilitated its deployment, using a QFD Online template (QFD Online, 2007). The rationale for using a case study was to empirically test the modelling technique, provide evidence and proof of concept of its application in this complex healthcare built environment context.

To develop the QFD framework, a series of eight workshops, attended by different groups of stakeholders, was organised and facilitated by the researcher. To reach a satisfying level of detail to support the design decision-making process, two iterations of the models were necessary. The decision-makers were actively involved in the data collection, analysis and interpretation. The decision-makers were composed of a multi-disciplinary team of 10 senior managers: three members from Estates, three from Primary care, two service providers, one clinician and one planner. Moreover, the stakeholder group was composed of a sample of 22 patients, service users and providers, who had a direct interest in this project. Throughout the project, the groups remained the same to avoid confusion and promote continuity in the decision-making process. Because of the nature and importance of this project, the decision-makers were committed and consistently actively participated to the workshops. Table 1 provides details regarding the different workshops organised.

As part of the public consultation for a new infrastructure develop process, the healthcare organisation collected a large set of data through patient needs' questionnaires (an extensive survey of  $N = 3055$  undertaken during the public consultation), focus group, and, from other consultation activities. These data were compiled to form the basis of the QFD inputs and was aggregated in the model during the series of workshop, as per Table 1.

Table 1. List of the QFD workshops.

No.	Participants	Workshop type	Outcomes
1	Decision-makers (10)	QFD presentation	Training and inputs
2	Decision-makers (10)	QFD development	Initial model: QFD step 1
3	Stakeholders (22)	QFD iteration	Iteration 1: QFD step 1–3
4	Decision-makers (10)	QFD iteration	Iteration 1: QFD step 4–9
5	Decision-makers (10)	QFD iteration	Iteration 2: QFD step 1–9
6	Decision-makers (10)	QFD assessment	Model sense making
7	Decision-makers (10)	QFD assessment	QFD interpretation
8	Decision-makers (10)	QFD assessment	Model feedback

The qualitative data collected from these four months of public consultation were analysed using thematic analysis and then coded to form the starting point of the QFD model. A coded comprehensive list of the needs and requirements from the different stakeholder groups (patients, service users and providers) was established with their associated importance. This informed element of the weights and trade-offs in the QFD model. The public consultation for a new infrastructure development enabled the organisation to capture a large amount of qualitative data about the future users' requirements, and 'the voice of the customer'. Hence, the public consultation (part of the planning phase) and the QFD (part of the design phase) became two integrated processes for this project.

The analysis and interpretation of the QFD model was organic, iterative, and was led by the decision-makers once the consensus was established.

### 3.2. Data analysis

The assessments were agreed and made by the team based on primary and secondary data.

The workshops were structured around the review of the QFD model and the data from the public consultation, which would have been distributed to all decision-makers prior to the workshops. A series of questions from the facilitator (the researcher) were asked throughout each workshop to ensure that all the different perspectives had been captured and the data fully analysed. This enabled the recording of extra valuable data based on the feedback, reflections and comments from the decision-makers.

### 3.3. The case background – the decision-makers' vision for Project K

Project K had a strategic and innovative focus. The healthcare organisation aimed to develop a state of the art building, to create an environment in which the local authorities, the council and the social services organisations could cohabit, under one roof, to offer and provide an integrated service to their local communities. This was part of the transformation programme, through which the decision-makers realised how important their infrastructure will be in the future as a vehicle, both to achieve their vision and to support the development of a competitive edge, and to become a world-class organisation.

The aim was to develop a range of innovative care packages, in collaboration with the aforementioned partners (local authorities, council and social services), in order to provide an optimum care service for the patient. One of the objectives was to reduce hospital admissions, by being able to provide a fast diagnosis, and to have a more preventive approach to healthcare. To achieve this model of excellence of care, it was clear that, firstly, the infrastructure needed to be adequately designed. After all, it is the interface and the physical resource from which to provide the services. Furthermore, a new clinical services portfolio needed to be developed for creating the innovative care package; this would be achieved through suitable service and operation design. The organisation's ambition for Project K was to design a patient-centred approach, so as to create a sustainable local health economy for the local population and to change the current healthcare model, which is dominated by hospital delivery.

Developing this infrastructure was a challenge for the organisation as this had not been planned or designed before. Therefore, QFD was proposed and tested to establish if it could offer a framework, to allow the decision-makers to conceptualise their ideas for Project K by integrating the voice of the local communities, and considering the financial and physical constraints.

## 4. Findings

### 4.1. The public consultation findings from the thematic analysis

Throughout the four months during which the local population and users directly engaged with the decision-makers to discuss Project K, a list of key requirements was developed. The following quotes represent some of the main and recurrent themes that were analysed from the different public consultation feedback documents. It was important to the local population to have a: *bright and welcoming building with lots of space, possibly with: multi-functional areas, ensuring maximum flexibility and some extra space for people to meet.*

Moreover, members of the public and staff said that they were expecting: *a building designed around people and their movements to ensure that it is cohesive.* It was recorded that the users also required good communication and clear signage.

Future users said: *the internal walls and static display should be used to provide information about where to access services.* It was also mentioned that: *signs should be written in several languages and pictures provided, so that everyone can understand them.* Some users explained that it would be important to have: *friendly guides, or buddies, to help people to find their way around the building.*

Furthermore, the aspects of sustainability and eco-friendliness were also specific requirements that the local population were keen to have: *a purpose-built, efficient and eco-friendly building, using technologies to minimise the building's environmental impact.* Also, it was mentioned that: *having an external area with wildlife and trees instead of shrubs would be beneficial.*

The accessibility was a recurrent theme. The public were expecting: *lots of free car parking, a dedicated space where people can be picked up or dropped off for appointments, and good bus routes, ideally with a bus stop outside the building.*

Other issues, such as security and safety, were raised. It seemed important to have: *security teams and cameras to help people feel secure, plus: first-class hygiene and infection control procedures were expected.*

### 4.2. The QFD process – first iteration

QFD is used to assess the stakeholders' key elements and requirements, by following the nine steps process presented above.

