Reliability Engineering and System Safety 147 (2016) 72–83

Contents lists available at ScienceDirect

Reliability Engineering and System Safety

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

Customer-oriented risk assessment in network utilities

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ARTICLE INFO

Article history:
Received 25 March 2015
Received in revised form
21 September 2015
Accepted 11 November 2015
Available online 2 December 2015

Keywords:
Network utilities
Customer affection
Reliability analysis
Generalized renewal process

ABSTRACT

For companies that distribute services such as telecommunications, water, energy, gas, etc., quality perceived by the customers has a strong impact on the fulfillment of financial goals, positively increasing the demand and negatively increasing the risk of customer churn (loss of customers). Failures by these companies may cause customer affection in a massive way, augmenting the intention to leave the company. Therefore, maintenance performance and specifically service reliability has a strong influence on financial goals. This paper proposes a methodology to evaluate the contribution of the maintenance department in economic terms, based on service unreliability by network failures. The developed methodology aims to provide an analysis of failures to facilitate decision making about maintenance (preventive/predictive and corrective) costs versus negative impacts in end-customer invoicing based on the probability of losing customers. Survival analysis of recurrent failures with the General Renewal Process distribution is used for this novel purpose with the intention to be applied as a standard procedure to calculate the expected maintenance financial impact, for a given period of time. Also, geographical areas of coverage are distinguished, enabling the comparison of different technical or management alternatives. Two case studies in a telecommunications services company are presented in order to illustrate the applicability of the methodology.

1. Introduction

Within the Services Sector, Network Utilities provide services to clients distributed in an infrastructure network (gas, water, electricity, telecommunications, etc.). Their infrastructures are usually organized and composed by a high number of dispersed elements, supported in hierarchical structures and replicated by distribution areas. These companies are capital intensive [5], meaning decades for pay-back on investments. Additionally, they have an intense and long lasting relationship with customers and consequently, quality perceived and demanded by them has a strong impact on the fulfillment of financial goals, through both a positive and a negative ways, increasing services demand and increasing risk of customer churn respectively. Accordingly, in a competitive market, these companies are always trying to increase their market share and "customer life-cycle value". The main strategies by which this is done are: retaining actual customers; building customer loyalty and; capturing new potential customers in geographical territories. Therefore, customer opinion is essential and extremely decisive for the consideration of future investments [7].

Customer requirements, attitudes and behavior are not always the same, even among similar groups or at different times. There are several methods for quality measurement according to the attributes of a service, considering their importance or their contribution for the company to provide value [11]. However, a global measurement of the quality perceived by customers is not an easy task, because of the influence of subjectivity in their opinions ("…*every customer perceives service quality differently*", [23]). This is why many authors concentrate their efforts in evaluating significant interactions (called *critical incidents*) [12,13]. Quality measurement in a service must evaluate feasible customer requirements about it, such as those related to the ability to respond to contingencies, the reliability and the security of the service [10]. Subsequently, service quality must be analyzed considering the positive and negative feelings of customers concerning service issues and the supplying company. For this, analysis of historical information on customer behavior, including, where applicable, geographical location of customers, is necessary to correctly define new segmentation criteria for future tailored actions [8].

Moreover, in a very competitive environment a fast response to problems may generate customer retention and loyalty [16,17]; better availability and cost reduction may allow a decrease in the price of the services; and the sum of these parts is internal motivation, image and external business reputation [18]. Thus, more reliable services are appreciated in the sector of network utilities where contracts and standards revolve around service

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http://dx.doi.org/10.1016/j.ress.2015.11.008
0951-8320/

Notation

GO	group of customers without failure experience,
GF	group of customers with failure experience,
CPV(l)	Customer Present Value (CPV) is the updated benefit per customer (l),
$j=1,\ldots, J$	the accounting periods in the customer life,
pr(l,j)	price paid by a customer (l) during the period j,
c(l,j)	direct cost of servicing the customer (l) during the period j,
AC(l)	acquisition costs per customer (l),
r	discount rate for the company,
t_i	time when a failure occurs ($t_1, t_2,\ldots, t_n$ with $t_0=0$),
x_i	variables representing the intervals between successive failures ($x_1, x_2,\ldots, x_n$), $x_i=t_i-t_i-1$,
$f(t)$	probability density function of failures (pdf),
$F(t)$	cumulative distribution function of failures (cdf),
$R(t)$	reliability function, $R(t)=1-F(t)$,
α, β	scale and shape parameters of the Weibull distribution of failures,
q	repair efficiency of an asset failure mode,
q_s	repair efficiency of service failures,
G	total number of customers included in the groups to analyze,
v_i	virtual Life represents the calculated age of a customer immediately after the ith repair and occurs taking into account the produced overall damage due to all the preceding failures (with $v_0=0$ for $t_0=0$),
$R_s(l,j)$	probability of customer (l) retention/survival in the period (j) modeled it with a Weibull, then $(1–Rs(l,j))=$ probability of customer abandonment in the period j,
δ_j	periods affected by failures, 1 for the first affected period and followings, 0 otherwise.
n_c	number of affected customers per failures,
cc(l,j)	direct cost of corrective activities per customer (l) during the period j,
Pc(j)	probability contribution equals to difference of customer survival probability in each period of the customer life, $\mathrm{Pc}(j)=\Delta R_s(j)=R_s^{\mathrm{GO}}(j)-R_s^{\mathrm{GF}}(j)$.

