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A decision support tool based on QFD and FMEA for the selection of manufacturing automation technologies

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Abstract

With the advent of the new challenge to design a more lean and responsive computer-integrated manufacturing system, firms have been striving to achieve a coherent interaction between technology, organisation, and people to meet this challenge. This paper describes an integrated approach developed for supporting management in addressing technology, organisation, and people at the earliest stages of manufacturing automation decision-making. The approach uses both the quality function deployment (QFD) technique and the failure mode and effects analysis (FMEA) technique. The principal concepts of both applications are merged together to form a decision tool; QFD in its ability to identify the most suitable manufacturing automation alternative and FMEA in its ability to identify the associated risk with that option to be addressed in the manufacturing system design and implementation phases. In addition, this paper presents the results of a practical evaluation conducted in industry.

Keywords: QFD; FMEA; Decision-making; Manufacturing systems; Automation; Man–machine interaction

1. Introduction

Today the manufacturing world is facing major pressures due to the globalisation of markets. Internal and external organisational pressures have led to increased competition, market complexity, and new customer demands. It has been noted how organisations adopt lean or agile manufacturing strategies to overcome this problem [1]. These strategies have different approaches and elements to address in the design of the manufacturing system, but they all depend on two common things: acquiring technology and the effective operation of this technology by humans.

Developments in computer-integrated manufacturing systems and the methods by which they are designed have induced firms to shift their emphasis towards human factors, particularly man–machine interaction, and to consider people as assets instead of costs. In the manufacturing systems design literature, emphasis is directed towards producing a coherent interaction between technology, organisation, and people to overcome new competitive challenges. Various authors have pointed out the importance of addressing human factors generally in the evaluation and design of manufacturing systems, calling specifically for the adoption of a balanced method based on technology, organisation, and people [2–4].

Furthermore, the literature on investment evaluation is continuously being updated to accommodate the new market demands and manufacturing technology [5]. The changes in the market environment and justification of new manufacturing technologies have caused management to shift away from relying on traditional economic justification to the incorporation of intangible benefits and organisational strategy [6]. However, there continue to be reports of investment failures and difficulties in computer-integrated manufacturing systems implementation, due to the lack of addressing man–machine interaction appropriately [2,7].

Moreover, an investigation into human factors and manufacturing automation clearly illustrated that despite managers' interest in having a balanced consideration of both technology and humans in the planning and designing of their manufacturing system, and their efforts in placing more emphasis on the importance of human elements in

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the manufacturing environment; in practice they were still not appropriately considering man–machine interaction in their manufacturing automation decision-making [8]. In addition, it was noticed that management needed to be supported in improving man–machine interaction at the earliest stage of their manufacturing automation decision-making process, in order for them to avoid the pitfalls of over-automation which can lead to the failure of computer-integrated manufacturing systems to deliver cost-effective and flexible operations.

In an attempt to respond to this, a decision tool for the integration of technology, organisation, and people during the automation decision-making process has been developed. The decision tool uses the quality function deployment (QFD) technique to link management's automation investment objectives with technology, organisation, and people evaluation to determine the best alternative. Thereafter, the failure mode and effects analysis (FMEA) technique is deployed to draw attention to any problems that might be associated with that option in terms of design and implementation.

This paper describes the approach and the results of an evaluation in industry. It is organised into five sections. Section 2 contains a general view of the developed method while Section 3 describes the technique in detail; the methodology is applied in a real case in Section 4 followed by a discussion in Section 5 and conclusions in Section 6.

2. The approach

The consideration of technology, organisation, and people issues in manufacturing automation investment is an activity that requires the evaluation of both tangible and intangible elements. The QFD method not only allows the consideration of both tangible and intangible elements, but also the identification of the importance of each of these elements in the decision. However, there are situations when taking a decision could result in accepting some trade-offs, and it becomes an obstacle for managers to revisit and plan for them in the implementation stage. Therefore, an extra technique (FMEA) was appended to highlight any related trade-offs or areas of concern for implementation review.

Rather than the traditional investment justification process, the proposed methodology uses the QFD technique as the prime method to link the automation investment objectives with technology, organisation, and people evaluation for the selection of the best alternative. Subsequently, the decision is fed into the FMEA technique to highlight the related potential problems associated with it. The combination of the QFD and FMEA techniques shown in Fig. 1 represents an outline of the developed methodology concept.

2.1. Quality function deployment review

The QFD technique is a systematic procedure for defining customer needs and interpreting them in terms of product features and process characteristics. The systematic analysis helps developers avoid rushed decisions that fail to take the entire product and all the customer needs into account [9]. It is a process that involves constructing one or a set of interlinked matrices, known as "quality tables." The first of these matrices is called the "House of Quality" (HOQ). The HOQ matrix has two principal parts; the horizontal part, which contains information relevant to the customer, and the vertical part, which contains corresponding technical translation of their needs [10]. The basic process underlying QFD resides in the centre of the matrix where the customer and technical parts intersect, providing an opportunity to examine each customer's voice versus each technical requirement, for a detailed description of QFD formation process [9].

The proposed methodology uses this concept to capture the automation investment objectives and link them with technology, organisation, and people evaluation criteria for the selection of the best alternative. Therefore, in this methodology rather than listing the design requirements along the top portion of the HOQ matrix the automation investment evaluation criteria are listed. The relationship examination allows management to examine each automation investment objective against the evaluation criteria, as well as identifying the importance of each evaluation criterion. Thereafter, a second house is used to identify the most appropriate automation alternative. Therefore, rather than listing the part/subsystem requirements along the top portion of the second matrix the automation alternatives are listed. The relationship examination allows management to examine each automation alternative against the evaluation criteria (input from HOQ) to identify the most appropriate option.

However, as in any evaluation process, there are situations in which making a decision involves trade-offs

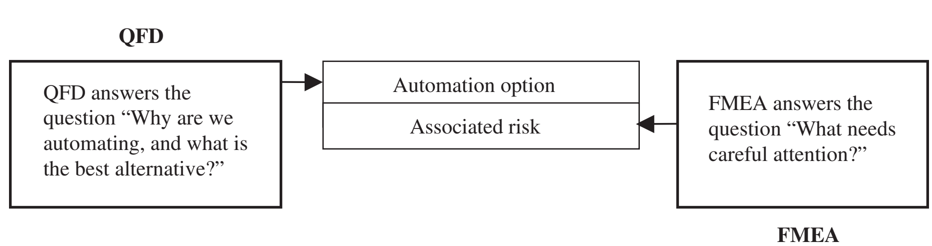

Fig. 1. Manufacturing automation decision tool concept.