#### 4.2.1. Define service user and stakeholders' requirements

The decision-makers needed to define both the user and stakeholders' requirements, based on their strategy and vision. This information was collected through the analysis of the patient needs' questionnaires, focus group feedback, and, especially, from the consultation activities reports. Within the QFD team, the consensus was established and 10 main demands of quality,

or stakeholder requirements, were identified. Therefore, the new infrastructure needed to meet the following requirements: (i) have very good accessibility; (ii) ensure minimum waiting time; (iii) have an effective workforce; (iv) demonstrate good communication; (v) provide an aesthetic environment; (vi) provide excellent customer service; (vii) have multiple, integrated services; (viii) respect patient security and privacy; (ix) achieve a design which is easy to navigate through, and; (x) be the main and unique healthcare point of contact for the local population.

These requirements were sorted into different domains, including clinical vs. non-clinical, or infrastructure vs. services. This step translated the strategy and vision of the decision-makers, and the users' expectations.

#### 4.2.2 Rates of importance

During the dedicated QFD workshop 3, 22 participants were asked to rate the importance of each of the 10 requirements, on a scale from 1 to 5 (1 = neutral, 2 = important, 3 = quite important, 4 = very important, 5 = extremely important). The mode for each of these 10 requirements was then selected, as shown in Table 2. This process allowed the decision-makers to focus on the features that the stakeholders perceived as being a priority in order to increase the user's satisfaction.

'Very good access to the centre' and 'high quality customer service' were the most important criteria agreed by the decision-makers to be 'extremely important', with an associated weighting of 5. Then, 'minimum or no waiting time', 'workforce effectiveness' and 'easy navigation of the building' were allocated a weighting of 4 and thought to be 'very important'. 'Multiple services', 'patient security and privacy' and 'main point of contact for healthcare' had a weighting of 3, meaning that they were 'quite important'. Finally, 'good communication' and 'aesthetic environment' had a weighting of 2.

#### 4.2.3. Establishing service and infrastructure characteristics

In this third stage, the decision-makers identified a set of 15 technical characteristics. These helped to define how it would be possible to deliver both patient and service users' needs within measurable and operational features. The decision-makers identified and agreed on the following: (i) a modern and flexible design; (ii) suitable car parking; (iii) specific transport links; (iv) an effective and transparent waiting time with queuing systems in place; (v) to provide extended opening hours; (vi) a successful service integration; (vii) deployment of an efficient communication culture and processes; (viii) an aesthetic interior decor (ix) to have an integrated IT system and to provide DIY technology; (x) to achieve top quality healthcare service; (xi) to provide multi-lingual support; (xii) to have complying disabled

access inside and outside; (xiii) to have different types of consulting rooms; (xiv) to have good signage and a clear layout, and; (xv) to be a single point of access with a pharmacy, physio and hot desk clinical specialist services.

Following the technical characteristics, the HoQ facilitated the analysis between the requirements and the technical characteristics by analysis of each relationship, establishing a coefficient.

#### 4.2.4. Analysing the requirements' relationships with the characteristics

The team of decision-makers analysed the relationships between each requirement and each characteristic in order to assess to what extent there was a correlation, according to a predefined scale. This needed to be agreed so as to build a consensus (1 or  $\Delta$  = weak relationship; 3 or O = moderate relationship; 9 or  $\Theta$  = strong relationship), as Figure 2 shows.

The two most important requirements identified were 'very good access to the centre', and 'high quality customer service'.

In this matrix, the decision-makers considered and agreed that 'very good access to the centre' had a weak relationship with 'modern and flexible design', 'service integration/appropriate service design', 'IT system and DIY technology', 'multi-lingual support/council services', and 'single point of access'. The decision-makers deemed that 'very good access to the centre' would be achieved through the use of different aspects, and they did not think of it as external accessibility alone. Therefore, it was discussed that the use of performing IT systems and technology would support improvements in the access (i.e. use of telecare and providing an online booking website). Moreover, the decision-makers thought that providing 'multi-lingual support/council services' would increase access to a non-English speaking population, which happened to be high in this area. Furthermore, it was believed that, if the infrastructure was modern, patients would be more likely to use the services there instead of going to hospital. Lastly, if the service portfolio was to be integrated and the infrastructure had a single point of access strategy, then the patients would have greater access to the right care.

Furthermore, 'very good access to the centre' had a moderate relationship with 'extended opening hours'. If the centre is open until 9 pm instead of 5 pm, more patients will have a greater access to care.

Finally, it was established that 'very good access to the centre' had a strong relationship with 'car parking', 'transport links' and 'disabled access inside/outside'. The decision-makers agreed that these three characteristics would have a strong, positive impact on accessibility.

The researcher facilitated each intersection of the matrix during the workshops, in order to build a complete agreement with the decision-makers.

#### 4.2.5. Modifying the requirements as necessary

At this stage, a revision of the service/product characteristics is useful; this step created the opportunity to challenge the QFD results and the data input within the framework. As a result, it was decided to step back and review the process. The decision-makers agreed on the consensus, and aligned even further, their strategies and processes, in order to achieve the objectives which had started to emerge from the QFD, especially between Estates and Primary Care.

Table 2. Requirement weightings.

