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Developing a performance index with a Poisson process and an exponential distribution for operations management and continuous improvement

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HIGHLIGHTS

- An operating performance index with a Poisson process and an exponential distribution is developed.
- The statistical properties of the operating performance index are given.
- Exact confidence intervals and regions are constructed.
- The performance goal of Six Sigma is achieved.
- Useful insights are offered to business managers.

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ABSTRACT

The adoption of performance measurements is becoming increasingly widespread and represents the key success factor for companies seeking to gain a sustainable competitive advantage. Consequently, there is a need to develop a systematic method for companies to be more performance-measurement focused. This study presents an operating performance index (OPI) based on the concept of customers arriving at a store from a Poisson process and an exponential distribution. To support the efficient use of the proposed method, the statistical properties of OPI are given and a step-by-step operating procedure is constructed. The proposed method can not only evaluate and determine whether the current performance meets the level of Six Sigma, but also improve the precision when estimating a parameter. To validate the application and viability of the proposed method, it is applied to a realistic case study for operating performance measurement and improvement. The results reveal that the proposed method provides a more effective way to achieve Six Sigma, and that it can easily be implemented in practice for operations management and continuous improvement.

1. Introduction

In the competitive global business environment of the 21st century, business managers should conduct frequent inspections and analyses of the performance of the company to enhance their competitiveness. This helps the company

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to re-define and measure progress towards their goals [1]. Ammara et al. [2] suggested that an in-depth and thorough performance measurement analysis encourages the business manager to find out how to improve, where to increase quality, how to reduce waste or how to save time for a business. Obviously, understanding variation of performance is critical, and is the key to success because a high-performing company not only improves efficiency and productivity for all members of the supply chain, but also delivers quality products consistently for consumers. Consequently, the company must assess their performance with a powerful performance measurement tool to become more competitive in its industry.

However, with rapid economic and social development, performance measurement for a company has become increasingly complex and difficult in recent years. To deal with this issue, Gutierrez et al. [3] suggested that the concept of a performance index can be used as a fundamental managerial tool for evaluating the performance of company. Rodriguez et al. [4] pointed out that a performance index can play a crucial role improving the decision-making process as well as the re-orientation of the objectives for a company. Kucukaltan et al. [5] stated that the identification and implementation of a performance index is beneficial for a company seeking to achieve a higher degree of competitiveness in the industry. As a result, the use of a performance index is widely accepted for measuring performance and achieving different levels of performance within and outside a company.

Closely related to the performance index, Six Sigma is an efficient method in performance measurement and improvement of product/service for companies and customers [6]. Six Sigma was first proposed by Motorola in the early 1980s to measure, monitor and evaluate the variations of products or processes, and provides a failure rate of 3.4 parts per million. This provides opportunities for improving or optimizing existing products or processes in quality management [7,8]. It is an effective improvement method that focuses on process variation reduction and takes into consideration the rejection loss for the non-conforming parts, thereby reducing number of defects [9]. Swink and Jacobs [10] noted that Six Sigma adoption makes a positive impact on return on assets (ROA) and improves sales growth in manufacturing and service firms. Shafer and Moeller [11] indicated that adopting Six Sigma positively impacts organizational performance, especially with respect to employee productivity. Thus, business managers can utilize Six Sigma to determine whether a product/service is *in-control* or *out-of-control*, and ensure quality products and services that enhance customer satisfaction and the performance of company [12]. Up to now, Six Sigma has received significant interest from researchers in many industries, most of which use data-based and applied statistical methods. Ouyang et al. [13] used a quality characteristic analysis chart (QCAC) with Six Sigma to measure the quality performance of the bicycle quick release. Chang et al. [14] proposed a process quality-level analysis chart (PQLAC) with Six Sigma to evaluate the process performance of the five-way pipe. Lucato et al. [15] presented an Eco-Six Sigma method, which incorporated environmental variables to improve the eco-efficiency level of a computerized numerical control (CNC) lathes manufacturing process. Riley et al. [16] developed a manual of policies and procedures by using Design for Six Sigma (DFSS) in a financial institution. Chang et al. [17] presented a process quality index (PQI) based on the relationship between various process capability indices (PCIs) and Six Sigma quality levels to determine the quality performance of a ratchet torque wrench. Sagnak and Kazancoglu [18] proposed an integrated method based on the green lean approach with Six Sigma to assess the performance of flue gas emissions in order to decrease unfavorable ecological impacts of companies' products or services. Wang et al. [19] used the DFSS with the theory of inventive problem solving (TRIZ) to serve as a mechanism for a new product development. Yu and Chen [20] utilized an integrated quality test chart (IQTC) with the quality-level concept of Six Sigma to test the processing performance of a silicon-filler.

In addition to Six Sigma, the performance index has been discussed from different perspectives in many studies. For example, Chen and Chen [21] applied 23 service quality attributes as a performance index to assess the service performance for a tourist hotel. Chen and Chen [22] used the service speeds (also referred to as waiting times) to evaluate the service performance of a campus restaurant. Wang et al. [23] employed customer satisfaction to measure the service quality performance of a company. Wu and Lin [24] used a performance index C_L to assess the performance of lifetime of product with Weibull distribution. Chen and Yang [25], Yang and Chen [26], Chen et al. [27], and Chen and Chen [28] applied customer complaints as a performance index to evaluate the service quality of companies. Although various performance indices have been proposed and widely used in various industries because they are easy to use, some problems remain in application, such as the following. (1) service processes follow non-normal distribution in most cases [29]; (2) service quality is difficult to measure because a service may not have a physical characteristic and or a clear indicator related to profitability [30]; (3) Chen and Chen [28] proposed a performance index based on the time interval of customer complaints with a gamma distribution, but the characteristic of the proposed performance index is not sufficient for large time intervals, and then the variance is higher for the gamma distribution; (4) no complaints does not mean no problems or that all customers are satisfied (implicit problem); (5) good service performance is not the only factor in good business performance for the company. Sometimes, a customer is dissatisfied if a certain service is provided [31]; and (6) these aforementioned methods are irrelevant to Six Sigma.

From a practical viewpoint, the number of customers arriving at a store provides a good solution for performance measurement of a company since it immediately affects profitability and operating costs (for example, employees, utilities, materials, and so on) which in turn affects the long-run financial performance of a company [32,33]. Obviously, if the concept of customers arriving is used as the performance index, it will assist the company in resource allocation, making the company's performance improvement strategy more effective and increasing the company's competitive position in the market. In accordance with the above, this study develops an operating performance index (OPI) based on the concept of customers arriving at a store from a Poisson process and an exponential distribution. Six Sigma is also considered in order to activate and advance improvements of the performance of the company, leading to sustainable business practices. Moreover,