PERFORMANCE ANALYSIS AND DEVELOPMENT OF PULL-TYPE PRODUCTION CONTROL STRATEGIES FOR EVOLUTIONARY OPTIMISATION OF CLOSED-LOOP SUPPLY CHAINS

Author:

Jonathan Reinholt Ebner Junior

This thesis is submitted in accordance with the requirements of
Dublin City University for the award of the degree of
Doctor of Philosophy (PhD)

Supervisors:

Dr. John Geraghty
Dr. Paul Young

School of Mechanical & Manufacturing Engineering
DCU - Dublin City University

January 2018

DECLARATION

I hereby certify that this material, which I now submit for assessment on the programme of study leading to the award of Doctor of Philosophy is entirely my own work, and that I have exercised reasonable care to ensure that the work is original, and does not to the best of my knowledge breach any law of copyright, and has not been taken from the work of others save and to the extent that such work has been cited and acknowledged within the text of my work.

Signed: ____ID No.:15210017

Jonathan Reinholt Ebner Jr.

Date: ___________________

DEDICATION

To God for the unlimited wisdom, inspiring greatness and for allowing the grace of technological development and scientific research.

To my beloved parents Mr. Jonathan Reinholt Ebner and Ms. Neuza Rosa Ebner, who generously devoted their lives to my success. For their love, unconditional support and outstanding education provided.

ACKNOWLEDGEMENTS

Dr. John Geraghty and Dr. Paul Young for the extensive knowledge, brilliant intelligence, the relentless guidance, support and the amazing personality to mentor and successfully manage the development of so many students.

Dr. Joseph Stokes, Dr Brian Corcoran, Dr. Bryan MacDonald, Dr.Yann Delaure, Ms. Caoimhe O'Broin and all the academic and non-academic staff of the School of Mechanical and Manufacturing Engineering - DCU. Thank you for all your kind support during my research time at Dublin City University.

The Brazilian Government, through the CNPq (National Council for Scientific and Technological Development), for their wise investment in higher education, research and technology, while the Nation faces one of the longest and deepest economic depressions on record.

To all Professors, Lecturers, Authors and Researchers that to any extent had a positive impact on my research work.

To my siblings: Fabio, Joana D'arc and Stenio for their presence, the great support, their helpfulness and inspiring example.

To all my friends and colleagues in Dublin City University: Thank you for your support and friendship.

TABLE OF CONTENTS

DECLARATION .... **I**

DEDICATION .... **II**

ACKNOWLEDGEMENTS .... **III**

TABLE OF CONTENTS .... **IV**

LIST OF FIGURES .... **VIII**

LIST OF TABLES .... **XII**

NOMENCLATURE .... **XIV**

ABSTRACT .... **XVII**

CHAPTER 1. INTRODUCTION **1**

1.1. RESEARCH OBJECTIVES, DELIMITATION AND GENERALISATIONS 2

1.2. THESIS STRUCTURE 3

CHAPTER 2. LITERATURE REVIEW **5**

2.1. PRODUCTION CONTROL STRATEGIES 6

2.1.1. KANBAN CONTROL STRATEGY (KB) 6

2.1.2. CONWIP CONTROL STRATEGY (CW) 7

2.1.3. BASE STOCK CONTROL STRATEGY (BS) 9

2.1.4. HYBRID KANBAN CONWIP CONTROL STRATEGY (HKC) 10

2.1.5. GENERALISED KANBAN CONTROL STRATEGY (GK) 11

2.1.6. EXTENDED KANBAN CONTROL STRATEGY (EKB) 12

2.1.7. ADAPTIVE KANBAN CONTROL STRATEGY (AKB) 13

2.1.8. ADAPTIVE EXTENDED KANBAN AND ADAPTIVE GENERIC KANBAN CONTROL STRATEGIES (AGRK AND AEK) 14

2.1.9. DYNAMIC CONWIP CONTROL STRATEGY 17

2.1.10. FLEXIBLE CONTROL STRATEGY (FKS) 18

2.1.11. DYNAMIC CARD CONTROL STRATEGY BASED ON CENTRALISED KANBAN AND CONWIP CONTROL STRATEGY 19
2.1.12. SUMMARY AND POSITIONING OF THIS RESEARCH 19
2.2. SIMULATION MODELLING AND OPTIMISATION OF MANUFACTURING SYSTEMS 21
2.2.1. MULTI-OBJECTIVE EVOLUTIONARY ALGORITHM 21
2.2.2. PERFORMANCE METRICS 24
2.2.3. WARMUP PERIOD 24
2.2.4. SUMMARY 25
2.3. DATA ANALYSIS AND TOOLS FOR DESIGN OF EXPERIMENTS 26
2.3.1. ROBUSTNESS TEST 26
2.3.2. RESPONSE SURFACE METHODOLOGY 28
2.4. MATERIAL RECOVERY AND ENVIRONMENTAL REGULATION ON MANUFACTURERS 29
2.4.1. SUMMARY AND POSITIONING OF THIS RESEARCH 35

CHAPTER 3. PRELIMINARY PRODUCTION CONTROL STRATEGY EXPERIMENTAL APPROACH..36

3.1. DEDICATED AND SHARED CONWIP CONTROL STRATEGIES REVIEW 36
3.2. EXPERIMENTAL DESIGN 37
3.3. EXPERIMENTAL RESULTS 42
3.4. SUMMARY 46

CHAPTER 4. RESEARCH METHODOLOGY 48

4.1. SYSTEM DESCRIPTION 48
4.2. RESEARCH SPACE SPECIFICATIONS 64
4.3. MODIFICATION APPROACH 65

CHAPTER 5. EXPERIMENTAL RESULTS 71

5.1. INTRODUCTION 71
5.2. EXPERIMENTAL RESULTS FOR SCENARIOS WITH UPPER PROCESSING TIME VARIABILITY AND 90% RETURNED MATERIALS 72
5.3. EXPERIMENTAL RESULTS FOR SCENARIOS WITH LOWER PROCESSING TIME VARIABILITY AND 90% RETURNED MATERIALS 74
5.4. EXPERIMENTAL RESULTS FOR SCENARIOS WITH UPPER PROCESSING TIME VARIABILITY AND 40% RETURNED MATERIALS 76
5.5. EXPERIMENTAL RESULTS FOR SCENARIOS WITH LOWER PROCESSING TIME VARIABILITY AND 40% RETURNED MATERIALS 78
5.6. RELATIONSHIP BETWEEN BACKLOG (BL) AND SERVICE LEVEL (SL) 80
5.7. SUMMARY 83

CHAPTER 6. DATA ANALYTICS 84

6.1. ROBUSTNESS TEST 84

6.1.1. WIP AND BL ROBUSTNESS TO INCREASED SYSTEM WORKLOAD – UPPER VARIABILITY AND HIGHER RATE OF RECYCLED SUPPLY 85

6.1.2. WIP AND BL ROBUSTNESS TO INCREASED SYSTEM WORKLOAD – LOWER VARIABILITY AND HIGHER RATE OF RECYCLED SUPPLY 89

6.1.3. WIP AND BL ROBUSTNESS TO INCREASED SYSTEM WORKLOAD – UPPER VARIABILITY AND LOWER RATE OF RECYCLED SUPPLY 92

6.1.4. WIP AND BL ROBUSTNESS TO INCREASED SYSTEM WORKLOAD – LOWER VARIABILITY AND LOWER RATE OF RECYCLED SUPPLY 96

6.1.5. SUMMARY........ 99

6.2. RESPONSE SURFACE METHODOLOGY (RSM) 99

6.2.1. RESPONSES FOR DNC HEKC-II STRATEGY WITH UPPER PROCESSING TIME VARIABILITY AND 90% RECYCLED SUPPLY........ 100

6.2.2. RESPONSES FOR HKC STRATEGY WITH UPPER PROCESSING TIME VARIABILITY AND 90% RECYCLED SUPPLY 102

6.2.3. RESPONSES FOR DNC HEKC-II STRATEGY WITH UPPER PROCESSING TIME VARIABILITY AND 40% RECYCLED SUPPLY........ 104

6.2.4. RESPONSES FOR HKC STRATEGY WITH UPPER PROCESSING TIME VARIABILITY AND 40% RECYCLED SUPPLY 107

6.2.5. SUMMARY........ 109

CHAPTER 7. PERFORMANCE ASSESSMENT OF THE PROPOSED INTELLIGENT SELF-DESIGNING PRODUCTION CONTROL STRATEGY 111

7.1. DESCRIPTION AND SPECIFICATION OF THE SYSTEM 111

7.2. EXPERIMENTAL RESULTS 114

7.3. SUMMARY 116

CHAPTER 8. CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH 119

8.1. SUMMARY OF CONTRIBUTIONS TO THE THEORY 119

8.2. RECOMMENDATIONS FOR FUTURE RESEARCH AND DEVELOPMENT 121

REFERENCES 124

LIST OF PUBLICATIONS AND OTHER WORKS 136

APPENDIX A. ROBUSTNESS TEST RESULTS FOR INCREASED SYSTEM WORKLOAD FROM 85% TO 95% A1

APPENDIX B. EVOLUTIONARY OPTIMISATION RESULTS FOR ALL STRATEGIES WITH 90% RETURNED MATERIALS B1

APPENDIX C. EVOLUTIONARY OPTIMISATION RESULTS FOR ALL STRATEGIES WITH 40% RETURNED MATERIALS C1

APPENDIX D. SERVICE LEVEL AND BACKLOG COMPARISON D1

APPENDIX E. ANOVA TABLES AND REPORTS E1

LIST OF FIGURES

FIGURE 2-1. KANBAN CONTROLLED TWO-STAGES PRODUCTION LINE. [9] 7

FIGURE 2-2. CONWIP CONTROLLED TWO-STAGES PRODUCTION LINE. [9] 8

FIGURE 2-3. BASE STOCK CONTROLLED TWO-STAGES PRODUCTION LINE. [9] 9

FIGURE 2-4. HYBRID KANBAN CONWIP CONTROLLED PRODUCTION LINE [3, 20] 11

FIGURE 2-5. GENERALIZED KANBAN CONTROLLED TWO-STAGES PRODUCTION LINE [9]................. 11

FIGURE 2-6. EXTENDED KANBAN CONTROLLED TWO-STAGES PRODUCTION. [9]............................ 13

FIGURE 2-7. ADAPTIVE KANBAN CONTROLLED PRODUCTION LINE. [24].. 14

FIGURE 2-8. ADAPTIVE GENERIC KANBAN CONTROLLED PRODUCTION LINE (AGRK) [27]................ 15

FIGURE 2-9. ADAPTIVE EXTENDED KANBAN CONTROLLED PRODUCTION LINE [27]......................... 16

FIGURE 2-10. DYNAMIC CONWIP CONTROLLED DECISION PROCESS [32]...................................... 17

FIGURE 2-11. DYNAMIC CARD CONTROL STRATEGY BASED ON CENTRALISED KANBAN AND CONWIP DECISION PROCESS [43] 19

FIGURE 2-12. FIRST-ORDER STOCHASTIC DOMINANCE [92].. 27

FIGURE 2-13. SECOND-ORDER STOCHASTIC DOMINANCE: OPTION A SECOND-ORDER STOCHASTICALLY DOMINATES OPTION B [92] 28

FIGURE 2-14 SECOND-ORDER STOCHASTIC DOMINANCE: OPTION A DOES NOT SECOND-ORDER STOCHASTICALLY DOMINATES OPTION B [92] 28

FIGURE 2-15. INTEGRATED CLOSED-LOOP SUPPLY CHAIN FRAMEWORK [97] 30

FIGURE 2-16. TOYOTA RECYCLING/RECOVERY SYSTEM FOR END OF LIFE VEHICLES IN JAPAN [115] 34

FIGURE 3-1. DEDICATED CONWIP DIAGRAM OF THE AUTHORISATION CARDS ALLOCATION POLICY AND THE WORKFLOW OF CLSC 39

FIGURE 3-2. SHARED CONWIP DIAGRAM OF THE AUTHORISATION CARDS ALLOCATION POLICY AND THE WORKFLOW OF CLSC 40

FIGURE 3-3. CONTROL STRATEGIES PERFORMANCE FOR THE 40% RECOVERY SCENARIOS 43

FIGURE 3-4. CONTROL STRATEGIES PERFORMANCE FOR THE 90% RECOVERY SCENARIOS 44

FIGURE 3-5. MINIMAL BLOCKING STRATEGY VS HYBRID MINIMAL BLOCKING-CONWIP STRATEGY – PERFORMANCE SPREAD [47]. 45

FIGURE 3-6. MULTIPLE STRATEGIES PARETO FRONT COMPARISON [47].. 45

FIGURE 4-1. HEKC-II DIAGRAM OF THE AUTHORISATION CARDS ALLOCATION POLICY AND THE WORKFLOW OF CLSC 51
FIGURE 4-2. HKC DIAGRAM OF THE AUTHORISATION CARDS ALLOCATION POLICY AND THE WORKFLOW OF CLSC 52
FIGURE 4-3. DNC HEKC-II DIAGRAM OF THE AUTHORISATION CARDS ALLOCATION POLICY AND THE WORKFLOW OF CLSC 56
FIGURE 4-4. DNC HKC DIAGRAM OF THE AUTHORISATION CARDS ALLOCATION POLICY AND THE WORKFLOW OF CLSC 57
FIGURE 4-5. DISTRIBUTED DEMAND LEVEL COMPARISON FOR EACH DEMAND BUFFER ON HEKC-II WITH DE = 0 AND BASE STOCK = 20 66
FIGURE 4-6. WIP AND BL PLOT DISPLAYING INSTANT VARIATIONS OF THE FINISHED GOOD BUFFER (BLUE) AND BL (RED) ON HEKC-II WITH DE = 0 AND BASE STOCK = 20 67
FIGURE 4-7. DISTRIBUTED DEMAND LEVEL COMPARISON FOR EACH DEMAND BUFFER ON HEKC-II WITH DE = 0 AND BASE STOCK = 100 67
FIGURE 4-8. WIP AND BL PLOT DISPLAYING INSTANT VARIATIONS OF THE FINISHED GOODS BUFFER (BLUE) AND BL (RED) ON HEKC-II WITH DE = 0 AND BASE STOCK = 100 68
FIGURE 4-9. DISTRIBUTED DEMAND LEVEL COMPARISON FOR EACH DEMAND BUFFER ON HEKC-II WITH PARETO-OPTIMUM SETTING: DE = 1 AND BASE STOCK = 20 68
FIGURE 4-10. WIP AND BL PLOT DISPLAYING INSTANT VARIATIONS OF THE FINISHED GOOD BUFFER (BLUE) AND BL (RED) ON HEKC-II WITH THE PARETO-OPTIMUM SETTING: DE = 1 AND BASE STOCK = 20 69
FIGURE 4-11. WIP AND BL PLOT DISPLAYING INSTANT VARIATIONS OF THE FINISHED GOOD BUFFER (BLUE) AND BL (RED) ON DNC HEKC-II. SETTING WITH ADDED MP: DE = 1, BASE STOCK = 20 AND ADDED MP=120 70
FIGURE 5-1. PARETO OPTIMUM PERFORMANCE FRONTIER, HIGH PROCESSING TIME VARIABILITY AND 90% OF RETURNED MATERIALS - LOWER WIP RANGE 73
FIGURE 5-2. PARETO OPTIMUM PERFORMANCE FRONTIER, HIGH PROCESSING TIME VARIABILITY AND 90% OF RETURNED MATERIALS - LOWER BL RANGE 73
FIGURE 5-3. PARETO OPTIMUM PERFORMANCE FRONTIER, LOWER PROCESSING TIME VARIABILITY AND 90% OF RETURNED MATERIALS - LOWER WIP RANGE 75
FIGURE 5-4. PARETO OPTIMUM PERFORMANCE FRONTIER, LOWER PROCESSING TIME VARIABILITY AND 90% OF RETURNED MATERIALS - LOWER BL RANGE 75
FIGURE 5-5. PARETO OPTIMUM PERFORMANCE FRONTIER, HIGH PROCESSING TIME VARIABILITY AND 40% OF RETURNED MATERIALS - LOWER WIP RANGE 77
FIGURE 5-6 PARETO OPTIMUM PERFORMANCE FRONTIER, HIGH PROCESSING TIME VARIABILITY AND 40% OF RETURNED MATERIALS - LOWER BL RANGE 77

FIGURE 5-7. PARETO OPTIMUM PERFORMANCE FRONTIER, LOWER PROCESSING TIME VARIABILITY AND 40% OF RETURNED MATERIALS - LOWER WIP RANGE 79
FIGURE 5-8. PARETO OPTIMUM PERFORMANCE FRONTIER, LOWER PROCESSING TIME VARIABILITY AND 40% OF RETURNED MATERIALS - LOWER BL RANGE 79
FIGURE 5-9. DNC HKC – RELATION BETWEEN BL AND SL - HIGH PROCESSING TIME VARIABILITY AND 90% OF RETURNED MATERIALS 81
FIGURE 5-10. DNC HKC – RELATION BETWEEN BL AND SL - HIGH PROCESSING TIME VARIABILITY AND 90% OF RETURNED MATERIALS- WIP RANGE FOR HIGH SERVICE LEVEL RESULTS.......... 81
FIGURE 5-11. HKC – RELATION BETWEEN BL AND SL - HIGH PROCESSING TIME VARIABILITY AND 40% OF RETURNED MATERIALS.. 82
FIGURE 5-12. HKC – RELATION BETWEEN BL AND SL - HIGH PROCESSING TIME VARIABILITY AND 40% OF RETURNED MATERIALS – WIP RANGE FOR HIGH SERVICE LEVEL RESULTS................ 82
FIGURE 6-1. BL CUMULATIVE DISTRIBUTION FUNCTION - 90% HV 86
FIGURE 6-2. WIP CUMULATIVE DISTRIBUTION FUNCTION - 90% HV 87
FIGURE 6-3. BL AND WIP DIRECT TRADE-OFF DATA POINTS FOR THE ROBUSTNESS TEST ANALYSIS - 90% HV 88
FIGURE 6-4. BL CUMULATIVE DISTRIBUTION FUNCTION - 90% LV 89
FIGURE 6-5. WIP CUMULATIVE DISTRIBUTION FUNCTION - 90% LV 90
FIGURE 6-6. BL AND WIP DIRECT TRADE-OFF DATA POINTS FOR THE ROBUSTNESS TEST ANALYSIS - 90% LV.. 91
FIGURE 6-7. BL CUMULATIVE DISTRIBUTION FUNCTION - 40% HV 93
FIGURE 6-8. WIP CUMULATIVE DISTRIBUTION FUNCTION - 40% HV 94
FIGURE 6-9. BL AND WIP DIRECT TRADE-OFF DATA POINTS FOR THE ROBUSTNESS TEST ANALYSIS - 40% HV 95
FIGURE 6-10. BL CUMULATIVE DISTRIBUTION FUNCTION - 40% LV.. 96
FIGURE 6-11. WIP CUMULATIVE DISTRIBUTION FUNCTION - 40% LV 97
FIGURE 6-12. BL AND WIP DIRECT TRADE-OFF DATA POINTS FOR THE ROBUSTNESS TEST ANALYSIS - 40% LV.. 98
FIGURE 6-13. RESPONSE SURFACE GRAPH DISPLAYING THE IMPACT OF RELATED FACTORS ON THE MULTI-OBJECTIVE MINIMISATION OF CLSC INVENTORY FOR THE DNC HEKC-II STRATEGY WITH HV 90% RETURNS 101
FIGURE 6-14. RESPONSE SURFACE GRAPH DISPLAYING THE IMPACT OF RELATED FACTORS ON THE MULTI-OBJECTIVE MINIMISATION OF CLSC INVENTORY FOR THE HKC STRATEGY WITH HV 90% RETURNS.. 103

FIGURE 6-15 RESPONSE SURFACE GRAPH DISPLAYING THE IMPACT OF RELATED FACTORS ON THE MULTI-OBJECTIVE MINIMISATION OF CLSC INVENTORY FOR THE DNC HEKC-II STRATEGY WITH HV 40% RETURNS 106
FIGURE 6-16 RESPONSE SURFACE GRAPH DISPLAYING THE IMPACT OF RELATED FACTORS ON THE MULTI-OBJECTIVE MINIMISATION OF CLSC INVENTORY FOR THE HKC STRATEGY WITH HV 40% RETURNS 108
FIGURE 7-1. PARETO OPTIMUM PERFORMANCE FRONTIER, UPPER PROCESSING TIME VARIABILITY AND 90% OF RETURNED MATERIALS - LOWER BL RANGE 115
FIGURE 7-2. PARETO OPTIMUM PERFORMANCE FRONTIER, UPPER PROCESSING TIME VARIABILITY AND 90% OF RETURNED MATERIALS - LOWER WIP RANGE 115
FIGURE 7-3. PARETO OPTIMUM PERFORMANCE FRONTIER, UPPER PROCESSING TIME VARIABILITY AND 90% OF RETURNED MATERIALS - TOTAL RANGE 115
FIGURE 7-4. WIP AND BL PLOT DISPLAYING INSTANT VARIATIONS OF THE FINISHED GOODS BUFFER (BLUE) AND BL (RED) FOR DNC HEKC-II. PARETO OPTIMUM SETTINGS WITH MP = 12.. 116
FIGURE 7-5. WIP AND BL PLOT DISPLAYING INSTANT VARIATIONS OF THE FINISHED GOODS BUFFER (BLUE) AND BL (RED) ON INTELLIGENT SELF-DESIGNING PCS, MODIFICATION OF DNC HEKC-II. CHANGING ONLY MP SETTING TO MP = 48 117
FIGURE 7-6. WIP AND BL PLOT DISPLAYING INSTANT VARIATIONS OF THE FINISHED GOODS BUFFER (BLUE) AND BL (RED) ON INTELLIGENT SELF-DESIGNING PCS, MODIFICATION OF DNC HEKC-II. CHANGING ONLY MP AND TA PARAMETERS TO MP = 48 AND TA = 12 WITH ACCELERATION/DECELERATION ENABLED. 117
FIGURE 7-7. FREQUENCY INTERVAL DISTRIBUTION OF THE FINISHED GOODS BUFFER FOR THE DNC HEKC-II OPTIMISED AT BL = 1 118
FIGURE 7-8. FREQUENCY INTERVAL DISTRIBUTION OF THE FINISHED GOODS BUFFER FOR THE DNC HEKC-II OPTIMISED AT BL = 1 (TA=5 AND MP=48) 118

LIST OF TABLES

TABLE 3-1. RANGE OF THE AUTHORISATION CARDS 42
TABLE 4-1. AUTHORISATION CARDS LEGEND 50
TABLE 4-2. RANGE OF AUTHORISATION CARDS SETTING FOR HEKC-II PRODUCTION CONTROL STRATEGY WITH 90% RETURNED MATERIAL. 53
TABLE 4-3. RANGE OF AUTHORISATION CARDS SETTING FOR HKC PRODUCTION CONTROL STRATEGY WITH 90% RETURNED MATERIAL. 53
TABLE 4-4. RANGE OF AUTHORISATION CARDS SETTING FOR HEKC-II PRODUCTION CONTROL STRATEGY WITH 40% RETURNED MATERIAL. 54
TABLE 4-5. RANGE OF AUTHORISATION CARDS SETTING FOR HKC PRODUCTION CONTROL STRATEGY WITH 40% RETURNED MATERIAL. 54
TABLE 4-6. RANGE OF AUTHORISATION CARDS SETTING FOR DNC HEKC-II PRODUCTION CONTROL STRATEGY WITH 90% RETURNED MATERIAL. 58
TABLE 4-7. RANGE OF AUTHORISATION CARDS SETTING FOR DNC HKC PRODUCTION CONTROL STRATEGY WITH 90% RETURNED MATERIAL. 58
TABLE 4-8. CHANGES IN AUTHORISATION CARDS SETTING FOR DNC HEKC-II AND FOR DNC HKC PRODUCTION CONTROL STRATEGY WITH 90% RETURNED MATERIAL. 59
TABLE 4-9. RANGE OF AUTHORISATION CARDS SETTINGS FOR DNC HEKC-II PRODUCTION CONTROL STRATEGY WITH 40% RETURNED MATERIAL. 60
TABLE 4-10. RANGE OF AUTHORISATION CARDS SETTINGS FOR DNC HKC PRODUCTION CONTROL STRATEGY WITH 40% RETURNED MATERIAL. 60
TABLE 4-11. RANGE OF AUTHORISATION CARDS SETTINGS DNC HEKC-II AND FOR DNC HKC PRODUCTION CONTROL STRATEGY WITH 40% RETURNED MATERIAL. 61
TABLE 5-1. SOLUTIONS PER STRATEGY FOR HIGH PROCESSING TIME VARIABILITY AND 90% OF RETURNED MATERIALS 72
TABLE 5-2. SOLUTIONS PER STRATEGY FOR LOWER PROCESSING TIME VARIABILITY AND 90% OF RETURNED MATERIALS 74
TABLE 5-3. SOLUTIONS PER STRATEGY FOR HIGH PROCESSING TIME VARIABILITY AND 40% OF RETURNED MATERIALS 76
TABLE 5-4. SOLUTIONS PER STRATEGY FOR LOWER PROCESSING TIME VARIABILITY AND 40% OF RETURNED MATERIALS 78

TABLE 6-1. AUTHORISATION CARDS SETTING OPTIMISED AT BL 0.5 FOR THE ROBUSTNESS TEST - HV 90% 85
TABLE 6-2. BL STOCHASTIC DOMINANCE TEST RESULTS FOR STRATEGIES AT 90% HV 86
TABLE 6-3. WIP STOCHASTIC DOMINANCE TEST RESULTS FOR STRATEGIES AT 90% HV 87
TABLE 6-4. AUTHORISATION CARDS SETTING OPTIMISED AT BL 0.5 FOR THE ROBUSTNESS TEST - LV 90% 89
TABLE 6-5. BL STOCHASTIC DOMINANCE TEST RESULTS FOR STRATEGIES AT 90% LV 90
TABLE 6-6. WIP STOCHASTIC DOMINANCE TEST RESULTS FOR STRATEGIES AT 90% LV 90
TABLE 6-7. AUTHORISATION CARDS SETTING OPTIMISED AT BL 0.5 FOR THE ROBUSTNESS TEST - HV 40% 92
TABLE 6-8. BL STOCHASTIC DOMINANCE TEST RESULTS FOR STRATEGIES AT 40% HV 93
TABLE 6-9. WIP STOCHASTIC DOMINANCE TEST RESULTS FOR STRATEGIES AT 40% HV 94
TABLE 6-10. AUTHORISATION CARDS SETTING OPTIMISED AT BL 0.5 FOR THE ROBUSTNESS TEST - LV 40% 96
TABLE 6-11. BL STOCHASTIC DOMINANCE TEST RESULTS FOR STRATEGIES AT 40% LV 97
TABLE 6-12. WIP STOCHASTIC DOMINANCE TEST RESULTS FOR STRATEGIES AT 40% LV 97
TABLE 6-13. UPPER AND LOWER PARAMETERS LIMIT FOR THE DESIGN OF EXPERIMENTS - DNC HEKC-II, BL TARGETED WITHIN 0.3 AND 0.5 100
TABLE 6-14. RSM VS GA OPTIMISED RESULTS COMPARISON - DNC HEKC-II 102
TABLE 6-15. UPPER AND LOWER PARAMETERS LIMIT FOR THE DESIGN OF EXPERIMENT – HKC, BL TARGETED TO BE WITHIN 0.3 AND 0.5 103
TABLE 6-16. RSM VS GA OPTIMISED RESULTS COMPARISON – HKC 104
TABLE 6-17. UPPER AND LOWER PARAMETERS LIMIT FOR THE DESIGN OF EXPERIMENT – DNC HEKC-II, BL TARGETED TO BE WITHIN 0.3 AND 0.5 105
TABLE 6-18. RSM VS GA OPTIMISED RESULTS COMPARISON - DNC HEKC-II 107
TABLE 6-19. UPPER AND LOWER PARAMETERS LIMIT FOR THE DESIGN OF EXPERIMENT – HKC, BL TARGETED WITHIN 0.3 AND 0.5 108
TABLE 6-20. RSM VS GA OPTIMISED RESULTS COMPARISON – HKC 109
TABLE 7-1. RANGE OF PARAMETERS AND AUTHORISATION CARDS FOR THE INTELLIGENT SELF-DESIGNING PRODUCTION CONTROL STRATEGY WITH 90% RETURNED MATERIAL. 113
TABLE 7-2. FORMULAS FOR THE DYNAMIC CHANGES ON THE NUMBER OF THE AUTHORISATION CARDS FOR INTELLIGENT SELF-DESIGNING PRODUCTION CONTROL STRATEGY WITH 90% RETURNED MATERIAL. 113
TABLE 7-3. SOLUTIONS FOR UPPER PROCESSING TIME VARIABILITY AND 90% OF RETURNED MATERIALS 114

NOMENCLATURE

Abbreviation	Description
ANOVA	Analysis of Variance
BL	Backlog of Customer Demand
CDF	Cumulative Density Function
CLSC	Closed-Loop Supply Chain
CONWIP	Constant Work-In-Process control strategy
DOE	Design of Experiment
EA	Evolutionary Algorithm
ELV	End-of-Life Vehicle
EPR	Extended Producer Responsibility
LHD	Latin Hypercube Design
LHS	Latin Hypercube Sampling
NSGA	Non-dominated Sorting Genetic Algorithm
PAC	Production Authorisation Card
PCS	Production Control Strategy
POGA	Pareto Optimal Genetic Algorithm
RSM	Response Surface Methodology
SA	Starvation Avoidance
SD	Standard Deviation of Demand
SL	Service Level

WIP	Work-In-Process inventory
DNC HEKC-II	Dynamic Allocation Hybrid Extended Kanban CONWIP special case
DNC HKC	Dynamic Allocation Hybrid Kanban CONWIP
HEKC-II	Hybrid Extended Kanban CONWIP special case
AEK	Adaptive Extended Kanban Strategy
AGRK	Adaptive Generic Kanban Control Strategy
AKB	Adaptive Kanban Control Strategy
BS	Base Stock Control Strategy
CW	CONWIP Control Strategy
EKB	Extended Kanban Control Strategy
FKS	Flexible Control Strategy
GK	Generalised Kanban Control Strategy
HKC	Hybrid Kanban CONWIP Control Strategy
KB	Kanban Control Strategy
Cwn	Number of CONWIP cards at the new material supply
Cwr	Number of CONWIP cards at the recycling process
Cwf	Number of CONWIP cards at the remanufacturing process
Cwe	Number of CONWIP cards at the refurbishment process
Ks	Number of Kanban cards at the new material supply
Kr	Number of Kanban cards at the recycling process
Ke	Number of Kanban cards at the remanufacturing process
Kf	Number of Kanban cards at the refurbishment process
Km	Number of Kanban cards at the manufacturing process
Ksr	Number of Kanban cards at the recycled supply
Kmf	Number of Kanban cards at the remanufactured supply

MP	Number of dynamically allocated cards, according to formula
DE	Parameter for the distributed demand starvation avoidance and production speed decrease during low customer demand

ABSTRACT

The objective of this thesis is to establish a Closed-Loop Supply Chain (CLSC) design that is analysed through a series of simulation models, aimed at defining the highest performing production control strategy, whilst considering multiple related variables on both the forward and reverse flow of materials in manufacturing environments. Due to its stochastic nature, the reverse logistics side of the CLSC represents an increased source of variance for the inventory management and control strategies as it implies the erratic supply of returned materials, in addition to the very random customer demand, hence with highly variable inputs on both sides of the productive system, intrinsically inherent to this line of research.

To test the operational performance of several pull-type production control strategies, a simulation-based research method was designed. The strategies experimented were: Hybrid Extended Kanban CONWIP special case (HEKC-II), Hybrid Kanban CONWIP (HKC), Dynamic Allocation Hybrid Extended Kanban CONWIP special case (DNC HEKC-II) and Dynamic Allocation Hybrid Kanban CONWIP (DNC HKC). All were tested in scenarios with high and low processing time variability and with 90% returned products and 40% returns from an open market system, therefore totaling 16 simulation models. Multi-objective evolutionary algorithms were utilised to generate the Pareto-optimum performance frontier with the objective of simultaneously minimising both performance metrics: The overall average work in progress (WIP) and the average backlog queue length (BL) for the entire CLSC. Processes used in the recovery and recycling of end of life manufactured goods were examined. This research method structures leading factors towards improved economic viability and sustainability of technologies required for the effective implementation of inventory control strategies on highly complex closed-loop supply chains with the focus on the performance metrics and optimum utilisation of resources available for the industry.

The dynamic allocation strategies proved significant performance improvement, shifting the entire Pareto frontier forward with major advances on both metrics. Furthermore, it happened on all scenarios tested. The modified HEKC-II, with an optimisable parameter that enables it to be overwritten in a way that it can match the well-established HKC, also performed as originally intended and had better results than HKC in some cases, especially with the higher variability level. It also provided grounds for the suggested improvements and flexibilisation of the HEKC strategy.

A major contribution of this thesis was the successful implementation of another advanced control methodology, entitled here the Intelligent Self-Designing Production Control Strategy, which provided maximum control performance. It consisted essentially of DNC HEKC-II with the following modifications: I) Extensive increase of dynamically allocated authorisation cards; II) Further anticipation of the time to trigger the change in the number of cards according to the finished goods buffer level, plus an acceleration/deceleration factor of this change; III) The capability of downsizing itself to become similar to HKC in an optimisation process if diverse production system conditions and variability would require. It displayed a very significant shift of the performance frontier.

CHAPTER 1. INTRODUCTION

The development of advanced hybrid production control strategies in addition to improved engineering design can lead to significantly greater production performance levels, that enable the efficient and highly pursued technical and economic feasibility of Closed-Loop Supply Chain (CLSC) operations allowing it to be the optimum industry standard.

Reverse supply chain refers to the logistics of finished products from the consumer market back to a merchant. This is the opposite process of the traditional supply chain forward direction of goods from manufacturers to the customer. The reverse supply chain theory entails that the product life-cycle does not end with the delivery to customers, nonetheless continues with a new use at the end-of-use or end-of-life, which may be reprocessed by manufacturers for reuse, recycle, repair or disposal. Some of the examples of the reverse supply chain include product returns and management of their electric and electronic waste deposition; remanufacturing and refurbishing activities; management of warrant returns and production surplus, as well as returned machineries from leasing contracts. Other examples of product reversing direction in the supply chain are product recalls, manufacturing returns, commercial returns, end-of-use returns, and end-of-life returns. Two of the factors that affect the justification of setting up aftermarket reproduction runs are the flow rate and the composition of reusable returned materials [1, 2]. These factors are stochastic functions of production rate and reliability of individual subassemblies.

CLSC presents technical challenges; although it has already achieved improved viability when the production system and the products themselves are engineered with lifecycle conscious projects. The industrial shredding systems are among the most suitable treatment for end-of-life goods. It has been implemented on a large scale by major global automakers such as Toyota and Volkswagen. This standardised process can meet demanding regulations with recovery rates of up to 95% of the materials processed.