Very good access to the centre	5.0
Minimum or no waiting time (capacity mgt)	4.0
Workforce effectiveness	4.0
Good communication	2.0
Aesthetic environment	2.0
High quality customer service	5.0
Multiple services	3.0
Patient security and privacy	3.0
Easy navigation in the building	4.0
Main point of contact for healthcare	3.0

Quality Characteristics v Demand Quality	Modern and flexible design	Car parking	Transport links	Waiting time and queuing system	Extended opening hours	Service integration / appropriate service design	Communication culture and processes	Aesthetic interior decor	IT system and DIY technology	Top quality healthcare service	Multi-lingual support / council services	Disabled access inside/outside	Different types of consultancy rooms	Good signage and clear layout	Single point of access (pharmacy, physio, hot desk specialist services)
Very good access to the centre	Δ	Θ	Θ		O	Δ			Δ		Δ	Θ			Δ
Minimum or no waiting time (capacity mgt)	O			Θ	Θ	Θ	Δ		O				Δ		Δ
Workforce effectiveness					Δ	O	Θ		O	Δ			Δ		Δ
Good communication						Θ	Θ		Δ	Δ	Δ				Δ
Aesthetic environment	Θ							Θ				Δ	Δ	O	
High quality customer service	O	Δ	Δ	Θ	Θ	O	Δ	O	O	Θ	Δ	Δ			O
Multiple services	Θ				O	Θ	O		Δ		O		Δ		Θ
Patient security and privacy	Δ			Δ		O	Δ				Δ		O		O
Easy navigation in the building	Θ					Δ		Δ	Δ			O		Θ	Δ
Main point of contact for healthcare					O	Θ			O	Θ			Δ		Θ

Figure 2. Relationships analysis.  
 Note: Δ = weak; O = moderate; Θ = strong.

4.2.6. Analysing services correlations and trade-offs

For each of the 15 characteristics, under the standard HoQ framework, the decision-makers needed to identify the correlation – either positive, neutral or negative – between all the other characteristics. This was facilitated by the ‘roof’ of the framework. It allowed for consideration of trade-offs and balances the resources at the design phase, as Figure 3 illustrates. To evaluate the correlations, the standard notation is used.

The decision-makers considered and agreed that ‘modern and flexible design’ had a negative correlation with ‘car parking’. They were thinking that the car parking will consume space that could be otherwise utilised. However, they thought that ‘modern and flexible design’ had a positive correlation with ‘transport links’, ‘waiting time and queuing system’, ‘IT system and DIY technology’, ‘top quality healthcare service’, ‘disabled access inside/outside’, ‘good signage and clear layout’, and ‘single point of access’. It shows that, by achieving one of the characteristics (i.e. ‘modern and flexible design’), other features will also be impacted positively.

In terms of the decision-making process, it is the negative correlations that must be looked at carefully, and, where necessary, trade-offs will need to be considered. It is relevant to note that, out of the 105 possible correlations, only 12 were marked with a negative coefficient and 38 marked with a positive, or strongly positive, coefficient, which left 55 uncorrelated characteristics. Therefore, in terms of investment, the possible negative trade-offs, were between ‘car parking’ and ‘transport links’. There might be a negative correlation between ‘transport links’ and the perception of ‘disabled access inside / outside’ the infrastructure, as well as a negative correlation with ‘good signage and clear layout’, because these might be outside of the scope of the healthcare organisation. However, if not included within the design phase, these factors will still prove detrimental to ‘top quality healthcare service’, and, therefore, must be considered, so as to reduce risks in the future.

Furthermore, there is a negative correlation between ‘waiting time and queuing system’ and ‘single point of access’, as, logically,

‘single point of access’ would create more demand for the healthcare’s services; hence, ‘waiting time and queuing system’ can be affected if suitable processes are not designed effectively. The same rationale applies to ‘extended opening hours’.

Moreover, the decision-makers identified that ‘aesthetic interior decor’ could have a negative correlation both with ‘good signage and clear layout’, as well as with ‘disabled access inside/outside’, even if this could prove a controversial issue, as was mentioned by the decision-makers. ‘IT system and DIY technology’ could be perceived as being negatively correlated with ‘top quality healthcare service’, as, normally within the service industry, DIY technology emerges only within the low-cost organisations. This step was extremely powerful in starting to identify potential issues and make the decision-makers think about the challenges associated with the design decision-making process. It was also noted that every trade-off would impact either the cost of the design or the quality of the service delivery.

4.2.7. Technical comparison and competitive assessment

Within the framework, the seventh stage is used to self-assess the demand criteria against the competition, or against identified benchmarks. The HoQ framework enables the decision-makers to rate and compare the 10 stakeholders’ requirements against identified schemes, by allocating a score ranging between 0 and 5: 0 = worst and 5 = best. Five schemes were identified as appropriate benchmarks; two were internal Benchmarks (the current K centre and the B centre) and three of the schemes were external (the P and W gateways and Sutter Health). Firstly, the scores allocated to the current centres, within the area of the Project K, were the lowest. In the K area, the healthcare services were not performing at an acceptable standard (the scores for which ranges between 0 and 3), which was one of the reasons for this new development, and this was clearly translated into the framework. These centres will be replaced by the Project K. On the other hand, Sutter Health was the best performing scheme, with scores ranging between 4 and 5. Finally, in the middle,

