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The total cost of ownership of durable consumer goods: A conceptual model and an empirical application

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ABSTRACT

This paper proposes a general model to evaluate the Total Cost of Ownership (TCO) of durable consumer goods (e.g. cars, household appliances). The TCO approach has been developed to support purchasing decisions in the business-to-business domain: here we use similar principles to consider the business-to-consumer context. The new customer-oriented activity-based model includes 37 activities, classified by process and temporal phase. The model allows computing the costs incurred by the customer from the search and selection phase to the end of the product life. Furthermore, the paper discusses four modes of application of the model: *One-to-one TCO evaluation, Average Product TCO evaluation, Average Customer TCO evaluation,* and *Average TCO*. An empirical test on a sample of washing machines shows that customer habits (e.g. the usage frequency or the detergents used) are the most relevant factor affecting the TCO, with a far greater impact than the purchasing price. Thanks to the resolution of a number of gaps pointed out by a literature review on TCO research, the new model can be used as a decision support tool by enabling product comparisons and cost structure analysis.

1. Introduction

Demand saturation, in addition to the rise of offshore competitors with aggressive pricing, has led to an increased price competition among both manufacturers and retailers of durable consumer goods. Therefore, firms increasingly seek differentiation through quality, functional innovation and technology, with a market-orientated approach (Narver et al., 2004). Manufacturers are also moving towards offering integrated packages of product and services (Baines et al., 2007) and are thus incentivised to reduce the total cost of ownership for the customer starting from the product design phase (Kleyner and Sandborn, 2008; Folgado et al., 2010; Settanni et al., 2014). At the same time, private customers are more aware that, rather than the purchasing price alone, all the costs incurred during the product life should be considered when making purchasing decisions (Woodward, 1997).

Hence, this paper develops a general Total Cost of Ownership (TCO) model meant to support end customers in the purchasing process by considering all the cost factors connected to the product purchase, usage, maintenance, and disposal. The TCO approach, generally used for business-to-business contexts, is here transferred to a business-to-consumer perspective, addressing a gap in the literature.

The paper is organized as follows: Section 2 provides a literature review of TCO models; Section 3 presents the new general TCO model for durable consumer goods; Section 4 describes an application test for washing machines; and Section 5 discusses the validity and general applicability of the model. Finally, the last section summarises the main implications and limitations of this study.

2. Background

2.1. The TCO concept

The TCO approach stems from the early literature on purchasing (Harriman, 1928) and has been adopted by firms since the eighties (Ellram and Siferd, 1993). The Total Cost of Ownership can be defined as the sum of costs associated to the acquisition, ownership, use and subsequent disposal of a good or a service (Ellram, 1995). The TCO concept is therefore related to that of Life Cycle Costing (LCC), "*an analysis technique which encompasses all costs associated with a product from its inception to its disposal*" (Sherif and Kolarik, 1981, p. 287). However, there is one main difference: the LCC adopts the product perspective, computing costs (independent from the subjects incurring them) connected with the conception, design, manufacture, distribution, operation, disposal of the good, while the TCO adopts the purchaser's standpoint, computing the costs related to the search, acquisition, installation, operation and disposal for a customer, and has

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thus a time horizon shorter than the whole product life cycle.

2.2. A review of TCO models in the literature

A literature review was carried out on relevant applications of the TCO approach. Starting from over 1300 papers resulting from a search in the SCOPUS database using the keywords "Total Cost of Ownership", we selected 45 papers that: i.) have appeared in scientific journals; and ii.) developed AND applied empirically TCO models.[1] Twenty-eight papers (63% of the sample) were published from 2011 onwards, testifying to the increased interest in the topic by researchers in recent years.

Fig. 1 summarises the analysis of the literature. The subject of the model is in most cases either a final product/system or a component, while the application of TCO models to services is still limited. As shown in Fig. 1, the most common application sectors are the automotive and ICT ones. Only five models have not been developed for a specific industrial context, but in three cases they concern a specific purchasing object: a RFID logistic system (Kim and Sohn, 2009), testing and measuring equipment (Lycette and Lowenstein, 2011), professional hardware and software (David et al.. 2002). Only two models address both a general application object and industry: a model facility location selection (Dogan and Aydin, 2011) and a work comparing TCO and Analytic Hierarchy Process approaches for supplier selection (Bhutta and Huq, 2002).

