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Multiple generation product life cycle predictions using a novel two-stage fuzzy piecewise regression analysis method

Chi-Yo Huang [a], Gwo-Hshiung Tzeng [b,c,*]

[a] *Department of Industrial Education, National Taiwan Normal University, 162, He-Ping East Road, Section 1, Taipei 106, Taiwan*
[b] *Department of Business Administration, Kainan University, No. 1 Kainan Road, Luchu, Taoyuan 338, Taiwan*
[c] *Institute of Management of Technology, National Chiao-Tung University, 1001, Ta-Hsueh Road, Hsin-Chu, Taiwan*

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Abstract

Product life cycle (PLC) prediction plays a crucial role in strategic planning and policy definition for high-technology products. Forecast methodologies which can predict PLCs accurately can help to achieve successful strategic decision-making, forecasting, and foresight activities in high-technology firms, research institutes, governments, and universities. Over the past few decades, even though analytic framework strategies have been proposed for production, marketing, R&D (research and development), and finance, aiming at each stage of PLCs, forecast methodologies with which to predict PLCs are few. The purpose of this research is to develop a novel forecast methodology to allow for predictions of product life time (PLT) and the annual shipment of products during the entire PLC of multiple generation products. A novel two-stage fuzzy piecewise regression analysis method is proposed in this paper. In the first stage, the product life-time of the specific generation to be analyzed will be predicted by the fuzzy piecewise regression line that is derived based upon the product life-time of earlier generations. In the second stage of the forecast methodology, the annual shipment of products of the specified generation will be predicted by deriving annual fuzzy regression lines for each generation, based upon the historical data on the earlier generations' products. An empirical study predicting the life-time and the annual shipment of the 16 Mb (Mega bit) DRAM (Dynamic Random Access Memory) PLC is illustrated to validate the analytical process. The results demonstrate that two-stage fuzzy piecewise regression analysis can predict multiple

* Corresponding author. Institute of Management of Technology, National Chiao-Tung University, 1001, Ta-Hsueh Road, Hsin-Chu, Taiwan. Tel.: +886 936 516698; fax: +886 3 5165185.
E-mail address: ghtzeng@cc.nctu.edu.tw (G.-H. Tzeng).

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generation PLT and PLC precisely, thereby serving as a foundation for future strategic planning, policy definitions and foresights.

Keywords: Product life cycle; Product life time; Forecasting; Piecewise regression; Fuzzy regression; DRAM; Semiconductor

1. Introduction

The probable course of industry evolution originated from the product life cycle (PLC) [1] — a foundation for strategic planning, policy definitions, resource allocation, human resource management, inventory control, etc. One of the major features of recent market evolution is that its products, especially high-tech products, become differentiated into multiple generations, with path dependency in the advancement of their technological performance [2]. A firm that is evaluating a new product should predict the PLC [3] in advance. The potential for forecasting key parameters – including the magnitude of sales, duration of stages, and the shape of the PLC curve – is one of the most important issues that must be faced in any meaningful application of the PLC concept [4].

Although strategic planning frameworks that aim at production, marketing, R&D (research and development), and finance for each stage of the PLCs have been proposed during recent decades, proposals for technological forecasting methodologies with which to predict PLCs have been rare. Meanwhile, most existing forecasting methodologies have focused on single-generation PLC prediction. For example, Solomon et al. [5] predicted both the number of years to obsolescence and the life cycle stages of electronic parts, using curve fitting of 16 Mb Dynamic Random Access Memory (DRAM) sales data by Gaussian distribution. Tsaur [6] predicted product sales in the next stage of a PLC, based upon a hybrid forecast model using AHP, trend analysis and fuzzy regression. Chang [7] predicted the stages of the PLC using fuzzy regression analysis. Very few studies (e.g. the researches by Norton and Bass [8] and Kim et al. [2]), have focused on multiple-generation PLC predictions. However, multiple generation products are common in high-technology industries. Semiconductor memories – like DRAM, Static Random Access Memory (SRAM), and Personal Computers (PC) – are typical examples.

In practical circumstances, it is difficult to grasp rules for predicting the non-traditional multiple generation product life time (PLT), based upon the non-linear annual shipments of earlier generations with historical data on fewer than five generations. Meanwhile, market research institutes always have difficulty in collecting exact historical market statistics, since firms seldom release actual shipment information. Therefore, the purpose of this paper is to develop a reliable model to allow for prediction of both the PLT and the annual shipments of a specific generation of a multiple-generation product. To accomplish this, we propose a new approach, comprised of two-stage fuzzy piecewise regression analysis, to predict the nonlinear time-series of PLCs. Fuzzy piecewise regression analysis was developed and validated by Yu et al. [9,10]. Meanwhile, the novel two-stage fuzzy regression method can grasp the dynamics of nonlinear time-series of PLCs. Thus, the observed PLC information can be reconstructed in a piece-wise manner. In order to show the practicality of this newly-proposed model, empirical studies on DRAM, a typical multiple-generation product, were validated by subjectively taking ten sampling points from the time-series experimental data in each DRAM generation. Here, DRAM was chosen as an empirical test of the proposed method, due to its long history, from 1970 to the present. Versus other multiple-generation products, the relatively larger numbers of DRAM generations and distinct features, and its clear path dependency in terms