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Conceptual process planning – an improvement approach using QFD, FMEA, and ABC methods

Alaa Hassan [a,b,*], Ali Siadat [a], Jean-Yves Dantan [a], Patrick Martin [a]

[a] LCFC Laboratory, Arts et Métiers ParisTech, 4 rue Augustin Fresnel, 57078 Metz, France
[b] Mechatronic Engineering Department, HISAT, Barza, Damascus, Syria

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ABSTRACT

Conceptual process planning (CPP) is an important technique for assessing the manufacturability and estimating the cost of conceptual design in the early product design stage. This paper presents an approach to develop a quality/cost-based conceptual process planning (QCCPP). This approach aims to determine key process resources with estimation of manufacturing cost, taking into account the risk cost associated to the process plan. It can serve as a useful methodology to support the decision making during the initial planning stage of the product development cycle. Quality function deployment (QFD) method is used to select the process alternatives by incorporating a capability function for process elements called a composite process capability index (CCP). The quality characteristics and the process elements in QFD method have been taken as input to complete process failure mode and effects analysis (FMEA) table. To estimate manufacturing cost, the proposed approach deploys activity-based costing (ABC) method. Then, an extended technique of classical FMEA method is employed to estimate the cost of risks associated to the studied process plan, this technique is called cost-based FMEA. For each resource combination, the output data is gathered in a selection table that helps for detailed process planning in order to improve product quality/cost ratio. A case study is presented to illustrate this approach.

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1. Introduction

The major manufacturing cost is determined in the early stages of product development. It is critical to be able to assess quality and cost as early as possible in the product development cycle. Conceptual process planning (CPP) is an activity for designers to evaluate manufacturability and manufacturing cost in the early product development stage [1]. This paper proposes an approach to develop a quality/cost-based conceptual process planning (QCCPP). This approach uses QFD (Quality Function Deployment) and FMEA (Failure Mode and Effects Analysis) tools to determine manufacturing resources with appropriate process capability to produce product characteristics. Then, it uses ABC (Activity-Based Costing) method to roughly estimate manufacturing cost. Fig. 1 shows the QFD, FMEA, and ABC methods in the product development process.

A number of different methods have been developed for evaluating the impacts of development process on product quality and cost. Some researchers focus on the first two phases of product development, i.e., product planning and parts deployment. For example, Bode and Fung introduce a method for incorporating financial elements into the house of quality in order to optimize product development resources towards customer satisfaction [2]. Eubanks [3] presents an Advanced FMEA method (AFMEA) applicable in the early stages of design to enhance life-cycle quality of ownership. The process begins by QFD method to identify customer requirements and relate them to engineering metrics and functional requirements responsible for satisfying the customer. Chen and Weng [4] apply fuzzy approaches and QFD process to determine the required fulfilment levels of design requirements for achieving the maximum satisfaction degree of several goals in total in the product design stage. Karsak [5] presents a zero–one goal programming methodology that includes importance levels of product technical requirements (PTRs) derived using an analytic network process, cost budget, extendibility level and manufacturability level goals to determine the PTRs to be considered in designing the product. Other researches focus on the later product development phases like process planning. Most of them deal with computer-aided process planning (CAPP). Culler and Burd [6] present architecture in which customer service, CAPP and ABC are incorporated into a single system, thereby allowing companies to monitor and study how expenditures are incurred and which resources are being

* Corresponding author at: LCFC Laboratory, Arts et Métiers ParisTech, 4 rue Augustin Fresnel, 57078 Metz, France. Tel.: +33 387375430; fax: +33 387375470.
E-mail address: alaa.hassan@metz.ensam.fr (A. Hassan).

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used by each process. Lau [7] introduces an intelligent computer-integrated system for reliable design feature recognition in order to achieve automatic process planning. Li [8] applies the genetic algorithm (GA) to CAPP system to generate optimal or near-optimal process plans based on the criterion chosen. Only a few efforts give attention to CPP that has significant impacts on manufacturing quality, cost and lead-time. Feng and Zhang [1] develop a conceptual process planning prototype for the preliminary manufacturability assessment of conceptual design in the early product design stage. It aims at determining manufacturing processes, selecting resources and equipment and roughly estimating the manufacturing cost. Chin [9] proposes an approach to carry out the preliminary process planning for quality, in which the QFD and the process FMEA are incorporated.

However, more efforts are required to be made to determine key process alternatives with an adequate process capability during conceptual process planning, to estimate the manufacturing cost, and to validate these alternatives before generating the detailed process plans. The goal of this paper is to propose an approach, to improve manufacturing process quality and to estimate the manufacturing cost of the product. As shown in Fig. 2, the role of the proposed QCCPP approach is to link process determining activity to detailed process planning, it is responsible for selecting process alternatives (resources) with an adequate process capability, process associated risks, and process cost. QCCPP is supported by quality methods and tools, and cost estimation methods, particularly QFD and FMEA methods, and ABC method. This approach enables designers to optimize manufacturing process plan concerning with resource determination in order to improve product quality/cost ratio, it can serve as a useful information system to support decision making in product development. The following sub-paragraphs describe briefly the methods used in QCCPP approach.

