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Preface

This dissertation is the result of my research work at the Chair of Production Management at the Faculty of Business Administration and Economics of the Catholic University of Eichstätt-Ingolstadt in the years 2001 to 2006. After his yearly production research meeting in Greece, my doctoral thesis supervisor, Prof. Dr. Heinrich Kuhn, suggested to take a look at a proceedings article of Kniker and Burman (2001). This article dealt with applying an operations research technique called revenue management, which was mainly used in the service sector up to this point, to the manufacturing sector.

After delving into the article I figured out that I now had a stochastic operations research topic although I had tried to avoid stochastics as much as possible during my previous studies. My knowledge accumulated for my diploma thesis on deterministic lotsizing on parallel machines certainly was of very little value for this topic. Nonetheless, after getting the book of Puterman (1994) and exploring the world of stochastic decision processes, I got to know and appreciate this world, while in parallel I was fittingly assigned to deepen students' knowledge of stochastic models in production systems.

After many intellectual sweats and tears I managed to finish my dissertation by September 2006. For the oral tests, though, the doctoral examination regulations dictate presenting two rather small theses which are not supposed to have any relation to the dissertation topic. After coming up with the first hypothesis concerned with opposing numerical student ratings of teachers, the second topic took quite some time because the first choice of topic did not prove really fruitful. After settling for a second choice of opposing national minimum wages, the oral tests took place successfully in January 2009.

I want to thank Prof. Dr. Heinrich Kuhn for providing me with an interesting research topic which also resulted in several joint publications. I also want to thank my second thesis supervisor, Prof. Dr. Ulrich Küsters, to make

the effort of reading through and refereeing my dissertation. Furthermore, I want to thank my colleagues at the Chair of Production Management, Dr. Daniel Quadt and Dr. Georg Krieg for providing me with many interesting discussions which most of the time did not have much to do with my research topic but were interesting nonetheless.

Also, I want to thank my wife Serene for providing me with continuous love and support and my parents for enabling me the education that was a prerequisite for this dissertation. Lastly, I want to thank God for empowering me to finish this project.

Freiburg im Breisgau, June 2009 Florian Defregger

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List of Symbols

Estimates are denoted by a hat, e.g. $\hat{g}$ is an estimate of g.

A	number of artificial order classes
a	an artificial order class
C_s	confidence interval for the sth proportion
c	remaining number of periods the capacity is booked out
$c^{\max}$	maximum that c can reach
$D(i)$	set of decisions that can be taken in state i
$\lvert D \rvert$	maximum number of decisions that can be taken in a certain state
d	a decision
$F(x)$	distribution function of supposedly lower values to be tested with the Mann-Whitney test
$G(x)$	distribution function of supposedly higher values to be tested with the Mann-Whitney test
g	average reward per period
$g(I)$	average reward resulting from a FCFS policy using a maximum inventory level of I
$g(\pi)$	average reward resulting from policy π
$g(\omega)$	average reward resulting from a policy that rejects ω artificial order classes
H_0	null hypothesis
H_1	alternative hypothesis
h	unit inventory holding cost per period
$\underline{h}, \overline{h}$	lower, upper bound for h

$\tilde{I}$	maximum inventory level
$\underline{I}, \overline{I}$	lower, upper bound for $\tilde{I}$
I_1, I_2	maximum inventory levels to be compared
$I^{\max}$	maximum inventory capacity
i	current level of inventory
$\tilde{i}$	inventory threshold
$l^{\max}$	maximum lead time, given by $l^{\max} = \max_n l_n$
l_n	lead time for an order of class n
$\underline{l}_n$	lower bound for the lead time for an order of class n
m_n	profit margin for an order of class n
m_n^{rel}	relative profit margin for an order of class n
N	number of order classes
n	an order class
O	variable to denote wether a company has the potential for revenue management
o_{mn}	setup cost from order class m to order class n
o_{mn}^{rel}	relative setup cost from order class m to order class n
$P^d(i,j)$	transition probability from state i to state j if decision d is taken
$P^\pi(i,j)$	transition probability from state i to state j under policy π
$\tilde{P}^d(i)$	stationary probability of state i if decision d is taken
$\tilde{P}^\pi(i)$	stationary probability of state i under policy π
p_n	arrival probability for an order of class n in each period
$R^d(i)$	reward that is received when decision d is taken in state i
$R^\pi(i)$	reward that is received when the system enters state i under policy π
r	share of u_n in x_n
S	set of all states
$\lvert S\rvert$	number of all states
$\lvert S\rvert^{\text{real}}$	actual number of states for a problem instance
$S_d(i)$	number of source states of state i where decision d is taken
$S_d^{\max}$	maximum number of source states where decision d is taken