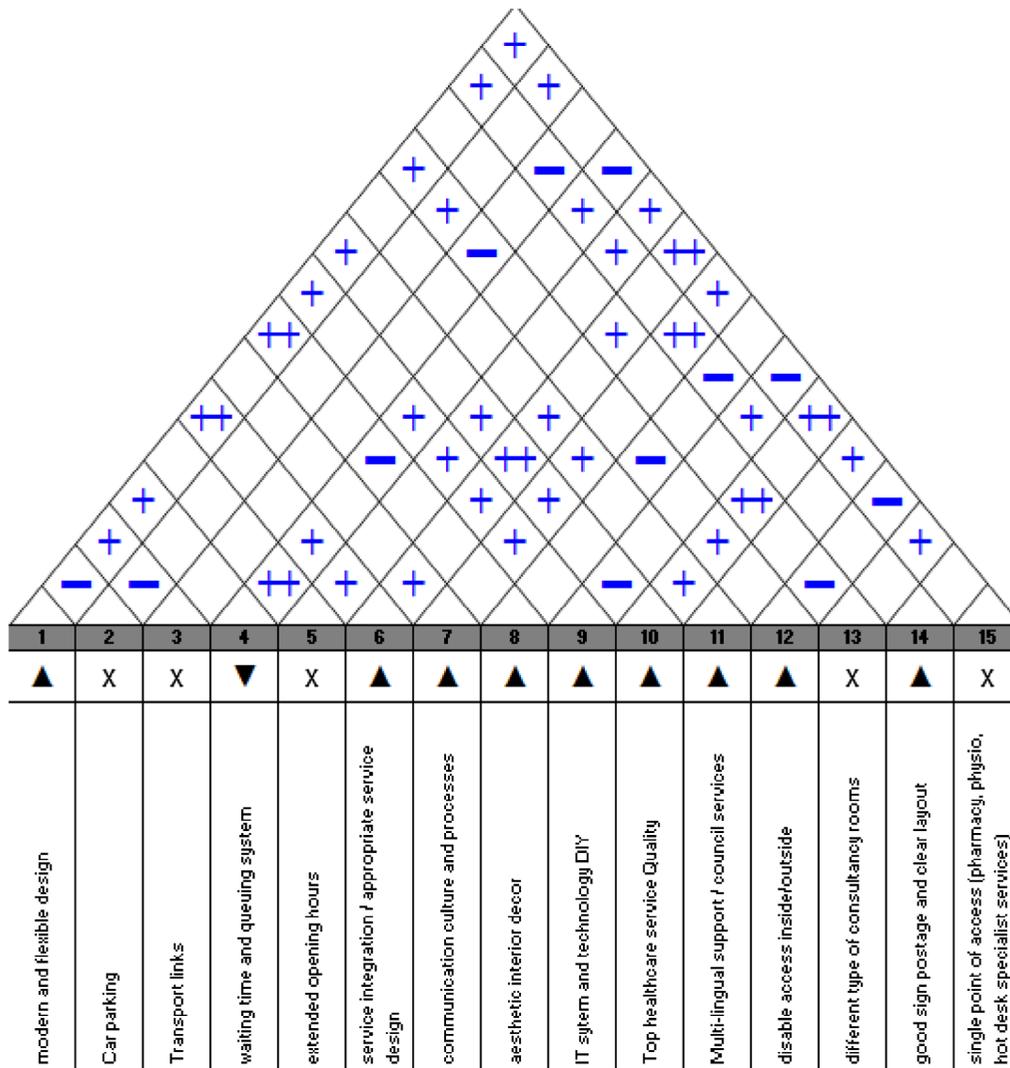


Figure 3. Trade-off analysis.  
 Note: ‘++’ = strong and positive correlation; ‘+’ = positive correlation; ‘-’ = negative correlation; and, ‘--’ = strong and negative correlation.

the internal B scheme and the external P and W gateways were comparable, with scores ranging between 3 and 4, as shown in Figure 4. The assessments were made by the team based on primary and secondary data.

4.2.8. Identify the targets values

The following step of the QFD process is designed to establish a measurable objective for each technical characteristic, whenever possible and coherent. The rationale for setting up objectives is associated with the old principle: *what gets measured gets achieved* (Kaplan 2001). Therefore, the decision-makers agreed on the design objectives, as Table 3 shows. The team agreed that 11 out of the 15 technical characteristics should be associated with a key target value. This also supports the decision-making process at the design stage. For example, it was established that 150 car parking spaces were going to be the minimum target value, to ensure that the accessibility element was met. In terms of accessibility and ‘transport links’, it was suggested that four bus routes should service the future healthcare centre. Moreover, the decision-makers agreed that, when patients are given appointments, 90% should wait 10 min or less, and that a process would need to be designed to monitor this target.

While the targets summarised in Table 3 are very challenging, the decision-makers wanted to set the bar high at the design phase so as to be innovative. It was also mentioned that this would be agreed with the different partners to see what was realistic and achievable and to be reviewed once the infrastructure is up and running.

4.2.9. Set initial requirement specification – absolute and relative scores

The last step of the QFD process is to quantify the requirements, based on the aggregation of the different types of information input into the HoQ model. It is important to quantify the requirements in order to focus on the attributes which have the most impact and return, as Table 4 shows.

It can be noted that, from the first iteration of the QFD process, ‘service integration/appropriate service design’ was the technical characteristic with the highest weighting (14.2), followed by ‘extended opening hours’ (11.0), then ‘modern and flexible design’ (10.8), and then ‘single point of access’ (8.8). At the bottom, ‘multi-lingual support’ (2.2), ‘different types of consultancy rooms’ (2.3) and ‘aesthetic interior decor’ (3.4) can be found.