level agreements (SLAs). Service quality will be accepted by the customers within a tolerance level, but how do we know what this level is? We know that customer perception will be affected by failure occurrence and recurrence. For that reason, maintenance departments should be considered crucial for network utilities [4], pursuing to keep the service delivery reliable, with maximum quality and performance. Focusing on the customer oriented service quality, a maintenance department contributes [1–3] strongly to:

- Satisfy customer needs and loyalty, fulfilling the service reliability;
- Enhance the business image along with the ability to capture new customers;
- Reduce service costs and avoid unexpected failure costs;
- Improve productivity, increase availability.

Questions at this point arise: How can we measure service quality and the impact that maintenance has on it? How can we estimate maintenance quality (and mainly non-quality) costs? In special cases, as for important clients, or when we may suffer risk of financial loss, it could be useful to launch alerts and alarms about these issues when failures appear due to maintenance performance. It is important to assess the value implications of existing maintenance policies based on maximizing value, instead of minimizing cost of maintenance [49]. The difficulty of measuring the impact of maintenance activities on the quality of service and estimation of non-quality costs complicates decision-making in maintenance departments [6]. Strategic, tactical and operative decisions will in turn become easier to handle if we could see the trade-offs between gaining in service performance versus increasing maintenance costs [30,31]. Well-managed proactive maintenance, through proper prevention and inspection, will reduce internal [9] and external non-quality costs in network utilities.

Thus, perceived and demanded service quality could be measured through critical incidents, positive or negative, depending on the maintenance effectiveness solving them. Consequently, the number and type of customer complaints because of service failures can be shown of this. That is, in order to assess the maintenance value, it has to surveillance not only asset reliability but also its financial impact during all the asset life cycle [51]. This research is aimed at raising these companies' awareness in order to define flexible and robust policies based on asset reliability according to its impact on customers.

Many authors on marketing and quality have tried to model customer behaviors through proportionality among quality features as covariates, using qualitative methods as opinion polls, or quantitative methods as parametric/semiparametric models [56–60]. This analysis allows the evaluation of the customer behavior against reliability service incidents, not only as a direct covariate but also considering the occurrence rate, and quantifying their direct and indirect financial consequences. We develop a methodology that technically and financially describes how the recurrence of failures is correlated with customer abandonment.

Important previous authors on reliability [49–55] have analyzed maintenance contribution linking engineering/reliability concepts to financial concepts in repairable systems. They explore the impact of a system's reliability on its revenue generation capability, considering direct relation between system reliability and the system's performed technical function from a financial standpoint. Thanks to the GRP statistical technique, a dynamic model is estimated of the duration of customer–company relationship based on the experience on the recurrence of service failures. Non-satisfactory experiences and more recently can reduce this relationship and financial revenues. That is, previous reliability authors model survival system probability, and here the customer-life survival probability is modeled. They treat recurrent failure modes of the technical system and the effect of partial renewal repairs in system status, recurrent service failures (independently the physical system in the network that causes them) and the impact of these events now is considered in the mind of the customer orientated to abandon the contract. The aim of this work is to model through GRP, psychological behavior instead of physical behavior, according to recurrent events (failures) and how the dynamism of their occurrence rate influences on trigging the customer abandonment and so on to extend/reduce the customer lifetime. Therefore, this paper deals with indirect behaviors and indirect impacts due to bad reputation of the services in its customers. To illustrate this, this paper provides a basic guidance for maintenance of decision-making processes, in evaluating the impact of network reliability on customer satisfaction and on customer retention and loyalty. With this purpose, our article is organized as follows: Section 2 reviews maintenance impact on