1.1. RESEARCH OBJECTIVES, DELIMITATION AND GENERALISATIONS

Four production control strategies are tested: HKC - Hybrid Kanban CONWIP (Constant Work-In-Process), which is the control group for its high performance in similar scenarios according to Bonvik et al. [3], Hybrid Extended Kanban CONWIP special case (HEKC-II) modified from Dallery and Liberopoulos [4], Dynamic Allocation Hybrid Extended Kanban CONWIP special case (DNC HEKC-II) and Dynamic Allocation Hybrid Kanban CONWIP (DNC HKC), in scenarios with high and low processing time variability and with different rates of returned products.

A novel mechanism was created to test if the distributed demand information in a modified HEKC strategy can benefit or not the production control efficiency, Furthermore, it is analysed the experimental results to define if the innovative logic of the dynamically allocated authorisation cards with the quantification of the optimum increase can lead to production control performance improvement.

This research program targets the development of production control strategies for manufacturers that are considering incorporating re-conditioned or recycled products into their raw material inputs. It is operationalised through the modeling and analysis of probabilistic systems to establish a standardised methodology that can define the economic impact of production control strategies for reverse supply chain management and related industrial engineering optimisation projects on the financial performance and influence on the future value of companies over the long-term.

Multiple inherent factors that lead to higher performance in the industrial and service sectors are analysed, simulated and quantified, such as reduced energy consumption throughout the entire product lifecycle, optimisation of the product engineering, decreased demand for raw material and reduced energy demand for production, hence lower emissions, and associated environmental externalities. The long-term economic advantage of the implementation of reverse logistics not only makes a corporation more competitive in a global marketplace but also enhances the positioning on the carbon trade scenario. This is a clear indicator of the macroeconomic incentive for more intelligent manufacturing principles and methods and for cleaner technologies moving towards better efficiencies, improved social responsibility and better cooperation among various stakeholders.

Thus, this project models and analyses multiple factors intrinsic to the supply chain and inter-correlated-in-production processes, such as but not limited to lean manufacturing practices, logistics, study of simulated models, clean and renewable energy implementation, efficiency monitoring, reliability and process re-engineering advancements. Today's overly leveraged companies would not usually rely merely on the rate of return on investment, or on their payback period for their decisioning on technology projects, so this research also analyses a broader spectrum of engineering economics. The acquisition, analysis, and preparation of data for both the model input and visualisation of the model output prove to be very significant obstacles that impacted on the time and expertise required to ensure that simulation-based decision support can provide meaningful, effective and timely results. Accordingly, this research project also investigates and develops tools and methodologies to automate this modeling functionality.

The production control strategy optimisations are performed by an evolutionary algorithm with exhaustively long simulations, throughout trillions of scenarios, hence effective search algorithm and high specification computing resources are required to run the multi-objective optimisation process on multiple cloud servers, as it can be extremely time-consuming. The thesis itself is based on these experimental results.

It is specified in detail within the research methodology chapter all assumptions and limitations of the production processes under investigation. It is a three-stage production line with three processes on the reverse side, returning materials into suppliers, manufacturing and distribution channels. Therefore, generalisations of the findings and contributions of this research work can be extended to all production lines where there is an unbalanced and not unlimited supply of materials, the stochastic customer orders demand and the variable production processing times, consequently similar to the production systems definitions considered in this CLSC study.

1.2. THESIS STRUCTURE

This thesis is structured into eight chapters. Given the introductory research scope, Chapter 2 presents a comprehensive state-of-the-art literature review on production control strategies and its applicability to CLSC. Chapter 3 describes preliminary research outcomes with a shared and dedicated CONWIP comparison. Chapter 4 details the research methodologies and Chapter 5 presents the experimental results of each strategy. Chapter 6 displays the analysis of the data and the robustness tests. Finally, Chapter 7 presents the high performance proposed Intelligent Self-Designing production control strategy while Chapter 8 describes the conclusions, suggestions for future research and further developments.

CHAPTER 2. LITERATURE REVIEW

One of the leading management objectives in manufacturing systems and supply chain is to perfectly balance the trade-off between minimising the overall inventory while keeping a low backlog of customer orders and high service levels. The decision of an optimum control mechanism is of utmost importance for maximum performance. Difficulties in the control mechanism are usually derived from demand and process variabilities, unconformities and the extensive complexity of many productive systems. In order to be implementable, some level of system simplifications and industrial case studies need to be executed. The Japanese Just in Time approach (JIT) led the investigation and the development of effective pull-type control strategies that focus on facilitating a quick response to demand rather than concentrating on timely decision actions on the supply side of the productive chain [5-7].

Pull system mechanisms authorise parts/items into a processing system in response to the arrival of actual demand by communicating via authorisation cards, while the push-type control strategies work with the scheduled release of raw material into production. Several performance analyses of push-type control over pull-type strategies have been investigated [5, 8], considering advantages and disadvantages of each strategy in decreasing demand backlogs and the overall inventory. The performance improvement of combining the best traits of multiple strategies can intuitively lead to the yielding of superior results for implementing hybrid control strategies.

A majority of research publications have focused on individual control strategies, although there are a few comprehensive comparison papers with a framework of pull-type strategies[9]. Recently, the advancement of communication and logistics technologies has enabled a greater proliferation of new products, usually with a shorter life. It led to regulatory implications for manufacturers to reuse and recycle materials, implying an improved design of control strategies for closed-loop supply chains. This also causes a very significant increase in the variability, not only of the demand side of the equation but also on the supply side with the material handling on the reverse logistics being transferred back to the production processes. Hence, control parameters should be easily adjustable in response to continuous changes in levels of supply and demand of a given system. Nevertheless, only a few publications concentrate on the dynamic allocation of authorisation cards and the continuous adjustment of control strategies' parameters [9, 10].

In this thesis, a new class of hybrid systems with dynamic changes of the number of authorisation cards is developed and experimented with the objective of improving the control mechanism at decreasing inventory while improving customer service level and minimising orders backlog.

2.1. PRODUCTION CONTROL STRATEGIES

2.1.1. Kanban Control Strategy (KB)

There are several strategies that apply pull mechanisms and one of the pioneers was the Kanban Control Strategy, originally used in Toyota production plants in the mid-seventies. It is frequently considered a good representation of the Just-In-Time philosophy [9, 11]. Kanbans are production authorisation cards that are used to limit or control the number of parts in a workstation and its respective buffer. The number of Kanbans sets the limit of parts within a given stage. When compared to another type of pull implementation strategy, the CONWIP i.e., it is noticeable that Kanban has a drawback, while the demand information is communicated upstream the production line, the time adjustment is not reasonably fast because the information must go stage by stage toward the supply side [8]. Nevertheless, the kanban allows for a perfect synchronisation between two directly related workstations. The kanban card itself does not have to be physical, it can be electronic as well [12, 13].

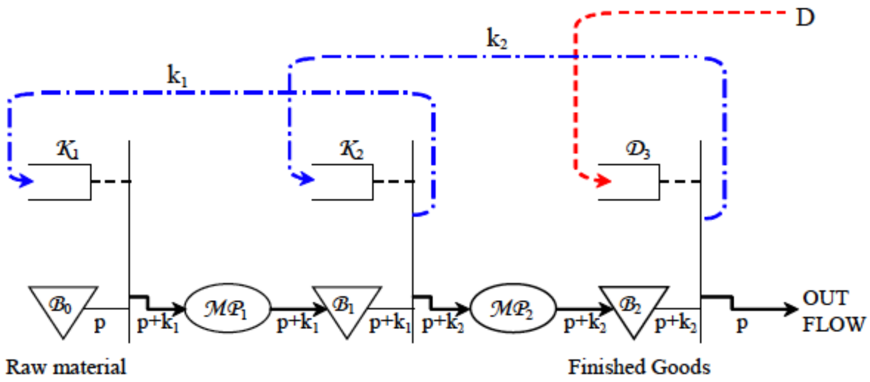

Figure 2-1. Kanban controlled two-stages production line. [9]

Kanban production control systems are the most well-known pull-type strategy for multi-stage lines. They set a maximum limit of inventory for each workstation including the output buffer. This maximum number of parts is equal to the pre-set number of kanbans [9, 14]. Figure 2-1 displays the queuing model for a single product Kanban Control Strategy with two workstations. *MP's* represent the manufacturing process and *B's* are output buffers, so forming a workstation. *K's* queue are kanban pools. The p+k represents a part in process with a kanban card attached to it.

The authorisation cards follow as indicated by dotted lines, while materials are released from buffers to the next workstations. When customer demand D arrives, it can be matched with finished goods in the final buffer if any are available, or be stored as a backlogged order until a product becomes available. When the demand is satisfied the kanban card is released upstream allowing the demand signal to flow, thereby enabling the authorisation card to control the inventory. The customer demand is communicated upstream workstation by workstation via the kanban card. The kanban control policy is controlled by a single parameter - the number of kanbans, which influence the transfer of material downstream and the demand information upstream through the production line. KB is in many cases suitable for production systems with low variability, low setup times and high reliability [15, 16].

2.1.2. CONWIP Control Strategy (CW)

Constant Work-In-Progress (CONWIP) proposed by Spearman *et al.* [9, 17] is designed with just a single card that limits the total amount of WIP within the production line. It was developed to maintain pull-type control advantages and to perform well in a number of manufacturing scenarios, in which KB (Kanban control strategy) was not entirely suitable. Implementation is straightforward, but in practice it can be defined as a pull control at the end of a production system and a push control at the beginning towards the end, therefore inheriting some of the issues present in push-type systems.

CONWIP controlled lines have a set upper limit of WIP for the entire system. New jobs are released into production by CONWIP cards (*C*), if available. When the production is matched with demand, the authorisation card is released allowing more parts to move forward in response to the demand. It is similar to a single kanban cell controlling all workstations together. Figure 2-2 displays the queuing model for a single product CONWIP control strategy with two workstations in tandem, although the intermediate workstation does not play any control function on the strategy.

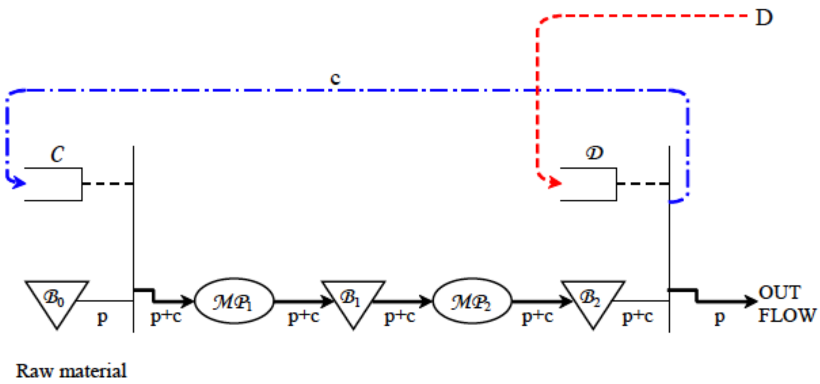

Figure 2-2. CONWIP controlled two-stages production line. [9]

B represents buffers, *D* signifies demand, *MP* the manufacturing stages and *C* is for the CONWIP cards. When demand arrives, it is met with a finished good part at the final buffer if available; if not, the demand is backlogged and is queued for the next production. If the demand is satisfied, the CONWIP card is released to the CONWIP pool to authorise the supply to workstation 1. CONWIP has a rather simple implementation as it depends on just one control parameter for the entire system. The maximum production rate depends on the number of CONWIP cards. When a finished part is sent to the customer, a card is detached from the product and released to the first stage to authorise another part into the system [7, 9, 18].

2.1.3. Base Stock Control Strategy (BS)

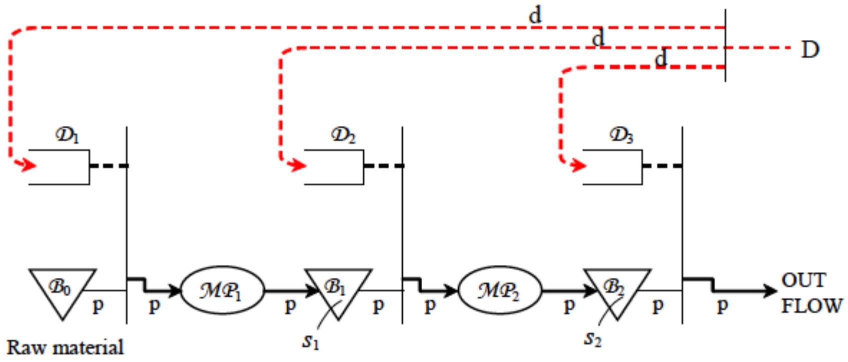

Figure 2-3. Base Stock controlled two-stages production line. [9]

Base Stock is a pull control strategy that adopts the concept of safety buffers between workstations for finished goods. Each stage has an initial predefined level of inventory; when a product demand arrives it is transmitted immediately to every workstation and it authorises the production of a new part [7, 19]. It improves the demand communication process which moves fast and seamlessly through the entire production line, however, it does not provide a limit to inventory. BS is a pull-type control mechanism that intends to keep a minimum level of inventory at each buffer. As it is self-explanatory by its name, demand information is immediately transferred to all stages simultaneously. Figure 2-3 displays the queuing model for a single product Base Stock control discipline in a two-workstation process. There is no control over two consecutive stages and parts will be transferred downstream as a result of demand and processing time. Base Stock control depends on only one parameter per stage, the base stock number (s1, s2), as it influences the release of parts downstream but does not have any effect on the upstream communication of demand information. BS has the advantage of immediately responding to demand, but it is often criticised for not providing the system with a tighter control of inventory between stages, hence allowing for excessive WIP [7, 9, 14].

2.1.4. Hybrid Kanban CONWIP Control Strategy (HKC)

Hybrid Kanban CONWIP, proposed by Bonvik et al. [3], describes how the CONWIP cards control the overall inventory and kanban cards control the local workstation level number of work-in-process. CONWIP cards also perform the demand communication function.

The Hybrid Kanban CONWIP Control Strategy (HKC) communicates the demand information directly from the finished goods buffer to the first stage of production via CONWIP cards. There is also the local workstation level inventory control via the number of kanban cards, as described in the queuing model of a single-product line with three stages controlled by the Hybrid Kanban CONWIP strategy as shown in Figure 2-4, some of the symbols and nomenclature provided in the figure differs from the previously mentioned strategies the original source as published [3, 20]. DA's are kanban pools and PA's are parts in process attached with a kanban card. When customer demand arrives and there are available finished goods in the final buffer, it is matched and shipped to the customer. The attached CONWIP card is released upstream to authorise production; otherwise, if there are no parts in the finished goods buffer, demand is backlogged and placed in a queue for the next available part. At the first workstation, it is required that both kanban and CONWIP cards are available, then production can be authorised and raw materials are released into processing. Therefore, the Hybrid Kanban CONWIP relies on one parameter per stage, the number of kanbans, and one additional parameter for the entire system, which is the number of CONWIP cards [9, 21, 22].

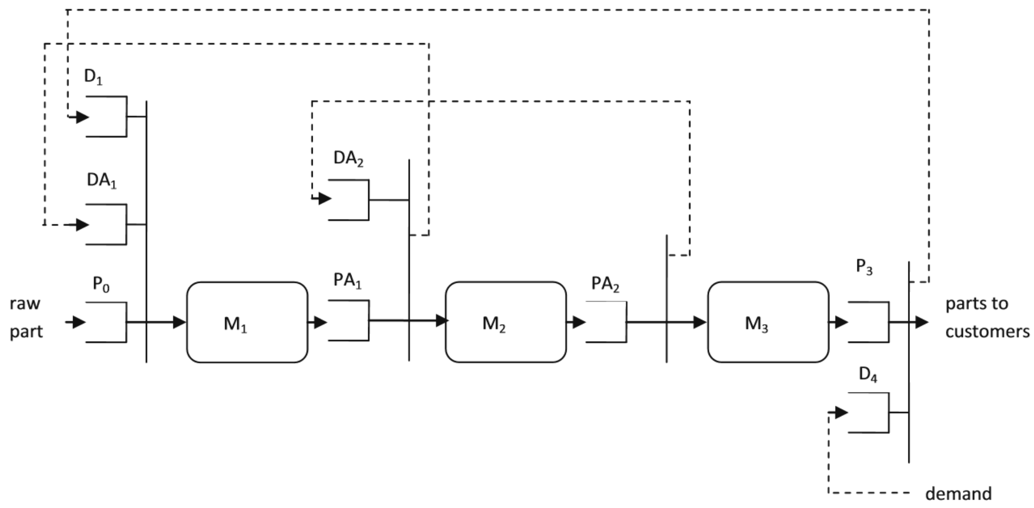

Figure 2-4. Hybrid Kanban CONWIP controlled production line [3, 20]

2.1.5. Generalised Kanban Control Strategy (GK)

Generalised Kanban Control Strategy, proposed by Buzacott [14], is a hybrid mechanism which combines base stock and kanban strategies. It is more complex but more sensitive to variabilities inherent to the system and the demand information flow is relayed upstream rather than directly transferred to the production process. The inventory is controlled by two parameters, the amount of base stocks and the number of kanbans [23].

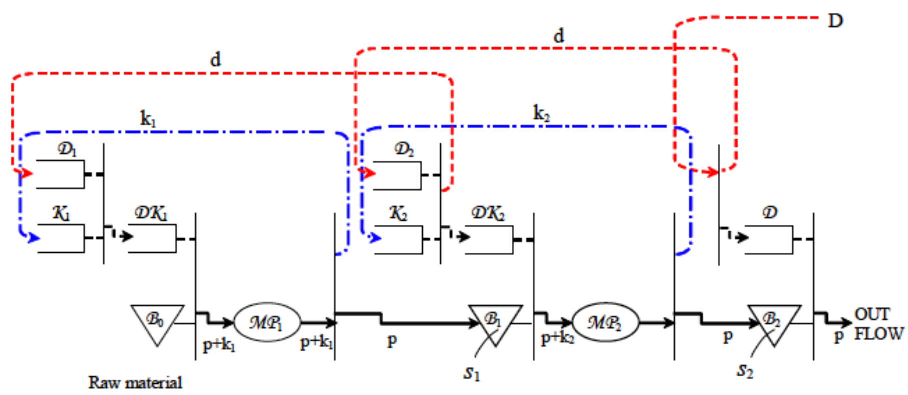

Figure 2-5. Generalized Kanban controlled two-stages production line [9]

The generalised kanban control system is a modification of the standard Kanban control policy. The demand information now is stored in two queues. *D's* only contain demands and *DK's* contain kanbans that had been trigged by demand information, as displayed on Figure 2-5, the queuing model for Generalised Kanban. Differently, from the Kanban Strategy, Generalised Kanban Control Strategy (GK) is ruled by two parameters per workstation, which are the number of kanbans and the number of base stock levels (s1 and s2) for each workstation. Customer demand information in GK works as follows: when it arrives, it is split into two demands, the first will go to the *D* queue and will request the delivery of a finished good as usual. The second one will go to the *D2* queue for the authorisation of production at Workstation 2, then it travels upstream when parts become available (in *B1*) so the production flow is authorised to go into the next manufacturing process *MP*. The demand moves upstream through the production process independent of the release of materials downstream, in Kanban systems the demand always moves attached to authorisations cards. So, this implies more decoupling in the return of demands and kanbans. Another difference of GK is that the kanban is detached as soon as the product leaves the manufacturing process, instead of being released after the buffer, so it happens earlier than in kanban strategy [7, 9, 19, 23].

2.1.6. Extended Kanban Control Strategy (EKB)

Extended Kanban proposed by Dallery and Liberopoulos [4], is also a combination of the Kanban and Base Stock strategies. It is less complex regarding its implementation as the demand is directly communicated to upstream workstations and the functions of both, the Kanban and Base Stock Control Strategies, are entirely independent. However, one flexible limitation is that the number of kanbans must be at least as large as the base stock level. [7, 14]

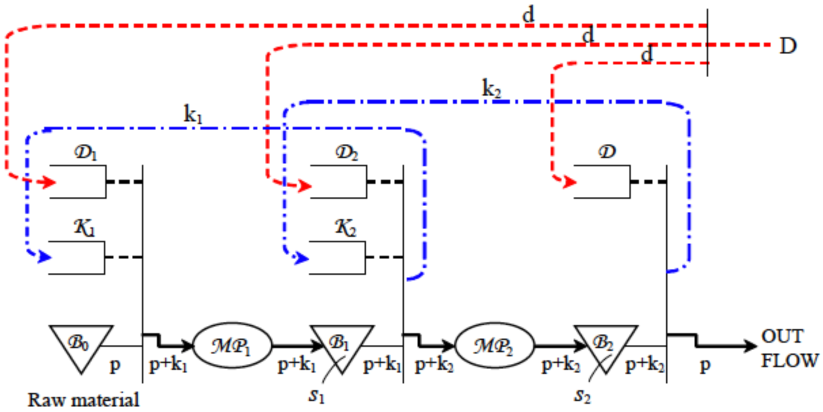

Figure 2-6. Extended Kanban controlled two-stages production. [9]

Extended Kanban Control Strategy (EKB) is a modification of Kanban Control Strategy, but it is also somewhat similar to the previously mentioned Generalised Kanban Control Strategy. The difference is that the demand information is communicated to all stages in order to authorise production, instead of being relayed through individual stages. As in Generalised Kanban Control, the Extended Kanban Control Strategy is ruled by two parameters per stage, the number of kanbans and the base stock level. The main differences between Extended Kanban Control Strategy and Generalised Kanban Control Strategy are: In Extended Kanban Control Strategy, parts always move with kanbans, while in Generalised Kanban Control Strategy, finished parts are already detached from them. In Extended Kanban Control, kanbans do not participate in the demand information flow upstream. In EKB, the number of kanbans must be higher than the number of base stock, while with Generalised Kanban Control Strategy, there are no such constraints. The differences between EKB and the Kanban Control Strategy are: In EKB the demand is immediately broadcasted to all workstations and kanbans move upstream independently from the demand information, thus the only function of the kanbans here is to authorise the downstream flow of finished parts. In EKB, there are two parameters per stage while in Kanban Control Strategy, there is only one. [7, 9, 14, 19]

2.1.7. Adaptive Kanban Control Strategy (AKB)

This adaptive pull system [24] dynamically readjusts the number of available Kanban cards in operation depending on the number of current work in progress, customer demands and backlog levels. Similar to the Kanban system it still remains rather easy to be implemented with few control parameters.

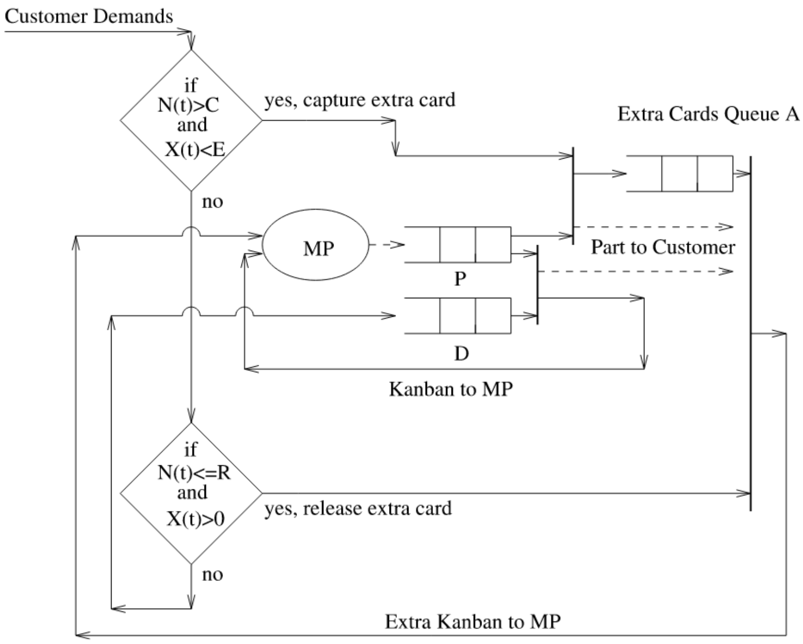

Figure 2-7. Adaptive Kanban controlled production line. [24]

Where queue P holds finished parts, MP represents the manufacturing process, and queue D is the back ordered demand. This single-stage adaptive mechanism example uses K (kanban cards) and E (extra cards) that are contained in queue A. On the given formula, N(t) is the total number of parts in queue P minus the total number of backorders in queue D at time t; X(t) is the number of extra cards not in use at time t; R is the release threshold for adding an extra card and C is the capture threshold for retrieving an extra card from the system. It was shown that in processes with random exponential processing times and demand arrival according to the Poisson process, this strategy can outperform the traditional kanban mechanism [24-26] due to the fact that the changeable level of inventory limit allows for lower WIP average, as it only allows an increase in number of kanbans during pick times.

2.1.8. Adaptive Extended Kanban and Adaptive Generic Kanban Control Strategies (AGRK and AEK)

Recently proposed strategy [27] the Adaptive Generic Kanban system logic is grounded on the decision of releasing free authorisation cards and retrieving them based on a service level management standard. The card release and capture are triggered by demand arrivals. Decisions on releasing and capturing cards are guided by the estimated service level, Se, and a targeted service level, St. The service level is defined by the number of demands satisfied on-time divided by the overall demands that arrived at the system.

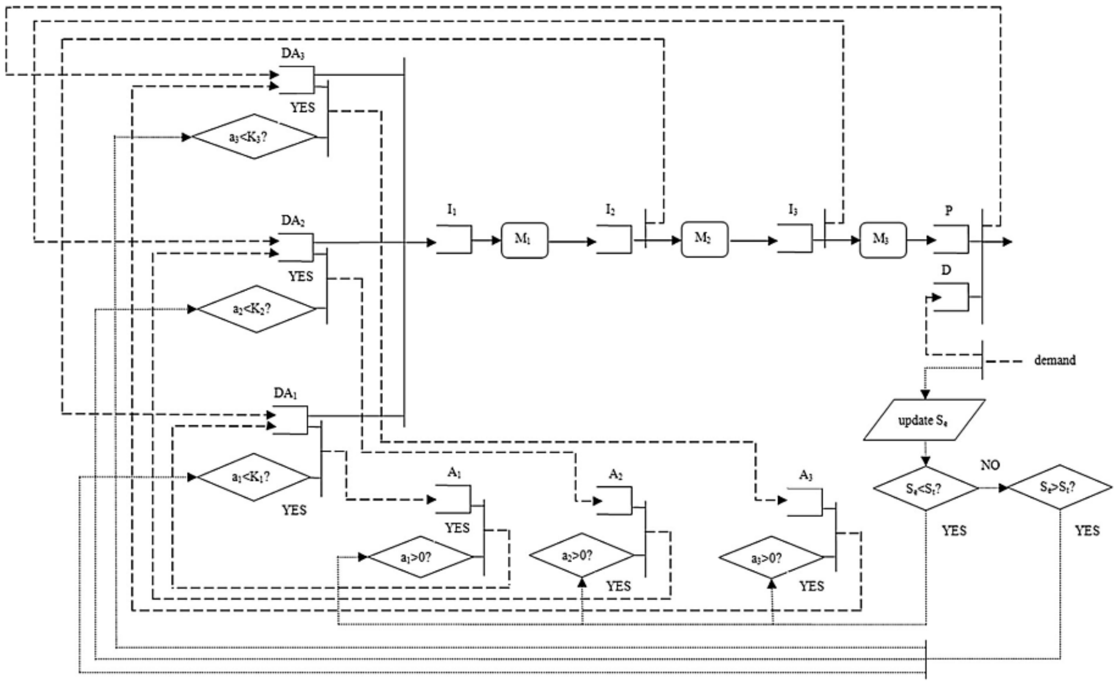

Figure 2-8. Adaptive Generic Kanban controlled production line (AGRK) [27]

At the demand arrival, the current service level estimate, Se, is compared to the service level target, St, where St is a constant parameter and if Se < St and a > 0, where, a, is the current number of free cards, then one card is released to DA. Otherwise, if Se > St and the current number of free cards, a, is less than the initial number K in queue A, then one card is captured back to the correspondent A queue. Cards might not be available in queue DA when a trigger action is authorised because all cards might be in use. If so, then a card is sent back to A, as soon as it enters queue DA. The Adaptive Generic Kanban Strategy is a development of the approach provided by Faminan et al. [28] in two ways: An exponential moving average is used for the service level estimate in order to respond quickly to demand changes. Since this system is based on the Generic Kanban by Chang [29], which provides a timely co-ordination between the production workstations and when compared to CONWIP, it is possible to keep WIP low and reduce the bottleneck effects. [27-29]

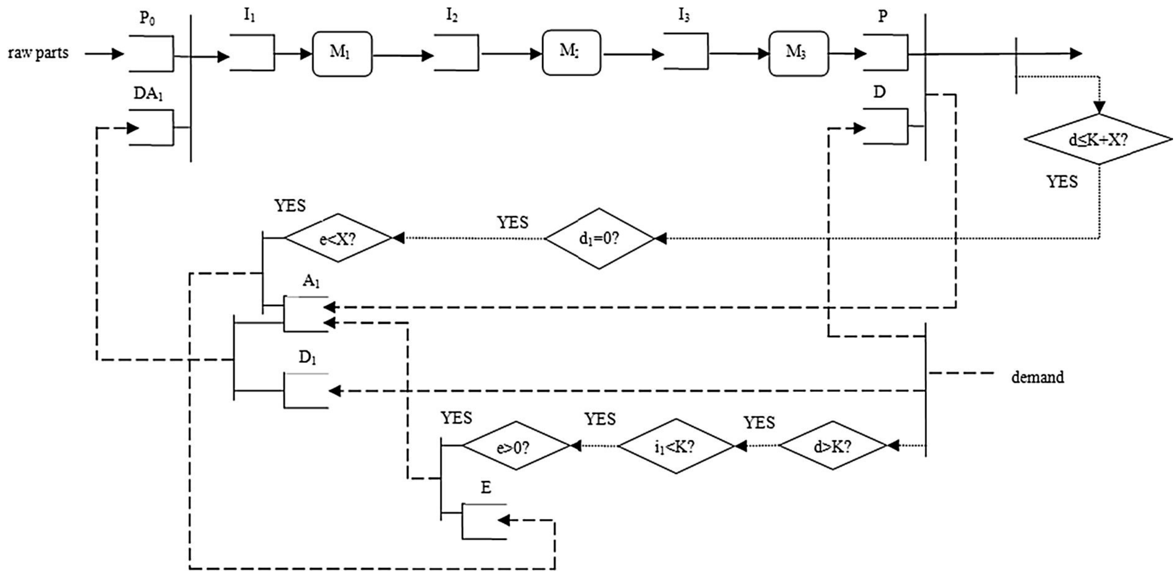

Figure 2-9. Adaptive Extended Kanban controlled production line [27]

The release of authorisation cards in Adaptive Extended Kanban Strategy happens in two phases. Demands are satisfied immediately if there is a part in the finished goods buffer, P, otherwise it is back ordered into queue D. K free cards are in queue A1 and X free cards are in queue E. The demand arrival process is immediately transmitted to queue D1. If there is a card in queue A1, then one card is sent to queue DA1 to authorise the production of a stage-1 part. As long as the number of backorders in D is less than the initial number of extra cards K in queue A1, then a free card is released from queue A1 at the occurrence of a demand arrival and under the condition that the finished goods buffer P is empty while there are free cards in queue A1. Cards that were released from queue A1 are captured back when the last stage produces a part and there is at least one back ordered demand in queue D and there is no demand in queue D1. In the second phase of this dynamic allocation, free cards are released from queue E by the demand arrival. If at that time the current number of backorders in queue D is greater than K, the current number of parts i in input queue I is less than K, and the number of free cards e in queue E is greater than 0, then one card is sent from queue E to queue A1. As the demand was instantaneously sent to queue D1, one production authorisation is sent to queue DA1. The departure of finished goods from buffer P triggers the capture of a card that was previously released from queue E. If the number of backorders d is less than or equal to K + X, there are no demands in queue D1, and the number of cards e in queue E is less than X, then the detached card from finished goods moved to queue A1, is sent back to queue E, ensuring that extra cards can be available and out of circulation. AEK is more advisable for production systems where the customer demand arrives in cyclical intervals and environments with seasonal demand with a relatively high average between arrivals [27, 29-31].

2.1.9. Dynamic CONWIP Control Strategy

The Dynamic CONWIP Control Strategy is based on monitoring a target metric. For make-to-order environments, when a job exits the system, the throughput is computed. For make-to-stock environments, every time a demand arrives, the service level is recorded. This strategy uses several extra cards that will be dynamically allocated to the system. The adding or subtracting cards of the system is based on the number of currently available extra cards and the system's throughput. If making to stock is the case, then the arrival of a demand will release or capture extra cards depending on the number of currently available extra cards and the customer service level [27, 32, 33], the logic is demonstrated in the Figure 2-10.

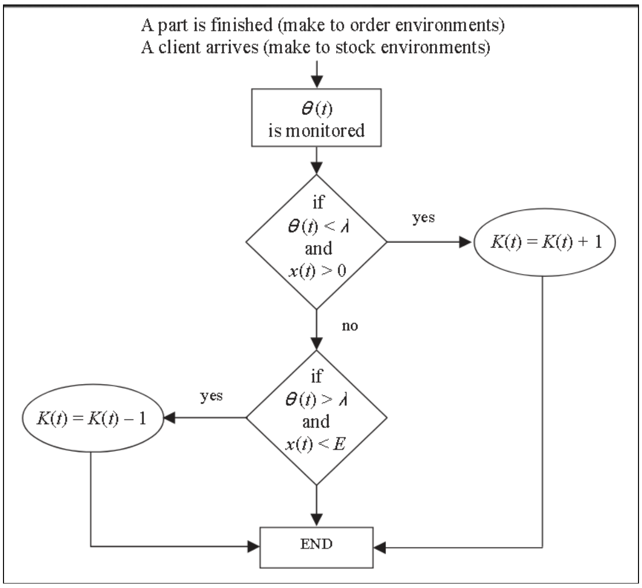

Figure 2-10. Dynamic CONWIP controlled decision process [32]

The variables are described as follows:

$x(t)$, number of not used extra cards at time t,

E, number of initial extra cards,

$K(t)$, number of cards operating in the system at time t,

$\theta(t)$, throughput (service level) of the system at time t,

λ, target throughput rate (service level). [32]

2.1.10. Flexible Control Strategy (FKS)

Flexible Kanban Control Strategies are described in the literature as being comparable to KB with the addition of a dynamic review of the number of authorisation cards in response to the production state of supply and demand. Experimental results have shown improvements in inventory level management and a decreased backlog of consumer orders [10, 34, 35]. However, another research paper states that the adjustment of the number of authorisation cards is not sufficient to effectively respond to the system's variabilities and that the monitoring of inventory level as an indicator of when to increase or decrease the number of cards available, might not be a precise measure to define when a production system is undergoing some instabilities [36]. Furthermore, it points to operational and strategic changes to the productive system as a measure to offset those instabilities. Nevertheless, the constant evaluation and optimisation of a dynamic control strategy not only presents a significant level of complexity for production engineering, but it is also expensive and time-consuming for some fast-paced lean environments. Thus, it can be more ideal for some system engineers to prudently select the best performing features of individual strategies into an implementable hybrid strategy, rather than optimising parameters with extensive variabilities inherent to productive system operations [10, 34, 35, 37]. Flexible approaches can combine many different traits of several strategies to form a new information structure and authorisation cards communication philosophies [9, 21, 22, 38].

