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computers & industrial engineering

Computers & Industrial Engineering 48 (2005) 657–677

www.elsevier.com/locate/dsw

Buffer allocation plan for a remanufacturing cell

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Received 1 April 2001; revised 1 October 2002; accepted 1 March 2003
Available online 19 January 2005

Abstract

We present a near optimal buffer allocation plan (NOBAP) specifically developed for a remanufacturing cell with finite buffers and unreliable servers. A remanufacturing cell is a self-reliant entity within which a variety of activities such as disassembly, inspection, material processing, remanufacturing, assembly and transportation are performed. The remanufacturing cell considered in this paper consists of three modules, viz. the disassembly and testing module for returned products, the disposition module for non-reusable returns and the remanufacturing module. We propose an algorithm that uses an open queueing network, decomposition principle and expansion methodology to analyze the remanufacturing cell. The buffer allocation algorithm distributes a given number of available buffer slots among the various stations (across the various modules) to optimize the cell's performance. The algorithm has been rigorously tested for both balanced and unbalanced cells. The results show that the performance of the algorithm is consistent, robust and produces excellent results in a variety of experimental conditions.

Keywords: Remanufacturing; Buffer allocation; Disassembly; Open queueing networks; Throughput

1. Introduction

The implementation of extended manufacturer responsibility, together with the new more rigid environmental legislation and public awareness, have caused a growing number of manufacturers to begin recycling and remanufacturing their used products (cores) after they are discarded by

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doi:10.1016/j.cie.2003.03.007

Nomenclature

α_i	breakdown rate of node (station) i
β_i	repair rate of node i
B_i	buffer capacity of node i
BA	checked buffer allocation list
c_d	disposition cost/item
c_{dis}	disassembly cost/item
c_{hs}	on-hand serviceable inventory cost/item
c_l	lost sales cost/item
c_m	outside procurement/manufacturing cost/item
c_p	purchase cost of cores/item
c_{ri}	remanufacturing cost/item ($i=1$–3)
c_{r4}	final inspection cost/item
c_{rej}	penalty cost of rejected items from the cell
c_t	testing cost/item
$D_{TC}\%$	absolute percentage difference between the optimal total cost obtained via exhaustive search and the total cost obtained from NOBAP
$D_{TH}\%$	absolute percentage difference between the optimal throughput obtained via exhaustive search and the throughput obtained from NOBAP
$d(i)$	immediate downstream station from station i
E(RP)	expected number of returned products
$E(D)$	expected number of disposed products
$E(T)$	expected number of tested products
E(Dis)	expected number of disassembled products
$E(R_i)$	expected number of remanufactured products by remanufacturing node i ($i=1$–4)
E(OP)	expected number of products procured from outside suppliers
E(Inv)	expected number of on hand inventory
E(Ls)	expected number of lost sales
E(Rej)	expected number of rejected items from the cell
γ	demand rate
i	node (station) number ($i=1,\ldots,I$)
I	number of stations in the network
j	iteration number for buffer allocation algorithm
$K_{i,j}$	job holding capacity of node i at iteration j (B_i+1)
$\bar{k}_j$	buffer vector at iteration j ($K_1,K_2,\ldots,K_i,\ldots$)
$\bar{k}^*$	best buffer allocation vector
$L_{i,j}$	average number of jobs at node i (buffer + service)
$Lq_{i,j}$	average number of jobs in the buffer at node i
λ_{ar}	arrival rate of cores (returned products) to the remanufacturing cell
λh_i	arrival rate of the jobs to the holding node after getting rejected by the full buffer at the destination node
λ_i	accumulation rate at node i