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A system design framework for the integration of public preferences into the design of large infrastructure projects☆

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A B S T R A C T

Large infrastructure projects such as new roads, railways and nuclear plants have often suffered from public opposition, causing significant delays and costs. In many cases poor engagement between the supporters of construction and the public have contributed to this. Therefore, this paper proposes a novel design framework with the aim of improving public engagement at an early design stage. Following a modified quality function deployment (QFD) process, it enables incorporation of public preferences into the design process, thus helping to improve the social acceptability of large infrastructure projects and reduce costs related to opposition and delays. The application of the framework is illustrated by a case study related to design of nuclear power plants.

Keywords: Large infrastructure; Nuclear power; Participatory design; Quality function deployment; Stakeholder engagement; System design

1. Introduction

Even the briefest review of the literature concerning large construction and infrastructure projects will reveal an almost bewildering array of papers and reports documenting public opposition. These include hydroelectric projects in South Africa and China (Tilt et al., 2009), high-speed rail construction in Italy (Della Porta and Andretta, 2002), waste disposal in Ireland (Ferreira and Gallagher, 2010) or new nuclear plants in India (Gauba, 2013), to name just a few. Approaches, such as focus group discussions, local liaison meetings and interviews, can be used to engage with the public in relation to such projects (see e.g. Powell and Colin, 2008). However, owing to the often complex and technical nature of the design of large infrastructure, it is currently uncommon for the public's view to be integrated into the design process. Indeed, a literature search for the use of participatory design processes in large construction and infrastructure projects yields no results to our knowledge.

Participatory design developed in the late 20th century, particularly in the field of information technology and computer systems, as detailed in Kensing and Blomberg (1998). Research has shown that the main benefits of participatory design processes lie not just in the fact that they lead to socially informed designs but also that stakeholders (who could otherwise block or delay the development) feel that their views and perspectives are valued by the designer (Schuler and Namioka, 1993). Providing a means for genuine two-way dialogue between designer and stakeholders, including the public, can help in developing mutual respect and trust. Ultimately, by building

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trust with the public a designer may be better positioned to elicit design requirements that can be integrated into the infrastructure in question, leading to designs which align with values, ideas and expectations of the public.

However, applying participatory design processes to complex construction and infrastructure projects is not a trivial task. One of the difficulties is engaging the public and eliciting their views so that they can be used in the design process in a meaningful way. A further important issue is that significant design changes can only be carried out cost-effectively at the early conceptual design stages which means that any effort to include a public input into design must also take place at the early stage. These and other issues are explored in more detail in the proposed participatory design framework, as described in Section 2. This is followed by a case study in Section 3 with the nuclear industry used as an example to illustrate how the framework can be applied. The case study presents a hypothetical conceptual design of a nuclear power plant generated using the framework. This design is compared to the two existing designs proposed for construction in the UK, Westinghouse's AP1000 (WEC, 2008) and Areva's EPR (AREVA, 2005). The relative strengths and weaknesses of the approach in the proposed framework are discussed in Section 4 and conclusions are drawn in Section 5. As far as the authors are aware, this is the first proposal for a participatory design framework for large infrastructure projects.

2. Design framework

2.1. *The participatory design framework*

A participatory design framework which enables incorporation of stakeholder preferences, including those of the public, must satisfy a number of criteria, as follows:

(i) allow different system design requirements to be considered by all relevant stakeholders;
(ii) cope with varied requirements, some of which would be technical and quantitative and some of which could be qualitative and ambiguous;
(iii) provide simple traceability of the integration of the requirements of different stakeholders, so that it could be demonstrated to all stakeholders that their input was considered seriously; and
(iv) allow for the weighting of different requirements to reflect their technical (design) importance as well as their significance to different stakeholders.

There are many decision-support methods that can be used in system design, including general morphological analysis, multi-attribute decision analysis, decision (Pugh) matrices and quality function deployment (QFD) (Blanchard and Fabrycky, 1998; Dieter, 2000; Azapagic and Perdan, 2005). Among these, QFD matches closely the above criteria and has therefore been selected for use in this work. A full description of the standard QFD method is beyond the scope of this paper but can be found, for example, in Chan and Wu (2002). In short, QFD uses matrices and a weighting system to help designers incorporate and prioritise client's preferences into product design. Fig. 1 shows a standard QFD layout which has been adapted for the purposes of this work by modifying the weighting system for design requirements, so that they are weighted both on their technical importance and on their importance to different stakeholders. This is illustrated in Fig. 2 and described in more detail in the following sections.

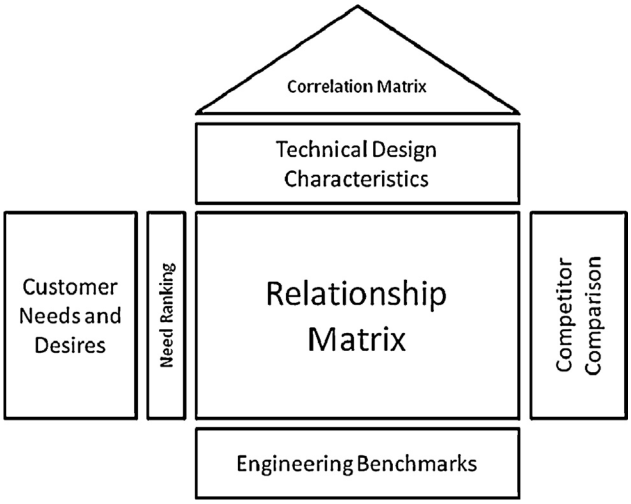

Fig. 1 – Layout of a standard quality function deployment (QFD) sheet.

2.2. *Framework steps*

As shown in Fig. 2, the main steps of the framework are:

1. determination of the requirements of all stakeholders, including the public;
2. completion of the system-level QFD sheet including the weighting of different requirements; and
3. interpretation of the output from the QFD to define the system-level specifications of the design.

Each of these steps is discussed below, with reference to Fig. 2 throughout. Note that the 'designer' referred to is assumed to be a team of engineering professionals with appropriate skills and experience to carry out such a task. The figures in the following section are based on the case study presented in Section 3 and whilst they refer to the nuclear industry to help illustrate the application, the steps described are equally applicable to the design of any other large infrastructure system.

2.2.1. *Step 1: Stakeholder requirements and public preferences*

The first step (as with many design processes) is to understand the requirements of the client. The proposed framework also calls for a set (or sets) of additional stakeholder requirements, such as the requirements of the public. In order to determine these additional stakeholder requirements, the client's requirements are combined with existing design knowledge to create a series of possible design options which are then put to the stakeholders to elicit their preferences. As mentioned previously, this can be achieved in a number of ways such as questionnaires, interviews, focus groups or liaison meetings. The approach used and the scope of consultation with the public will depend on many factors, including the available time and the budget. The designer can then use the input provided by the stakeholders as a set of 'external' stakeholder requirements, which can be integrated alongside the client's requirements in the QFD sheet.