It was proposed that a generic model of several pull-type strategies be optimised by an evolutionary algorithm assuming that the best traits of each of the single strategy would be inherited by the optimised solution, creating maximum output with minimum inventory held [9, 39]. The results show that a simplified hybrid system for a single product manufacturing line had the best performance, mainly due to the application of the CONWIP integral control and Kanban local control methods to further improve localised variabilities in long lines. Another study discovered that flexible kanban systems had superior performance levels when compared to traditional JIT strategies. In four cases under analysis, although they had slightly higher WIP when processing time was low [40-42], extra kanbans were added when required for starvation avoidance and withdrawn afterwards in order to respond accordingly only to peaks in performance and inventory.

2.1.11. Dynamic Card Control Strategy Based on Centralised Kanban and CONWIP Control Strategy

This dynamic control is time-driven, it allows for more than one extra cards to be released or captured in a decision-making approach. It allows the number of cards in use, for a given time period, to be decreased in relation to the initial number of cards. It is described according to the diagram in Figure 2-11. This method relies on two moving averages that deals with statistics of the time series of demand arrivals, it is applied to a CONWIP system and Kanban systems, where the changes in the number of cards in each stage happens in a centralized and decentralized fashion, respectively. The policies can be computationally demanding because of the number of parameters to be optimised. [43-46]

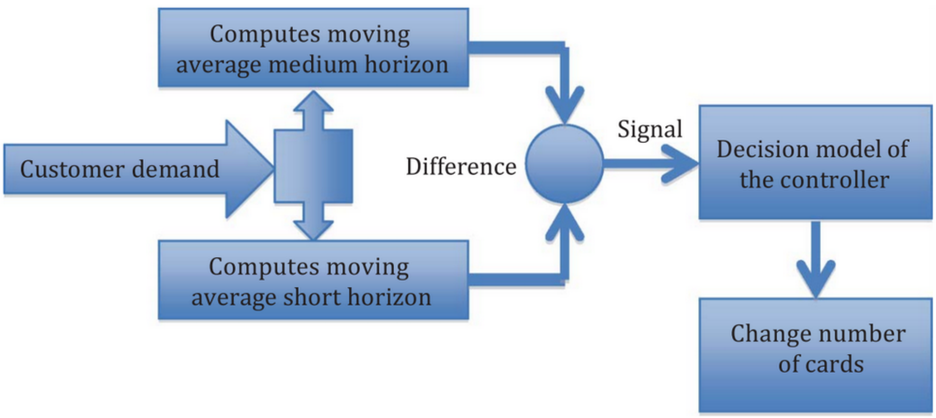

Figure 2-11. Dynamic Card Control Strategy based on Centralised Kanban and CONWIP decision process [43]

2.1.12. Summary and Positioning of this Research

The previous sections, 2.1 to 2.11, provided the fundamental understanding of the current state of the art of the research on pull-type production control strategies. The literature reveals that

Hybrid Kanban CONWIP, proposed by Bonvik et al. [3], provides notoriously superior performance in minimising the number work in process while reducing the backlog of customer demands. It occurs even with the presence of unbalanced demand rate and it is due to the simultaneous limitation of the local and global inventory level in the production system, hence providing optimum control performance. Such findings have been confirmed and validated in several comparative studies such as Wang et al. [47] where Hybrid strategies enabled higher performance in relation to single strategy mechanisms.

The Extended Kanban strategy designed by Dallery and Liberopoulos [4] can also be considered a hybrid of the Kanban and Base Stock strategies [19], it enables better demand communication to workstations upstream the production line. Boonlertvanich [9] implemented a Hybrid Extended Kanban CONWIP mechanism to forward production process and found performance gains in relation to single control mechanisms, however it was applied to a rather limited research space.

Adaptive production control strategies [27, 30-32] provide the advantage of having the amount inventory limit, which is operationalised by the number of authorisation cards, changed according to signals of instabilities in the production system. Having such flexibility tends to allow for better control when the change is performed at an accurate amount and at the right time considering the particularities of a given production line. [27, 32]

This research postulates and implements a novel Hybrid Extended Kanban CONWIP strategy with the dynamic allocation of authorization cards and a modification to the Extended Kanban without the use of a base stock parameter [19]. This modification is applied in order to simultaneously cope with very stochastic supply and demand, a characteristic inherent to the Closed-loop supply chain. The proposed improvements to the established theory on production control strategies are experimented through multi-objective optimisation and in comparison with the optimum Hybrid Kanban CONWIP, as designed by Bonvik et al. [3], which is the control group for all scenarios under analysis.

2.2. SIMULATION MODELLING AND OPTIMISATION OF MANUFACTURING SYSTEMS

Discrete event simulation approaches have been broadly recommended as an efficient way of evaluating complex supply chain networks and extensive variable factors influencing manufacturing production. This is due to its analytical ability to deal with large amounts of data and multiple possible scenarios for improvement without the need for large investments and the allocation of expensive materials for the execution of tests [48].

2.2.1. Multi-objective Evolutionary Algorithm

The production control strategy optimisation is performed through a design of rules presiding over the authorisation of production and the accurate management of parameters. These parameters are controlled with the objective of minimising costs, inventories and time consumption, while also improving performance metrics [49]. However, the number of combinations of multiple parameters in extensive production lines or compound systems can make the research space for the performance analysis significantly large. Hence, high-efficiency heuristics are a must when providing support for good decision making for optimum control strategies [34, 49-51].

Multi-objective optimisation problems with conflicting objectives infer that there is not one single optimum solution to a problem, so the decision-making process is achieved through the assessment of trade-offs among objectives, in order to arrive at optimum solutions at different levels of each parameter under analysis. The set of optimum solutions is known as the Pareto-Frontier. These sets of solutions are non-dominated or non-inferior, meaning that within the research space, no better solutions exist when the given set of objectives are taken into consideration [52-54].

Due to the practicality of such a multi-objective simulation-based optimisation approach, the simulation software, for example, Extendsim, has an in-built block that uses genetic algorithm, where parameters and objective functions can be specified to generate a Pareto optimum frontier to record the production system's performance. Genetic algorithms had their logic designed by replicating the mechanisms that have worked in the evolution through generations [55, 56]. They are operational through the crossover, mutation of populations and reproduction.

Populations are represented by the solution space of a simulated system under investigation. The reproduction operator selects the initial population of solutions and ranks them according to the best fitness. The best outcomes are combined to generate offsprings, which will go through some mutation and evaluation to assess their evolution in terms of performance and analyse if better individuals were generated [34, 57]. In the evolutionary algorithm context of optimising pull-type control strategies, an individual is seen as a given set of authorisation cards for the entire manufacturing system and the evolution has the objective of providing superior performance metrics.

Genetic Algorithms (GA) are search algorithms that are based on the Theory of Evolution as defined by Charles Darwin. The optimisation search begins with a set of random potential solutions chromosomes. GA evolves this initial population through generations towards a population that tends to retain the best traits through the survival of the fittest, most optimum solutions. Individuals from the current population are assessed and selected so that the fittest individuals have an increased chance of being selected for generating future generations. The reproduction process is comprised of selection, crossover, and mutation, accordingly, the selected individuals go through mutation and crossover recombination. The crossover mechanism allows for the mixing of parental information and passing it on to their offspring, while mutation introduces innovation into the population. Therefore, the population tends to develop into a better fit. [39, 51, 57-59]

The genetic algorithm used within the Extendsim simulation software to optimise the system's parameters and generate the Pareto optimal frontier was written and tested according to the work of Kernan and Geraghty [60]. Multi-objective Genetic Algorithms (MOGAs), have their search efficiency tied to the ability of the algorithm to quickly find similarities among solutions [51, 60]. The procedure for this MOGA code was designed according to the following logic:

1. Initialisation:
   An initial population is created with a random set of the parameters to be analysed, from a given research space
2. Dominance check:
   The results, multi-objective responses, are recorded to classify which individuals are non-dominated individuals, then a Boolean value is assigned

3. Adjustment:

   Individuals in the current population, which are dominated, are replaced by an offspring created from the two different non-dominated parents. These parents are randomly assigned from the current population with equal probability of being chosen. The chromosome that defines the offspring can suffer mutation, through a hybrid recombination referred to as Triad-Based Recombination (TRD). This exo-parental mutation has a probability set to it by the user. Then, the offspring's chromosome can take the value of either parents or a new mutated value

4. Dominance recheck:

   The performance results of the adjusted population are rechecked and classified to find the best traits and the non-dominated solutions

5. Increase population:

   If all individuals of the current populations are optimum, or non-dominated, five new offsprings are created

6. Repeat:

   The algorithm is repeated from step 2 and it can be terminated by the number of generations or the number of dead runs given by the user. The algorithm also ends if the entire decision space is searched. [51]

In its learning nature, Artificial Neural Network shares features with Reinforcement Learning [61], Ant Colony Optimisation [62, 63] and Evolutionary Algorithms, making the latter similarly suitable for simulation-based supply chain processes optimisation [39, 55, 64-66]. This simulation-based optimisation [67] experiments with multiple scenarios have the objective of researching, finding and improving the parameters to get the best fitting results, hence maximising the performance metrics of a simulated system. This performance is usually described as an objective function that will try to minimise or maximise metrics, such as simultaneously minimising the WIP and the backlog of demands BL [34-36, 68, 69].

The NSGA-II algorithm (Non-dominated Sorting Genetic Algorithm) was also tested for the optimisation processes involved in this research. It was designed according to the work of Deb et al. [70-73] and the optimisation results were similar to the ones achieved by the optimiser within Extendsim. Premature convergence of the data points on the Pareto frontier may become an issue as the size of the test increases. [74, 75]

2.2.2. Performance Metrics

Some of the common metrics for the evaluation of production control strategies are throughput rate, service level, cycle time, average wait time of backlogged demands, average number of backlogged demands and WIP [17, 34, 76]. Measures based on customer responsiveness, such as fill rate maximisation and customer response time minimisation, tend to be amongst the most desirable. An unfulfilled order on time is usually understood in industrial standards as a loss of market share, therefore a 99% service level can mean a 1% loss of the consumer market [51]. Other metrics recorded are cost related, such as profit maximisations, increased return on investments, overall assets productivity and cost minimisation. For this research work, the metrics adopted for the multi-objective optimisation processes were the average number of backlogged demands (BL) and the average number of WIP (work in process). Those averages are taken at the end of each run and replicated multiple times; then these results feed the evolutionary algorithm for the record and due calculations. They represent a direct trade-off between low inventory and the order fulfillment rate while being an operation management measure at the industrial floor, they are also intrinsically tied to the financial performance of productive systems as it keeps precisely optimised amounts of stock and maintains a speedy flow of materials [8, 77-80].

2.2.3. Warmup Period

To maintain high accuracy levels for simulation results it is important to remove any interference or bias due to the initial state of the simulated model. Three main approaches are used to eliminate or minimise to a maximum the imprecisions of the initial state, such as empty buffers, empty machines, inoperant bottlenecks or similar deviations from the normal system setting that may eventually alter the metrics recorded for analysis. These involve deleting the first set of data that is affected by the warm-up period, the second factor is to run the simulation long enough so averages are evened out and the third factor is to set the simulation in a steady state from the beginning [51, 81]. The Welch's graphical method is widely used for specifying the warm-up period of a simulation run, but it is recommended to assume more conservative estimates. Nevertheless, it is scientifically acceptable when compared to different procedures tested [34, 82, 83].

In addition to the warm-up data removal, two techniques can be applied to gather statistics from a simulation only process during a steady state. The first, called the deletion and replicate method, means to replicate a simulation run multiple times in order to get averages and improve the confidence of the statistics. The second is a batching method, that runs a very long single run divided into smaller subsets from which statistics averages are extracted [34, 73]. However, there is a trade-off between computational power requirements and the precision level needed. A sequential approach can be used to define it, measuring an acceptable confidence interval related to a given number of replications.

2.2.4. Summary

In this thesis, all simulations were designed and run in the ExtendSim simulation software and the multi-objective optimisations were performed using a working block coded within the software, it was developed by Kernan and Geraghty [60]. Using the genetic algorithm, it samples the entire research space and finds Pareto-optimum solutions with the best configurations for the production system and the strategy under investigation.

The search algorithm NSGA-II (Non-dominated Sorting Genetic Algorithm), according to Deb et al. [70-73] was coded in Python to be used in connection with the simulation software for the optimisation process, however it had some limitations in terms of the population size to be analysed through the evolutionary optimisation. The population would have to be set at very high number in order to get a reasonable number of data points on the pareto, additionally the comparison of generations was limited to only the previous generation. Therefore, the Kernan and Geraghty [60] was the optimiser chosen as the overall best Pareto optimum solutions were always recorded to be compared against the ongoing generation, so a higher number of solutions were provided, enabling better precision and details for the Pareto frontier.

Similar to a large amount of research on production control strategies literature [3, 20, 47, 84, 85], the performance metrics analysed in this research were the BL and WIP. BL stands for overall average number of backlogged customer demand throughout each simulation run, i.e. after 150.000 parts were produced. WIP represents the overall average of the number of work in process. So, both are conflicting objectives as one negatively correlates to the other. This trade-off between WIP and BL defines the optimum performance frontier of a system. The SL, service level, which represents the percentage of customer demand immediately satisfied with a ready product on the finished good buffer, was also analysed as it relates to the BL. It is detailed on the section 5.6.

2.3. DATA ANALYSIS AND TOOLS FOR DESIGN OF EXPERIMENTS

2.3.1. Robustness Test

The robustness of optimal solutions is also important in the design and implementation of productive systems. The stochastic dominance test provides a statistical means for determining how strong a production strategy or policy is in maintaining a given metric, such as the BL, while facing an external perturbation or stress, such as an increased system workload or inadequate authorisation cards settings [34, 86, 87].

It is advocated in some publications that the engineering of products for production, by means of the design of experiments, should aim at keeping performance metrics insensitive to any influence from production environmental changes [87, 88]. There is always a risk inherent in a chosen design, that system characteristics may change over time, uncertainties may increase or just change during the lifetime of an industrial system, therefore another design may be more desirable if it presents less risk and consequently superior robustness [77, 89].

The space filling design method is usually the preferred option in the design of experiments targeted with producing a training set of scenarios to be executed. It works by sampling an extensive input parameter space and filling it with a number of reasonably representative runs. The Latin Hypercube Sampling (LHS) process is the traditional space filling design method for experiments [54, 86, 90, 91].

The comparison of systems is based on the cumulative distribution function of one objective and the consequent stochastic dominance. It is used in decision theory and analysis, and with its selecting and ranking technique, it classifies all probability distributions in the examination and ranks them in order of superiority [54, 77].

Rendering from the results provided by the runs with LHS settings, the stochastic dominance test outcomes can be of first-order, second-order or inconclusive. Considering two cumulative density functions: $F_A(x)$ and $F_B(x)$, with the objective of maximising output. Option A will first-order stochastically dominate B if: $F_A(x) \leq F_B(x)$ for all x.

Then, this means, also as displayed in Figure 2-12, that the cumulative density function of A is to the right of option B.

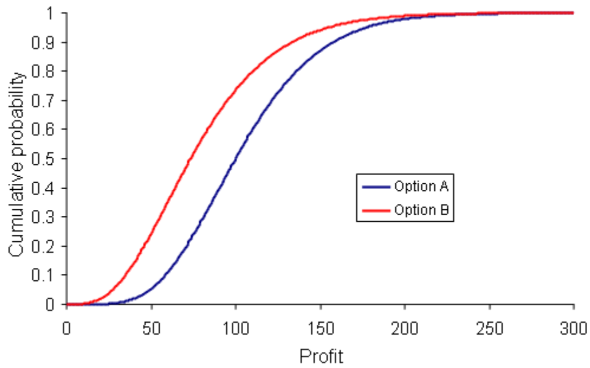

Figure 2-12. First-order stochastic dominance [92]

Option A is second-order stochastically dominant over option B if:

$$D(z) = \int_{min}^{z} \big(FB(x) - FA(x)\big)\, dx \ \geq 0 \quad for\ all\ z$$

z represents the number of functions or options to be considered or compared for the stochastic dominance.

Figure 2-13 displays the option A second-order stochastically dominant over option B, it happens because the area under FA is less than or equal to that under FB from min to all z. The function D(z) is always positive, otherwise it is the decision is inconclusive.

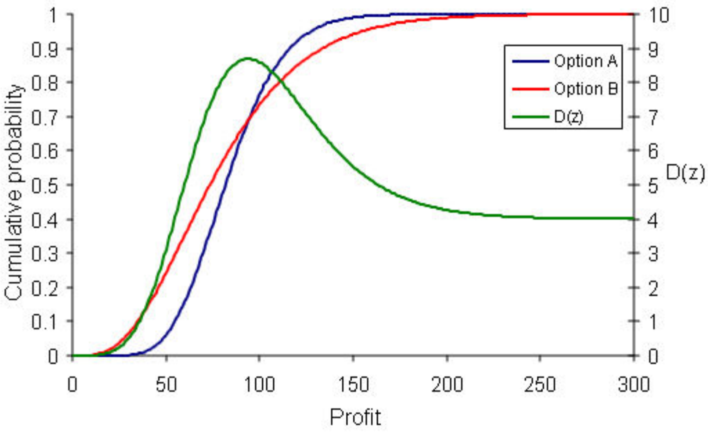

Figure 2-13. Second-order stochastic dominance: Option A second-order stochastically dominates option B [92]

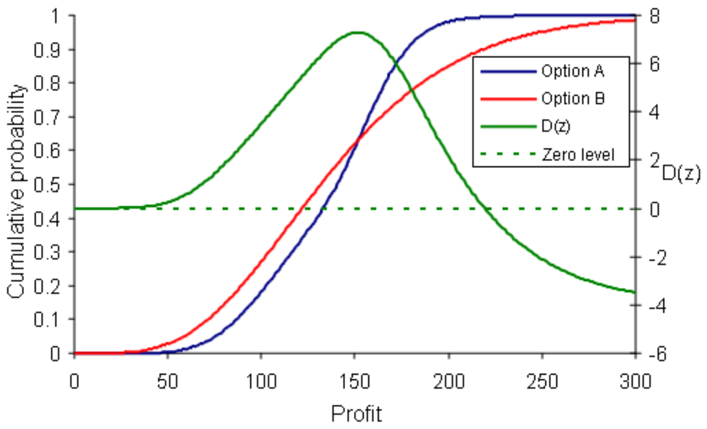

Figure 2-14 Second-order stochastic dominance: Option A does not second-order stochastically dominates option B [92]

This analysis is provided according to the Vose software [92]. It offers a Microsoft Excel plugin that computes these calculations and identifies the level of stochastic dominance among datasets in the analysis. It is marketed under the name of ModelRisk.

2.3.2. Response Surface Methodology

Response Surface Methodology (RSM) is a set of mathematical and statistical tools meant for the development, optimisation, and improvement of processes. It is an effective method for the research, design, and development of new products, as well as for the improvement of existing designs. RSM is extensively used in industrial environments mainly when multi-objectives are sought and are dependent on several parameters of independent variables. These performance measures are called the system responses that can be statistically treated to obtain an optimal response. It is very convenient, especially when data scientists or engineers need to display or communicate large amounts of data that can be viewed on the response surface in a three-dimensional time-temperature plane, those displays are called contour plots [51, 93, 94]. Nevertheless, within the scope of this research RSM will be used solely for the sensitive analysis of PCS parameters influencing inventory reduction.

Typical applications of RSM are applied to solve problems that can be categorised as follows: The mapping of a response surface over a particular region of interest, the optimisation of responses and the decision making about best operating conditions to achieve customer requirements or specifications, which is the case for the development of production control strategies under investigations here [93, 94]. RSM can map the authorisation card ranges and other variables, influencing the system performance and minimising the BL and the WIP.

2.4. MATERIAL RECOVERY AND ENVIRONMENTAL REGULATION ON MANUFACTURERS

CLSC emphasises on recovering added value by reusing products or components with the objective of recycling returned goods back into the production system.

A major factor leading to the creation and the strengthening of the CLSC is the growing number of environmental legislations and policies derived from Extended Producer Responsibility (EPR) policies, especially in OECD (Organisation for Economic Co-operation and Development) Countries. According to Lindhqvist [95], EPR was designed with an objective of decreasing environmental impact of manufactured products, by keeping the manufacturers accountable for the entire life-cycle of the product including its end-of-life and disposal.

The revised definition of EPR presents the concept as a policy principle [95]:

Extended Producer Responsibility (EPR) is a policy principle to promote total life cycle environmental improvements of product systems by extending the responsibilities of the *manufacturer of the product to various parts of the entire life cycle of the product, and especially to the take-back, recycling and final disposal of the product.* [95]

Therefore, ERP can drive improved engineering of products and of the production systems as well, leading to innovations and better technologies to deliver the functionalities of products in a more effective way and more sustainable over the long run. [95, 96]

Thierry et al. [97] presents a closed-loop supply chain framework integrating service, waste management and product recovery, as described in Figure 2-15. It has five product recovery options: Repair, refurbishment, remanufacturing, cannibalisation and recycling.

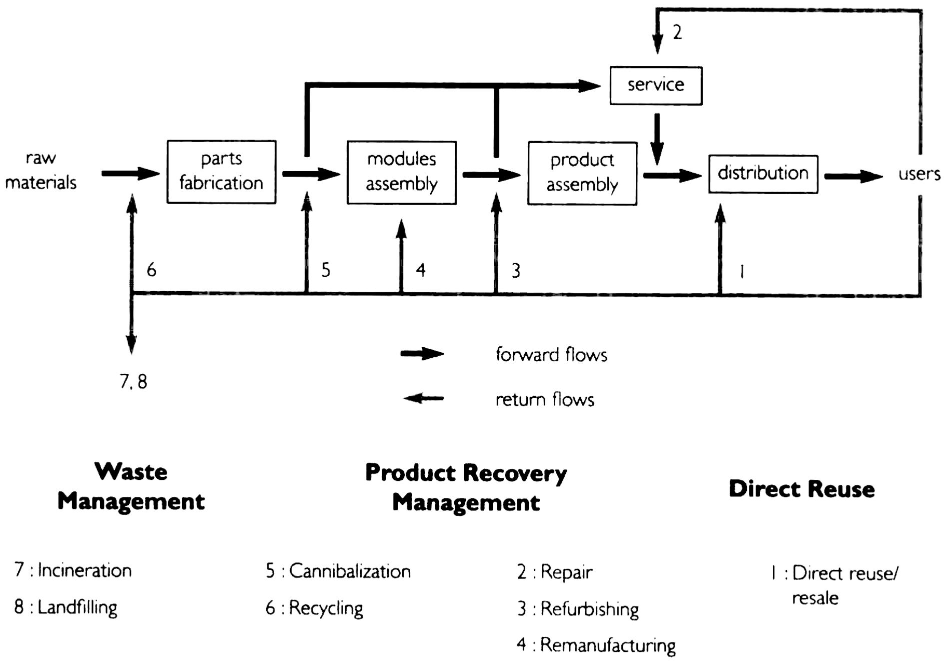

Figure 2-15. Integrated Closed-loop supply chain framework [97]

Repair implies replacing or fixing a limited number of parts, so it does not become economically less interesting than replacing a damaged product.

The refurbishment is the required process to bring the product back to the technical specification of a quality standards set by the manufacturer. Critical modules are replaced or fixed and it may also entail upgrading, so improving the quality and the service life of a product.

The remanufacturing is intended to make products with the quality standards as high as those for the new products. All modules are fixed and tested comprehensively. It can be combined with technological upgrading and tends to represent a very major cost saving measure, up to 50% cheaper than a totally new part or product.

The cannibalisation only recovers a very limited proportion of products or components. These parts are to be used in repair, refurbishment or remanufacturing of other products. The quality requirements are dependent on the specifics of the production process. It involves selective disassembly and detailed inspection for reusable parts. [97]

The purpose of recycling is the use of materials from used parts or products, while the previously described recovery options preserves the identity and functionality of the products, with recycling it is lost. These parts or products are separated into distinct material category. It is broadly used, for instance up to 75% of the weight of a vehicle is metal, easily and cost effectively recyclable.

Some issues with the closed-loop supply chains are difficulties in the reverse logistics, technical remanufacturing issues and market cannibalisation [98]. Another issue within the closed-loop supply chain can be the affordability of commodities, considered a substitute [99]. Initiatives such as the European Union directives on end-of-life products provide reasons for market growth, the advancement of closed-loop systems and the avoidance of the indiscriminate use of landfills. Researchers have found that remanufacturing is a reasonable strategy to decrease energy use and it can improve supplier selection [99]. In many cases, most of the products' life-cycle energy is used in the supply chain, which is a major cost component.

The closed-loop supply chain grows in importance due to the enforceability of environmental regulations and inherent incentives. Several related issues have also prompted the attention of researchers and practitioners, such as the practicality of EU carbon tax legislation and its relevant measurement mechanisms [100]. The remanufacturing process adds reverse logistic costs and the carbon embedded from the raw material are less than those found in remanufactured products. This is maximised by the amount of production, transportation, power consumption in operations, the and the weight of product and distances. A study proposes a reverse logistics framework [101, 102] defining that: Distribution, inventory control, production planning and the induced additional transportation required are decisive factors influencing the overall efficiency as return flows have high uncertainty in regards to timing, quantity, and quality. The knowledge base of closed-loop supply chains and its inherent factors can lead to greater operational efficiencies and higher economic performance within manufacturing and services entities. A number of issues and topics in need of further investigation have been identified. Areas of research needed are in public and sustainable procurement, the control strategy for the reverse logistics, commodities dependency, life cycle energy efficiency and carbon emissions costs in the supply chain.

The reverse logistics costs inherent to the remanufacturing and recycling procedures represent a barrier to the implementation of the closed-loop supply chain, as described in a comprehensive review [100]. Environmental proactivity does not necessarily lead directly to greater sales and increased profitability. However, sustainable supply chain practitioners have greater power to offset business cycles, commodities dependency, minimise risk and better dominate their own logistics and embedded technologies. It is remarkable that closed-loop supply chains can strengthen a recession-proof economic setting over the long run [100, 103].

The Volkswagen SiCon process, an end-of-life vehicle treatment system, is designed to classify multiple recyclable materials for future reuse in compliance with highly demanding environmental standards. It is a market-driven sustainable solution that reflects customer requirements and potential in the market for recovered materials. It displays significant economic and ecological advantages through several factors such as summer smog, eutrophication, global warming and acidification [104]. This technology was developed by SiCon GmbH and Volkswagen AG with other partners, it provides a flow of refined and treated shredded material from end-of-life vehicles to be used as a secondary source of raw material, substituting primary virgin raw material in existing plants. This final product, shredded material, must meet all quality standards specified by supplier companies. The shredding and classification process itself must satisfy emission requirement limits. An important premise on the development of this technology is that a sufficiently high demand for materials should exist for the produced fractions derived from the shredding processes. These fractions are defined as:

- Ferrous and non-ferrous metals;
- Shredder fibres, it can be used as a dewatering agent instead of coal dust;
- Shredder granulates are plastics with low chlorine and metal content to be used in blast furnaces as a reducing agent, substituting heavy oil;
- Shredder sand, consisting of rust, fine iron particles, glass, dust containing zinc, lead and other particles;
- Plastic fractions with high PVC content.

This process has been proved successful through many large-scale tests [104], including a test with 700 end-of-life vehicles (ELVs) with an average market mix and the resulting shredded materials that were supplied to several industrial plants. The European Union targets improved environmental performance by limiting the amount of waste created by ELVs (end-of-life vehicles). Research from major automotive industries study the technical and economic feasibility for recovery and processing. A case by case analysis is usually relevant as the exchange of proprietary processing data is an important requirement, nevertheless it has been shown that product development and eco-performance gains should focus on the overall life cycle improvement rather than on products weight reduction as no justification was found backing it [105].

Automotive shredding residue (ASR) includes heavy metals, high ash and calorific content and a variety of unclassified fine particles [106-108], it is considered hazardous waste and in order to meet the regulation standards of up to 95% recycling, highly effective industrial processes and, primarily, environmentally friendly engineering design during planning and manufacturing phases are required [108, 109]. Not only production costs but also the price fluctuations of scrap steel and raw materials are important factors to be accounted for.

Features of Japanese ELV recycling system includes: Manufacturers and importers are in charge of collecting the ASR, airbags and fluorocarbon gases; Vehicle buyers pay a recycling fee in advance; ELV handling is monitored in real time online; Operators are registered and certified [110, 111]. There are issues of invisible flow of end-of-life home appliances and illegal dumping that can also be covered under such recycling legislation being enforced. Efficient collection and transport for the reverse flow of goods also needs to be in consideration. It stays out of the system vehicles that are exported out of Japan as third-party regulations would apply, similar case of the European situation [107]. An estimated 8 to 9 million tons/year of ASR is generated in Europe compared to 500,000 tons/year in Japan. Melting and gasification technologies have been proven efficient in ASR treatment and destruction procedures [107]. An environmentally conscious resources cycle must minimize the amount of materials used, although the recycling has been the core of the material cycle, the priority of the 3Rs (reduction, reuse and recycling) should be on reducing the amount of energy and materials, reduction of waste during the upstream processes and the product design, not only on the ELV recovery and recycling methods. The ASR can be proportionally small in the case of Chinese industries [112], they may also recycle vehicles using less energy, less landfill and lower carbon emissions as China has a more comprehensive and bigger shredding base, it is easier to sort and recycle. The fast-growing metal consumption in China and the current environmental legislation of major players, the European Commission and the USA, have created an uneven market place that in theory directly impacts the technological advancement [111, 113].

The compound complexity of ASR hinders clean process efficiency and the reverse supply variability is enlarged by newly designed composite materials and the unpredictable length of useful life of vehicles. Polymers are acquiring more popularity in industrial production owing to their greater specific strength and greater resistance enabling better fuel efficiency. The use of polymers, however, results in problems at the end-of-life phase, since steel and other metals are more effectively sorted and recycled than polymers that tend to be sent to landfills [114].The environmental impact through a vehicle life cycle can be classified in: The disposal at the end of useful life; Waste generated during use and manufacturing; and the energy and resources used. Figure 2-16 depicts the Toyota recycling system for end of life vehicles in Japan.

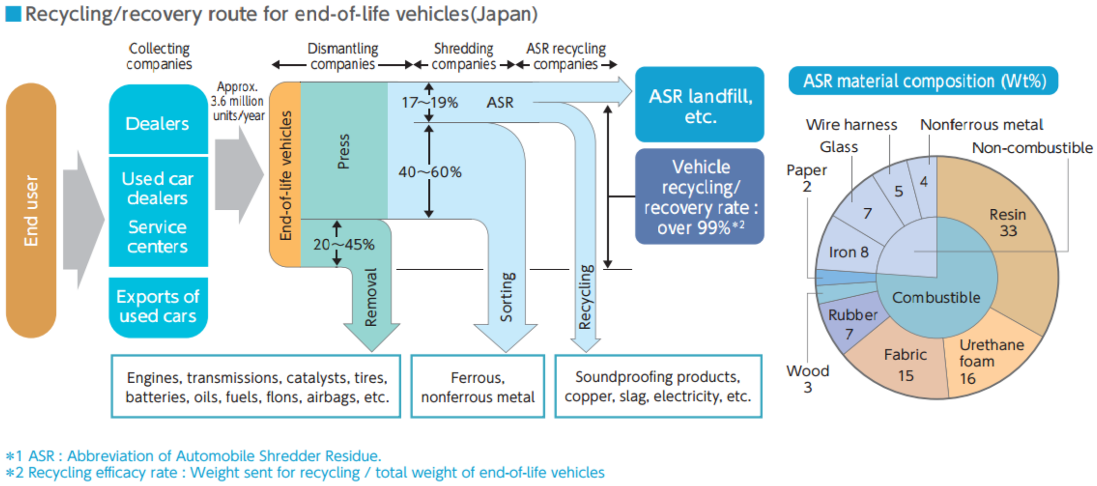

Figure 2-16. Toyota Recycling/Recovery System for End of Life Vehicles in Japan [115]

The rationalisation of scarce resources is a major factor in investment decisions in order to advance the economic performance of industrial producers. It is the driving force on the control and management of supply chain and manufacturing companies. The broad stakeholders' interests in industrial activities have demanded a more comprehensive approach for managing and controlling the production and delivery of goods. It can be well addressed by solutions developed through research in closed-loop supply chains tackling issues of energy use efficiency and recycling. Early research on the closed-loop supply chain [98, 116] was driven by increasing profitability of remanufacturing and the targeting of greater operational efficiency. CLSC focuses on recovering value added by reusing a product or its components with the objective of recycling returned goods into production processes. However, the general market demand for remanufactured or recycled parts or products is still undeveloped and needs technological advancement and further research.

Carbon emissions are considered the new *Muda*, Japanese for waste in lean supply chain management and just-in-time philosophy. According to Tao [103], the most effective carbon measurement mechanisms are carbon cap-and-trade and carbon tax, it provides an optimal lot size and cost strategies. Hence, methodologies on carbon pricing and carbon tax models can be used to classify the cost-effectiveness of CLSC strategies. Research on carbon emissions has grown in importance within the green supply chain influenced by customers, regulators, and corporations. Carbon emissions from supply chain activities are responsible for at least half of all global emissions. The methodology used by Tao [103], described that the adaptations of the economic order quantity (EOQ) and the economic production quantity (EPQ) in manufacturing, can be developed in addition to simulations integrating control strategies to quantify relevant output in order to further advance the experimental analysis modelling. Closed-loop supply chains' eco-footprint can be an effective policy instrument [117]. It assesses multiple environmental impacts, not only materials, energy, carbon, water, etc., but it also presents a comprehensive approach that integrates several stakeholders. As suggested in the literature: any additional footprint in the collection phase can be offset by the use of local repair and scrap recovery facilities. It is dependent on the network design and a decreased feasibility for reuse options means an increased feasibility for closed-loop recycling [117, 118].

2.4.1. Summary and Positioning of this Research

The Closed-Loop Supply Chain nowadays is still heavily reliant on environmental legislations and public governmental policies for its strengthening and more widespread participation to the broader range manufacturing producers worldwide. Specially in OECD Countries, it is closely related to the Extended Producer Responsibility (EPR) policies, according to Lindhqvist [95], EPR is meant to decrease environmental impact of manufactured goods, by keeping the manufacturing company responsible for the entire life-cycle of the product, including the end-of-life and final disposal.

Regulation standards mandate up to 95% of material recovery, therefore highly effective industrial processes and, primarily, environmentally friendly engineering design during planning and manufacturing phases are required in order to meet such legislations. [108, 109]

Other public incentives that could lead manufacturers to improved social responsibility and environmental performance was studied in order to identify reasons for justifiable investments in CLSC. However, the lack of a quantitative control metric tends to be an impediment in many environmental and public matters. such as the practicality of EU carbon credit and carbon tax legislation as it presents major deficiencies in relevant measurement mechanisms across multiple companies in supply chain networks and across borders. [100]

According to the work of Thierry et al. [97], as described in Figure 2-15, it is defined an overall closed-loop supply chain framework and a nomenclature standard that is the referential applied to this thesis in terms of the integration of return services, waste management and product recovery. Therefore, it provides the guiding terminology for the consequent design and implementation of simulation models used in the development of advanced control methodologies and inventory reduction in the research for the most optimum closed-loop supply chain management.

