

**COMPARISON OF PARALLEL KANBAN-BASE STOCK
SYSTEM TO CONTROL MULTI-PRODUCT
MULTI-STAGE PRODUCTION WITH REWORK
THROUGH SIMULATION**

by

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LIST OF ABBREVIATIONS

ANOVA	Analysis of variance
$AvHR$	Average flow time of HR
Avk_s	Average flow time for standard kanban
$AvLR$	Average flow time of LR
$AvThr$	Average throughput
$AvUtil$	Average utilization of machine
$AvWIP$	Average WIP level
BSS	Base stock System
CR	Critical ratio
DBD	Dynamic bottleneck dispatching
DES	Discrete-Event Simulation
DP	Depaneling machine
DR	Defect rate
EDD	Earliest due date
EKCS	Extended Kanban Control System
FBN	First bottleneck strategy
FIFO	First-in-first-out
GKCS	Generalized Kanban Control System
GRPD	Greedy rework probability with a due date
HIHSs	Horizontally Integrated Hybrid Systems
HL	High runner-Low runner
HPCS	Hybrid production control system

HR	High-runner
JIT	Just-In-Time
k_o	Order kanban
KS	Kanban System
k_s	Standard kanban
LH	Low runner-High runner
LM	Lean Manufacturing
LR	Low-runner
<i>LRB</i>	Low runner buffer
<i>LRR</i>	Low runner ratio
<i>LS</i>	Lot size
MPS	Master production schedule
MR	Merge reworking policy
MRP	Material Requirement Planning
MRPD	Minimum rework probabilities with due dates
MRPII	Manufacturing Resource Planning
ODD	Operational due date
OPT	Optimized Production Technology
OR	Original reworking policy
<i>OV</i>	Overall flow time
<i>P</i>	Push system
PAC	Production Authorization Card
PCB	Printed circuit board
PCS	Production controlsystem

<i>PD</i>	Probability defect
<i>PIHSs</i>	Parallel Integrated Hybrid Systems
<i>PKB</i>	Parallel Kanban-Base stock
<i>PKB-HL</i>	Parallel Kanban- Base stock system with HL dispatch rule
<i>PKB-HL-MR</i>	Parallel Kanban- Base stock system with HL dispatch rule and MR rework entrance policy
<i>PKB-HL-OR</i>	Parallel Kanban- Base stock system with HL dispatch rule and OR rework entrance policy
<i>PKB-LH</i>	Parallel Kanban- Base stock system with LH dispatch rule
<i>PKB-LH-MR</i>	Parallel Kanban- Base stock system with LH dispatch rule and MR rework entrance policy
<i>PKB-LH-OR</i>	Parallel Kanban- Base stock system with LH dispatch rule and OR rework entrance policy
<i>PM</i>	Probability of merging
<i>P-MR</i>	Push system with MR rework entrance policy
<i>P-OR</i>	Push system with OR rework entrance policy
<i>PPCS</i>	Production planning and control system
<i>PPS</i>	Production planningsystem
<i>PSBS</i>	Problem space based research
<i>REP</i>	Rework entrance policy
<i>RR</i>	Rework runner
<i>RSM</i>	Response Surface Methodology
<i>RV</i>	Rendezvous strategy
<i>RWK</i>	Rework priority

SA	Starvation avoidance
SIC	Statistical Inventory Control
SME	Surface mount equipment machine
SP	Split strategy
SP	Split strategy
SPT	Shortest processing time
SST	Shortest setup time
<i>TO</i>	Total output
UCELL	U-shaped cell
VIHSs	Vertically Integrated Hybrid Systems
WAIT	Wait strategy
WIP	Work-in-process
WIP_{max}	Maximum WIP level
WR	Workload regulating

LIST OF SYMBOLS

P_c	collective probability
n	number of RR orders waiting to be merged
t_1	production control system
t_2	dispatch rule
t_3	rework entrance policy
R^2	coefficient of determination

**PERBANDINGAN SISTEM STOK ASAS-KANBAN SELARI UNTUK
MENGAWAL PENGELUARAN PELBAGAI PRODUK DI PELBAGAI
PERINGKAT DENGAN MENGAMBILKIRA AKTIVITI KERJA SEMULA
MELALUI SIMULASI**