1.1. Quality function deployment (QFD)

QFD is a quality management technique which is very useful to improve the product's quality according to the customer's requirements. This method begins by analyzing market and customer's needs from a product. Then it translates the desires of the customer into product design or engineering characteristics, and subsequently into parts characteristics, process plans, and production requirements associated with its manufacture [10, 11]. This is a four-phase process: product planning, parts deployment, process planning, and production planning [12]. This four-phase approach is accomplished by using a series of matrixes, called House Of Quality (HOQ), that guide the product team's activities by providing standard documentation during product and process development (Fig. 3). Each phase has a matrix consisting of a horizontal row of "Whats" and a vertical column of "Hows". At each stage, the "Hows" are carried to the next phase as "Whats" [13].

1.2. Failure mode and effects analysis (FMEA)

FMEA is an important method of preventive quality and reliability assurance. It involves the investigation and assessment

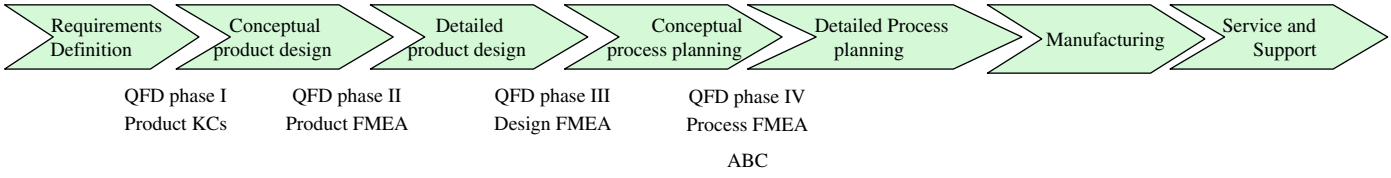

Fig. 1. QFD, FMEA, and ABC in the product development process.

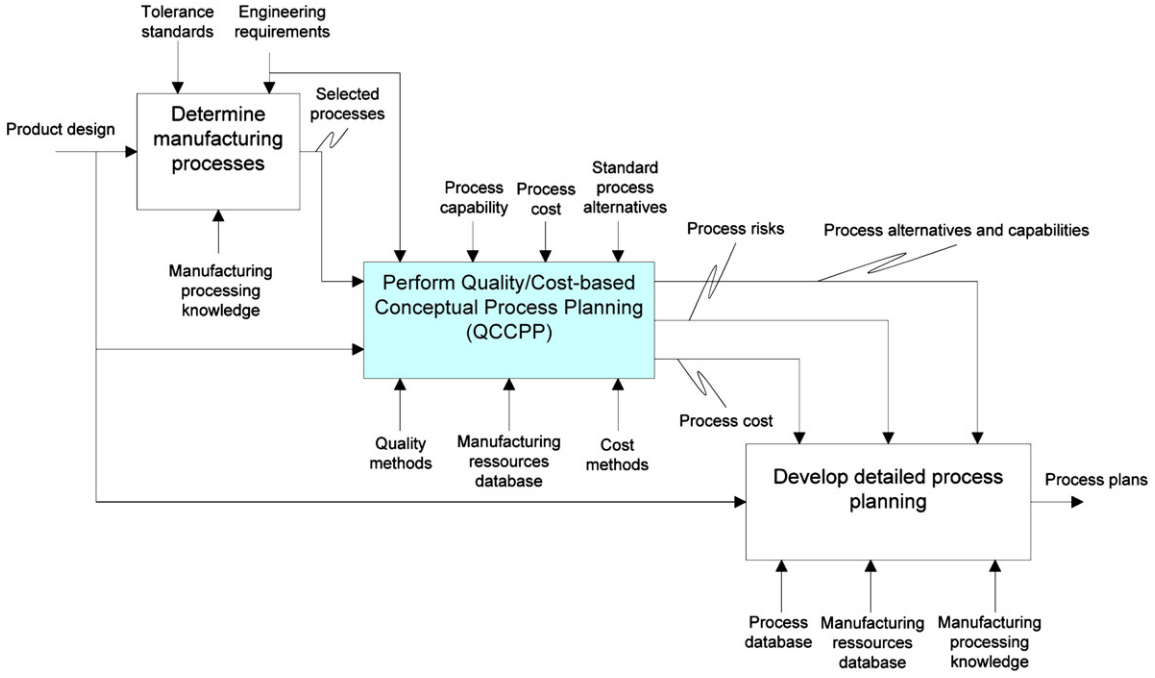

Fig. 2. The role of QCCPP.