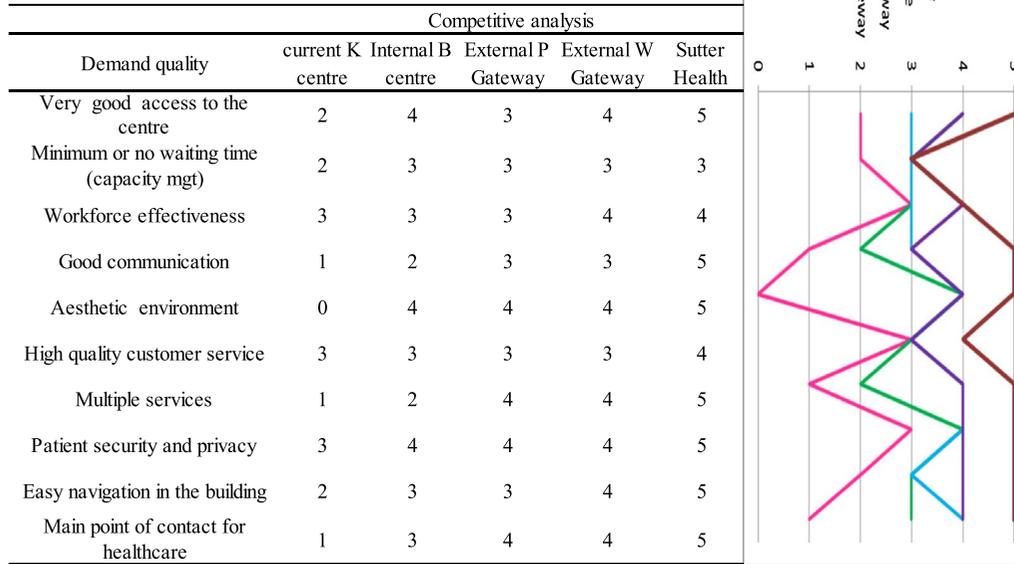


Figure 4. The comparative analysis.

Table 3. Identification of the target values.

Technical characteristics	Targets or limit values
Modern and flexible design	–
Car parking	Minimum 150 spaces
Transport links	4 bus routes/dedicated transport
Waiting time and queuing system	For appointments, 90% within 10 min waiting window
Extended opening hours	3 days a week open until 9 pm
Service integration/appropriate service design	No unproductive conflict between partners
Communication culture and processes	Communication SOP
Aesthetic interior decor	–
IT system and DIY technology	50% of customers using online appointments, check-in
Top quality healthcare service	13 points on the performance framework
Multi-lingual support/council services	–
Disabled access inside/outside	Over comply with regulations
Different types of consultancy rooms	–
Good signage and clear layout	Reduce number of direction queries
Single point of access (pharmacy, physio, hot desk specialist services)	Less than 20% of customers to be referred elsewhere

Table 4. Normalised relative weight.

Technical characteristics	Normalised relative weight
Modern and flexible design	10.8
Car parking	4.7
Transport links	4.7
Waiting time and queuing system	7.8
Extended opening hours	11.0
Service integration/appropriate service design	14.2
Communication culture and processes	7.0
Aesthetic interior décor	3.4
IT system and DIY technology	5.8
Top quality healthcare service	7.3
Multi-lingual support/council services	2.2
Disabled access inside/outside	6.0
Different types of consultancy rooms	2.3
Good signage and clear layout	4.1
Single point of access (pharmacy, physio, hot desk services)	8.8

#### 4.2.10. Representation of the QFD model – 1st iteration

Figure 5 shows the entire HoQ model after the first iteration. In this section, the QFD process was detailed and the HoQ application to the design of the new infrastructure development was explained. However, the QFD process is iterative; it starts at a high level and drills down further using the technical characteristics as the requirements, which initiates its second iteration. This enables the decision-makers to go a step further and supports the rationale behind each set of design decisions. The results of the second iteration are presented below.

#### 4.3. QFD case of K – second iteration

In this section, only the results of the second iteration are provided. In the subsequent, or second, iteration, all that is needed

is to transfer the previous characteristics into the requirements. Therefore, without interpretation, this second iteration comprises the 15 requirements, modified through the process of the first iteration as presented in Table 4, and the full cycle was undertaken again.

#### 4.3.1. Representation of the QFD model – second iteration

Figure 6 shows the entire HoQ model after the second iteration. This enabled the decision-makers to drill down a level to conceptualise the design even further, thus increasing their strategy alignment and developing a common vision. This also led the decision-makers to establish targets, which will need to be achieved in line with their future perfect vision.

## 5. Discussion

To provide a clear structure for the discussion, this section has been arranged around the research questions.

### 5.1. RQ1: To what extent is QFD a relevant and reliable solution to optimise new infrastructure design decisions?

The results presented two iterations at the infrastructure level, in which the operations strategies and the ‘voice of the stakeholders’ were the starting point. The aims were: (i) to capture the voices of the decision-makers, customers, users and patients, and then translate them into the design of both the infrastructure and the service operations; (ii) to further increase the alignment of the different departmental strategies (estates, finance, primary care); and, (iii) to support the decision-making process at the design phase.

QFD was used to achieve higher performances in the design decisions and to ensure fitness for purpose within the design of the new infrastructure, which lead to user satisfaction, and, theoretically, contribute to develop a competitive edge. This fits with the arguments put forward by Cauchick-Miguel (2005), Rahman and Qureshi (2008), and Sher (2006).

As with the work reported by Olhager and West (2002), the QFD process was well received by the team and they tangibly recognised its benefits. A decision-maker stated that

QFD adds value and supports the clarity of communication between the different stakeholder groups. It enabled synchronisation with the planners and architects. The more detailed information we can provide the architects, the designers, the planners, and the more accurate the tenant requirement documents are, the more chance we have got of getting the infrastructure fit for purpose.

It was explained that QFD enabled the organisation to

cut down on some of the waste. Because we are more tightly specifying what we want, there is less waste, as we have more chance of getting what we want by identifying the requirements and communicating them precisely, as opposed to providing vague instructions as we used to do.

It was observed that prior QFD, during a public consultation of a new infrastructure development, respondents sometimes struggled to generate positive, constructive feedback, and members of the public were only focused on the location rather than the service design (Bamford et al. 2015; Dehe

and Bamford 2015). However, much as with the application reported by Hamilton and Selen (2004), with the structured QFD framework in place, the respondents were more willing to share their ‘ambitious’ ideas, so that they could be taken into account. In terms of the synchronisation of agenda and strategy, QFD enabled the design process to be streamlined. Furthermore, echoing the research of Delano et al. (2000) it allowed materialising and visualising the decision-making processes, making the outcomes more objective and transparent for the stakeholders. This also aligns with the perspectives of Crowe and Cheng (1996).

