Usability Ranking of Intercity Bus Passenger Seats Using Fuzzy Axiomatic Design Theory

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Abstract. Usability, considering user satisfaction along with the user performance, is one of the key factors in determining the success of a product in today's competitive market. Designing usable intercity bus seats is important for passengers during the long hours of traveling. Comfort, aesthetic, safety, convenience to the body posture, durability, harmoniousness with the seat accessories and operability are expected usability dimensions of seats for both user and the designers. Aim of this study is to identify and rank ten alternative seats of an intercity bus manufacturing company according to these usability attributes. The products are evaluated by five subjects and assessed for each usability attributes by using linguistic variables. Then Fuzzy Axiomatic Design Theory (FADT), which is the combination of second axiom, is used as a multi attribute decision making tool to determine most usable seat design solution. Design range is defined by design engineers and system ranges for seats are obtained from linguistic assessment of five subjects for applying conformance testing in cooperative engineering.

Keywords: Usability, Fuzzy Axiomatic Design, Conformance Testing, Cooperative Engineering.

1 Introduction

Traveling becomes an integral part of human life nowadays. Among the travel options, traveling by bus is preferred commonly as it is economical compared to others. Passengers spend most of their time on seats of bus during the long travel hours. Therefore, seats are an important factor in seating industry to meet customer expectations. Generally the main task of the ergonomic seat design is increasing the seat conformance which is a complex and subjective notation related to a good physical and psychological well being of the interface between the passenger and the seat. Comfort and discomfort, which are not antonymous, are two main elements of seat design. They are related since it is necessary, but not sufficient to be "not uncomfortable" in order for a seat to be comfortable. While comfort is a subjective notation, and is hard to quantify, discomfort is an objective notation and is related to specific methods (e.g. pressure distribution, electromyography or posture analysis). Hence, discomfort is not only a feature of a seat, but also it expresses to what extent the seat is not sufficient [1],[2],[3].

Y. Luo (Ed.): CDVE 2006, LNCS 4101, pp. 141 – 148, 2006.

Therefore evaluation of seat design in literature is mostly related to the discomfort aspect [3],[4],[5],[6],[7]. However, comfort - discomfort related studies are not the only main design factors nowadays. Usability, a holistic view to ergonomic and collaborative product design, is seen as a critical dimension of which importance is increasing swiftly in product design [8],[9]. Usability is defined as effectiveness, efficiency, and satisfaction of a product for achieving specified goals for specified users in a particular environment. Designing usable products is seen a company philosophy for firms in today's competitive business environment [10]. It is an important stage to observe and analyze multi dimensional product usability attributes in product design. Aesthetic, safety, convenience to the body posture, durability, harmoniousness with the seat accessories and operability of seat are also expected features which are important usability factors for bus manufacturers. Manufacturers want to obtain seats from suppliers which satisfy those usability factors.

In this paper it is tried to identify the best seat among ten available alternative seats considering many usability factors for a factory producing passenger buses. Such problems are referred to as multi-attribute decision making problems in concurrent manufacturing. This study uses FADT to solve this multi attribute decision making problem. This paper is organized as follows. In section 2, FADT method is presented briefly. Section 3 discusses the implementation of FADT to cooperative seat usability decision problem, and the study ends in with section 4 with conclusion and discussions.

2 Fuzzy Axiomatic Design for Multi-attribute Decision Making

A key factor in cooperative product design is the optimization of product development decisions such as the costs, the quality and the time required to design a product. These factors are interrelated and an improvement of one factor may result in a decline in the others. Therefore all these issues have to be considered simultaneously to make the product design more successful. Axiomatic Design (*AD*) forms a scientific basis to design and improves designing activities by providing the designer with a theoretical foundation based on logical and traditional thought process and tools. *AD* provides a systematic search process through the design space to minimize the random search process and determine best design solution among many alternatives considering all product development decisions. In the literature, *AD* theory and principles are used to design products, systems, organizations and software [11]. In ergonomics, Helander and Lin (2002) used axiomatic design as a foundation of ergonomic design and demonstrated examples on how axiomatic design can be used for biomechanics design of hand tools and anthropometric design of workplaces [12]. Lo and Helander (2004) proposed axiomatic design as a formal method for usability analysis for consumer products [13]. Karwowski (2005) also emphasized the applicability of axiomatic design for solving complex ergonomics design problems [14].

Design axioms, namely independence axiom and information axiom, are two key stones of *AD*. Independence axiom is related to maintaining the independence of functional requirements (*FR*s), i.e., design solution must be such that each one of *FR*s can be satisfied without affecting the other *FR*s. Therefore, a correct set of design parameters have to be chosen to be able to satisfy the FRs and maintain their independences. Among the design solutions satisfying independence axiom, the design with the smallest information content must be chosen. This is the second