



An integrated performance driven manufacturing management strategy based on overall system effectiveness

Boyd A. Nicholds^a, John P.T. Mo^{a,*}, Leigh O'Rielly^b

^a School of Engineering, Manufacturing and Materials Engineering, RMIT University, P.O. Box 71, Bundoora, VIC 3083, Australia

^b Engineering, Silvan Australia Pty. Ltd., P.O. Box 4453, Dandenong South, VIC 3164, Australia

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ABSTRACT

The re-engineering of a manufacturing assembly line should allow an organisation to obtain significant performance improvement toward meeting company objectives. These performance improvements, often in the areas of quality, cost, and delivery (QCD) may be external in areas affecting customer satisfaction, and internal in areas such as improving average productivity obtained per staff member, or per unit of production area floor space. An Overall System Efficiency (OSE) decision support model is described for use in the analysis and prediction of customer satisfaction goals. The OSE model uses customer service level in terms of stockout frequency as a trade-off parameter when optimising overall performance achievable from the production line.

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1. Introduction

Manufacturers are always looking for ways to improve their productivity. Continual incremental changes are often adequate to an extent until at some point a step change in system configuration is deemed necessary to increase productivity significantly so as to keep ahead of competitors. One of the major challenges for making quantum leap is that there are many factors contributing to productivity, some may be counteracting to each other [1]. Re-configuration of manufacturing systems to achieve better performance can have many approaches. Savino and Mazza [2] applied lean principles to a case study in the automotive industry to optimise the design of an assembly line. Alternatively, Al-Chalabi et al. [3] focused on downtime of different drilling machines and suggested improvement in the reliability of critical components, so as to improve the system's performance. These approaches were best suitable for the specific target outcomes the algorithm was developed for.

In order to optimise the criteria of production throughput, cost, and flexibility, Stam and Kuula [4] presented a method for selecting a configuration of flexible manufacturing system. Bokrantz et al. [5] proposed a method that measured production disturbances as a means to prioritise strategies for optimising maintenance management in the manufacturing industry. Due to tight profit margin

and pressure of competition, manufacturing system re-configuration often has limited resources and time. Management needs to make a wise decision to select, among several options, a system design configuration that has the best potential to achieve significant productivity improvement within a defined time frame [6]. This requires using performance measures as objective functions to guide the system's design.

Many performance measures can be used but the main issue is to determine the performance measures that are actually useful [7]. The authors' experiences in actual manufacturing system design projects show that the following system design goals are most demanded in manufacturing system re-configuration:

- 1 Reduce labour hours per production unit
- 2 Reduce peak finished goods stock levels
- 3 Maximise output capacity available from the production line
- 4 Reduce the number of line staff required.

Moreover, while not specifically stated as primary goals during discussions with company management, two additional goals always emerge:

- 1 Service levels for a critical sole customer for the product line must be close to 100% to ensure continued high levels of customer satisfaction,
- 2 Improvement results predicted from it, must be sufficiently transparent to be accepted as realistic by top company management.

* Corresponding author.

E-mail addresses: boyd.nicholds@rmit.edu.au (B.A. Nicholds), john.mo@rmit.edu.au (J.P.T. Mo), leigho@silvanaust.com (L. O'Rielly).

These analysis criteria do not come individually. All of them need to be balanced while re-configuring the manufacturing system. It can be easily seen that performance goals 2 and 3 may be in conflict. Actions aiming at performance goals 4 and 5 are usually counteracting the effects from each other.

To make a good decision, management needs appropriate IT tools to consolidate data to meaningful indicators. In order to design, implement, and follow-up a process improvement it is necessary to have quantifiable performance measures as a basis, where these performance measures are firmly linked to desired company objectives. If not, then any gain obtained may be of little value in meeting company goals, which are primarily targeting effective of performance management systems and competitive advantage of the organisation [8]. Performance measures need to be properly designed and implemented if they are to be useful in support of decision making. Information from these measures are trustworthy and believable.

A manufacturing system is complex because it involves many entities in a company such as production equipment and facilities, production plans, managers and workers. The study of lean manufacturing and the focus on waste reduction has dominated the agenda of many manufacturing management theorists for some time. Implementation of lean manufacturing requires strong IT system support that consolidates production data for decision making. In turn, lean approach requires wastes in the system time to be systematically broken down into identifiable parts [9]. While many researches have been done to evaluate system performance, many are relying on a single performance measure such as production delay [10]. It is more important that a holistic viewpoint with multiple performance criteria. A system modification proposal should address all issues in one go and balance the effect of propagating undesirable consequences of change. To achieve this objective, a new simple and effective performance criteria but representative of all measures is required to support decision making.