### 5.2 RQ2: How can QFD be applied to support to capture the service needs, contribute towards the design decisions and enable the alignment of the firm’s departments strategies

QFD was used as a robust, user-oriented methodology, so as to speed-up the design decision process (Bamford et al. 2015) and help in achieving a consensus regarding service design, patient pathways, service integration and the building design, which came to pass through the discussions generated during the iterations of the HoQ. As with the Multiple Criteria Decision Analysis (MCDA) applications reported by Dehe and Bamford (2015), it tangibly helped to add transparency, rigour and robustness to the decision-making process, and was extremely effective when associated with the mapping of the service pathways and integrations. For this organisation, this was the first experiment to structure the design phase along with QFD or similar models such as EBD. The work of Bamford et al. (2015), reporting on the application of lean techniques within service and manufacturing domains, suggested that over time organisations will grow in maturity in their application of specific techniques. It can therefore be proposed that, each time QFD is applied the organisation will refine and develop its knowledge maturity and start the next application by populating it with even more accurate factors than the previous one. This then has the potential to further impact the tangible effectiveness and efficiency of the operational design decisions.

QFD also enables the focus to be on communication and creates appropriate synergies between the different functions – it enables silo structures to be challenged, which was one of the main sources of frustrations and inefficiencies (Bamford et al. 2015). As per the early work by Hauser and Clausing (1988) reporting the benefits of QFD, in this case it facilitated the planning and the communication, as well as supporting the co-ordination of skills, competencies and information needed to complete the design stage and optimise future construction and management of the infrastructure.

QFD was the planning and development technique deployed to provide the decision-makers, providers and suppliers, and contractors (Dehe and Bamford 2013) with a framework in which to collate and share structured information, in order to ensure that fitness for purpose was built into the design element of the infrastructure, as well as to take into account customer requirements. Ultimately, as per the work of Andronikidis et al. (2009) and Griffin (1992) this leads the organisation to achieve a competitive edge by satisfying customers, reducing costs, and, to a certain extent,





**Legend**

- Strong Relationship 9
- Moderate Relationship 3
- Weak Relationship 1
- Strong Positive Correlation
- Positive Correlation
- Negative Correlation
- Strong Negative Correlation
- Objective Is To Minimize
- Objective Is To Maximize
- Objective Is To Hit Target

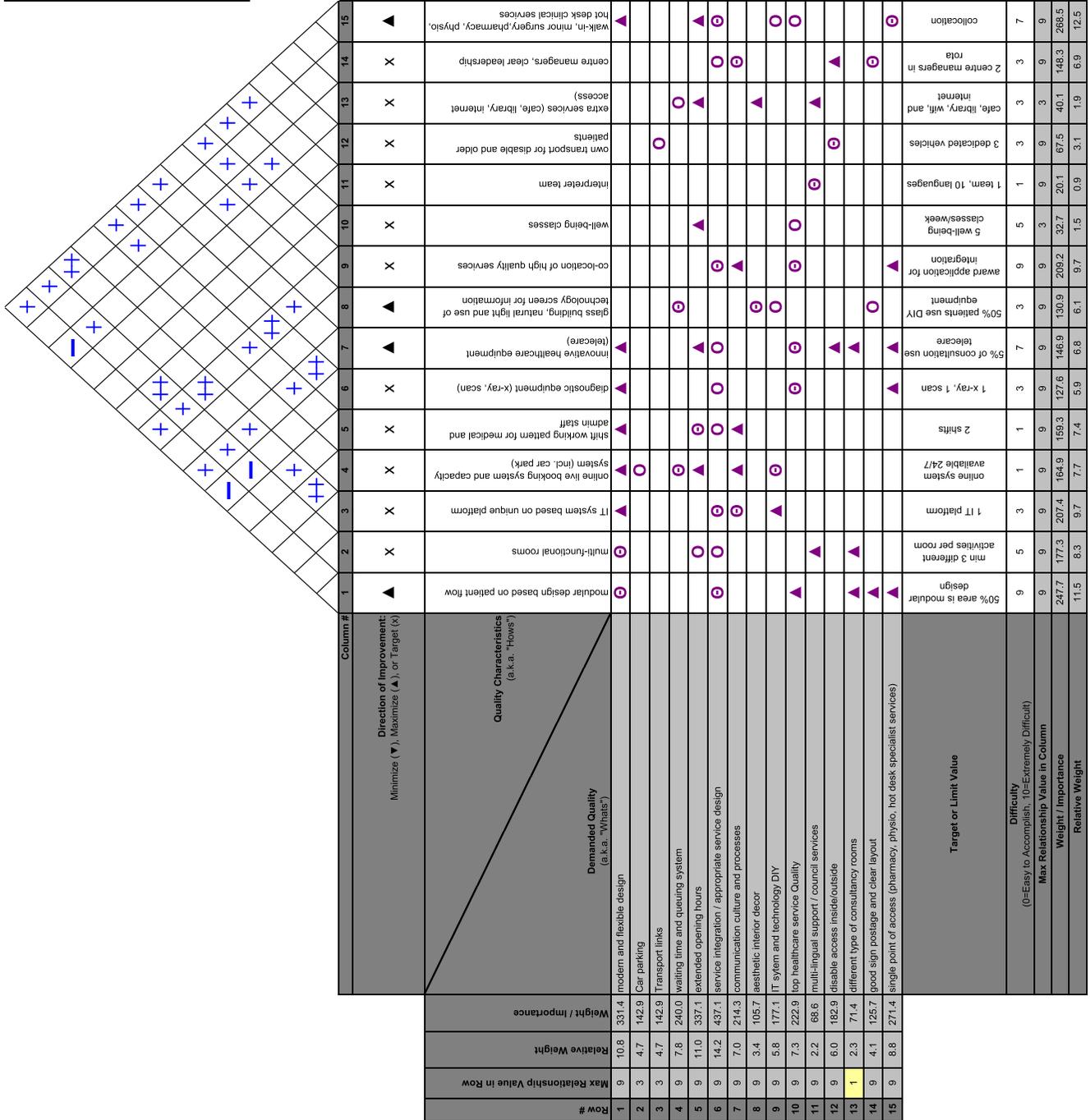


Figure 6. The entire HoQ for the second iteration.