CHAPTER 3. PRELIMINARY PRODUCTION CONTROL STRATEGY EXPERIMENTAL APPROACH

This simple and straightforward production control strategy, CONWIP and the related modification, is implemented here in the preliminary experimental approach in order to establish a scientifically based simulation model design validated against other similar PCS models present in the literature and broadly accepted in the industry. It also aims at providing a comparison framework to other PCS's and an initial implementation of the CONWIP PCS to the CLSC using a three forward workstations system, as shown by Wang et al. [47]. It is also presented here a minor modification using the shared and dedicated CONWIP mechanism.

3.1. DEDICATED AND SHARED CONWIP CONTROL STRATEGIES REVIEW

Simulation experiments have shown that, in a three-stage assembly line using Dedicated CONWIP and Shared CONWIP strategies, the dedicated strategy achieved lower WIP and higher throughput rate [119]. A comprehensive review of pull-type production control strategies addressing the performance trade-offs between WIP and service levels in an operating environment with low variability and medium demand was presented in [8]. Regarding the CONWIP strategy in specific, it was recorded that the main reason why CONWIP can outperform a Kanban strategy is that the authorisation card communication is immediate to the first stage of the production line allowing quicker response to demand, while with the Kanban policy the card information has to move upstream workstation by workstation, eventually delaying the updated adjustment to the required demand. It is also shown that CONWIP is a very simple strategy to implement, however, inventory levels are not monitored at the individual workstation level, which can lead to increased inventory before the bottlenecks of a production line.

In multi-stage serial manufacturing-inventory systems, [20] found that CONWIP was the best performer only when the production line configuration was perfectly balanced and operating at the maximum capacity, the entire analysis considered multiple strategies including hybrid ones. Considering reverse supply chain models with push and pull logistics, [84] found that the pull strategy will result in lower WIP. In a comparison of dedicated and shared Kanban policies, for multiproduct serial lines with negligible setup time [120, 121] found that dedicated cards allocation policies are preferred over their shared counterparts, yielding better trade-offs between WIP and service level after parameter optimisation and robustness tests. In contrast, according to [122] in a similar manufacturing setting, but evaluating the performance of hybrid strategies with shared and dedicated Kanban allocation policies for multi-products serial flow, the shared Kanban had quicker response to demand, as it requires smaller number of control parameter and it will keep a lower WIP compared to the same strategy settings combined with dedicated Kanban pools. Multi-product systems displaying erratic demand or very strict time sensitive customer demand should not use shared cards allocation policies, especially if products with low demand variability are produced in combination with other products with greater demand variability. Shared strategies can be compatible for parts or materials that have low and similar demand variability level [123]. In this study, it was considered shared and dedicated pools of authorisation cards for different processes of the reverse logistics and the above-mentioned production systems [120] had shared or dedicated pools of cards related to product type instead.

3.2. EXPERIMENTAL DESIGN

The simulation models were designed in the discrete event simulation software Extendsim 9, to represent a closed-loop supply chain with the production being delivered to an open market that returns 90% or 40% of products to be recycled, as detailed in Figures 3-1 and 3-2 below.

The reverse logistics had a majority of the production going through the shredding procedure as it is numerically detailed below and the forward supply chain is represented with the supplier, manufacturer and distributor for all models. Doted lines represent information flow of authorisation cards and solid lines are the flow of material.

The data used in the simulations were based on similar and reasonable standard models commonly acceptable for industrial procedures and validated according to similar works present in literature [3, 20, 47, 84, 85], it is not a case study for a specific company. Dedicated CONWIP and shared CONWIP are the two production control strategies implemented with the manufacturing system recycling 40% and 90% of the returned material.

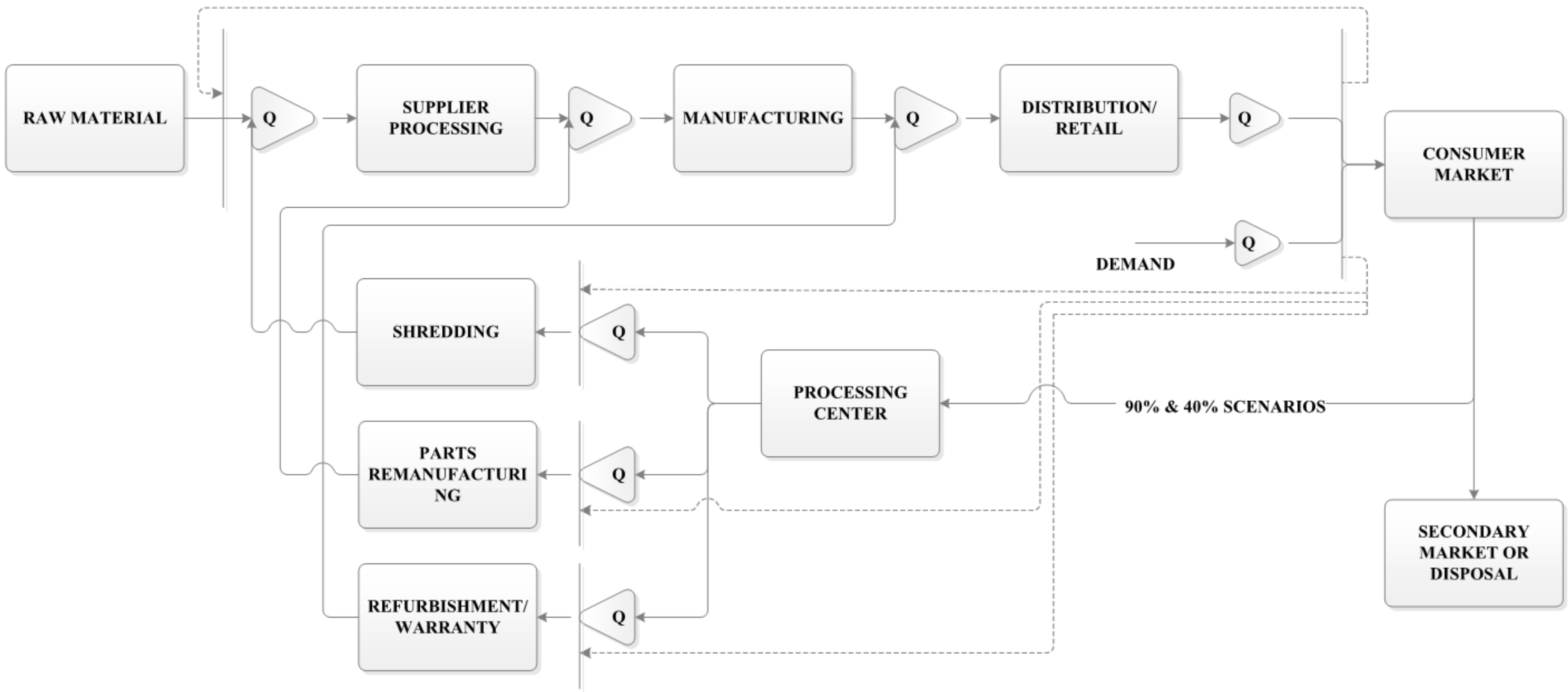

Figure 3-1. Dedicated CONWIP Diagram of the Authorisation Cards Allocation Policy and the Workflow of CLSC

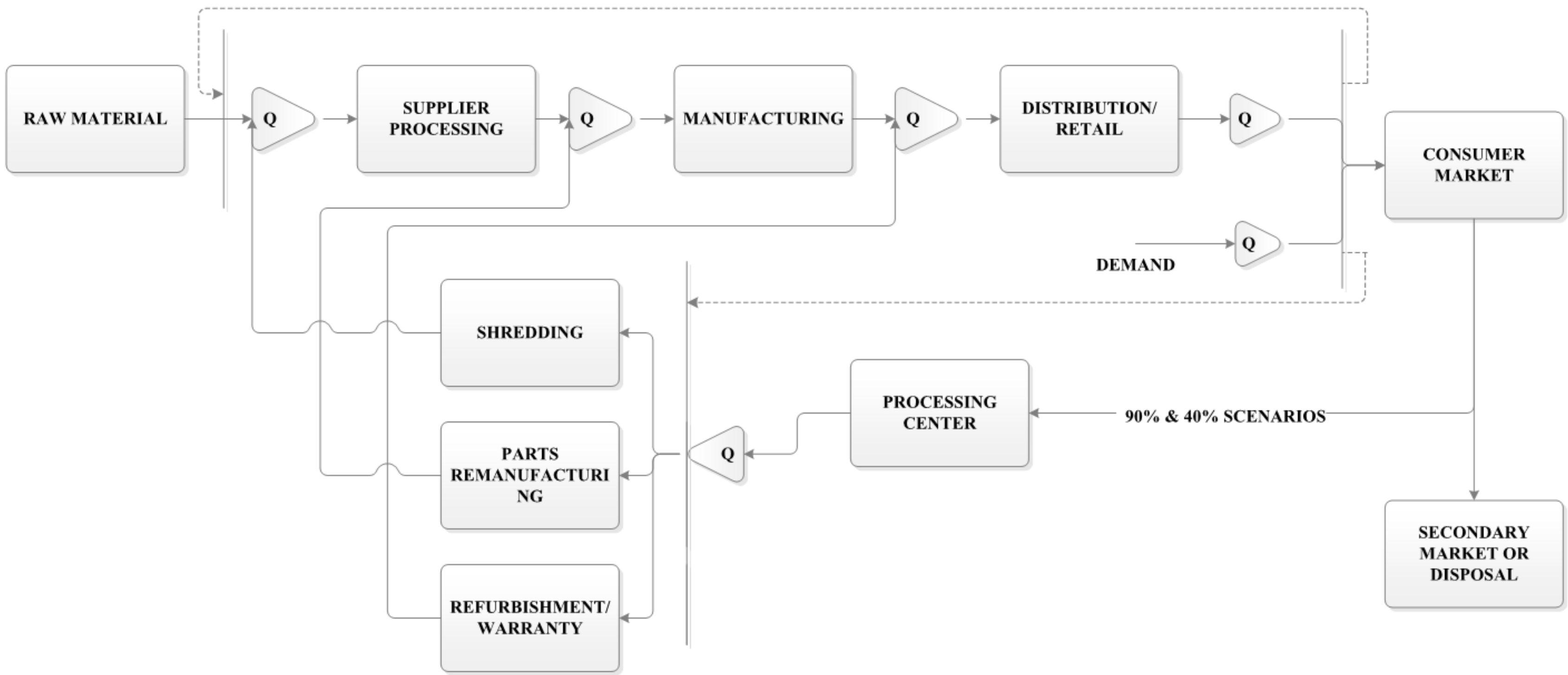

Figure 3-2. Shared CONWIP Diagram of the Authorisation Cards Allocation Policy and the Workflow of CLSC

The assumptions and limitations [3, 20, 47, 84, 85] to the system under analysis were:

I. Demand creation had an average of 10 parts/time with exponential distribution used for the time between arrivals, meaning a random demand, similarly to the standard set by Bonvik et al. [3];
II. Returned supply of products were respectively 9 and 4 parts/time, with random arrival (exponential distribution).
III. Each part in the system was considered to be 1 ton of material being handled, as in Wang et al. [47]
IV. Maximum production at the forward logistic was 11 parts/time with a lognormal distribution and it was adapted to have no bottleneck at any of the production stages;
V. The reverse side had double the production capacity and a normal distribution for processing to avoid increased effects of the arrival randomness of the returned material;
VI. The distribution of materials to the shredding process, remanufacturing and refurbishment was 7, 1 and 1 parts/time, respectively, for the 90% recovery models. Likewise, for the 40% models the reverse production capacity was obviously lower at 3, 0.5 and 0.5 parts/time, respectively. These proportions of returned materials needed a simplification in relation to the proposed number of processes described by Thierry et al. [97] in the CLSC, otherwise the research space as specified on table 3-1 would significantly increase beyond reasonable for the scope of this project;
VII. The standard deviation for all processing time distributions was set equal to the respective mean processing time. There was no lead time at any stage;
VIII. New materials were always available and entry to the system was limited by the number of authorisation cards set at each run. Each model setting had a 10% and 60% respectively limit rule for the forward CONWIP cards for every single run, hence it did not optimise completely independently to avoid the oversupply of unlimited available raw material;
IX. Queues and machines in the system follow a first in first out rule. If items arrive at the same time, items already flowing in the forward supply chain had the priority over items entering from the reverse supply chain;
X. Each run ended at 80,000 hours. Warm up period was 15,000 hours, all statistics before that were discarded from every single run. Similar to the standard set the simulation experiments by Bonvik et al. [3];
XI. Machine and authorisation cards must be available before materials went into processing [3];
XII. Demand created waited in the demand queue until it was met by finished goods supply;

XIII. Genetic algorithm settings were: 10% mutation rate, 5 replications for each scenario and up to 300 generations, according to the work of Onyeocha [124].

Table 3-1 provides the minimum and maximum settings for each of the control parameters for each strategy and scenario examined by the optimisation algorithm. The resulting data referent to the average backlog queue length and average time of work in progress were generated and recorded in the Extendsim 9, enabling the construction of the Pareto optimal frontier for each of the 4 scenarios under investigation. For the Dedicated CONWIP model with 90% recovery, which had the larger experimental space to be simulated, 69 solutions were generated after 125 generations covering 8.7% of the possible experimental space. It is worth mentioning that for the shared control strategies the optimiser was not deployed as the experimental spaces in both cases were relatively small and full enumeration of the experimental spaces was performed.

Table 3-1. Range of the Authorisation Cards

Control Strategy	Recycled Percentage	Number of Authorisation Cards		
Dedicated CONWIP	90	Shredding	50	105
		Remanufacturing	6	16
		Refurbishment	6	12
		New material (Limit 10%)	7	15
	40	Shredding	16	35
		Remanufacturing	2	7
		Refurbishment	1	5
		New material (Limit 60%)	29	71
Shared CONWIP	90	Shared pool	50	110
		New material (Limit 10%)	6	12
	40	Shared pool	18	40
		New material (Limit 60%)	27	60

3.3. EXPERIMENTAL RESULTS

The resulting Pareto optimal frontiers are as plotted on Figures 3-3 and 3-4 and it is clear that the Dedicated CONWIP production control strategy performed significantly better than the Shared CONWIP in both scenarios considered.

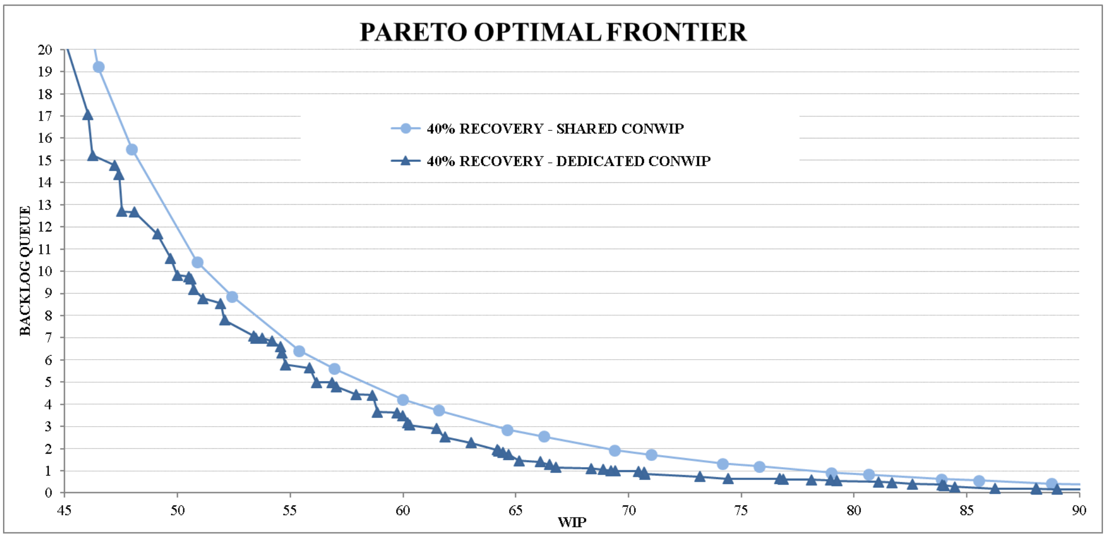

Figure 3-3. Control Strategies Performance for the 40% Recovery Scenarios

Concluding from Figure 3-3, it is worth mentioning that:

I. Dedicated CONWIP control is the best performer during the entire observation space. Relatively high improvement area is located where WIP ranges from 45 to 70.

II. From an optimisation point of view, the shared CONWIP has significantly more simplified optimisation process. The total sample size of optimisable parameters for Shared CONWIP is 23, smaller than for Dedicated CONWIP with a total sample size of 600 to be analysed.

III. Both control strategies: Shared CONWIP and Dedicated CONWIP required the decision maker to trade higher backlog order numbers when aiming to minimize the work in progress.

IV. The Pareto frontier is smoother for Shared CONWIP than for Dedicated CONWIP. There is no significant change between two adjacent points. However, Dedicated CONWIP has a higher result density which provides better decision coverage as there is a greater concentration of data points allowing for a more precise and plentiful range of solutions.

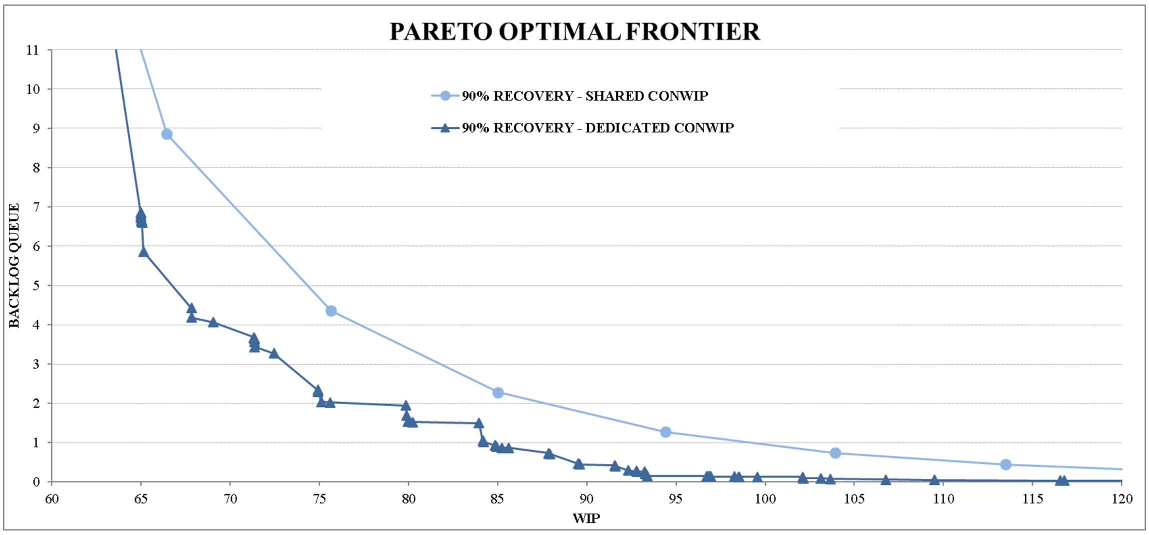

Figure 3-4. Control Strategies Performance for the 90% Recovery Scenarios

Similar to what was stated in regards to the 40% scenarios, analogous conclusions can be drawn by observing the Figure 3-4. The Dedicated CONWIP always outperformed the Shared CONWIP strategy and the improvement is even larger when considering the 90% recovery models than for the prior 40% recovery. The differences start to decrease for the area where WIP is beyond 100 and area where WIP is below 65. But the Dedicated CONWIP strategy converges quicker towards a zero-backlog state than the Shared CONWIP strategy.

The Dedicated CONWIP strategy for the 90% returns simulations presented a higher number of points on the Pareto Frontier than the Shared CONWIP strategy; hence decision makers can adjust system performance more meticulously. As previously mentioned for the 40% recovery scenarios; the research space is much larger for the Dedicated CONWIP strategy, in this case with 4,312 possible combinations to be analysed and processed by the optimiser, which demands very high computational power and it tends to be rather time-consuming. The total sample size of optimisable parameters for the Shared CONWIP strategy was 61.

Furthermore, in conclusion from similar production line published by Wang et al. [47] designed for forward supply chain and in comparison with Bonvik et al. [3], it displays the differences in the distribution of solutions throughout the entire experimental space with the upper and lower Pareto frontier depicting the spread between the best and worst performance. The results for Minimal Blocking strategies data and Hybrid Minimal Blocking-CONWIP Strategy were plotted in Figure 3-5, detailing the spread between the Pareto performance frontiers:

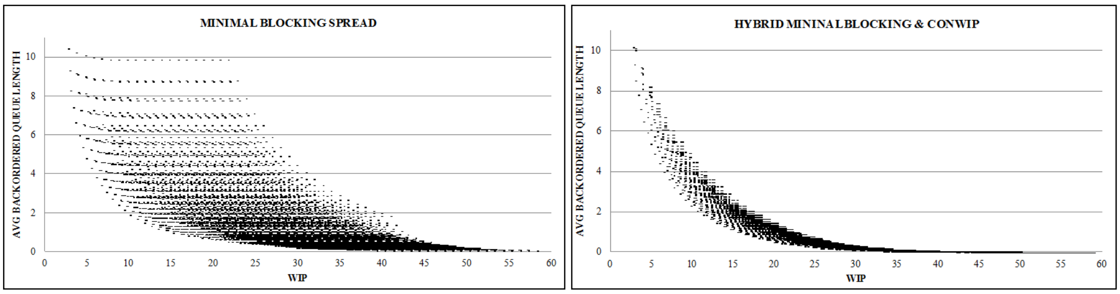

Figure 3-5. Minimal Blocking Strategy vs Hybrid Minimal Blocking-CONWIP Strategy – Performance Spread [47].

It is possible to verify the overall nature of the performance points spread. It was found that the tested hybrid strategies consistently perform better with significantly lower and spread in relation to any other control strategy in the study. Non-hybrid control strategies presented a broad spread between the lower (optimum) and upper performance limits [47]. The spread between upper and lower Pareto fronts was described in detail in Figure 3-6.

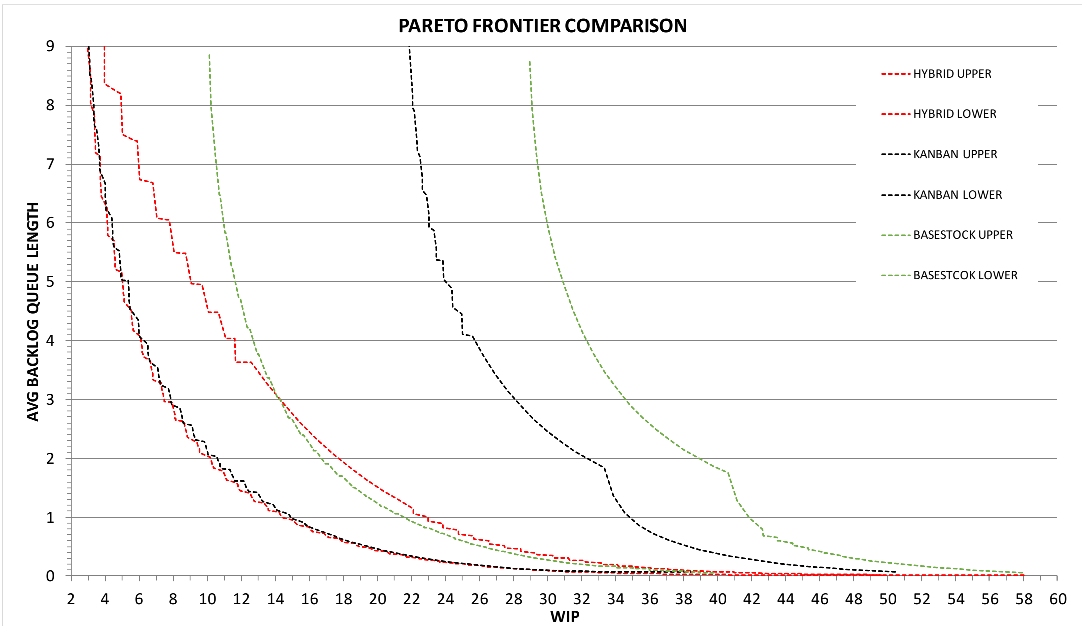

Figure 3-6. Multiple Strategies Pareto Front Comparison [47].

It can be observed that: As there is more emphasis on minimizing WIP, Base Stock becomes the worst performer and Hybrid Kanban-CONWIP the best performer. Both Kanban and the Base Stock have significantly higher upper Pareto fronts than the two hybrid strategies. [47].

3.4. SUMMARY

Designing and evaluating closed-loop supply chains requires thorough investigation due to the high degree of complexity and inherent cost factors involved in reverse logistics and in recycling or remanufacturing processes. From preliminary results of this study the following findings can be stated and reflects the possibilities related to future tests to be performed:

Hybrid Kanban CONWIP production control strategies [3, 20, 47], similarly to the Dedicated CONWIP and other hybrid strategy can provide significant improvement to the inventory level and order satisfaction in comparison to other tested strategies, with even greater advantage when having the higher rate of recovered products.

Hybrid control strategies, dynamic allocation of authorisation cards and multi product scenarios need to be tested on the CLSC as optimum solutions have been provided for highly variable supply and demand processes, along with more complex productive systems with significantly larger solution spaces and optimisations defined by other evolutionary algorithms.

Decision makers should consider the system utilisation, the production load and the company objective (minimising WIP and managing a higher backorder level or reducing backorder level and accepting a higher WIP) when implementing Dedicated CONWIP or any other control strategy to their system in order to find the trade-off point of a given system performance and to establish the optimised production settings.

For production with the greater variability of the reprocessed supply, the overall performance improvement derived from the Dedicated CONWIP strategy was greater than with the Shared CONWIP strategy.

The shredding system is the one major industrial process that enables the technical and economic viability of CLSC at a large scale; it has great potential for growth and to become the industry standard in years to come. It tends to be rather energy intensive, hence further research is needed to measure the environmental and socioeconomic impact and overall benefits of such technology over the long term. OECD environment regulations require a recycling rate of up to 95% and the manufacturer is in charge of that, especially in automotive and electronics industries. The remaining 5% is usually treated as hazardous waste and is sent for further processing or is contained in landfills.

Research and the development production performance strategies can effectively work as a public policy instrument to oversee and provide incentives for cleaner and more sustainable industrial technologies to boost economic activity. Case studies with industry specific data and scenarios can be optimised for greater efficiency and further benefit from these technological advancements.

CHAPTER 4. RESEARCH METHODOLOGY

4.1. SYSTEM DESCRIPTION

This research work tested the Closed-Loop Supply Chain design to analyse the optimum performance frontiers of a series of simulation models aimed at defining superior production control strategies considering inherent variables. The strategies experimented were:

I. HEKC-II - Hybrid Extended Kanban CONWIP special case, a modification approach from the work of Dallery and Liberopoulos [4], explained more in details in section 4.3;

II. HKC - Hybrid Kanban CONWIP, the control group and designed according to Bonvik et al. [3];

III. DNC HEKC-II - Dynamic Allocation Hybrid Extended Kanban CONWIP special case;

IV. DNC HKC - Dynamic Allocation Hybrid Kanban CONWIP.

Each of the four inventory control strategies was simulated in scenarios with:

I. 90% returned products, environmental legislation targets can demand even higher percentage Thierry et al. [97], however as this study is not a case study in specific the simplification is necessary in order to keep the research space to a reasonable level;

II. 40% returns from an open market system;

III. Processing times for each production stage with upper variability, deviation equals to 50% of the mean processing time, comparable to other publications on PCS [3, 20, 47];

IV. Processing times for each production stage with lower variability, deviation equals to 1% of the mean processing time, [3, 20, 47];

The control group, against which all results were compared, was defined as the HKC - Hybrid Kanban CONWIP, as designed by Bonvik et al. [3], due to its high performance in controlling inventory locally and globally throughout the entire supply chain, and because it provides a better demand communication upstream through the production line, it is its suitable for erratic environments providing a low spread between the lower and upper-performance frontiers. Therefore, all other strategies tested in this research were of a hybrid nature, since they can inherit the best traits of individual strategies, improving their communication and control abilities while adapting to the modification approach proposed here. So, it is proposed a novel type of dynamic change of the number of authorisation cards available and the starvation avoidance of the distributed demand parameter (DE) in the Extended Kanban Strategy modified from the Dallery and Liberopoulos [4] , shown in previous Chapter 2.

The simulation models were designed in the discrete event simulation software Extendsim 9, to represent the closed-loop supply chain, with the production being delivered to an open market that returns products to be recycled, remanufactured or refurbished for each of the control strategies and scenarios, allowing a minimum disposal rate, as detailed in the figures and assumptions forthcoming in the next sections. The reverse logistics process had a majority of the production going through the recycling procedure and the forward supply chain is represented with the supplier, manufacturer, and retail/distributor for all models.

All 16 simulation models, used for the evolutionary optimisation, robustness tests, and RSM, were processed on individual virtual machines set on the Google Cloud Platform using dedicated servers with SSDs (Solid-state drive) locally and dual-core CPUs, as the software is not designed to effectively use multicores. The simulation processes and optimisations are very computationally intensive and the research space for those CLSC scenarios is highly extensive. Consequently, in order to get timely results, as provided in the next chapters, large amounts of computational resources were required for the period of this research project.

The runtime for each replication is dependent of the complexity level of each strategy, one replication of the HKC took approximately 1.5s, while the more complex DNC HEKC-II with additional parameters, features and calculations took just over 3.3s.

The following diagrams, Figures 4-1 to 4-2, describe the logic and workflow of each of the production control strategies under analysis and their extensive number of scenario combinations are provided according to the tables that follow, specifying the range of authorisation cards settings. Subsequent to that, more detailed explanations of the strategies are provided.

The data used in the simulations were based on similar and reasonable standard models commonly used for industrial procedures and were validated according to previous work and similar systems published in the literature [3, 20, 47, 84, 85], it is not a case study for a specific company, but theoretically applicable for production systems with similar rates of supply, demand, processing time variability and configurations also comparable to same optimum Hybrid Kanban CONWIP control group as designed by Bonvik et al. [3].

The identification of each authorisation cards pools is according to Table 4-1:

Table 4-1. Authorisation Cards Legend

CWn	Number of CONWIP cards at the new material supply;
CWr	Number of CONWIP cards at the recycling process;
CWf	Number of CONWIP cards at the remanufacturing process;
CWe	Number of CONWIP cards at the refurbishment process;
Ks	Number of Kanban cards at the new material supply;
Kr	Number of Kanban cards at the recycling process;
Kf	Number of Kanban cards at the remanufacturing process;
Ke	Number of Kanban cards at the refurbishment process;
Km	Number of Kanban cards at the manufacturing process;
Ksr	Number of Kanban cards at the recycled supply;
Kmf	Number of Kanban cards at the remanufactured supply;
MP	Number of dynamically allocated cards, according to formula;
DE	Parameter for the distributed demand starvation avoidance and production speed decrease during low customer demand.