This paper describes the development of a unique system design criterion based on the new concept of performance measurement, overall system effectiveness (OSE). The data to compute the objective function of OSE comes from actual performance of a company. The OSE represents a consolidated set of performance measures linked to company objectives, to assist decision makers in the selection of a production system configuration. Using a top-down approach, the performance measures are broken down into different time elements. This is combined with a bottom-up approach determining production batch sizes based on shop-floor observation and proven production models. An example is provided illustrating the OSE method in a manufacturing optimisation project.

2. Literature review

Identification of critical factors or objectives, and their corresponding performance measures, design and operational parameters, is an important step to understand the system. These factors are categorised as either fixed or variable depending on their effect on system performance resulting on a sensitivity analysis over parameter value limits. Evaluation by typical methods such as simulation, analytical formulas, and linear programming, may typically be used to develop proposals to optimise manufacturing system performance [11]. This literature review will focus on the methods to analyse performance outcomes for the purpose of supporting decisions made in manufacturing operations.

2.1. Production characteristics driven methods

Many flow shop or assembly line problems methods and solutions are described in the literature. Ribas et al. [12] classified a

selection of available solution approaches used for solving flow shop problems in a hierarchy to enable focus on certain aspects of system design from a top-down perspective. The performance measures matching the objectives to be obtained are frequently makespan (max. completion time), tardiness, cycle time, and flow time.

Makespan minimisation aims to reduce the time of a job staying in production so that the assembly line can be balanced and the system turnover can be increased [13]. Akpinar and Bayhan [14] compared the performances of iterative ant colony optimization (ACO) based solution strategies on a mixed-model assembly line balancing problem by addressing some particular features of real-world assembly line balancing problems such as parallel workstations and zoning constraints, and where the objective is to minimise cycle time. Lin and Ying [15] presented a bi-objective multi-start simulated-annealing algorithm for permutation flow-shop scheduling problems with the dual objectives of minimizing the makespan and total flowtime of jobs. A non-dominated front for these objective measures is created from the algorithm.

Flow shop scheduling problem is usually regarded as NP-hard problems. Zhang and Gen [16] proposed a multi-objective genetic algorithm for minimising cycle time in a mixed-model assembly line based on demand ratio of each model, and the human resource cost. The operating cost of workers with varying skill level, experience, and wages were particular factors in the model. Cycle time minimisation was investigated by Yoosefelihi et al. [17] for a robot operated line. A mixed-integer model was developed to solve the assembly line balancing problem. The Pareto front of non-dominated solution for the two objectives cycle time and robot cost was produced, providing the basis for decisions on reduced cycle time achievable against the use of higher cost robot models.

Lot stream scheduling aims to minimise the effect of setup time in production. Setup is a non-productive time that must exist before a batch production starts. If one setup can support a larger batch, the cost of setup can be amortized to all production units. Zang and Li [18] proposed an estimation of distribution algorithm (EDA) which integrated a variable neighbourhood search (VNS) to solve the problem of minimising total flowtime in permutation flow shops. Samarghandi [19] considered the no-wait flow shop scheduling problem with due date constraints with the objective of makespan minimisation. A particle swarm optimisation (PSO) algorithm was developed and tested against benchmark problems with diverse settings.

Lot sizing and scheduling problem is to allocate work to people in the system. Gao et al. [20] outlined a tabu algorithm for solving the distributed permutation flow shop scheduling problem, where jobs were distributed between multiple factories, with the objective of overall makespan minimisation. Pan and Ruiz [21] introduced an EDA for the n-job m-machine lot-streaming flow shop scheduling problem with sequence-dependent setup times under both the idling and no-idling production cases. The objective was to minimise the maximum completion time or makespan.

The objective of tardiness minimisation is to schedule jobs in such a way that the idle times between machines can be reduced. Dubois-Lacoste et al. [22] designed hybrid stochastic local search algorithms for bi-objective permutation flow shop scheduling problems. They computed makespan of individual jobs and the sum of completion times so that the weighted total tardiness of all jobs could be estimated. Mousavi et al. [23] used a simulated annealing algorithm to perform local search in order to find the total tardiness of the job shop scheduling problem, in addition to optimising the makespan. Tasgetiren et al. [24] investigated the use of a differential evolution algorithm for the no-idle permutation flow shop scheduling problem with tardiness criterion.

Line balancing problem is to reduce the idle time of work stations when the job is still handled by other stations. Fatih

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