ABSTRAK

Cabaranglobalisasi kinimemaksaindustri pembuatanuntuk menawarkanpelbagai produk dengan keperluan yang berbeza-bezauntuk memenuhi keperluan pelanggan mereka. Walau bagaimanapun,senario kompleks ini telah menyebabkan kerja dalam proses (WIP) dan kecacatan yang tinggi, dengan itu memberi inspirasi kepada penyelidik untuk menyelidik cara-cara yang optimum untuk menguruskansistem pembuatanyang kompleks ini dalam skop sistemkawalan pengeluaran(PCS). Kebanyakan penyelidikan dalamPCSsebelum inimemberi tumpuan kepadasistem pengeluaranyang idealdankerja semulajarangdipertimbangkan.Kajian inibertujuan untuk membangunkandan menilaiprestasi suatuPCShibridyang baru yang dikenali sebagaisistem Stok asas-Kanban Selari(PKB) untuk mengawal seliapelbagai produk pengeluaran pelbagai peringkatdenganpintu masukkerja semula. Berbeza dengansistem hibridstok asas-kanban asal,sistemPKBmengambil kiratiga varian.Varianpertamaadalah duakelasprodukkeluarga dikenali sebagai pelari tinggi(HR)dan pelari rendah (LR) berdasarkan permintaancampuranproduk.Variankedua ialahvariasikaedah untuk mengawal seliapenghantaranproduk keluargadikategori sebagaipelaritinggi-pelari rendah (HL) dan pelari rendah-pelari tinggi (LH). Varianketigamempertimbangkan duapolisipintu masukkerja semuladiklasifikasikan sebagaicantum(MR) dan asli(OR).

Sistem yang dikaji telah dimodelkan menggunakan simulasi peristiwa diskret. Keputusan simulasi dianalisis berdasarkan kaedah statistik termasuk analisis varians, regresi dan metodologi permukaan sambutan. Pemilihan parameter, pembolehubah dan prestasi yang diukur adalah berdasarkan kajian ilmiah dan amalan semasa syarikat kajian kes. Kajian ini telah dibahagikan kepada tiga kes. Bagi Kes 1, di antara polisi masuk kerja semula, MR polisi masuk kerja semula memberi hasil yang lebih wajar seperti yang dikaji bagi pengukuran prestasi berbanding OR polisi masuk kerja semula. Bagi Kes 2, keputusan menunjukkan bahawa sistem PKB dengan permintaan pelanggan yang berbeza menunjukkan peraturan penghantaran HL adalah lebih baik berbanding peraturan penghantaran LH. Bagi Kes 3, *PKB-HL-MR* memberikan hasil optimum berbanding model lain. Secara keseluruhan keputusan menunjukkan, sistem PKB mempunyai kelebihan sistem stok asas (untuk LR) dengan menghasilkan hampir 1.3% jumlah keluaran lebih tinggi dan kelebihan sistem kanban (untuk HR) dengan mempunyai WIP terkawal. Lebih penting lagi, kajian ini menyumbang kepada pengetahuan dalam bidang PCS dalam persekitaran pelbagai produk pelbagai peringkat dengan mengambil kira proses kerja semula. Bagi penyelidikan masa depan, kajian ini boleh dilanjutkan kepada analisis konfigurasi sistem yang lebih rumit seperti kerosakan mesin dan menjalankan model simulasi untuk pelbagai jenis industri.

**COMPARISON OF PARALLEL KANBAN-BASE STOCK SYSTEM TO
CONTROL MULTI-PRODUCT MULTI-STAGE PRODUCTION WITH
REWORK THROUGH SIMULATION**

ABSTRACT

A recent globalization challenge compels manufacturing industries to offer a large variety of products with varied demands to suit their customers' needs. However, these complex scenarios have led to high work-in-process (WIP) and defects, thus inspires many researches to investigate the optimum ways to manage this complex manufacturing system within the scope of production control system (PCS). Most research in PCS has previously focused on the ideal production system and rework is seldom being considered. This study aims to develop and to evaluate the performance of a new hybrid PCS known as Parallel Kanban-Base stock (PKB) system to regulate a multi-product multi-stage production with the entrance of rework. In contrast to the original hybrid kanban-base stock system, PKB system takes into account of three variants. First variant are two classes of the product families known as high-runner (HR) and low-runner (LR) based on the demand of the product mix. The second variant is the variations of dispatch rules to regulate product families categorized as high runner-low runner (HL) and low runner-high runner (LH). Third variant considered was two rework entrance policies classified as merge (MR) and original (OR). The studied systems have been modeled using discrete-event simulation. The simulation results are analyzed based on statistical methods including analysis of variance, regression and response surface

methodology. The selection of related parameters, variables and performance measures is relatively based on literature study and current practice of a case study company. This study has been divided into three cases. For Case 1, among rework entrance policies, predominantly MR rework entrance policy yields more desirable results as observed within the performance measures, compared to OR rework entrance policy. For Case 2, the results revealed that PKB system with different customer demands shows HL dispatch rule is superior to LH dispatch rule. For Case 3, *PKB-HL-MR* gives the optimum results compared to other models. Overall findings show that PKB system possesses the advantage of a Base stock System (for LR) by causing an approximately 1.3% higher total output and the advantage of a Kanban System (for HR) by having controllable WIP levels. Significantly, this research contributes to the knowledge in the area of PCS in multi-product multi-stage environment considering reworking process. For future research, this work can be extended to the analysis of more complicated system configurations such as a machine breakdown and run the simulation model for various types of industries.