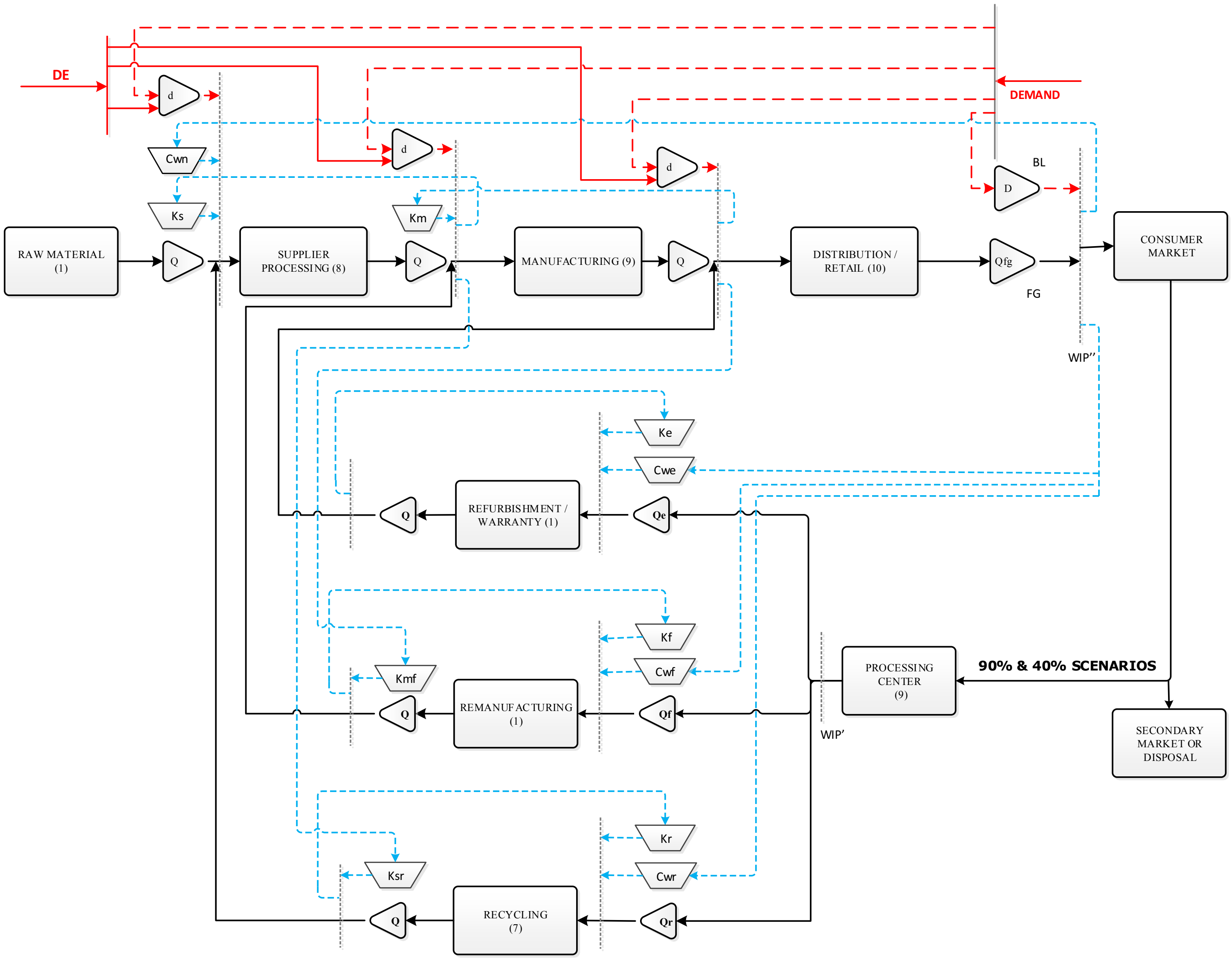

Figure 4-1. HEKC-II Diagram of the Authorisation Cards Allocation Policy and the Workflow of CLSC

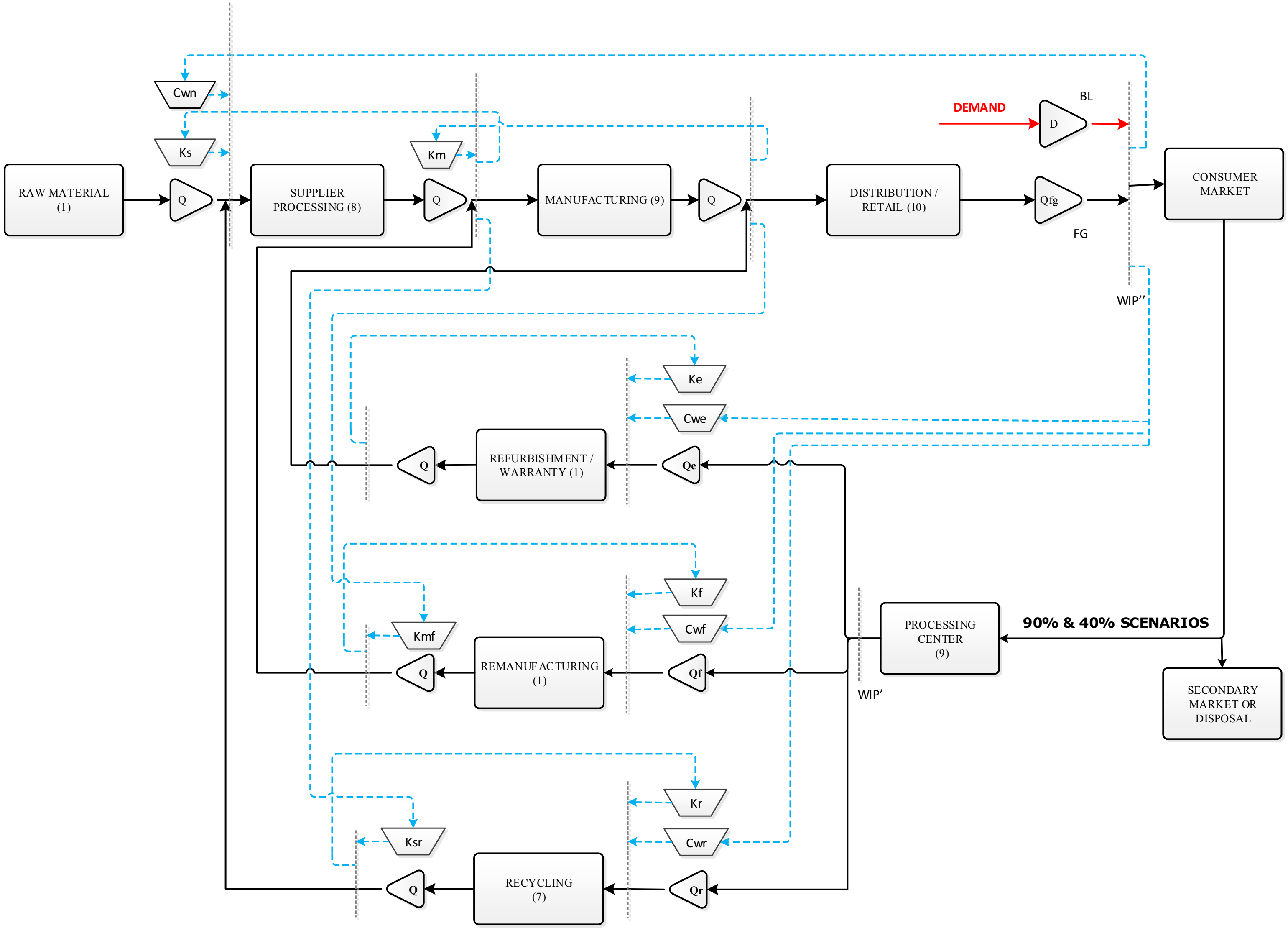

Figure 4-2. HKC Diagram of the Authorisation Cards Allocation Policy and the Workflow of CLSC

Table 4-2. Range of Authorisation Cards Setting for HEKC-II Production Control Strategy with 90% Returned Material.

Low and High Limits of Authorisation Cards			Range
DE	**0**	**9**	**10**
Cwn	4	9	**6**
Cwr	60	110	**51**
Cwf	8	18	**11**
Cwe	7	17	**11**
Ks	2	6	**5**
Ksr	7	15	**9**
Kr	8	22	**15**
Kf	2	5	**4**
Ke	2	5	**4**
Km	8	20	**13**
Kmf	2	5	**4**
Total Number of Scenarios			**2.08E+11**

Table 4-3. Range of Authorisation Cards Setting for HKC Production Control Strategy with 90% Returned Material.

Low and High Limits of Authorisation Cards			Range
Cwn	4	9	**6**
Cwr	60	110	**51**
Cwf	8	18	**11**
Cwe	7	17	**11**
Ks	2	6	**5**
Ksr	7	15	**9**
Kr	8	22	**15**
Kf	2	5	**4**
Ke	2	5	**4**
Km	8	20	**13**
Kmf	2	5	**4**
Total Number of Scenarios			**2.08E+10**

Table 4-4. Range of Authorisation Cards Setting for HEKC-II Production Control Strategy with 40% Returned Material.

Low and High Limits of Authorisation Cards			Range
DE	**0**	**10**	**11**
Cwn	10	60	**51**
Cwr	14	60	**47**
Cwf	3	9	**7**
Cwe	2	8	**7**
Ks	4	18	**15**
Ksr	4	10	**7**
Kr	4	10	**7**
Kf	1	4	**4**
Ke	1	4	**4**
Km	7	20	**14**
Kmf	1	4	**4**
Total Number of Scenarios			**8.51E+11**

Table 4-5. Range of Authorisation Cards Setting for HKC Production Control Strategy with 40% Returned Material.

Low and High Limits of Authorisation Cards			Range
Cwn	10	60	**51**
Cwr	14	60	**47**
Cwf	3	9	**7**
Cwe	2	8	**7**
Ks	4	18	**15**
Ksr	4	10	**7**
Kr	4	10	**7**
Kf	1	4	**4**
Ke	1	4	**4**
Km	7	20	**14**
Kmf	1	4	**4**
Total Number of Scenarios			**7.73E+10**

Solid lines represent the material flow and dashed lines are information flows, red being the demand communication and blue the authorisation cards communication across the production processes, with the kanban and CONWIP loops limiting the inventory within them. At the supply process for the HEKC-II strategy, for instance, it is needed one kanban card, one CONWIP, one demand in the buffer and one part available in the new or recycled buffer, then the material is authorised to go into processing.

The parameter DE is a modification introduced for the HEKC-II, originally based on Dallery and Liberopoulos [4], it provides the slowdown of production instead of a stoppage, as it would occur in the standard Base Stock strategy [7]. It allows for the total overwriting of the shared demand distribution, avoiding the starvation of any of the demand buffers and creating the possibility for the HEKC-II to perform similarly to HKC when the DE number is high or equal to the demand level, therefore neutralising any negative effect of the distributed demand stopping production. Thus, it allows for a slowdown of production instead of a stoppage. For instance, if the average production rate is 10 parts per time period and DE=4, when the shared demand buffers get empty, the production for this workstation is authorised by the rate of four parts per time, lowering its pace during lower demand periods.

The following diagrams, Figures 4-3 and 4-4, describe the logic and workflow of the dynamic production control strategies under analysis and their extensive number of scenario combinations are provided according to the tables that follow, specifying the range of authorisation cards settings. Subsequent to that, more detailed explanations of the strategies are provided.

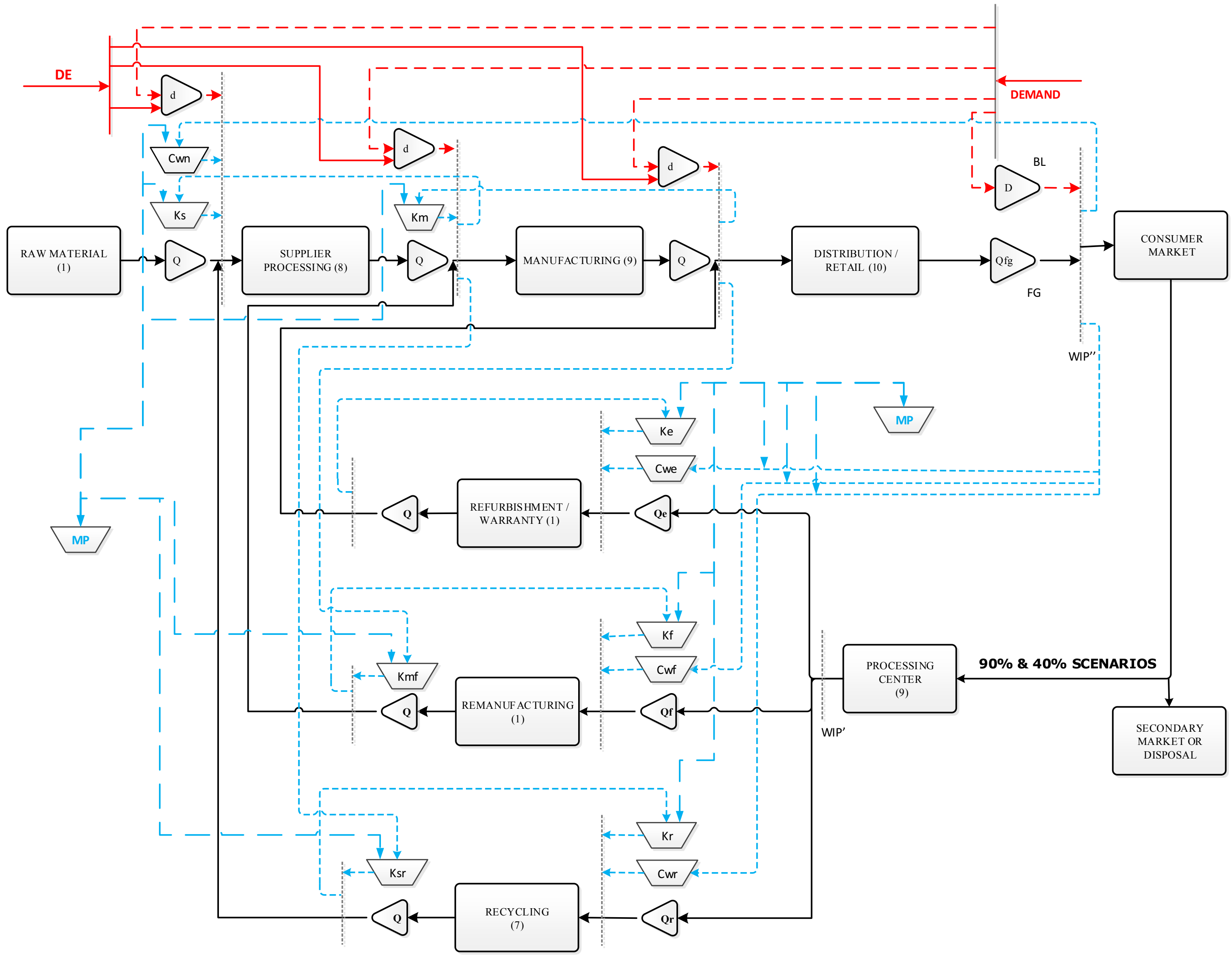

Figure 4-3. DNC HEKC-II Diagram of the Authorisation Cards Allocation Policy and the Workflow of CLSC

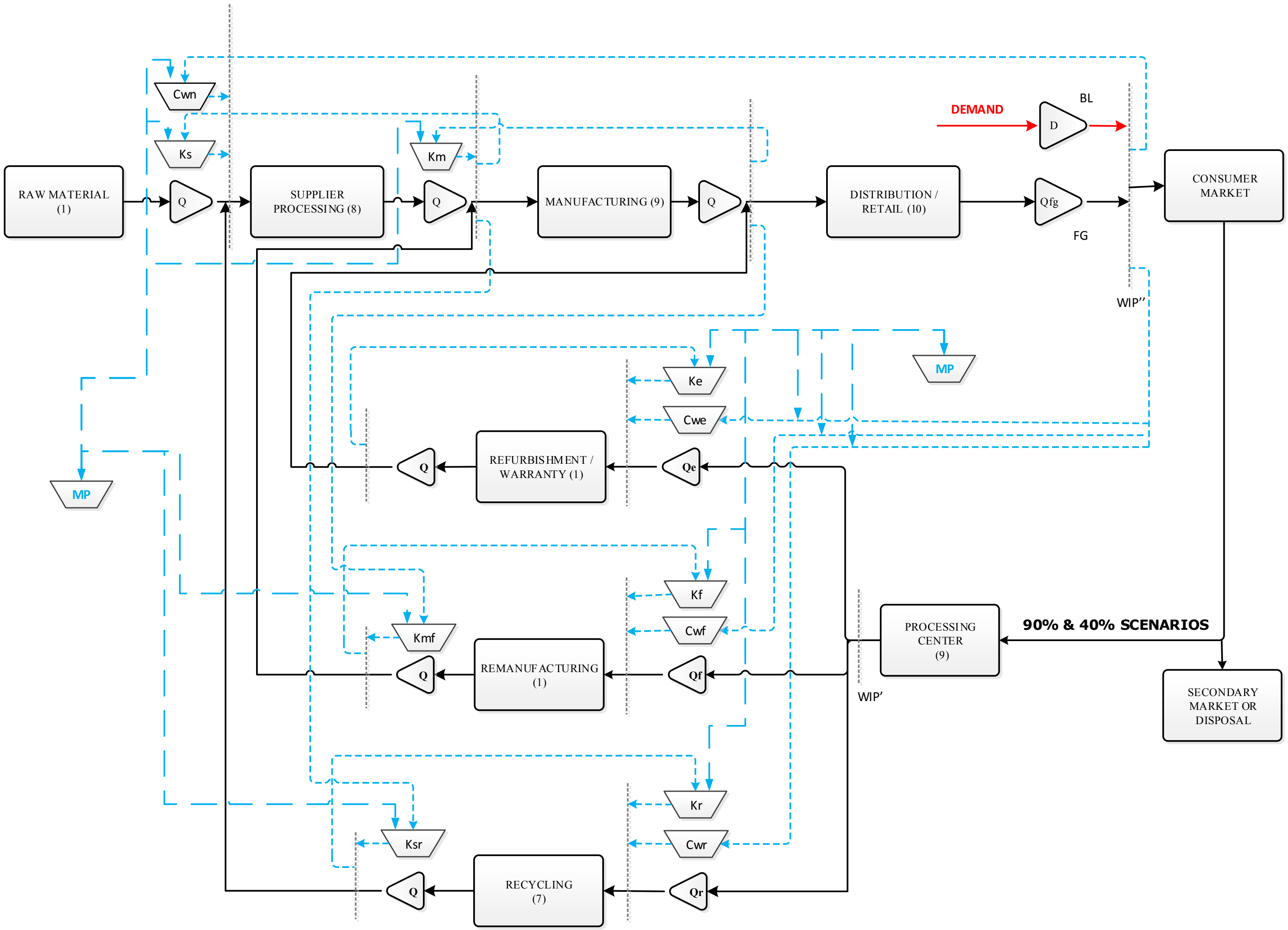

Figure 4-4. DNC HKC Diagram of the Authorisation Cards Allocation Policy and the Workflow of CLSC

Table 4-6. Range of Authorisation Cards Setting for DNC HEKC-II Production Control Strategy with 90% Returned Material.

Low and High Limits of Authorisation Cards			Range
MP	**50**	**120**	**8**
Cwn	3	9	**7**
Cwr	40	85	**46**
Cwf	7	15	**9**
Cwe	6	14	**9**
Ks	2	6	**5**
Ksr	6	12	**7**
Kr	7	18	**12**
Kf	1	4	**4**
Ke	1	4	**4**
Km	7	16	**10**
Kmf	1	4	**4**
DE	**0**	**9**	**10**
Total Number of Scenarios			**5.61E+11**

Table 4-7. Range of Authorisation Cards Setting for DNC HKC Production Control Strategy with 90% Returned Material.

Low and High Limits of Authorisation Cards			Range
MP	**50**	**120**	**8**
Cwn	3	9	**7**
Cwr	40	85	**46**
Cwf	7	15	**9**
Cwe	6	14	**9**
Ks	2	6	**5**
Ksr	6	12	**7**
Kr	7	18	**12**
Kf	1	4	**4**
Ke	1	4	**4**
Km	7	16	**10**
Kmf	1	4	**4**
Total Number of Scenarios			**5.61E+10**

Table 4-8. Changes in Authorisation Cards Setting for DNC HEKC-II and for DNC HKC Production Control Strategy with 90% Returned Material.

Optimised Cards Setting for HKC 0.5 BL			**Initial Card Pool Size**	**Pool Size Change Triggered by Supply/Demand Queues**			
			Qfg >3 - Standard 0	**Qfg < 4 - Stand. 1 - Demand Antec.**	**Qr > 5 - Stand. 2**	**Qf > 5 - Stand. 3**	**Qe > 5- Stand. 4**
Cwn	6	3.0%	IP1	IP1+MPx0.5x3%			
Cwr	100	50.8%	IP2	IP2+MPx0.5x51%	IP2+MPx0.5x51%		
Cwf	13	6.6%	IP3	IP3+MPx0.5x6.6%		IP3+MPx0.5x6.6%	
Cwe	17	8.6%	IP4	IP4+MPx0.5x7.2%			IP4+MPx0.5x8.6%
Ks	6	3.0%	IP5	IP5+MPx0.5x3%			
Ksr	7	3.6%	IP6	IP6+MPx0.5x3.6%	IP6+MPx0.5x3.6%		
Kr	19	9.6%	IP7		**IP7+MPx9.6%**		
Kf	4	2.0%	IP8			**IP8+MPx2%**	
Ke	4	2.0%	IP9				**IP9+MPx2%**
Km	17	8.6%	IP10	**IP10+MPx8.6%**			
Kmf	4	2.0%	IP11			IP11+MPx0.5x2%	
Total	**197**	**100.00%**					

Table 4-9. Range of Authorisation Cards Settings for DNC HEKC-II Production Control Strategy with 40% Returned Material.

Low and High Limits of Authorisation Cards			**Range**
MP	**20**	**80**	**7**
Cwn	10	48	**39**
Cwr	14	48	**35**
Cwf	2	7	**6**
Cwe	2	7	**6**
Ks	4	14	**11**
Ksr	3	8	**6**
Kr	3	8	**6**
Kf	1	4	**4**
Ke	1	4	**4**
Km	7	16	**10**
Kmf	1	4	**4**
DE	0	10	**11**
Total Number of Scenarios			**9.59E+11**

Table 4-10. Range of Authorisation Cards Settings for DNC HKC Production Control Strategy with 40% Returned Material.

Low and High Limits of Authorisation Cards			**Range**
MP	**20**	**80**	**7**
Cwn	10	48	**39**
Cwr	14	48	**35**
Cwf	2	7	**6**
Cwe	2	7	**6**
Ks	4	14	**11**
Ksr	3	8	**6**
Kr	3	8	**6**
Kf	1	4	**4**
Ke	1	4	**4**
Km	7	16	**10**
Kmf	1	4	**4**
Total Number of Scenarios			**8.72E+10**

Table 4-11. Range of Authorisation Cards Settings DNC HEKC-II and for DNC HKC Production Control Strategy with 40% Returned Material.

Optimised Cards Setting for HKC 0.5 BL			**Initial Card Pool Size**	**Pool Size Change Triggered by Supply/Demand Queue**			
			Qfg >3 - Standard 0	**Qfg < 4 - Stand. 1 - Demand Antec.**	**Qr > 5 - Stand. 2**	**Qf > 5 - Stand. 3**	**Qe > 5- Stand. 4**
Cwn	26	19.5%	IP1	IP1+MPx0.5x20%			
Cwr	45	33.8%	IP2	IP2+MPx0.5x34%	IP2+MPx0.5x51%		
Cwf	6	4.5%	IP3	IP3+MPx0.5x4.5%		IP3+MPx0.5x6.6%	
Cwe	5	3.8%	IP4	IP4+MPx0.5x3.8%			IP4+MPx0.5x8.6%
Ks	12	9.0%	IP5	IP5+MPx0.5x9%			
Ksr	7	5.3%	IP6	IP6+MPx0.5x5.3%	IP6+MPx0.5x5.3%		
Kr	8	6.0%	IP7		**IP7+MPx6%**		
Kf	3	2.3%	IP8			**IP8+MPx2.3%**	
Ke	2	1.5%	IP9				**IP9+MPx1.5%**
Km	16	12.0%	IP10	**IP10+MPx12%**			
Kmf	3	2.3%	IP11			IP11+MPx0.5x2.3%	
Total	**133**	**100.00%**					

The workflow for the dynamic strategies is the same as described for the HEKC-II and HKC with the exception that the number of cards on the PAC pools are not constant and can be changed according to the formulas provided.

The Master Pool (MP) is the deciding factor for the quantification of an increase in the number of cards to be dynamically allocated. It is triggered when supply or demand queues are above a certain level. Further specifications in relation to all the parameters are provided throughout this chapter.

The logic for the dynamic allocation had a prioritisation of the local inventory, via kanbans over the global inventory, set by CONWIP cards, at the rate of 1 to 2 as described in Tables 4-8 and 4-11. The triggers at the supply side were Qr, Qe and Qf queues. They allowed for the number of PACs to increase when more than five units were stored in the respective buffer, so the number of kanbans for the immediate next workstation increased by 100% of the master pool, times the HKC optimised percentage detailed on the tables and 50% increase for the second next workstation. On the demand side, the queue used to trigger the increase in the number of cards allowed was the finished good buffer, Qfg, instead of the backlog queue (BL) itself. This was put in place to anticipate the build-up of backlogged customer demand and to minimise it. The increase in PACs, according to the formulas, provided on the previously mentioned tables, was allowed when the Qfg was below four. So, increasing all CONWIPs by 50% of MP and by 100% at the nearest Kanban pool, similarly to the above-mentioned supply side.

It is worth noting that, as can be seen in Tables 4-6, 4-7, 4-9 and 4-10, for the dynamic allocation strategies, the number of authorisation cards in the range were reduced by around a quarter on all pools. Only after the dynamic increase was triggered, these strategies would be able to get a similar range of cards as in the control group, making the limits placed on the dynamic allocation strategies, even more restricted than for the non-dynamic ones. Therefore, any performance improvement achieved would be linked solely to the merit of the logic and within the same standards and constraints.

Only integer numbers were possible for the card pool sizes, so the formula rounds up the result for all authorisation card loops. The decrease back to the initial pool size condition, after the surge that triggered the dynamic change, followed the same standard of inventory level of the initial triggering on both ends, supply, and demand.

The dynamic allocation had a referential on the optimised setting for a backlog of 0.5. It represents a level where both of the objective metrics are taken into consideration, and it places a higher preference for low backlog and a high service level. It meant that the HKC had to be previously optimised to provide those proportions of cards for each pool, so it can be considered a two-level optimisation. It was designed in this manner to avoid using arbitrary numbers or just picking a proportion based on the production level of a given process, which would, for example, leave the dynamic change without a consideration for the variability of supply.

Since the research space was significantly large, the genetic algorithm optimiser was set to use increments of 10 to run the master pool range limits, with the objective of minimising the number of scenarios to be executed and making the optimisation process faster.

Evolutionary algorithms [60, 70] were used to generate the Pareto-optimum performance frontier with the objective of simultaneously minimising both production metrics: The average number of work in progress (WIP) for the entire closed-loop supply chain, which counts from the processing centre on the reverse logistics until the finished good delivered to the customer. The other metric is the average backlog queue for the customer demand (BL), orders that are not immediately satisfied by finished goods.

The settings of the algorithm and the research space for all abovementioned scenarios were set as follows, based in similar research in the literature [3, 20, 47]:

I. Final number of generations: 5,000. The high number was in order to allow for all scenarios to reach a similar percentage of the research space;
II. Mutation rate: 40%, it was determined according to work of Onyeocha [124] in multiple scenarios and experimentally confirmed to the suitability of this research, so avoiding early convergence of solution on the Pareto frontier;
III. Replications of each card allocation setting: 5 [124];
IV. Run length: 150,000 produced parts, 15,000-time period [3, 20, 47];
V. Warmup period: 1,000-time period;
VI. Production spare capacity: 15% and additional 10% for the reverse logistics.

It was designed as a termination mechanism for the simulation run in order to speed up and facilitate the search for optimum responses and reduce the number of scenarios to be executed within the researched space. It was meant to remove the outliner performance, accordingly, after the 7,000-time period if the average WIP was above 170 units or the average back ordered demand (BL) was above 20. This run was terminated and its correspondent card setting was recorded on the optimiser with high values for the two metrics. It was set to be out of the Pareto frontier as it was an outliner performer, thus saving computing time to be used with optimum solutions.

4.2. RESEARCH SPACE SPECIFICATIONS

The assumptions and limitations to the simulated meta-models of the production system [3, 20, 47, 84, 85] with the implemented closed-loop supply chain under analysis were set according to the following considerations:

I. Stochastic customer demand creation had an average of 10 parts/time with exponential distribution used for the time between arrivals, similar to the standard set by Bonvik et al. [3];
II. Returned supply of products were also random with respectively 9 and 4 parts/time for 90% and 40% returns, with exponential distribution;
III. The distribution of materials to the recycling process, remanufacturing and refurbishment was 7, 1 and 1 parts/time, respectively, for the 90% recovery models. These proportions of returned goods were simplified from the proposed by Thierry et al. [97] in Figure 2-15 (Integrated Closed-loop supply chain framework), otherwise the research space as specified in table 3-1 would significantly increase beyond reasonable for the scope of this work. So, in the simulation the cannibalisation and remanufacturing were considered to be just one process, also the refurbishment process included the direct reuse and repair [97];
IV. For the 40% models, the reverse production capacity was lower at 3, 0.5 and 0.5 parts/time, respectively. Similar to the previous item, the 40% could represent companies that are at early stages of adopting CLSC. Additionally, the production growth over time and the lifetime of a product is not accounted in this research [97];
V. The simulations were designed to have three processing stages, workstations, on the forward supply chain and three workstations on the reverse side with the returned material;
VI. There was no lead time at any stage;
VII. Information flow of demand and authorisation cards were instantaneous;
VIII. Raw material was nearly always available [125], however, it had these limitations:

Safety stock for 24-time periods of the average raw material demand for any of the specific scenarios in consideration, plus an additional supply capacity of 1 part/time

XIV. Production processing times had a lognormal distribution, as in Wang et al. [47];

IX. The simulation starting state had the production system with all stages fully supplied with materials and in an operation condition to minimise the warmup time;

X. Base stock levels used for all HEKC-II scenarios were set to 20 and not optimised, modification from Dallery and Liberopoulos [4], so the strategy was solely dependent on the DE parameter to avoid the demand starvation;

XI. Parts received in the buffers of the reverse logistics processes were counted in the statistics for the average WIP;

XII. No bottleneck at any of the production stages, mean processing time was the same for all forward supply chain stages;

XIII. Spare production capacity was 15% for the forward side of supply chain with an additional 10% for the reverse logistic, this was in order to avoid the increased effects of the arrival randomness of the recycled supply;

XIV. Parts derived from the reverse supply chain had priority over items entering the process from the forward supply chain or any new raw material. This in order to offset the higher variability of the reverse logistics and because there were no quality constraints for the materials handled in the model;

XV. Each part in the system was considered to be a given weight of material being moved along the supply chain;

XVI. Queues and machines in the system follow a first in first out rule;

XVII. Machine and authorisation cards had to be available before materials went into processing;

XVIII. Demand created waited in the demand queue until it was met by a supply of finished goods.

4.3. MODIFICATION APPROACH

The Extended Kanban Strategy by Dallery and Liberopoulos [4] as described in Section 2.1.6 provides the benefit of instant communication of demand to all workstations, thus limiting the production during times of low demand. However, with increased variabilities in the system, the numbers of base stock can be very high, and the research space would greatly increase, while an optimisable performance frontier tends to have quite low base stock values in order to keep a low WIP [47]. Figures 4-5 to 4-8 clearly display that when the distributed demand buffers are starved during periods of very low demand rate, then both metrics, the average WIP and BL, start growing in an uncontrolled fashion and without any opportunity for recovery. This happens, because, when it occurs, the demand rate, 10 in this study, will limit the production processing to the same rate, on average, similar to the demand rate. Although low variability processes tend to be able to recover from this stoppage in production, over longer time periods and with a high variability of supply and demand, it creates a very limiting factor that does not allow the production system to use its spare capacity.

The DE parameter, for the starvation avoidance was designed to resolve this by providing a slowing of production rate instead of a stoppage, while benefitting from distributed demand communication and maintaining a minimum base stock level in order to lower the WIP.

Figures 4-5 to 4-8 display the deterioration of the performance metrics when the distributed demand is starved with DE=0, BS=20. Even with the BS increased up to 100 level, the poor performance remains because the production rate is limited, and the spare capacity is totally lost, not authorised to be used due to one starved demand buffer which is permanently kept at the same demand rate, with no spare capacity.

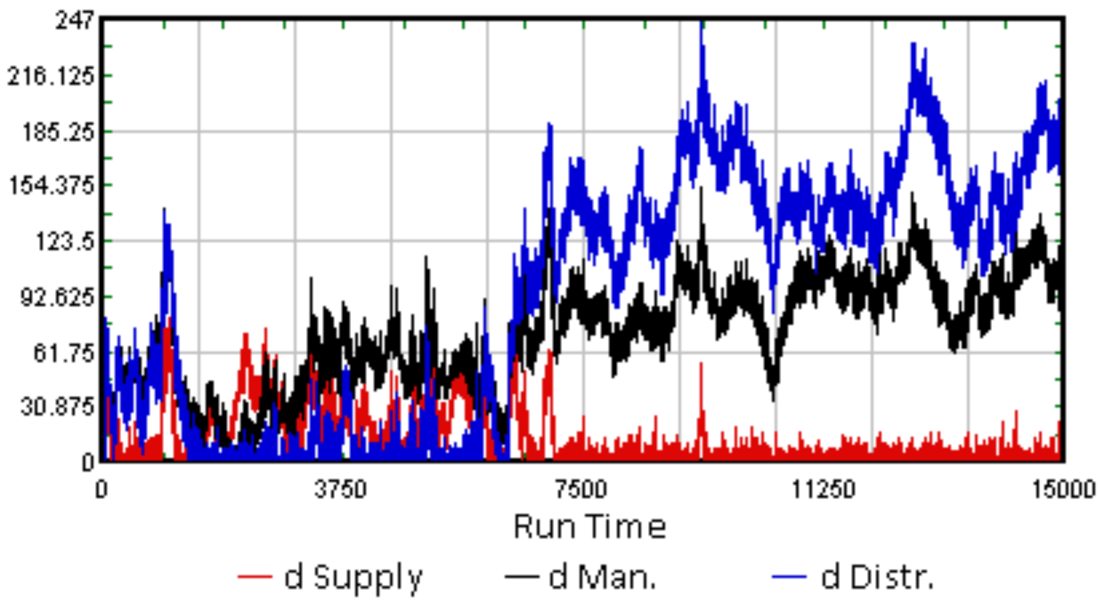

Figure 4-5. Distributed Demand Level Comparison for each Demand Buffer on HEKC-II with DE = 0 and Base Stock = 20

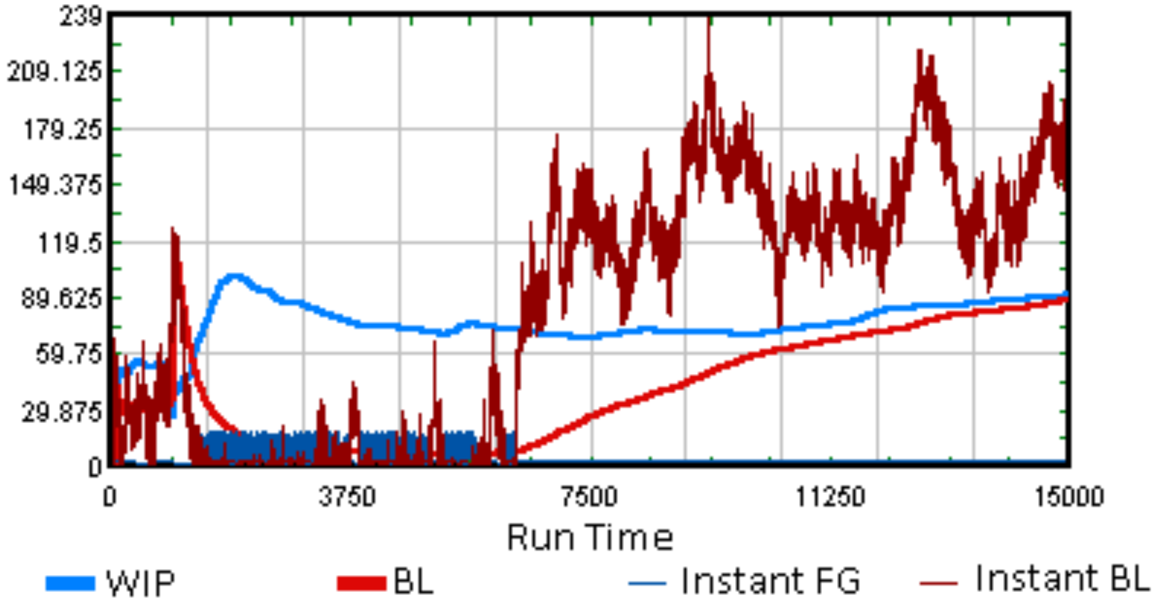

Figure 4-6. WIP and BL Plot Displaying Instant Variations of the Finished Good Buffer (blue) and BL (red) on HEKC-II with DE = 0 and Base Stock = 20

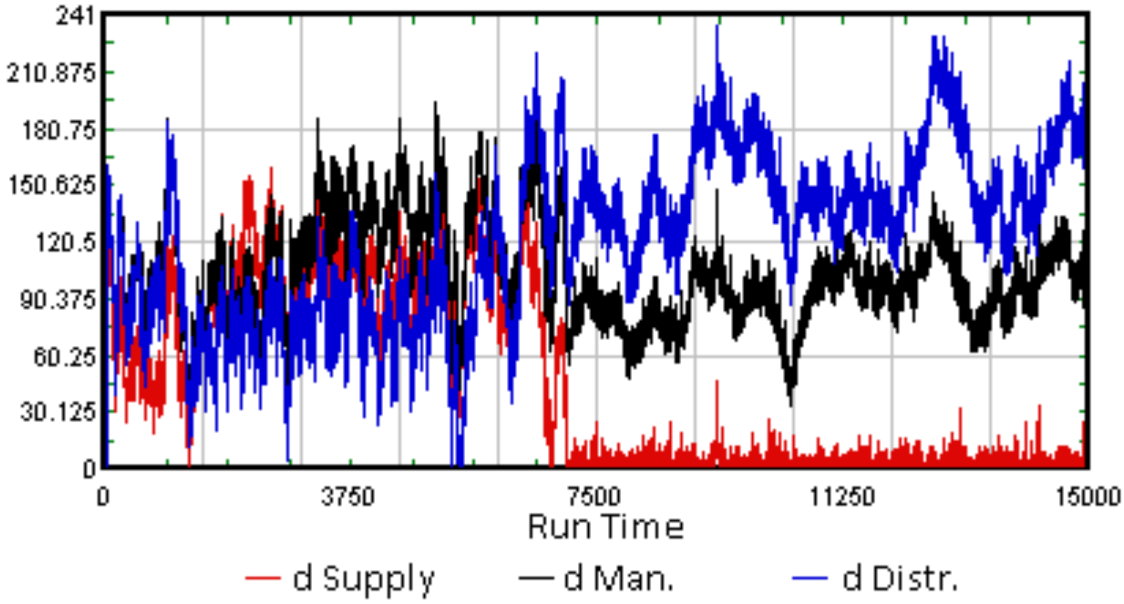

Figure 4-7. Distributed Demand Level Comparison for each Demand Buffer on HEKC-II with DE = 0 and Base Stock = 100

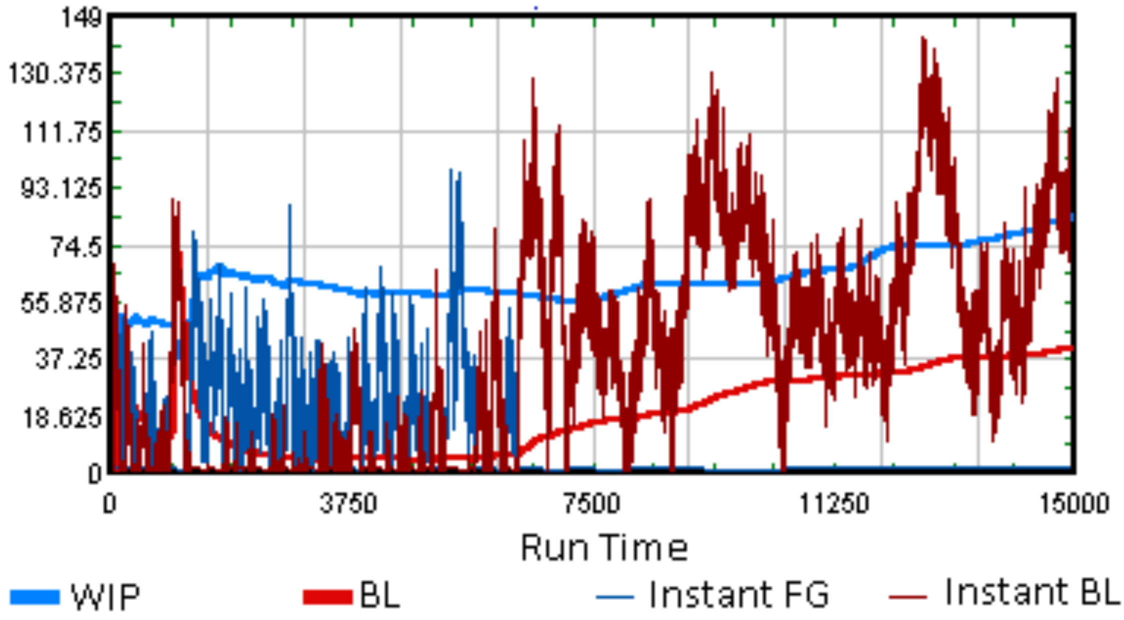

Figure 4-8. WIP and BL Plot Displaying Instant Variations of the Finished Goods Buffer (blue) and BL (red) on HEKC-II with DE = 0 and Base Stock = 100

When the additional demand is added to avoid starvation, the production works effectively maintaining a controlled level of both metrics as on Figure 4-9 and Figure 4-10. This was a Pareto-optimum result with DE=1, which represents just 10% of the demand rate. So, during times of low demand, the production for a given workstation was decelerated by 90% to avoid the predicted oversupply.

