European Journal of Operational Research 220 (2012) 762–776

Contents lists available at SciVerse ScienceDirect

European Journal of Operational Research

journal homepage: www.elsevier.com/locate/ejor

Innovative Applications of O.R.

Estimation, modeling, and aggregation of missing survey data for prioritizing customer voices

Anil Kumar Maddulapalli [a,*], Jian-Bo Yang [b,1], Dong-Ling Xu [b,2]

[a] General Motors R&D, GMTCI, 2nd Floor Creator Bldg, ITPB, Whitefield Road, Bangalore 560066, India
[b] Manchester Business School, The University of Manchester, Manchester M15 6PB, UK

ARTICLE INFO

Article history:
Received 4 January 2011
Accepted 23 January 2012
Available online 18 February 2012

Keywords:
Decision analysis
Evidential reasoning
Nonlinear optimization
Voices of customer
Partial information

ABSTRACT

It is widely acknowledged that understanding and prioritizing the voice of customer is a critical step in new product development. In this work, we propose a novel approach to handle missing and incomplete data while combining information from different surveys for prioritizing customer voices. Our new approach comprises of the following stages: estimating and representing missing and incomplete data; estimating intervals for the criteria used in analyzing data; mapping data on criteria to a common scale; modeling interval data using interval belief structure; and aggregating evidence and ranking customer voices using the interval evidential reasoning algorithm. We demonstrate our approach using a case study from automotive domain with a given criteria hierarchy for analyzing data from three different surveys. We propose new optimization formulations for estimating intervals of the criteria used in our case study and logical yet pragmatic transformation functions for mapping criteria values to a common scale.

1. Introduction

Quality Function Deployment (QFD) is a widely accepted practice for deploying customer needs (referred to as the voices of customer) through product planning, design and manufacturing (Besterfield et al., 2003; Chan and Wu, 2002). An important step in QFD is to prioritize voices of customer in order to allocate resources appropriately. In many industries, customer satisfaction surveys are routinely conducted for identifying what the customers want, what the strengths of products in market are and where improvements should be made for new products. Data from different surveys are often used to identify those voices of customer that should be given higher priority (sometimes referred to as Key Voices of Customer) within the context and constraints of the overall product or service program (Xie et al., 2010; Yang et al., 2011). For this work, we assume that a list of customer voices to analyze has already been created and we focus on prioritizing the voices with missing and incomplete survey data.

Prioritising voices of customer using data from different surveys involves data analysis with suitable criteria for a survey and then aggregation across criteria and surveys. We are interested in surveys that collect ratings on various voices using a fixed point scale (e.g., 5-point scale with 1 being least satisfied and 5 being most satisfied). For evaluating a voice of customer, raw data from the surveys in the form of ratings is converted into criteria using different metrics (e.g., mean rating) depending on the nature of the survey. Typically multiple criteria are used to evaluate a voice and these criteria can be arranged in a hierarchical structure if the surveys are assumed independent. The criteria hierarchy we use for our case study is shown in Fig. 1 (see Section 3 for more details). Looking at the criteria hierarchy in Fig. 1, it is clear that multiple attribute decision making (MADM) methods are well-suited for aggregating survey data and then prioritizing voices of customer.

Many methods have been proposed in the research community for addressing MADM problems, reader can refer to (Olson, 1996; Okudan and Tauhid, 2008) for good reviews. The Evidential Reasoning (ER) approach (Yang and Singh, 1994; Yang and Sen, 1994; Yang, 2001; Yang and Xu, 2002a,b; Yang et al., 2006) is a unique reasoning-based MADM method that has been applied to many areas such as design and product assessment (Yang and Xu, 1998; Chin et al., 2009). In a previous work (Yang et al., 2011), we have argued that the ER approach is well suited for prioritising voices of customer using survey data. In this work, we use recent developments of the ER approach for prioritising voices of customer with missing and incomplete survey data.

Typically surveys are conducted by external or syndicated agencies (e.g., J.D. Power Associates, Consumer Reports) and the manufacturer or service provider has limited scope in influencing the questionnaires. Due to this, many a time a voice is covered only in a subset of surveys used for analysis. If a voice is not covered in a survey, we refer to it as *missing data* for that voice. Even if a

* Corresponding author. Tel.: +91 80 4041 4766.
E-mail addresses: anil.maddulapalli@gm.com, maklegilimen@yahoo.com (A.K. Maddulapalli), jian-bo.yang@mbs.ac.uk (J.-B. Yang), ling.xu@mbs.ac.uk (D.-L. Xu).
[1] Tel.: +44 161 306 3427.
[2] Tel.: +44 161 275 0941.