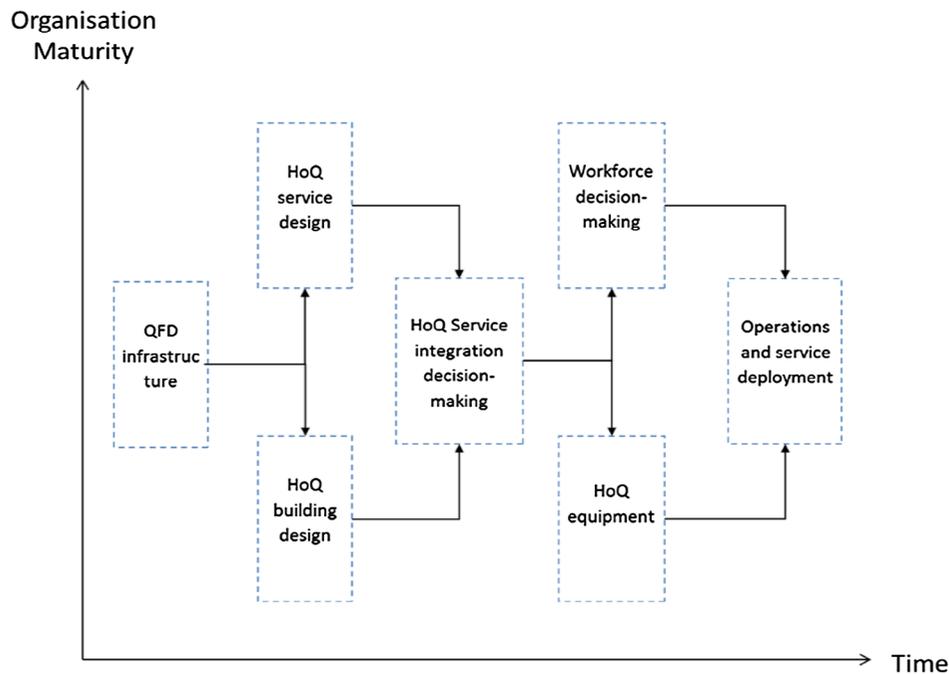


Figure 7. QFD derivation.

by enhancing innovation (Vinodh, Devadasan, and Rajanayagam 2008) at infrastructure level.

However, it is suggested that QFD could be used at different design levels: infrastructure, service, building, workforce and equipment, with further iterations, until saturation is reached, as Kutucuoglu et al. (2001) suggested. This would then lead to re-organise even further the design stage around the QFD process, as illustrated in Figure 7. It will ultimately optimise the decision-making behind the construction, operations and services provision.

It is suggested that the QFD process should start during the planning phase, as demonstrated using Project K in conjunction with the public consultation. The HoQ framework is used to collect and integrate data from the different sources, using the information gathered from the public consultation. The decision-makers and other key stakeholders can then develop the design decisions with their shared vision in mind. In this specific experiment, two iterations were shown. However, the decision-makers could decide to go through third and fourth iterations, in order to refine the design features and support the decision-making processes still further. Once saturation is reached and agreed upon by the decision-makers, and the firm's vision and departments strategies have been shared, communicated and are aligned, then, they will know the type of resources needed and be aware of the potential trade-offs (Delano et al. 2000). This is a very useful and informed position to be in. Eventually, the decision-makers are able to build the full business case, providing accurate information to any external parties, such as architects, planners and builders.

However, the decision-makers could go even further. As suggested in Figure 7, the results generated by QFD, at infrastructure level, have generated design characteristics that could be split, either into building design, or operations and service design. For instance: 'modern and flexible design'; 'car parking'; 'aesthetic

interior decor'; 'disabled access inside/outside'; 'different types of consultancy rooms'; 'good signage and clear layout'; 'modular design based on patient flow'; 'multi-functional rooms'; 'diagnostic equipment (X-ray, scan)'; 'glass building, natural light and use of technology screen for information'; 'walk-in, minor surgery, pharmacy, physio, hot desk clinical and specialist services' are all characteristics generated by and linked to the building structure, to a certain extent.

Conversely, 'transport links'; 'waiting time and queuing system'; 'extended opening hours'; 'service integration/appropriate service design'; 'communication culture and processes'; 'IT system and DIY technology'; 'top quality healthcare service'; 'multi-lingual support/council services'; 'IT system based on unique platform'; 'online, live booking system and capacity system (incl. car park)'; 'shift working pattern for medical and admin staff'; 'innovative healthcare equipment (telecare)'; 'co-location of high quality services'; 'well-being classes'; 'interpreter team'; 'own transport for disabled and older patients'; 'extra services (cafe, library, internet access)'; 'centre managers, clear leadership' are all characteristics generated by and linked to the structure of the operations and services.

Hence, it could be suggested that HoQ models simulate each specific focus, increasing and optimising the decision-making processes still further, during the design phase, by bringing downstream stakeholders into upstream decision-making processes, and by increasing transparency and rationality. This helps to define and design the service integration, by overlaying the two structures – the building and the services. Ultimately, the decision-makers will be in position to reduce uncertainty and define the equipment and the workforce needs, with precision, by the end of the design phase.