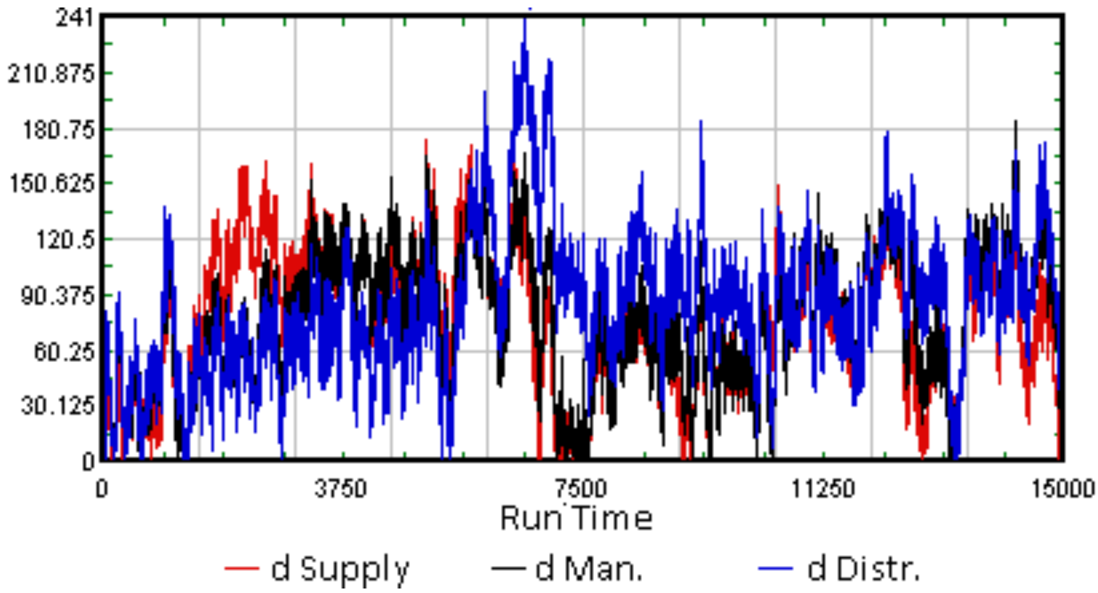

Figure 4-9. Distributed Demand Level Comparison for each Demand Buffer on HEKC-II with Pareto-Optimum Setting: DE = 1 and Base Stock = 20

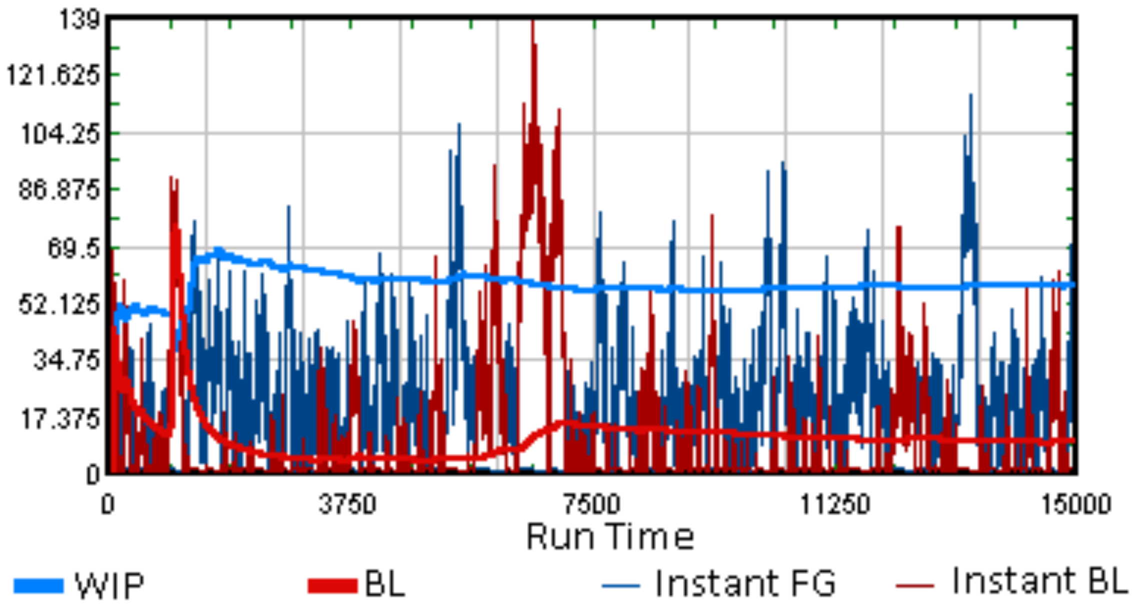

Figure 4-10. WIP and BL Plot Displaying Instant Variations of the Finished Good Buffer (blue) and BL (red) on HEKC-II with the Pareto-Optimum Setting: DE = 1 and Base Stock = 20

It is important to note that this DE parameter is optimisable from 0 to 10 in this research. Therefore, it allows for any of the HEKC-II strategies under investigation to be fully overwritten, when DE=10 for instance. It also allows them to operate exactly like the HKC but without the distributed demand capacity of the limiting production authorisation, thus using the DE range only to an extent beneficial to the lowering of the two objectives.

The Master Pool (MP) parameter was meant to precisely quantify the exact amount by which the number of authorisation cards should be increased, instead of using a random or a constant value of increase.

MP is linked to all Kanban and CONWIP loops and it operates the dynamic allocation according to the above-mentioned formulas, prioritising the local inventory to quickly cope with increased demand and erratic supply, by allowing higher throughput and improving the likelihood of maximum use of spare capacity, while keeping a low inventory and responding to the pull-type production strategy signals.

Figures 4-11 display the highly positive impact of the dynamic allocation, with the Master Pool of 120. In comparison with the Figure 4-10, it displays a significant decrease in the backlog peak times on multiple instances, as well as the average backlog, the metric recorded by the genetic optimiser decision of non-dominated solutions.

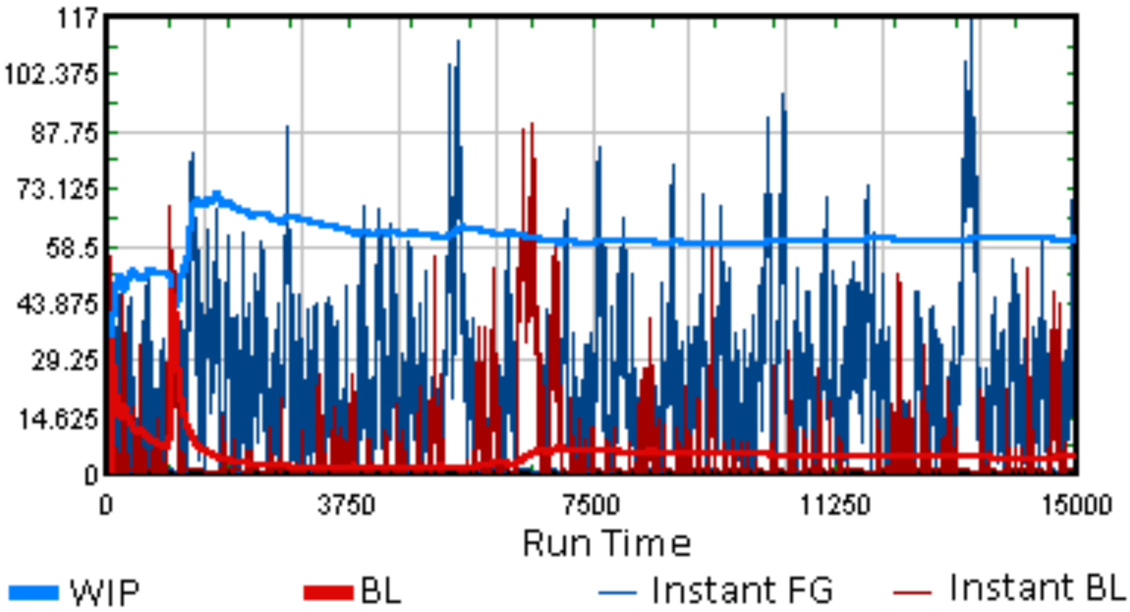

Figure 4-11. WIP and BL Plot Displaying Instant Variations of the Finished Good Buffer (blue) and BL (red) on DNC HEKC-II. Setting with added MP: DE = 1, Base Stock = 20 and added MP=120

CHAPTER 5. EXPERIMENTAL RESULTS

5.1. INTRODUCTION

The experimental results of this research are classified and presented here in this chapter according to the level of processing time variability and the rate of recycled supply for each simulated scenario. Firstly, it specifies the extension of the solution space for individual strategies under analysis. Secondly, the Pareto-optimum performance frontiers are presented with the final set of non-dominated responses defining the superior performing production control strategy, which is the main objective of this entire research.

The Pareto frontier, as provided throughout this chapter, clearly displays the direct trade-off between the conflicting performance metrics, for this research: The BL and WIP minimisation, while it could also be other comparable sets of multi-objectives to be optimised through an evolutionary algorithm.

Even a small shift forward of the performance frontier means a measurable and consistent improvement in the productivity enabled by a superior and more efficient production control strategy. This occurs by the PCS providing the capability of maintaining lower inventories along the CLSC while delivering faster response times to the stochastic customer demand. Therefore, it provides a clear development on the quality and efficiency of the industrial operations under investigation and to the entire supply chain management as well, because the development of production control strategy and the supply chain optimisation share similar technical features in terms of the control logic.

5.2. EXPERIMENTAL RESULTS FOR SCENARIOS WITH UPPER PROCESSING TIME VARIABILITY AND 90% RETURNED MATERIALS

The description of the percent-based amount of the searched experimental space for each strategy and the number of solutions found through the evolutionary optimisation process are displayed in Table 5-1 that follows. It is noticeable that the percentage of space searched for all scenarios was meant to be within a similar range so allowing for equal chances for all strategies to find the most optimum solutions.

Table 5-1. Solutions per Strategy for High Processing Time Variability and 90% of Returned Materials

	No. of Solutions on the Pareto	No. of Generations	Percentage of Space Searched
DNC HEKC-II 90 HV	330	2274	3.76E-04 %
DNC HKC 90 HV	255	1580	6.00E-04 %
HEKC-II 90 HV	270	2413	3.75E-04 %
HKC 90 HV	150	480	2.50E-04 %

Summarising from Figures 5-1 and 5-2, it is conclusive, for this system setting, that the dynamic allocation strategies achieved significant shift forward of the performance frontier and the DNC HEKC-II had the highest overall effectiveness in managing the lowest possible inventory level while lowering the backlog of customer demand.

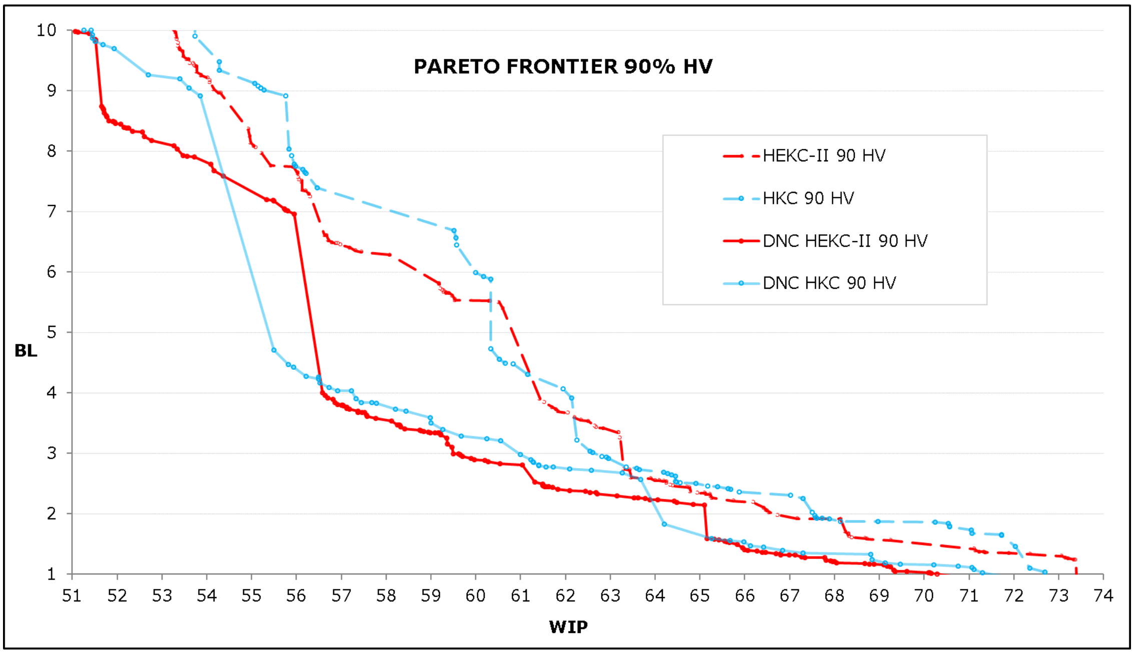

Figure 5-1. Pareto Optimum Performance Frontier, High Processing Time Variability and 90% of Returned Materials - Lower WIP Range

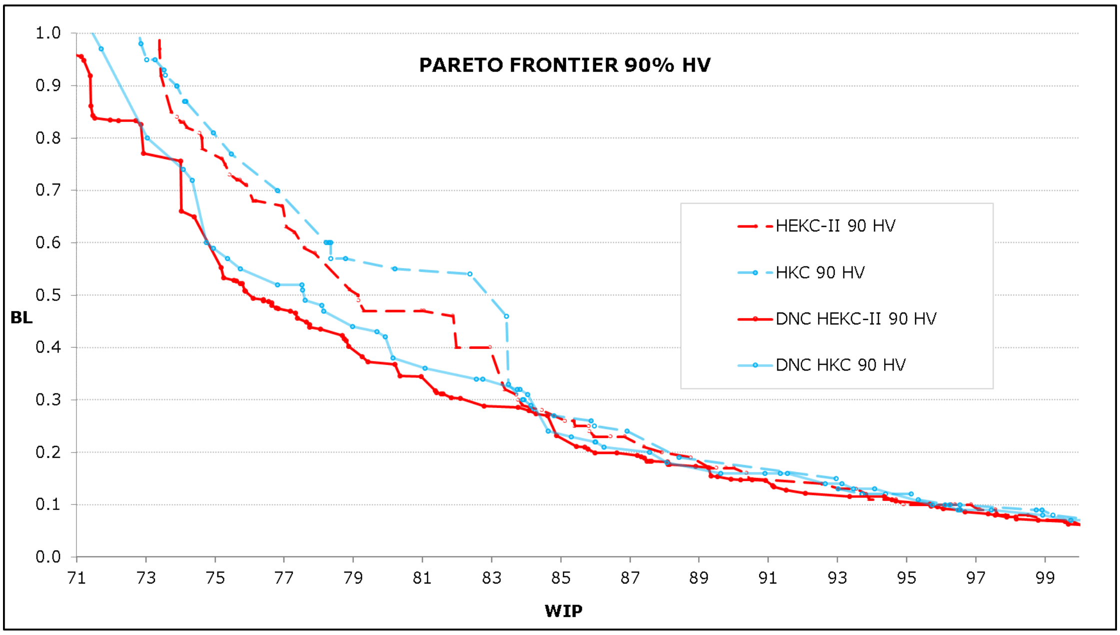

Figure 5-2. Pareto Optimum Performance Frontier, High Processing Time Variability and 90% of Returned Materials - Lower BL Range

Similarly, from Figures 5-1 and 5-2, it is also proven that the modified strategy HEKC-II outperformed the control group HKC for the most part of the solution space, with up to 10% decrease in the backlog. For instance, when BL=5.5, while the DNC HEKC-II enabled the backlog reduction up to 50%, for instance when BL=3.9, maintaining the similar WIP and in comparison, with the same referential of the HKC.

The DNC HEKC-II also performed better in comparison with the DNC HKC, with gains of over 10% in BL in some cases. When the BL is very low, below 0.1 the differences among all strategies are diminished because the stochastic demand can have massive surges that will always place a record on the average BL.

The optimised number of authorisation cards for each of the non-dominated points on the frontier are provided in the Appendices B2 to B5. They detail the level of each parameter and cards allocated at each of the Pareto-optimum solution.

5.3. EXPERIMENTAL RESULTS FOR SCENARIOS WITH LOWER PROCESSING TIME VARIABILITY AND 90% RETURNED MATERIALS

The percentual amount of the searched space for each strategy and the number of solutions found through the optimisation process are displayed on the following Table 5-2. The percentage of space searched was meant to be within a similar range so equally allowing all strategies to find optimum solutions.

Table 5-2. Solutions per Strategy for Lower Processing Time Variability and 90% of Returned Materials

	No. of Solutions on the Pareto	No. of Generations	Percentage of Space Searched
DNC HEKC-II 90 LV	621	2272	3.36E-04 %
DNC HKC 90 LV	270	473	5.00E-04 %
HEKC-II 90 LV	529	2313	3.41E-04 %
HKC 90 LV	264	471	2.00E-04 %

Concluding from Figures 5-3 and 5-4, for this given setting, the DNC HEKC-II also had superior performance efficiency in minimising both metrics, similar to the system with upper variability.

In this scenario, the advantage was present throughout the entire range of solutions on the frontier. Both dynamic allocation strategies provided considerable performance improvement.

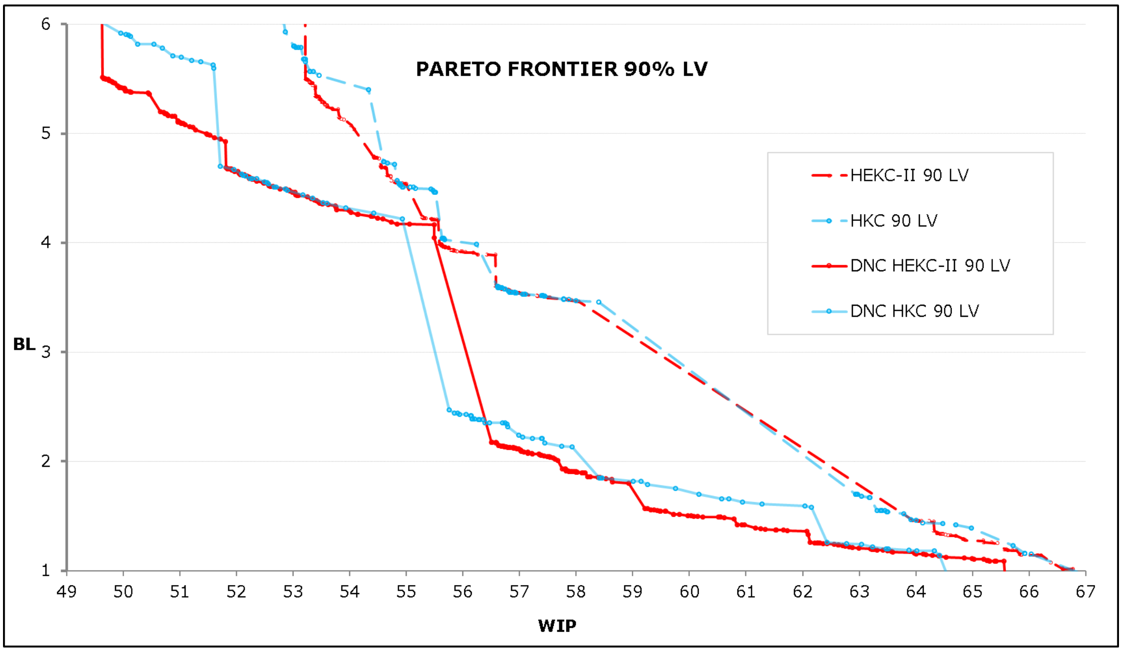

Figure 5-3. Pareto Optimum Performance Frontier, Lower Processing Time Variability and 90% of Returned Materials - Lower WIP Range

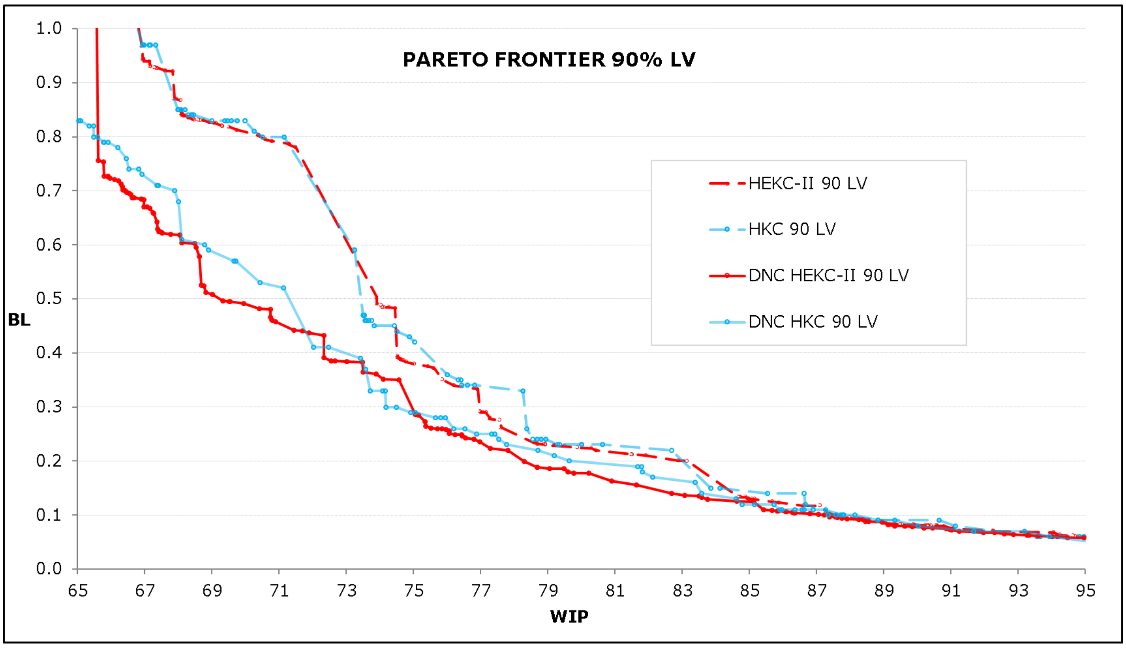

Figure 5-4. Pareto Optimum Performance Frontier, Lower Processing Time Variability and 90% of Returned Materials - Lower BL Range

It is also established that the DNC HEKC-II had backlog reduction of about 30%, for instance when its BL=0.7 outclassing the control group HKC and maintaining similar WIP. The modified HEKC-II strategy for the most part of its Pareto frontier had a marginal improvement, but positive, in comparison with the same referential of the HKC, with a few points having a minor decrease in backlog for instance when BL had high values.

The DNC HEKC-II had better performance in comparison with the DNC HKC as well, with gains of up to 20% when BL=0.5 for example. When the BL is very low, below 0.1 the differences among strategies are very minimum due to the random demand that requires high numbers of parts in the finished good buffer to cope with variability.

Full details on the optimised number of authorisation cards for each of the Pareto solutions are provided in the Appendices B6 to B9, they detail the level of each parameter at each of the frontier point.

5.4. EXPERIMENTAL RESULTS FOR SCENARIOS WITH UPPER PROCESSING TIME VARIABILITY AND 40% RETURNED MATERIALS

The amount of research space for all strategies and the number of solutions found through the optimisation process are displayed on table 5-3 that follows. The percentage of space was meant to be within a similar range so equally allowing all strategies to find optimum solutions.

Table 5-3. Solutions per Strategy for High Processing Time Variability and 40% of Returned Materials

	No. of Solutions on the Pareto	No. of Generations	Percentage of Space Searched
DNC HEKC-II 40 HV	322	2596	7.30E-04 %
DNC HKC 40 HV	251	1537	2.70E-04 %
HEKC-II 40 HV	425	2983	2.00E-03 %
HKC 40 HV	234	1260	8.00E-03 %

From Figures 5-5 and 5-6, according to this system setting, the dynamic allocation strategies achieved significant shift forward of the performance frontier and the DNC HKC had very slightly higher efficiency in managing the inventory level while lowering the backlog of customer demand.

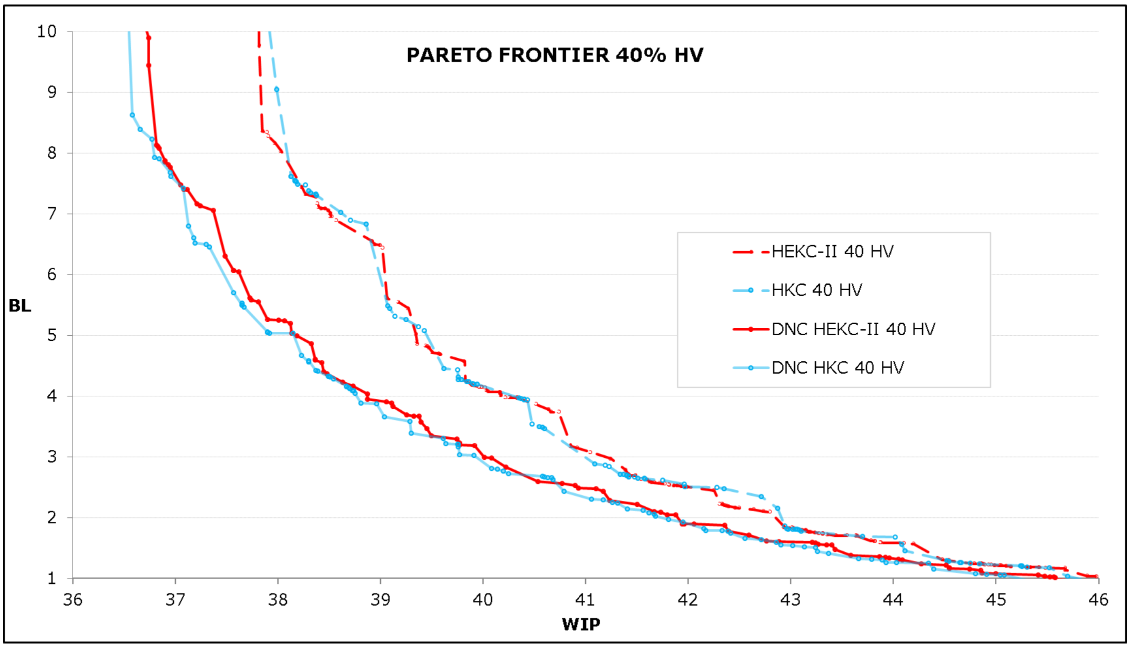

Figure 5-5. Pareto Optimum Performance Frontier, High Processing Time Variability and 40% of Returned Materials - Lower WIP Range

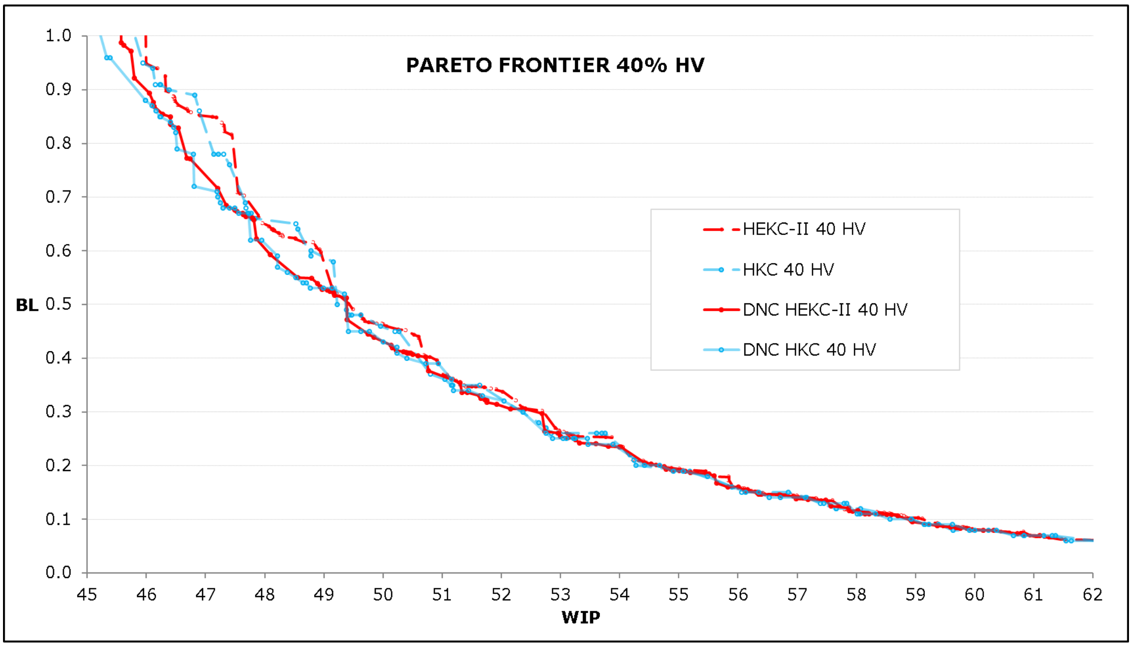

Figure 5-6 Pareto Optimum Performance Frontier, High Processing Time Variability and 40% of Returned Materials - Lower BL Range

Similarly, from Figures 5-5 and 5-6 it is displayed that when the BL is below 1 the differences among all strategies are very minimal because even the dynamic allocation only is operational when finished good buffers had less than 4 parts in stock, which is not often the case here with lower variability of supply that allows for very low WIP overall.

For solutions with low WIP, both dynamic allocation strategies outperformed the control group HKC, with up to 40% decrease in backlog for instance when BL=5 and WIP=38.

Very minimum performance difference between the DNC HEKC-II in comparison with the DNC HKC, likewise between HEKC-II and HKC. However, it is noticeable that HEKC-II maintained a likelihood of keeping slightly higher WIP and lower BL in relation the HKC, but this slope of the trade-off between both metrics did now allow for a forward shift of the performance frontier.

The optimised number of authorisation cards for each of the non-dominated point on the frontier are provided in the Appendices C1 to C4, they detail the level of each parameter and cards allocated at each of the Pareto-optimum solution.

5.5. EXPERIMENTAL RESULTS FOR SCENARIOS WITH LOWER PROCESSING TIME VARIABILITY AND 40% RETURNED MATERIALS

The percentual amount of the searched space for each strategy and the number of solutions found through the evolutionary optimisation process are displayed on the following Table 5-4. The percentage of space was intended to be within a similar range so equally allowing all control mechanisms to find optimum solutions.

Table 5-4. Solutions per Strategy for Lower Processing Time Variability and 40% of Returned Materials

	No. of Solutions on the Pareto	No. of Generations	Percentage of Space Searched
DNC HEKC-II 40 LV	457	2040	7.10E-04 %
DNC HKC 40 LV	251	1537	2.60E-04 %
HEKC-II 40 LV	756	3436	2.00E-03 %
HKC 40 LV	405	1325	8.00E-03 %

Concluding from Figures 5-7 and 5-8, according to this setup, the dynamic allocation strategies achieved significant shift forward of the performance frontier and the DNC HKC had very slightly higher efficiency in minimising both metrics simultaneously, especially with lower backlog levels.