0377-2217/$ - see front matter © 2012 Elsevier B.V. All rights reserved.
doi:10.1016/j.ejor.2012.01.045

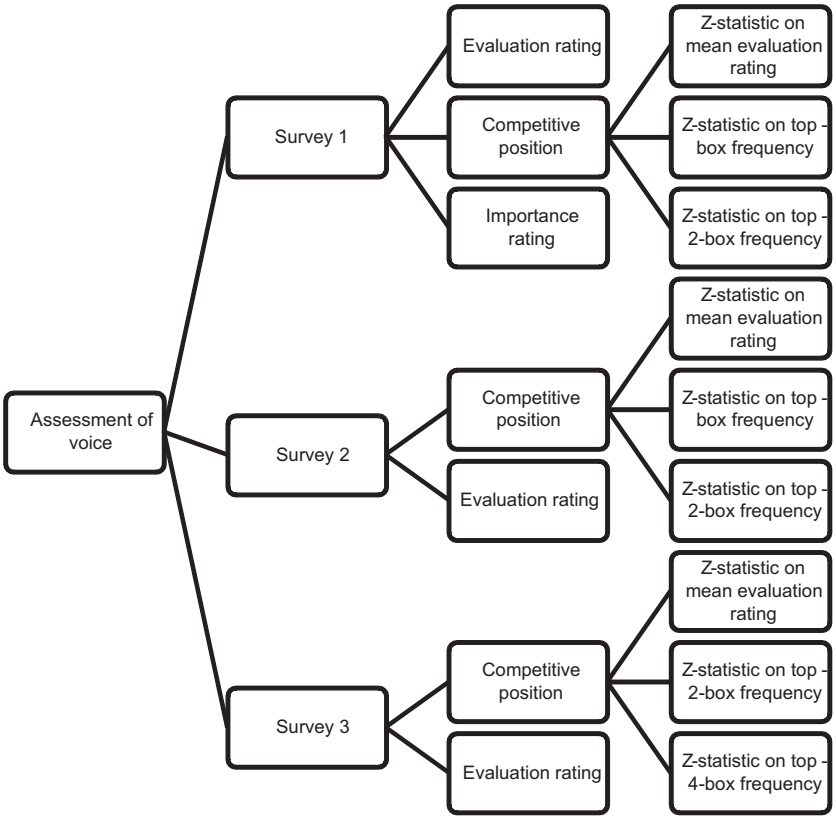

Fig. 1. Criteria hierarchy for evaluating voice of customer in our case study.

voice is covered by a survey, not all respondents give their ratings and this we refer to as *incomplete data* for that voice. In Fig. 1, if there is missing data for a voice, the corresponding survey branch has no information thus leading to imbalance in the way different voices are evaluated. This mismatch in survey coverage for various voices is the motivation for our work. Note that, we use data and information interchangeably throughout this paper.

As the voices of customer for a product are typically related to each other, we wish to exploit those relationships for estimating the missing data for a voice. For each voice, we assume that the set of relevant voices that give good indication about its ratings is known (e.g., a voice hierarchy as shown in Fig. 2). For example, a voice "V1A: Overall, rear seating area roominess meets my needs", can have up to three child voices in a hierarchy, namely "V1A01: Rear seating area has adequate head room", "V1A02: Rear seating area has adequate shoulder room", and "V1A03: Rear seating area has adequate leg room". If the parent voice V1A is not covered by a survey but some or all of the child voices (i.e., V1A01-V1A03) are covered by the same survey or vice-versa, reasonable estimates can be obtained for the voice not covered, using data from voices that are covered (see Section 2.1 for proposed rules of estimation).

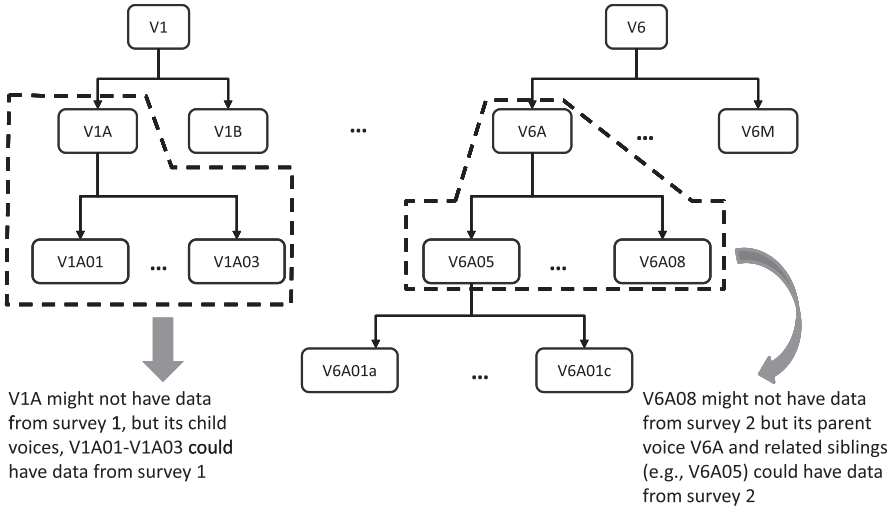

Fig. 2. Example of a voice hierarchy stating relationships between different voices of customer.