In common with the results stated by Xie, Tan, and Goh (2003) regards the actual application of QFD, it tangibly sped up the design process compared to the original process; and hence,

reduced the overall cycle time, as well as bringing stability into the quality assurance planning, along with increased possibility for innovation (Bamford et al. 2015; Vinodh, Devadasan, and Rajanayagam 2008). This also fits with the reported works of Griffin (1992) regards the outputs from capturing the VoC. Furthermore, as per the works of Bouchereau and Rowlands (2000), who examined the ways QFD could be helped, and Gonzalez et al. (2004), who observed customer satisfaction of using QFD with e-banking, it perceptibly contributes towards cost reductions in the new infrastructure, by reducing the rework and design changes and reducing the risks of failure. Additionally, QFD allows the enhancement of cross-functional team communication, as mentioned by Chan and Wu (2002), and Waterworth and Eldridge (2010). Finally, it will have improved the organisation's overall, operational performances, by meeting or exceeding customer demands and requirements, thus increasing their overall satisfaction (Andronikidis et al. 2009; Bouchereau and Rowlands 2000; Chan and Wu 2002; Gonzalez et al. 2004).

The authors strongly believe that QFD can be used as an innovative solution to support the entire design phase (Vinodh, Devadasan, and Rajanayagam 2008). It has many similarities with EBD, as Codinhoto et al. (2010) suggested in their work focused on improving the healthcare built environment. Malkin (2008) also helped highlight the potential of providing a visual reference for EBD; like EBD, QFD assists the decision-makers in optimising decisions, regarding size and design of the infrastructure and the equipment needed, based on the available knowledge and information.

## 6. Conclusion

The purpose of this paper was to demonstrate how QFD has been implemented to support healthcare infrastructure design decisions. The planning and design phases need to be effectively linked – it was observed that a loss of momentum and time was occurring between these two phases (Bamford et al. 2015). It was established that using QFD, as the design process, could allow generating effectiveness and efficiency into the design phase. Through analysing the data collected during the planning phase, using QFD, it becomes possible to transparently build quality into the design of the operations and infrastructure, especially when the integration of the services is being sought.

In terms of key messages, during the design phase of this £15 million project, it was important to create an information exchange structure between all the stakeholders involved. Here it was: GPs, clinical staff, the architects, the contractors, the sub-contractors and the experts: Estates, Finance, Service Development and Primary Care, which became possible through the use of QFD. By having a robust process in place to organise the design phase, the tenant requirements and the full business case, along with the financial modelling, could be integrated and synchronised. Through doing this, decision-making processes, within the design phase, were tangibly improved.

### 6.1 Managerial and theoretical contribution

The attractiveness of QFD is irrefutable and applications have been well documented, however, very few successful

implementations have been actively described within the built environment sector (Ahmed, Sang, and Torbica 2003; Cudney and Gillis 2016; Delgado-Hernandez, Bampton, and Aspinwall 2007; Dikmen, Birgonul, and Kiziltas 2005). This study addressed issues raised by academics (Cudney and Gillis 2016; Eldin and Hikle 2003; Moghimi et al. 2017) by demonstrating how QFD, based on its standard framework, the HoQ, was used by the decision-makers to support design decisions, in a very transparent and rational way, in a complex healthcare construction environment. Moreover, this led to the practical contribution of this study addressing concrete organisational problems. Design is an extremely complex activity; often lagging behind the overall phase, and is regularly passed on to the external planners and architects, leading to long delays and poor decisions because disconnected to the users. QFD was implemented into Project K and demonstrated how: (i) it captures the 'voice of the stakeholders, customers and patients', and translating them into the design of both the infrastructure and the service operations; (ii) it further increases the alignment between the different departmental strategies, and; (iii) it supports the decision-making process during the design phase. This was achieved through an iterative process, facilitated by the HoQ, which enabled the cross-functional teams to drill down to the service design level, by analysing the service/product characteristics and setting up specific, explicit, transparent and measurable target values, based upon the desired requirements. QFD enabled: (i) the decision-makers to explore the relationships between the stakeholders' vision and integrate it with the requirements from the local population, at the end of the planning phase and during the design phase; as well as, (ii) capturing the service needs to support the design decisions. This detailed, unique and documented application of QFD constitutes relevant empirical findings for managers and project managers alike in the built environment, it offers a structured alternative to their planning and design practices. Moreover, it provides academics with a successful and in-depth case study, building on the embryonic and scarce body of evidence of QFD implementations in the construction industry, complementing Ahmed, Sang, and Torbica (2003), Delgado-Hernandez, Bampton, and Aspinwall (2007), Dikmen, Birgonul, and Kiziltas (2005) and Eldin and Hikle (2003) works and addressing Cudney and Gillis (2016) calls.

### 6.2. Limitations and future research

Despite the contribution, we acknowledge three limitations. First, this study was ambitious in scope and scale but was still subject to restrictions in terms of time and access. It would have been beneficial to have been able to track further in time the implementation and to analyse its impact onto the overall service quality. However, the practicalities of the research did not allow this. Second, arguably more iterations would lead to more accurate and detailed results. The study stopped after two iterations due its novelty for the decision-makers and the organisation's maturity. We anticipate that the organisation convinced of the QFD impact will fully adopt it as part of its design processes in the future and run several iterations until saturation is reached. Third, these sets of findings are based on a single case study. This does not diminish the results' quality and validity, but does not allow for their generalisation, and further applications will be studied.

With regard to potential future research, the authors would highly recommend increase used of QFD within innovative design projects to enhance infrastructure service quality. For instance, similar techniques can be used to optimise universities' infrastructure design, where decision-makers face comparable issues. As QFD emerged from manufacturing, there is great potential for it to be used on a more frequent basis with regard to aspects of infrastructure design and service provision. Perhaps the use of more quality techniques such as QFD, design of experiment, benchmarking and MCDA would result in more seamless construction delivery?

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