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Omega 35 (2007) 524–532
omega
The International Journal of Management Science
www.elsevier.com/locate/omega

A net present value assessment of make-to-order and make-to-stock manufacturing systems

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Received 5 August 2003; accepted 14 September 2005
Available online 7 November 2005

Abstract

This paper shows the impact of using the net present value (NPV) on parameter selection in the ordering policy of a production planning and control system. Using a well understood and documented model, the net present value is used as an objective function to determine the discounted future variance costs resulting from the model's dynamics. The NPV of the variance (NPV_v) is defined and applied to the model under make-to-order and make-to-stock conditions. We show that the cost structure of the manufacturing system defines the NPV_v and hence aids in identifying the most appropriate control strategy to apply.

Keywords: System simulation; Dynamic modelling; Financial performance

1. Introduction

The net present value (NPV) is a financial measure that ascertains the time value of money invested in a business. Grubbström [1] has shown that where the economic consequences of production planning decisions need to be known then the NPV may be applied. In particular, the NPV discounting takes the form of an exponential function thus making the discounted cash flow analysis amenable to solution using the Laplace transform [2]. A number of production planning studies have subsequently been undertaken with the aim of maximising the NPV [3,4].

We aim to extend previous studies by researching the application of NPV on a generic dynamic model of a production planning and control system. Wikner [5] has undertaken some early analysis of the generic model using NPV. We will show that the standard NPV is not a sufficient criterion for analysing the dynamic behaviour of a closed-loop form of production planning and inventory control system. There is a need to extend the NPV criterion to encapsulate costs associated with the variances that occur in the system variables.

The variance costs can be defined as all the "on-costs" [6,7] associated with not being in perfect control of a system. A perfectly controlled system is then defined as a system that faithfully tracks some reference or target signal. In addition to the "on-costs" we of course also have the base costs, so that our total costs = base costs + on-costs. Base costs, that could include traditional fixed and variable costs, are those which the system suffers

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doi:10.1016/j.omega.2005.09.006

even when it perfectly tracks the target, so that in a make-to-order environment there are costs associated even with production faithfully tracking customer orders, which may be stable or fluctuating.

In this paper, we are specifically addressing the "on-costs". Two key "on-costs" are related to production and inventory:

- Production on-costs are due to production's inability to match a given target and therefore will under produce in some periods and over produce in others. These variations put strain on production that needs to provide volume flexibility.
- Inventory on-costs are based on deviations from a target inventory leading to excessive inventory holding in some periods and insufficient holding in others. The inventory on-costs are the increased costs of handling associated, say with the increased number of movements of stock within a warehouse or capacity fluctuation in the longer term.

We use the inventory and order-based production control system (IOBPCS) archetype as a benchmark to determine the impact of using the NPV in assessing the "on-costs". The IOBPCS was first developed by Towill [8] to show that the production and inventory model developed by Coyle [9] could be solved analytically. The dynamic characteristics of IOBPCS are now well documented and understood [8,10,11]. Understanding the dynamic properties of the IOBPCS has been useful in extending knowledge of a whole suite of production planning and control systems as IOBPCS has been found to be an archetype for such systems [12–14]. The IOBPCS archetype has also been used to extend our understanding of the dynamic behaviour of supply chains [15,16]. The IOBPCS archetype and its analysis is not only theoretical but has been applied in industry [8–10].

By applying NPV to the IOBPCS we are extending the knowledge base associated with the model by studying the financial implications of its dynamic behaviour. Specifically, we focus our study on particular variants of the IOBPCS which lead to classic scenarios found in industry, namely make-to-stock (MTS) and make-to-order (MTO) systems. Therefore we are interested in some of the practical aspects of applying NPV to MTO and MTS systems. Theoretical studies on generic production planning and control systems are being investigated elsewhere (e.g., Disney and Grubbström [17]) and are beyond the scope of this paper.

The paper next outlines our method and describes the model coding. This is followed by a presentation of the NPV formulae and its application. Next, we justify the need to use an alternative form of the NPV, which is then applied to MTO and MTS systems. Finally, we discuss our results and conclude.

2. Method

This paper adopts the simulation approach to explore the use of the NPV in evaluating the dynamics of MTS/MTO systems. In particular, the model utilised is a difference equation representation of the IOBPCS that is well understood from a dynamic sense using a combination of continuous control theory, via the Laplace transform method, discrete control theory and system dynamics simulation [7,9,12,18,19].

Continuous mathematical modelling, using Laplace transforms, has also been combined with economic techniques, such as NPV, by Grubbström [2–4] to understand production planning and control systems. While other accounting methods are available, such as annualised costing (AC), Grubbström [2] has shown that the NPV discounted rate of interest, ρ is directly equivalent to the Laplace operator, s.

To ensure consistency with previous modelling approaches used to analyse the IOBPCS, we maintain the nomenclature previously adopted and utilise the NPV criteria as our objective function. The latter enables transferability between our results and other ongoing research that is attempting to determine exact mathematical solutions using NPV [17].

3. Simulation model formulation

We utilise the well-known IOBPCS archetype as previously discussed. The difference algorithms adopted, and implemented on a spreadsheet, are given in Table 1.

The ordering policy in the IOBPCS may be given descriptively by:

> the order placed is equal to the average sales rate plus a fraction ($1/T_{\mathrm{i}}$) of the inventory error where T_{i} is termed the time to adjust inventory.

A causal loop diagram representation of the IOBPCS is shown in Fig. 1 (Table 1) which highlights the interrelationship between variables in the model. A causal loop diagram is a standard form used previously to study the IOBPCS and its various forms (e.g. [8,13,18]). The difference algorithms adopted for the simulation, and implemented in a spreadsheet, are given in Table 1, where, as with previous research, infinite production capacity is assumed to retain the linearity of the