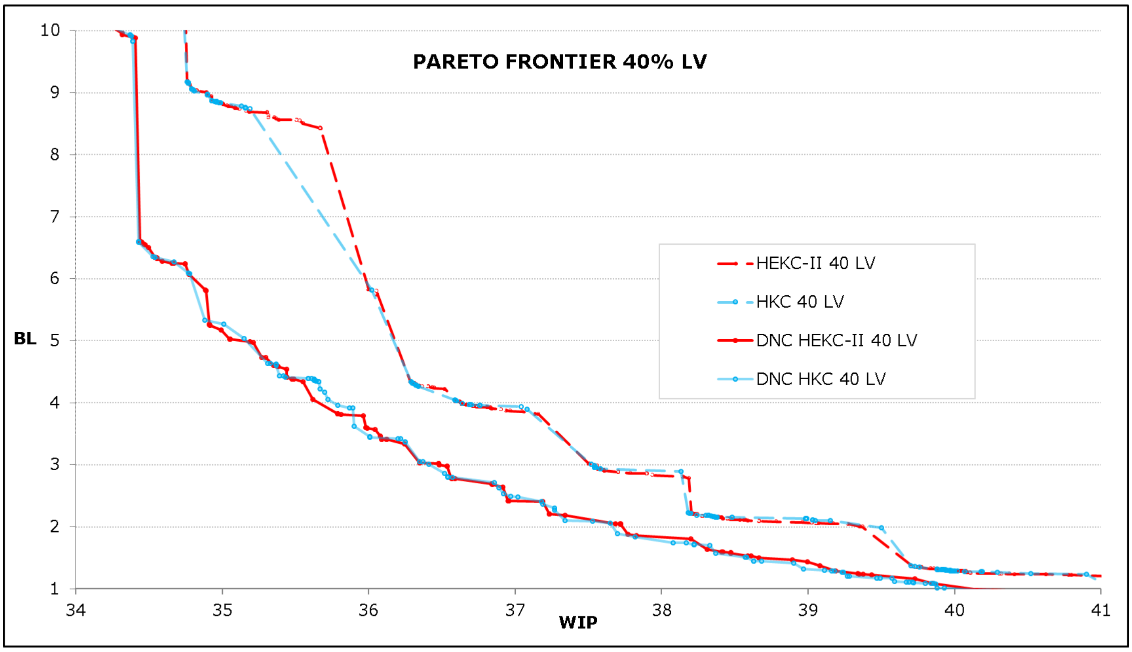

Figure 5-7. Pareto Optimum Performance Frontier, Lower Processing Time Variability and 40% of Returned Materials - Lower WIP Range

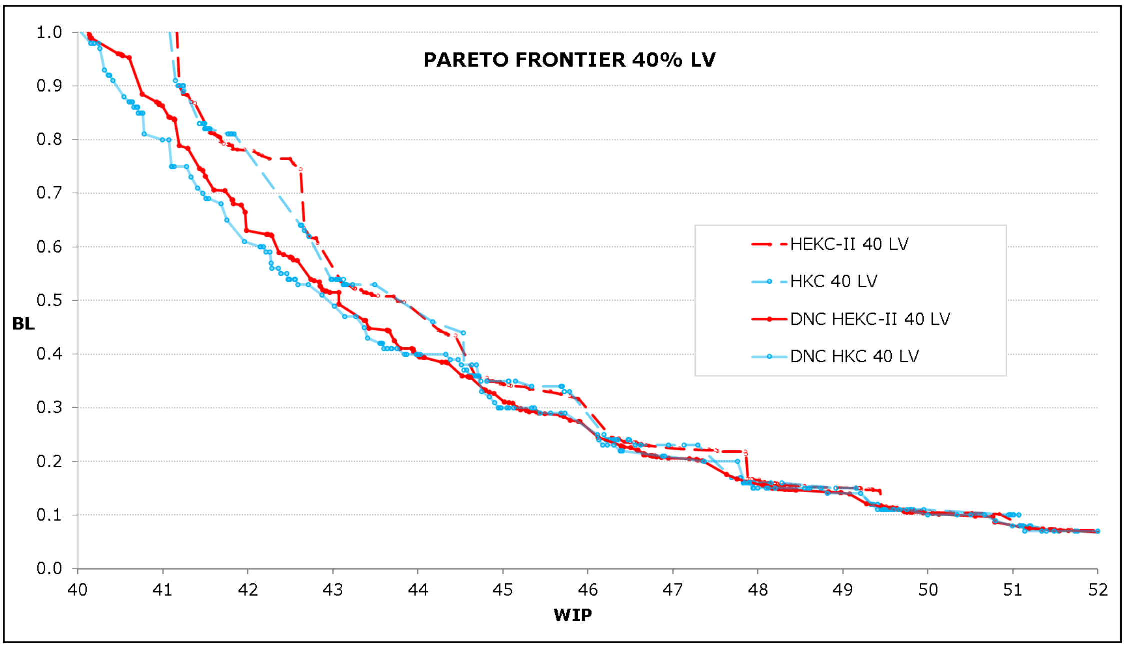

Figure 5-8. Pareto Optimum Performance Frontier, Lower Processing Time Variability and 40% of Returned Materials - Lower BL Range

Equally, from Figures 5-7 and 5-8, when the BL is below 0.3 the differences among all strategies are very minimal because the dynamic allocation is only operational when finished good buffers had less than 4 parts in stock, which is not often the case here, with lower variabilities that allow for very low WIP overall.

Aimed at solutions with low WIP range, both dynamic allocation strategies outperformed the control group HKC, with up to 45% decrease in backlog for instance when BL=5 and WIP=35.

Very minimum performance difference between the DNC HEKC-II in comparison with the DNC HKC, similarly between HEKC-II and HKC. However, it is noticeable that HEKC-II maintained a likelihood of keeping slightly higher WIP and lower BL in relation the HKC with a very small advantage for the HEKC-II throughout most of the solution space. Nevertheless, the slope of the trade-off between both metrics did now allow for a forward shift of the performance frontier.

The optimised number of authorisation cards for each of the points on the frontier are provided in the Appendices C5 to C8, they detail the level of each parameter and cards allocated at each of the Pareto solution.

5.6. RELATIONSHIP BETWEEN BACKLOG (BL) AND SERVICE LEVEL (SL)

The service level is in many cases described in the literature as an important performance metric as an unmatched customer demand if not immediately satisfied may lead to lost market share. SL is usually calculated by the ratio of number of demand created and number of orders immediately satisfied by a finished good ready for delivery on the final buffer. When a demand is backlogged, it decreases the customer service level responsiveness. Therefore, there is a direct relationship between keeping a high service level and a low backlog of demands.

Two examples are provided here, both with upper processing time variability, one with 90% returned materials and another one with 40% as they represent distinct WIP range. So, the cards allocation optimised settings were re-run to calculate the service level for the same setting in order to establish the correlation, as detailed in Figures 5-9 and 5-10.

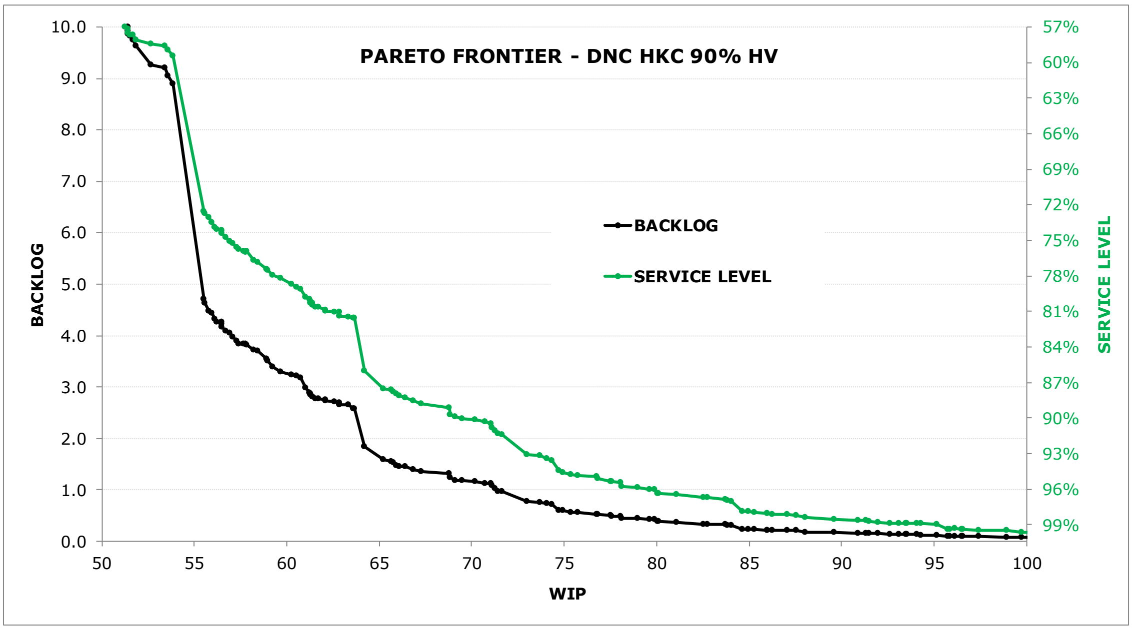

Figure 5-9. DNC HKC – Relation between BL and SL - High Processing Time Variability and 90% of Returned Materials

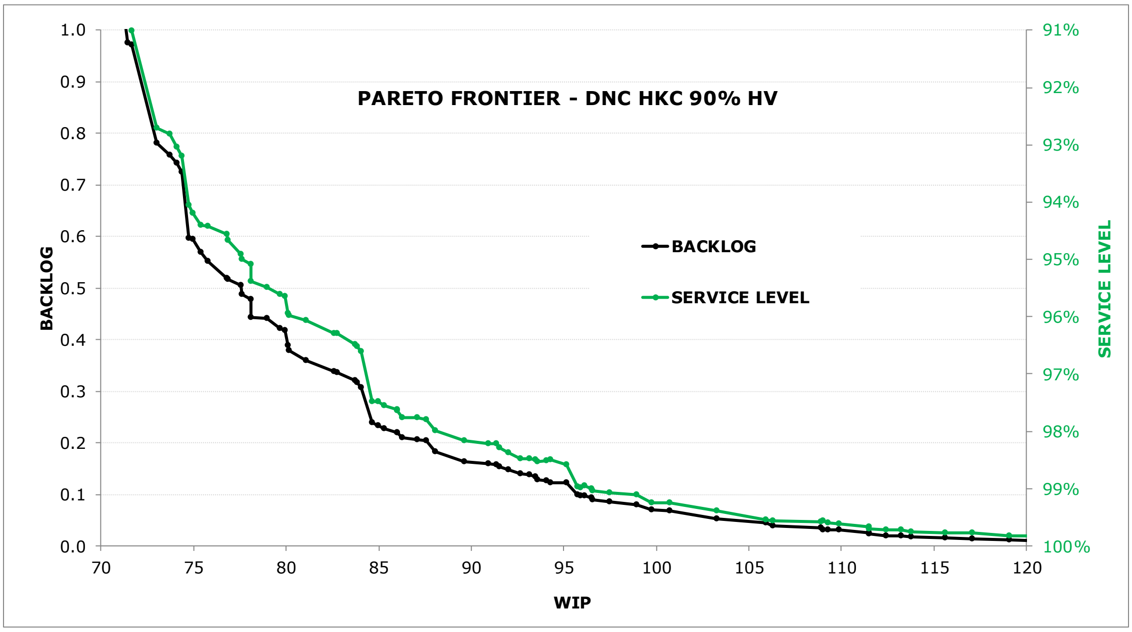

Figure 5-10. DNC HKC – Relation between BL and SL - High Processing Time Variability and 90% of Returned Materials- WIP Range for High Service Level Results

In Figures 5-11 and 5-12 it is displayed the Pareto curve for the lower percentage of recycled supply, so with more raw material readily available, the WIP range is much lower, thus providing different ratios between BL and SL.

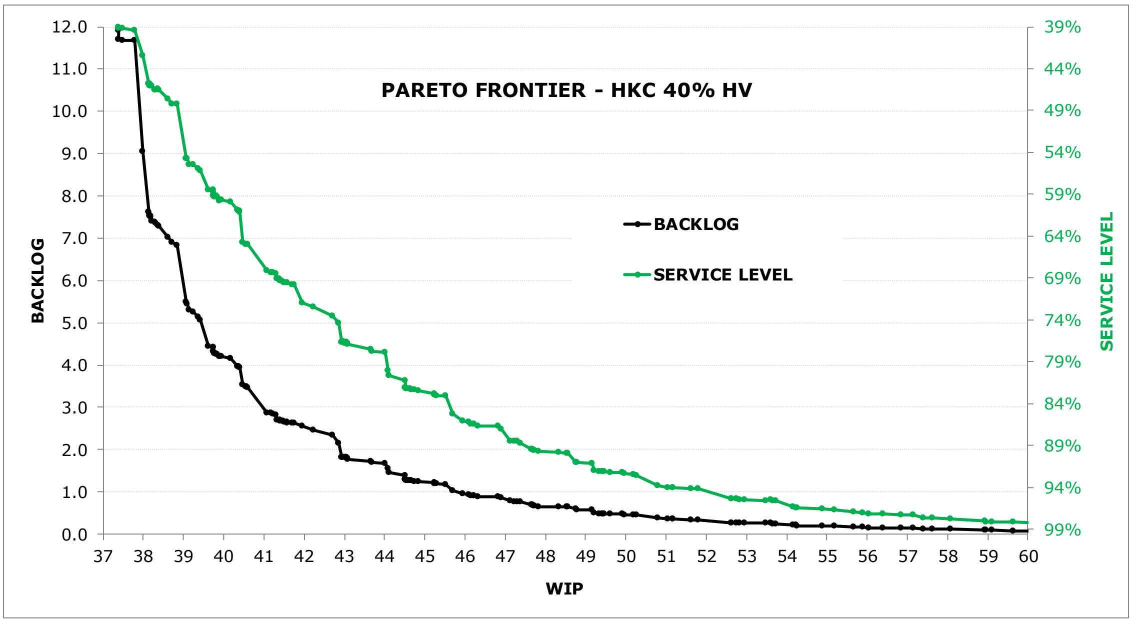

Figure 5-11. HKC – Relation between BL and SL - High Processing Time Variability and 40% of Returned Materials

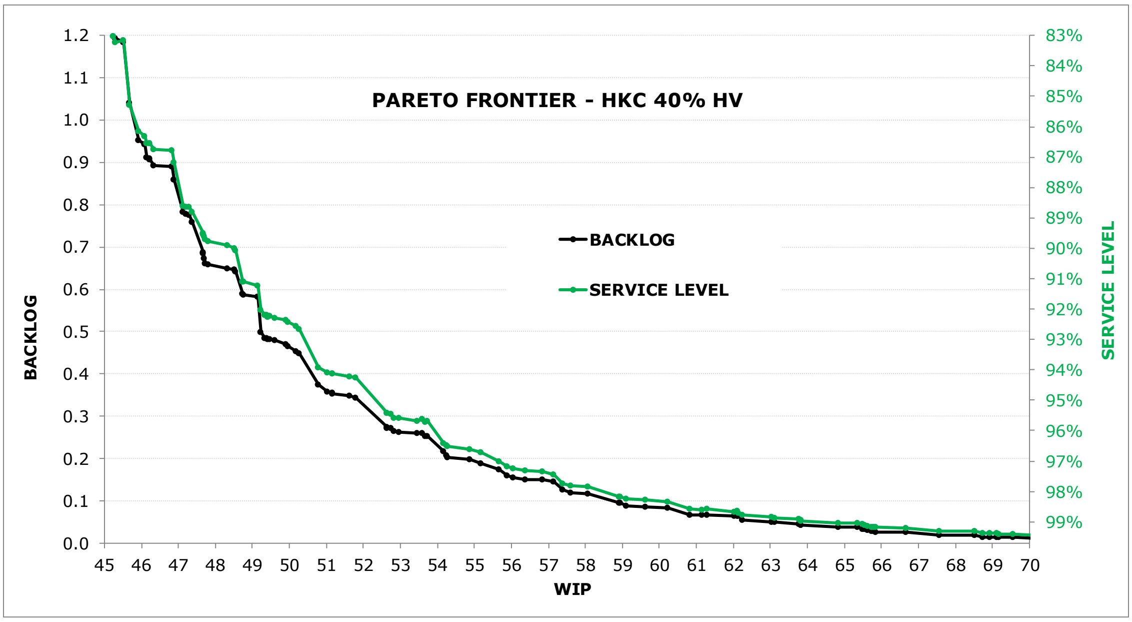

Figure 5-12. HKC – Relation between BL and SL - High Processing Time Variability and 40% of Returned Materials – WIP Range for High Service Level Results

It is worth mentioning that to achieve a 90% service level on the scenario with a higher rate of stochastic recycled supply, a BL of 1.12 is needed. While for lower rates of recycled supply, a BL must be much lower at 0.66. This happens because the WIP is much higher in the first scenario, 70 and 47.8 respectively, therefore the number of parts in the finished goods buffer is much higher, so allowing for customer demand to be more likely and more often satisfied immediately and making the same 90% service level achievable even with the higher backlog of 1.12.

Appendices D1 and D2 provide the detailment for all three metrics (SL, WIP, and BL) at each point of the Pareto performance frontier in order to establish a referential.

5.7. SUMMARY

The dynamic allocation policies, particularly the Dynamic Hybrid Extended Kanban CONWIP special case (DNC HEKC-II), throughout the research space in consideration, evidenced very superior production control performance overall.

The proposed factors on the modification approach, namely: I) The Master Pool (MP) to decide the quantifiable level of the authorisation cards dynamic change and, II) The additional demand communication (DE) to provide slower production pace during low demand periods and to avoid the distributed demand starvation. Both provided a measurable development on the inventory management and operations efficiency for the tested strategies implemented in a Closed-Loop Supply Chain environment, as demonstrated in this chapter.

Significant performance improvement was achieved through the multi-objective optimisation, which directly correlates to the technological viability of the CLSCs strength to cope with a high degree of variabilities simultaneously derived from the processing times, supply and demand. This contribution also provided grounds for the architecture of the Intelligent Self-Designing production control strategy as proposed in Chapter 7.

The dynamic allocation strategies with results provided here in this chapter had very tight constraints with regards to the allowable range of PACs available. They had less cards available and they would only have had an equal range of cards after the dynamic change triggered it, so it was even more restricted in order to keep the validity for the comparative analysis against the control group HKC.

Scenarios with 40% recycled supply had less observable improvements because of the dynamic change being operational less often and due to the lower variability of the reverse logistics.

The HEKC-II, modified from the work of Dallery and Liberopoulos [4], had better results than HKC by Bonvik et al. [3] in scenarios with higher variability of supply with 90% returned material. It matched the control group HKC results with a lower variability of supply. It also provided grounds for the suggested improvements and flexibilisation of the HEKC Control Strategy.

Appendices B1 to C8 provides more details of the evolutionary optimisation processes with PAC allocation settings for all scenarios investigated.

CHAPTER 6. DATA ANALYTICS

6.1. ROBUSTNESS TEST

The robustness test is designed to compare how well a production strategy can deal with an external stress or perturbation without losing its original optimised performance while still maintaining the multi-objective metrics with minimum or no change [87].

This section provides the robustness test results organised according to the level of processing time variability and the rate of recycled supply. All tests were performed to increased system workload from 85% to 95%, with a total of 30 points equally distributed in this range and with the optimised PAC settings targeted at 0.5 backlog, so prioritising a high rate of service level over WIP. The decision factors for the test were defined via the Latin Hypercube Sampling (LHS) technique in the JMP software by SAS. The stochastic dominance evaluation was performed in all scenarios by means of ModelRisk from Vose Software.

It is also proposed here a differentiated stochastic dominance test analysed with the multi-objective. It is a direct trade-off display of both objectives reaction to the added perturbation. This enables the instant analysis of how a strategy can manage the stress while maintain original performance.

6.1.1. WIP and BL Robustness to Increased System Workload – Upper Variability and Higher Rate of Recycled Supply

The optimised production system setting used for the execution of the robustness tests for WIP and BL was according to the following Table 6-1.

Table 6-1. Authorisation Cards Setting Optimised at BL 0.5 for the Robustness Test - HV 90%

DNC HEKC-II														
CWn	**CWr**	**CWe**	**CWf**	**Ks**	**Ksr**	**Kr**	**MP**	**Kf**	**Km**	**Kmf**	**Ke**	**DE**	**WIP**	**BL**
6	85	14	14	6	10	8	12	1	14	2	3	6	**76.40**	**0.49**

DNC HKC													
CWn	**CWr**	**CWe**	**CWf**	**Ks**	**Ksr**	**Kr**	**MP**	**Kf**	**Km**	**Kmf**	**Ke**	**WIP**	**BL**
6	70	13	13	4	9	7	12	1	9	3	4	**77.6**	**0.49**

HEKC-II													
CWn	**CWr**	**CWe**	**CWf**	**Ks**	**Ksr**	**Kr**	**Kf**	**Km**	**Kmf**	**Ke**	**DE**	**WIP**	**BL**
6	108	18	14	5	8	16	2	16	3	2	7	**79.15**	**0.49**

HKC												
CWn	**CWr**	**CWe**	**CWf**	**Ks**	**Ksr**	**Kr**	**Kf**	**Km**	**Kmf**	**Ke**	**WIP**	**BL**
6	104	12	17	6	7	12	2	13	3	3	**83.43**	**0.46**

The results for the demand backlog robustness test to the increased system workload from 85% to 95% are displayed in Figure 6-1.

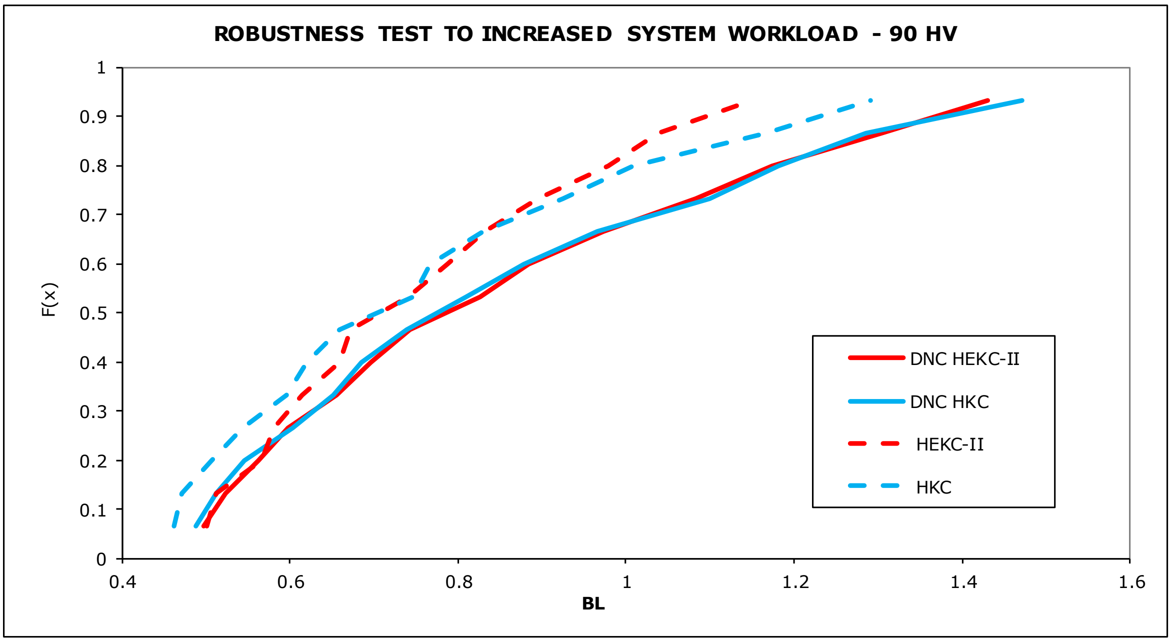

Figure 6-1. BL Cumulative Distribution Function - 90% HV

Table 6-2. BL Stochastic Dominance Test Results for Strategies at 90% HV

Dominance	DNC HEKC-II	DNC HCK	HEKC-II	HKC
DNC HEKC-II		Inconclusive	HEKC-II is 2d over DNC HEKC-II	HKC is 1d over DNC HEKC-II
DNC HCK	Inconclusive		HEKC-II is 2d over DNC HCK	HKC is 1d over DNC HCK
HEKC-II	HEKC-II is 2d over DNC HEKC-II	HEKC-II is 2d over DNC HCK		Inconclusive
HKC	HKC is 1d over DNC HEKC-II	HKC is 1d over DNC HCK	Inconclusive	

As described in Table 6-2, the ModelRisk dominance analysis, HKC is first order stochastically dominant over all other strategies and inconclusive against HEKC-II in regard to the demand backlog management.

The results for the WIP robustness to the increased system workload from 85% to 95% are displayed in Figure 6-2.

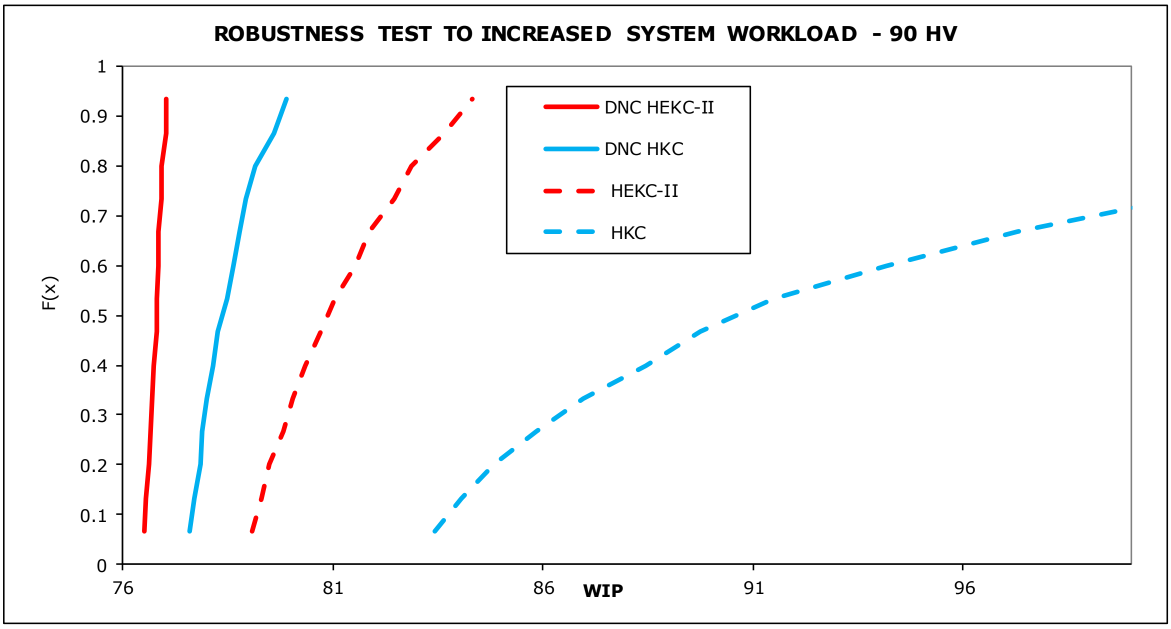

Figure 6-2. WIP Cumulative Distribution Function - 90% HV

Table 6-3. WIP Stochastic Dominance Test Results for Strategies at 90% HV

Dominance	DNC HEKC-II	DNC HKC	HEKC-II	HKC
DNC HEKC-II		DNC HEKC-II is 1d over DNC HKC	DNC HEKC-II is 1d over HEKC-II	DNC HEKC-II is 1d over HKC
DNC HKC	DNC HEKC-II is 1d over DNC HKC		DNC HKC is 1d over HEKC-II	DNC HKC is 1d over HKC
HEKC-II	DNC HEKC-II is 1d over HEKC-II	DNC HKC is 1d over HEKC-II		HEKC-II is 1d over HKC
HKC	DNC HEKC-II is 1d over HKC	DNC HKC is 1d over HKC	HEKC-II is 1d over HKC	

As described in Table 6-3, the ModelRisk dominance analysis, DNC HECK-II is first order stochastically dominant over all other strategies in regard to the WIP management.

The results for the direct trade-off between BL and WIP robustness to the increased system workload from 85% to 95% are displayed on Figure 6-3.

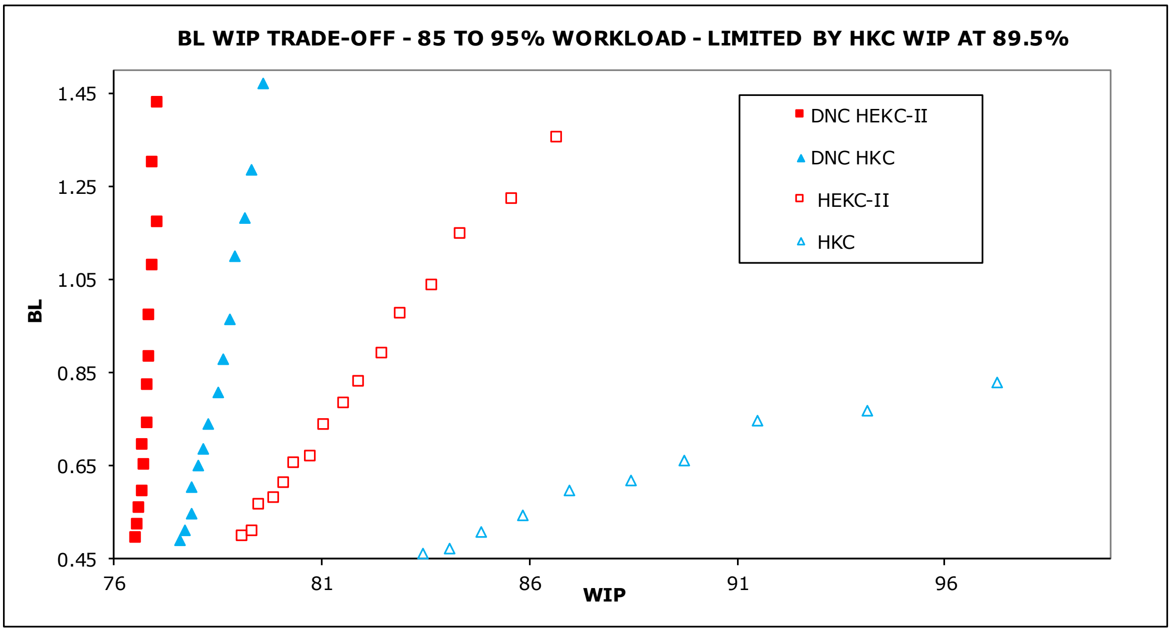

Figure 6-3. BL and WIP Direct Trade-off Data Points for the Robustness Test Analysis - 90% HV

It is important to consider both performance metrics simultaneously in order to keep an accountability of the strategy's ability to cope with the added stress in relation to or in detriment to the other metric. It is user-defined, however considering a referential ratio of 1 to 10 trade-off between the BL and WIP for the performance loss during the robustness test and a maximum acceptable limit for increasing the backlog of 1 unit.

Consequently, it provides a slope to which the multi-objective metrics can be compared against and determine which strategy maintains the loss in performance, during the added stress, more similar or closer to the tolerable trade-off slope.

Therefore, from the Figure 6-3, considering the tolerance being WIP up to 86 and BL of 1.5 as a maximum, HEKC-II is the first order stochastically dominant control strategy as it could maintain both metrics within reasonable range simultaneously.

6.1.2. WIP and BL Robustness to Increased System Workload – Lower Variability and Higher Rate of Recycled Supply

The optimised production system setting used for the execution of the robustness tests for WIP and BL was according to the following Table 6-4.

Table 6-4. Authorisation Cards Setting Optimised at BL 0.5 for the Robustness Test - LV 90%

DNC HEKC-II														
CWn	CWr	CWe	CWf	Ks	Ksr	Kr	MP	Kf	Km	Kmf	Ke	DE	WIP	BL
5	81	11	13	6	7	9	10	2	13	1	2	3	**69.33**	**0.50**

DNC HKC													
CWn	CWr	CWe	CWf	Ks	Ksr	Kr	MP	Kf	Km	Kmf	Ke	WIP	BL
5	59	15	14	6	6	12	12	2	14	4	2	**71.33**	**0.51**

HEKC-II													
CWn	CWr	CWe	CWf	Ks	Ksr	Kr	Kf	Km	Kmf	Ke	DE	WIP	BL
6	107	17	17	2	14	18	4	20	2	3	1	**73.906**	**0.49**

HKC												
CWn	CWr	CWe	CWf	Ks	Ksr	Kr	Kf	Km	Kmf	Ke	WIP	BL
6	108	13	16	3	13	21	2	18	2	5	**73.5**	**0.47**

The results for the backlog robustness to the increased system workload from 85% to 95% are displayed in Figure 6-4.

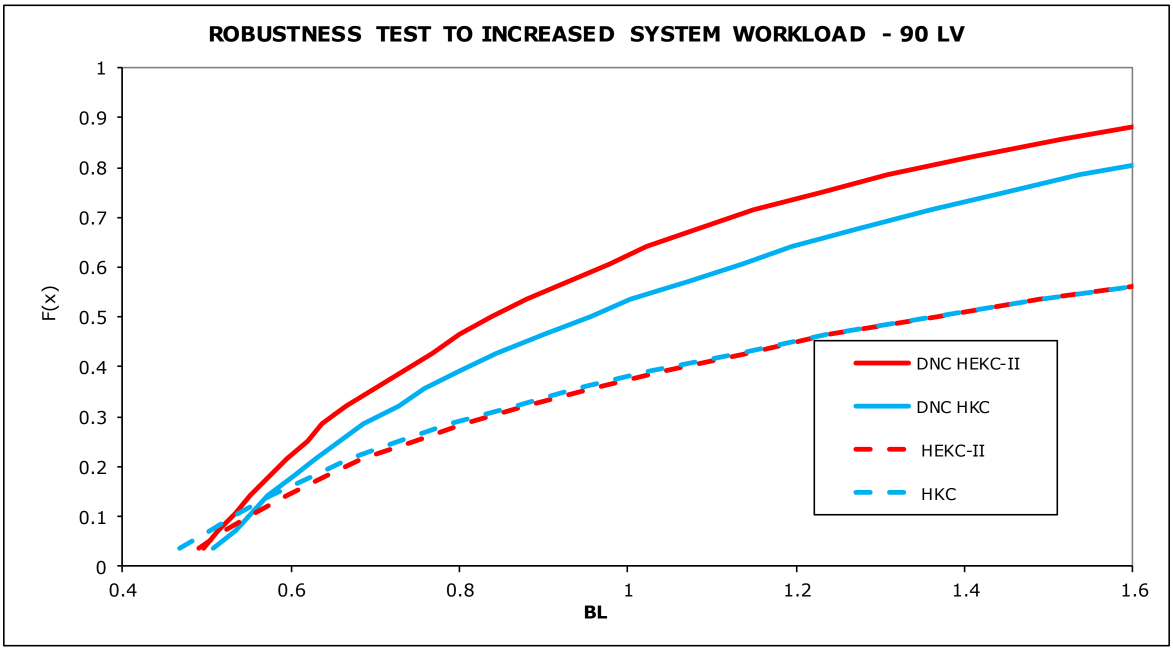

Figure 6-4. BL Cumulative Distribution Function - 90% LV

Table 6-5. BL Stochastic Dominance Test Results for Strategies at 90% LV

Dominance	DNC HEKC-II	DNC HCK	HEKC-II	HKC
DNC HEKC-II		DNC HEKC-II is 1d over DNC HCK	DNC HEKC-II is 2d over HEKC-II	DNC HEKC-II is 2d over HKC
DNC HCK	DNC HEKC-II is 1d over DNC HCK		DNC HCK is 2d over HEKC-II	DNC HCK is 2d over HKC
HEKC-II	DNC HEKC-II is 2d over HEKC-II	DNC HCK is 2d over HEKC-II		Inconclusive
HKC	DNC HEKC-II is 2d over HKC	DNC HCK is 2d over HKC	Inconclusive	

As provided in Table 6-5, the ModelRisk dominance analysis, DNC HECK-II is first order stochastically dominant over DNC HKC strategies and second order dominant against all other strategies regarding the demand backlog management.