$S^{\max}$	maximum number of source states where any decision is taken
$S_{v=0}$	set of states with a relative value of 0
s	current setup state
t_{mn}	setup time from order class m to order class n
$\bar{t}_n$	average of the setup times $t_{mn}, \forall m$ into order class n
$\bar{t}'_n$	average of the setup times $t_{mn}, m \neq n$ into order class n
U	size of a company
u_n	capacity usage in periods for an order of class n
$V_n(i)$	value of state i if the stochastic process would end in n periods
$v(i)$	relative value of state i
W	variable to denote wether a company uses revenue management
$X_{\pi i}$	average reward obtained from replication i under policy π
X_{1i}, X_{2i}	average rewards obtained from replication i under two policies that are currently compared
$\overline{X}_\pi(n)$	average of the average rewards $X_{\pi i}$ after n replications
x_n	sum of u_n and $\bar{t}_n$
x'_n	sum of u_n and $\bar{t}'_n$
Z_i	difference of two average rewards X_{1i} and X_{2i}
$\overline{Z}(n)$	average of the Z_i after n replications
α	level of significance
α_s	level of significance for the sth proportion
β	special convergence criterion for the Gauss-Seidel iterative method
γ	maximum relative error of simulation estimates $\overline{X}_\pi(n)$
$\Delta^{\text{FCFS}-\text{opt}}$	percentage deviation of the average reward of a FCFS policy compared to the optimal average reward
$\Delta^{\text{H}-\text{opt}}$	percentage deviation of the average reward of a heuristic policy compared to the optimal average reward
$\Delta V(i)$	difference of $V_n(i)$ and $V_{n-1}(i)$, given by $\Delta V(i) = V_n(i) - V_{n-1}(i)$
$\underline{\Delta V}$	lower bound for all $\Delta V(i)$

$\overline{\Delta V}$	upper bound for all $\Delta V(i)$
δ	convergence criterion for the Gauss-Seidel iterative method
ϵ	convergence criterion for the value iteration method
θ^T	vector of τ_n, $\theta^T = (\tau_0, \tau_1, \ldots, \tau_N)$
ι	number of units taken from the inventory to fulfill an order
$\iota_{\min}$	minimum amount of inventory that has to be used in order to fulfill an accepted order
$\iota_{\max}$	maximum amount of inventory that can be used in order to fulfill an accepted order
μ_s	true value of the sth proportion
$\tilde{\omega}$	best number of rejected artificial order classes found by the heuristic procedure
$\underline{\omega}, \overline{\omega}$	lower, upper bound for $\tilde{\omega}$
ω_1, ω_2	numbers of rejected artificial order classes to be compared
Π	investigation period
π	a policy for a Markov decision process
π^{com}	policy which induces an irreducible Markov reward process
π^{FCFS}	FCFS policy
π^{opt}	optimal policy for a Markov decision process
π^{ϵ}	average reward of the ϵ-optimal policy
$\tilde{\pi}$	best policy found by a heuristic procedure
$\tilde{\pi}^{\text{opt}}$	approximate optimal policy found by the value iteration algorithm
ρ	traffic intensity
$\tilde{\rho}$	approximate traffic intensity
ρ_n	traffic intensity of order class n
σ_n	share of order class n in the traffic intensity ρ
$\underline{\sigma}, \overline{\sigma}$	global lower, upper bound for all σ_n
$\overline{\sigma}_v$	variable upper bound for σ_n
τ_n	heuristic order acceptance threshold of order class n