The application context is usually B2B. The 13 papers (29%) that compute TCO for a private customer all concern the car industry. In those papers, however, rather than supporting the customer's purchasing choice (e.g. among specific product models), the TCO models assess the acceptability on the market of a new technology – plug-in electric vehicles - from an economic point of view. More specifically, the TCO applications reviewed address four objectives (see Fig. 1):

- *Assessment of the economic viability and market acceptance* of new technologies, (14 papers, 11 concerning the automotive industry). For instance, Bickert et al., (2015) analyse whether and under which conditions electric vehicles are financially competitive for private consumers and emission savings can be achieved;
- *Supplier selection* (12 papers). The TCO model supports the selection or ranking of potential suppliers for a component or a service. For example, Degraeve and Roodhooft (1999) develop a TCO model for selecting suppliers and determining order quantities. The model considers costs at different levels: supplier (e.g. personnel dedicated to supplier management), order (ordering and invoicing), batch (reception costs, price discounts for large batches) and unit (e.g. quality, inventory holding);
- *"One-off" purchase*. In 10 papers, TCO models have been developed for supporting purchasing decisions about specific products or systems in B2B contexts, such as colourant dispensing machines, assembly lines, heavy equipment, hardware and software, medical devices, RFID logistic systems, electronic test equipment and weapon systems. Chen and Keys (2009), for instance, develop a model to analyse the cost of heavy equipment in its utilisation stage, designed to improve strategic purchasing decisions by business customers.
- *Technical optimisation or dimensioning decisions* are the objectives of 8 papers. For example, the model by Ghosh et al. (2014) is designed to determine the number of physical machines for providing IT infrastructure-as-a-service that minimises the TCO for a given Service Level Agreement (SLA). As a second objective, they assess the most cost effective machine configuration for achieving a given SLA. A second example is Redelbach et al. (2014), who develop a model to optimise the battery sizes of plug-in hybrid and extended range electric vehicles.

We found that most papers adopt an Activity Based Costing approach (Kaplan and Johnson, 1987; Ellram and Siferd, 1993). However, the ABC approach is mentioned as a specific premise of the model development in 14 papers only (31%), while it remains implicit in others. In some cases, only the distinction between Capex and Opex costs is assumed (Charni and Maier, 2014; Goudarzi, 2014), while other papers combine the TCO approach with other techniques, such as Bayesian networks (Dogan and Aydin, 2011; Dogan, 2012), or supplier risk analysis (Micheli et al., 2009). However, the majority of the analysed papers (80%, see Fig. 1) do not provide a clear indication of the activities underlying the cost items included in the model, and in addition, the classification of these activities into processes, temporal phases or other categories is generally missing. Although in some papers the underlying activities may be quite easily identified from the cost items measured, this evidence highlights that the reviewed literature tends to focus on specific cases of application rather than on the general applicability of the proposed models.

Most TCO models consider purchase and operation costs, quantifying the impact of quality and maintenance activities. However, while the TCO approach should adopt the customer perspective, a comprehensive evaluation of the costs incurred by the customers – also encompassing the initial costs (search and evaluation of product and suppliers) and the product disposal or end-of-life – is uncommon. In particular, only two papers address the costs related to the search and selection of products and suppliers. Prabhakar and Sandborn (2012), proposing a TCO model for purchasing components for electronic equipment, consider the costs of selecting and approving the parts. Walterbusch et al. (2013) include in their model for the purchase of cloud computing services the initial costs for the strategic decision, selection of cloud-computing services and cloud type. For the end-of-life or end-of-ownership costs, some TCO models include the depreciation costs or the resale value: they are models for the automotive industry (Spitzley et al., 2005; Sharma et al., 2012; Al-Alawi and Bradley, 2013; Hou et al., 2014; Redelbach et al., 2014; Rusich and Danielis, 2015; Wu et al., 2015), and also models supporting the purchase of heavy equipment (Chen and Keys, 2009) and electronic testing equipment (Lycette and Lowenstein, 2011). Costs related to the end-of-life product disposal, on the other hand, have been included in the models by Heilala et al. (2008), Lycette and Lowenstein (2011), Gass et al. (2012), Prabhakar and Sandborn (2012), Ibbotson et al. (2013) and Caniato et al. (2015).

Finally, TCO models may follow a dollar-based or a value-based approach (Ellram, 1995). In the former, only monetary costs are included (23 papers, as reported in Fig. 1). In the latter, instead, opportunity costs or value items are also included (e.g. company reputation; product/service availability; timeliness of deliveries) and expressed in monetary terms. This more comprehensive approach is adopted in 22 papers. The non-monetary costs most frequently included are those related to downtime (15 papers). Models measuring the TCO for the final customer in the automotive sector may also include a cost evaluation of environmental impacts (Spitzley et al., 2005; Redelbach et al., 2014; Bickert et al., 2015; Rusich and Danielis, 2015).

Based on the literature review above, some critical considerations arise:

- The TCO approach has been limited to B2B settings, except for the car industry, where it mainly served to analyse whether new technologies can be economically viable, while it was not used to support purchasing decisions by end customers.
- The models analysed are, in most cases, *unique* (Ellram, 1995), since they are created specifically for a particular context in which relevant cost factors differ significantly from usual decisions, and are

[1] A supplementary dataset with the literature analysis in Excel format is attached to the paper.