The results for the WIP robustness to the increased system workload from 85% to 95% are displayed in Figure 6-5.

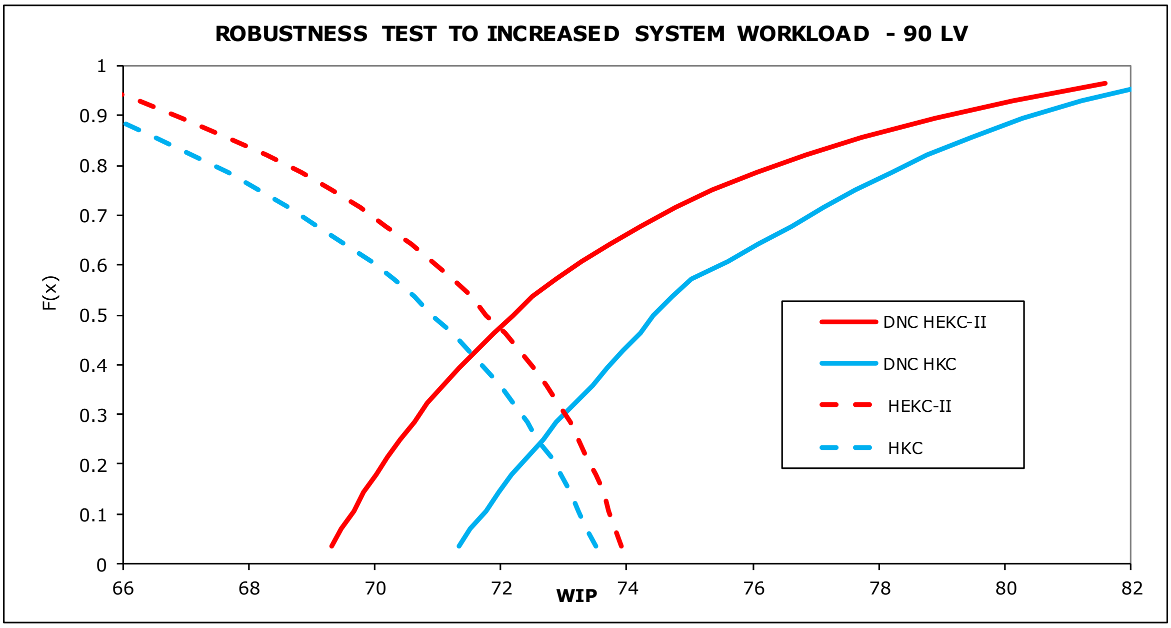

Figure 6-5. WIP Cumulative Distribution Function - 90% LV

Table 6-6. WIP Stochastic Dominance Test Results for Strategies at 90% LV

Dominance	DNC HEKC-II	DNC HKC	HEKC-II	HKC
DNC HEKC-II		DNC HEKC-II is 1d over DNC HKC	HEKC-II is 1d over DNC HEKC-II	HKC is 1d over DNC HEKC-II
DNC HKC	DNC HEKC-II is 1d over DNC HKC		HEKC-II is 1d over DNC HKC	HKC is 1d over DNC HKC
HEKC-II	HEKC-II is 1d over DNC HEKC-II	HEKC-II is 1d over DNC HKC		HKC is 1d over HEKC-II
HKC	HKC is 1d over DNC HEKC-II	HKC is 1d over DNC HKC	HKC is 1d over HEKC-II	

As designated in Table 6-6, the ModelRisk dominance analysis, HKC is first order stochastically dominant over all other in regard to the WIP management.

The results for the direct trade-off between BL and WIP robustness to the increased system workload from 85% to 95% are displayed in Figure 6-6.

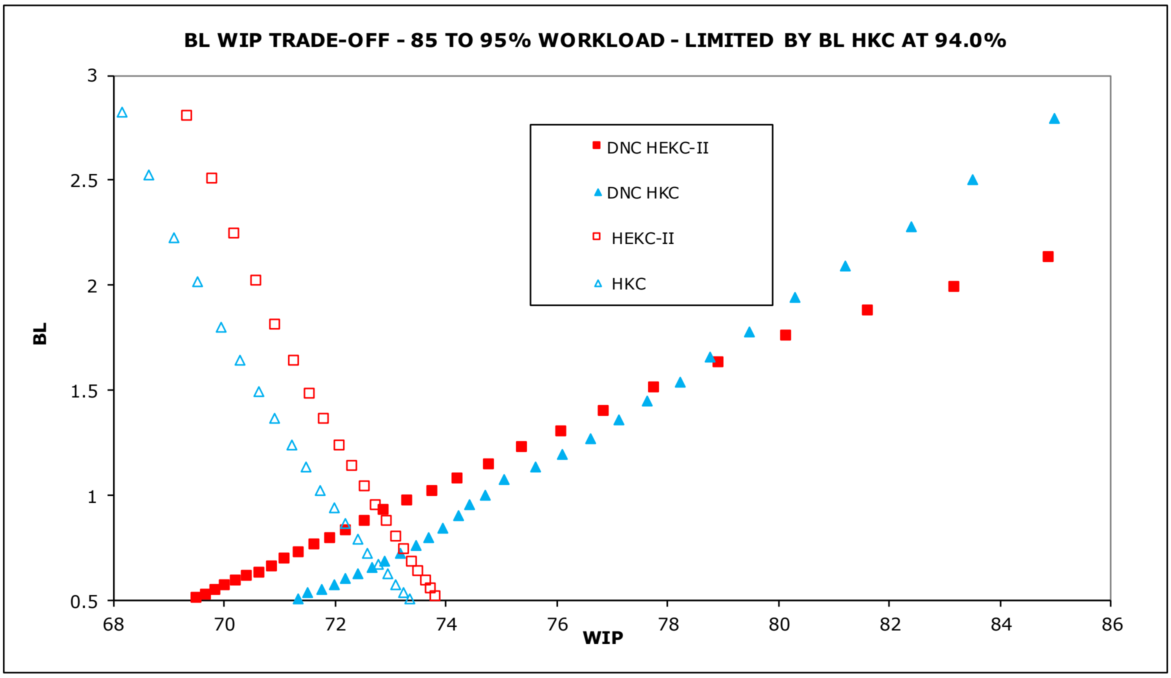

Figure 6-6. BL and WIP Direct Trade-off Data Points for the Robustness Test Analysis - 90% LV

As proposed in the previous section 6.1.2, maintaining the same referential trade-off rate of 1 to 10 in BL vs WIP and considering both performance metrics simultaneously, it provides a slope to which the multi-objective metrics can be compared against and determine which strategy maintains the loss in performance, during the added stress, more similar or closer to the tolerable trade-off slope.

Therefore, from the Figure 6-6, considering the tolerance being WIP up to 79 and BL of 1.5 as a maximum, DNC HEKC-II is the first order stochastically dominant over all other strategies as it could maintain both metrics within reasonable range simultaneously.

6.1.3. WIP and BL Robustness to Increased System Workload – Upper Variability and Lower Rate of Recycled Supply

The optimised production system setting used for the execution of the robustness tests for WIP and BL was according to the following Table 6-7.

Table 6-7. Authorisation Cards Setting Optimised at BL 0.5 for the Robustness Test - HV 40%

DNC HEKC-II														
CWn	**CWr**	**CWe**	**CWf**	**Ks**	**Ksr**	**Kr**	**MP**	**Kf**	**Km**	**Kmf**	**Ke**	**DE**	**WIP**	**BL**
26	29	7	6	8	8	3	8	4	10	4	1	4	**49.84**	**0.44**

DNC HKC													
CWn	**CWr**	**CWe**	**CWf**	**Ks**	**Ksr**	**Kr**	**MP**	**Kf**	**Km**	**Kmf**	**Ke**	**WIP**	**BL**
26	39	6	5	8	7	7	7	4	16	2	4	**49.41**	**0.45**

HEKC-II													
CWn	**CWr**	**CWe**	**CWf**	**Ks**	**Ksr**	**Kr**	**DE**	**Kf**	**Km**	**Kmf**	**Ke**	**WIP**	**BL**
26	46	6	6	10	7	6	5	4	18	1	4	**49.657**	**0.47**

HKC												
CWn	**CWr**	**CWe**	**CWf**	**Ks**	**Ksr**	**Kr**	**Kf**	**Km**	**Kmf**	**Ke**	**WIP**	**BL**
26	60	8	4	18	5	4	1	20	2	2	**49.82**	**0.47**

The results for the demand backlog robustness to the increased system workload from 85% to 95% are displayed in Figure 6-7.

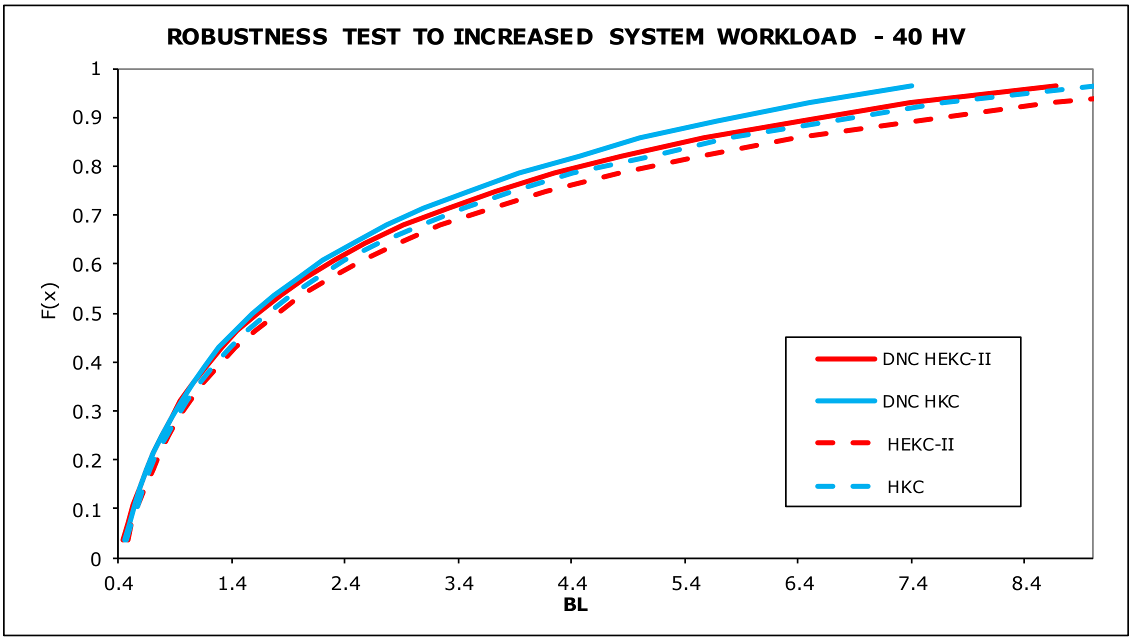

Figure 6-7. BL Cumulative Distribution Function - 40% HV

Table 6-8. BL Stochastic Dominance Test Results for Strategies at 40% HV

Dominance	DNC HEKC-II	DNC HCK	HEKC-II	HKC
DNC HEKC-II		DNC HCK is 2d over DNC HEKC-II	DNC HEKC-II is 1d over HEKC-II	DNC HEKC-II is 2d over HKC
DNC HCK	DNC HCK is 2d over DNC HEKC-II		DNC HCK is 1d over HEKC-II	DNC HCK is 1d over HKC
HEKC-II	DNC HEKC-II is 1d over HEKC-II	DNC HCK is 1d over HEKC-II		HKC is 1d over HEKC-II
HKC	DNC HEKC-II is 2d over HKC	DNC HCK is 1d over HKC	HKC is 1d over HEKC-II	

As provided in Table 6-8, the ModelRisk dominance analysis, DNC HCK is first order stochastically dominant over HECK-II and HKC strategies and second order stochastically dominant against DNC HECK-II regarding the demand backlog management.

The results for the WIP robustness to the increased system workload from 85% to 95% are displayed in Figure 6-8.

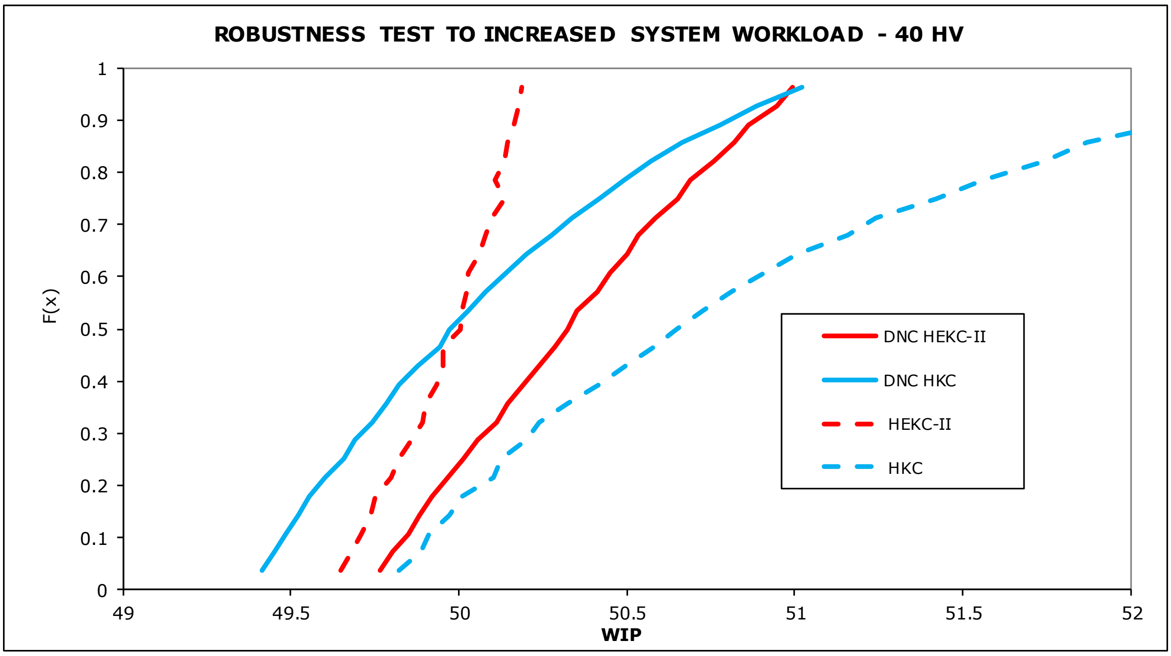

Figure 6-8. WIP Cumulative Distribution Function - 40% HV

Table 6-9. WIP Stochastic Dominance Test Results for Strategies at 40% HV

Dominance	**DNC HEKC-II**	**DNC HKC**	**HEKC-II**	**HKC**
DNC HEKC-II		DNC HKC is 2d over DNC HEKC-II	HEKC-II is 1d over DNC HEKC-II	DNC HEKC-II is 1d over HKC
DNC HKC	DNC HKC is 2d over DNC HEKC-II		HEKC-II is 2d over DNC HKC	DNC HKC is 1d over HKC
HEKC-II	HEKC-II is 1d over DNC HEKC-II	HEKC-II is 2d over DNC HKC		HEKC-II is 1d over HKC
HKC	DNC HEKC-II is 1d over HKC	DNC HKC is 1d over HKC	HEKC-II is 1d over HKC	

As described in Table 6-9, the ModelRisk dominance analysis, HECK-II is first order stochastically dominant over all other strategies but second order stochastically dominant against DNC HKC regarding the WIP management.

The results for the WIP robustness to the increased system workload from 85% to 95% are displayed in Figure 6-9.

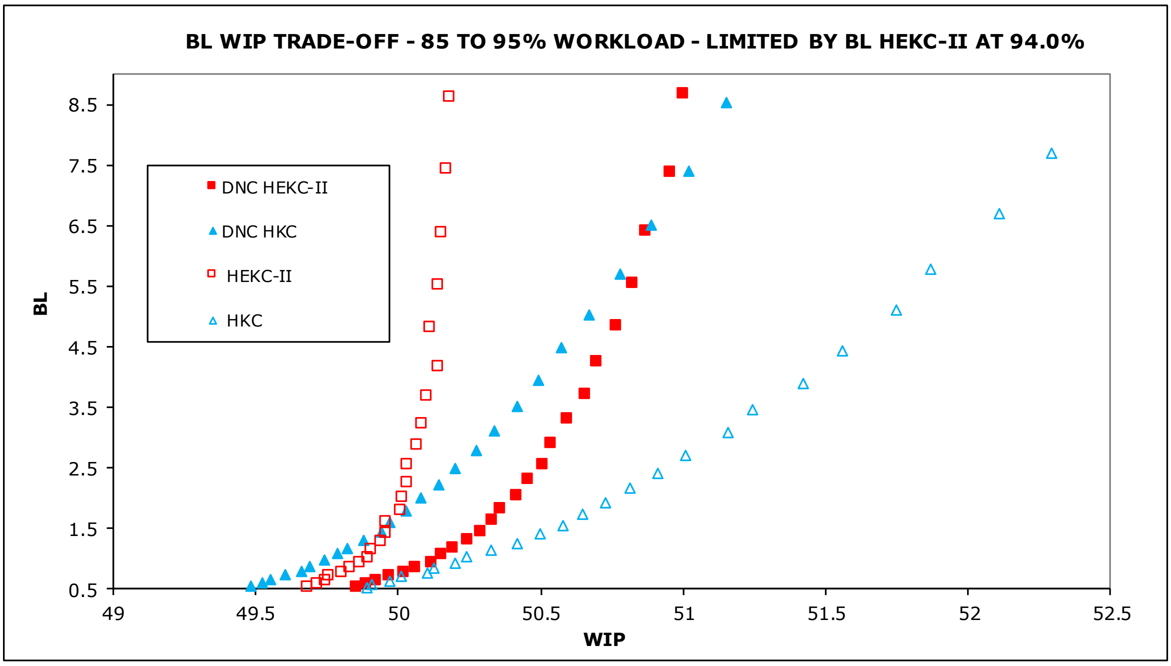

Figure 6-9. BL and WIP Direct Trade-off Data Points for the Robustness Test Analysis - 40% HV

As proposed in the previous section 6.1.2, maintaining the same referential trade-off rate of 1 to 10 in BL vs WIP and considering both performance metrics simultaneously, it provides a slope to which the multi-objective metrics can be compared against and determine which strategy maintains the loss in performance, during the added stress, more similar or closer to the tolerable trade-off slope.

Hence, from the Figure 6-9, considering the tolerance being WIP up to 59 and BL of 1.5 as a maximum, HKC is the first order stochastically dominant control strategy over all others as it could maintain both metrics within reasonable range simultaneously.

6.1.4. WIP and BL Robustness to Increased System Workload – Lower Variability and Lower Rate of Recycled Supply

The optimised production system setting used for the execution of the robustness tests for WIP and BL was according to the following Table 6-10.

Table 6-10. Authorisation Cards Setting Optimised at BL 0.5 for the Robustness Test - LV 40%

DNC HEKC-II														
CWn	CWr	CWe	CWf	Ks	Ksr	Kr	MP	Kf	Km	Kmf	Ke	DE	WIP	BL
21	45	5	4	14	8	8	6	4	12	3	2	5	**42.85**	**0.53**

DNC HKC													
CWn	CWr	CWe	CWf	Ks	Ksr	Kr	MP	Kf	Km	Kmf	Ke	WIP	BL
22	32	7	4	6	6	6	5	2	14	4	4	**42.87**	**0.51**

HEKC-II													
CWn	CWr	CWe	CWf	Ks	Ksr	Kr	DE	Kf	Km	Kmf	Ke	WIP	BL
22	30	7	3	10	4	6	9	2	18	2	1	**43.449**	**0.51**

HKC												
CWn	CWr	CWe	CWf	Ks	Ksr	Kr	Kf	Km	Kmf	Ke	WIP	BL
22	53	3	4	16	8	9	3	11	4	1	**43.49**	**0.53**

The results for the demand backlog robustness to the increased system workload from 85% to 95% are displayed in Figure 6-10.

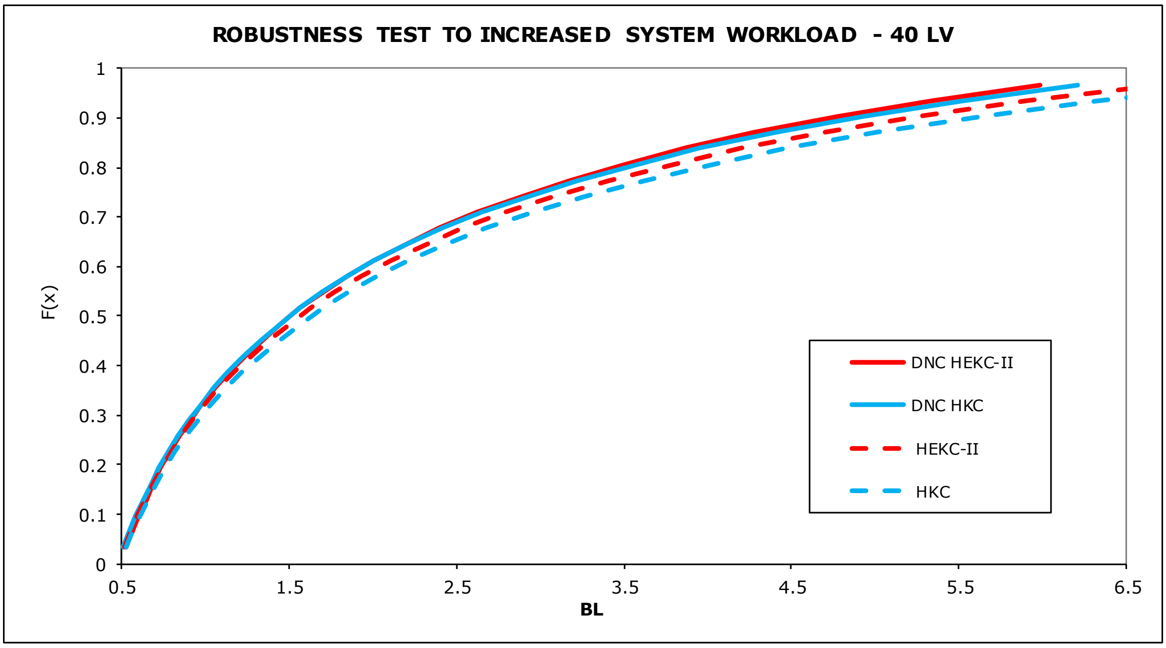

Figure 6-10. BL Cumulative Distribution Function - 40% LV

Table 6-11. BL Stochastic Dominance Test Results for Strategies at 40% LV

Dominance	DNC HEKC-II	DNC HCK	HEKC-II	HKC
DNC HEKC-II		Inconclusive	DNC HEKC-II is 2d over HEKC-II	DNC HEKC-II is 1d over HKC
DNC HCK	Inconclusive		DNC HCK is 1d over HEKC-II	DNC HCK is 1d over HKC
HEKC-II	DNC HEKC-II is 2d over HEKC-II	DNC HCK is 1d over HEKC-II		HEKC-II is 1d over HKC
HKC	DNC HEKC-II is 1d over HKC	DNC HCK is 1d over HKC	HEKC-II is 1d over HKC	

As defined in Table 6-11, the ModelRisk dominance analysis, DNC HKC is first order stochastically dominant over all strategies but inconclusive against DNC HEKC-II in regard to the demand backlog management.

The results for the WIP robustness to the increased system workload from 85% to 95% are displayed in Figure 6-11.

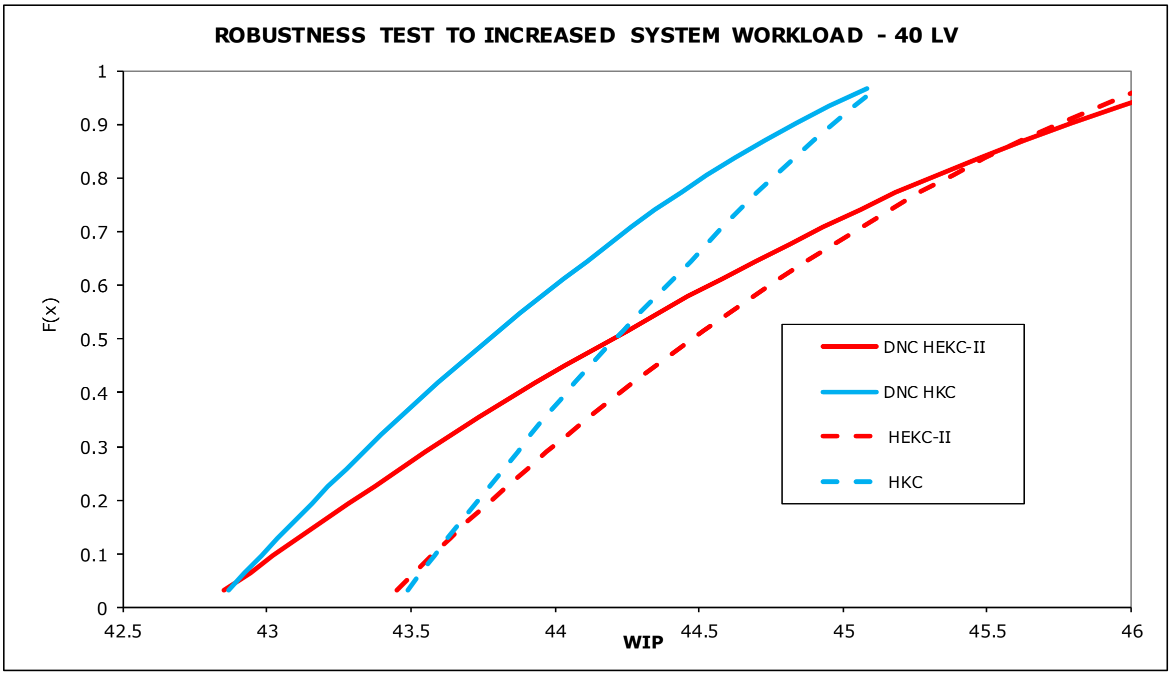

Figure 6-11. WIP Cumulative Distribution Function - 40% LV

Table 6-12. WIP Stochastic Dominance Test Results for Strategies at 40% LV

Dominance	DNC HEKC-II	DNC HKC	HEKC-II	HKC
DNC HEKC-II		DNC HKC is 2d over DNC HEKC-II	Inconclusive	HKC is 2d over DNC HEKC-II
DNC HKC	DNC HKC is 2d over DNC HEKC-II		DNC HKC is 1d over HEKC-II	DNC HKC is 1d over HKC
HEKC-II	Inconclusive	DNC HKC is 1d over HEKC-II		HKC is 2d over HEKC-II
HKC	HKC is 2d over DNC HEKC-II	DNC HKC is 1d over HKC	HKC is 2d over HEKC-II	

As described in Table 6-12, the ModelRisk dominance analysis, DNC HKC is first order stochastically dominant over all other strategies but second order stochastically dominant against DNC HEKC-II in regard to the WIP management.

The results for the direct trade-off between BL and WIP robustness to the increased system workload from 85% to 95% are plotted in Figure 6-12.

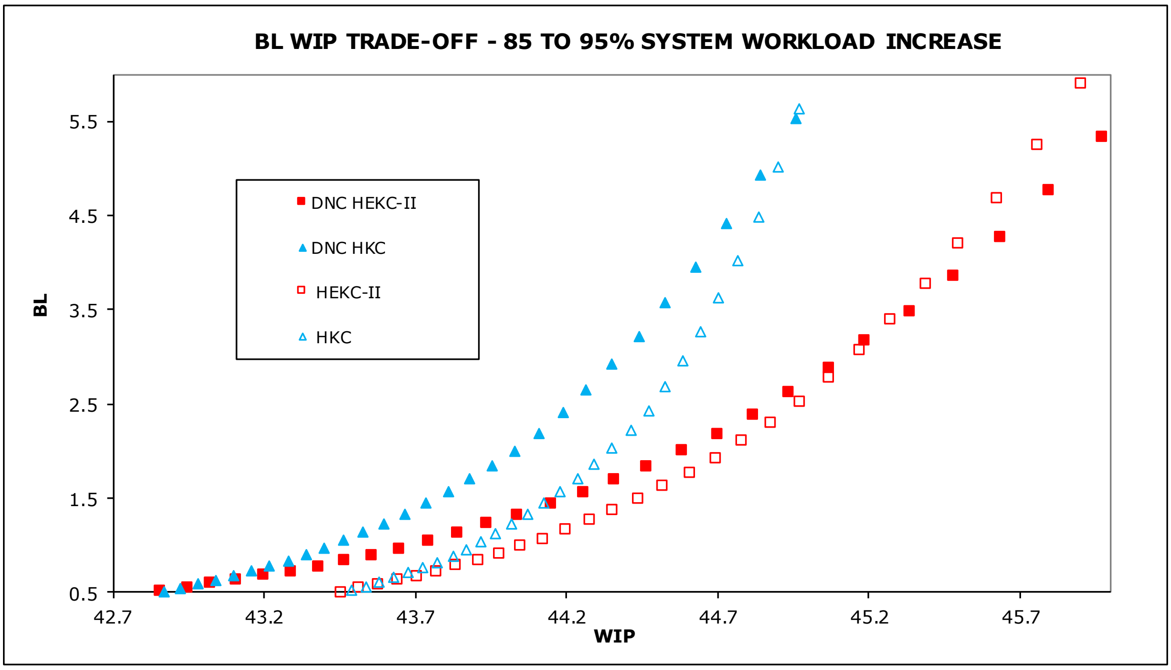

Figure 6-12. BL and WIP Direct Trade-off Data Points for the Robustness Test Analysis - 40% LV

As proposed in the previous section 6.1.2, maintaining the same referential trade-off rate of 1 to 10 in BL vs WIP and considering both performance metrics simultaneously, it provides a slope to which the multi-objective metrics can be compared against and determine which strategy maintains the loss in performance, during the added stress, more similar or closer to the tolerable trade-off slope.

Therefore, from the Figure 6-12, in view of the tolerance being WIP up to 53 and BL of 1.5 as a maximum, DNC HEKC-II is the first order stochastically dominant control strategy over all other strategies as it could maintain both metrics within reasonable range simultaneously.

6.1.5. Summary

The stochastic dominance test when analysed through the multi-objective plot and with the considerations for the termination mechanism that limits outlining performers, as demonstrated above, it can provide a more conclusive insight on the robustness test as proposed and implemented here. It is a direct trade-off display of both conflicting objectives reaction to the added stress or perturbation while the system operates with a non-optimised setting. This enables the instant analysis of how a strategy can manage the stress while trying to maintain original performance [124].

DNC HEKC-II Strategy had superior robustness to increased system workload considering both objectives in scenarios with low processing time variabilities and with both upper and lower rate of recycled supply. It was also the strategy with the higher upper limit of maximum possible workload that the system can achieve during the robustness test.

HEKC-II presented stochastic dominance over all other strategies for the scenario with upper variability level and 90% of recycled supply, while HKC was the dominant with the upper variability and 40% returned products.

6.2. RESPONSE SURFACE METHODOLOGY (RSM)

Within the scope of this research RSM experiments are intended solely for sensitivity analysis and visualisation of the modification parameters introduced to control strategies. It is not aimed at comparing the optimisation performance of different methodologies as done by Smew [47, 51]. Nevertheless, the differences between results derived from genetic algorithm and the RSM are recorded just in case it may be useful for the theoretical development of search algorithms or similar approaches.

These RSM experiments were designed with the software Design Expert v8 to estimate the interactions among terms of the production system and to obtain the corresponding response surface visualisation. Through the two-level factorial design, it was generated an optimal sequence of randomised runs that can minimise systematic bias, 2^{13} and 2^{11} factorial design, respectively [47, 51]. These experiments considered only DNC HEKC-II and HKC strategies with high processing time variability, as they were the best and worst performers according to the Chapter 5 results. It was designed to analyse only a small central stretch of the Pareto, within the 0.3 and 0.5 range of average customer backorder of demands. A total of 512 experiments were conducted according to the parameters of each scenario.

6.2.1. Responses for DNC HEKC-II Strategy with Upper Processing Time Variability and 90% Recycled Supply

The boundaries of this experiment were based on the upper and lower limits of the card setting achieved by the optimised GA performance frontier within the range of 0.3 to 0.5 demand backlog. The following Table 6-13 shows those limits in which the design experts software sets the experiments to be carried out.

Table 6-13. Upper and Lower Parameters Limit for the Design of Experiments - DNC HEKC-II, BL Targeted within 0.3 and 0.5

DNC HEKC-II 90 HV		
CWn	6	7
CWr	75	85
CWe	9	15
CWf	10	14
Ks	3	6
Ksr	7	12
Kr	7	10
Ke	1	4
Kf	1	4
Km	9	16
Kmf	1	4
MP	7	12
DE	1	9

The model graphs in Figures 6-13 the effect of input factors on the minimisation of the two performance metrics. It is shown the importance of the MP high value in achieving better results. The graph is based on the parameter optimisation provided by the RSM solutions in Table 6-14.

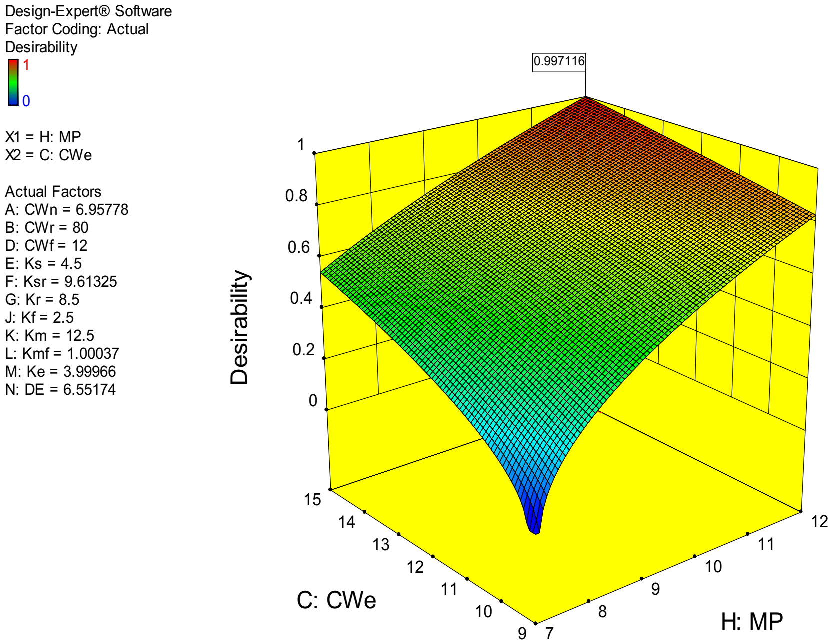

Figure 6-13. Response Surface Graph displaying the Impact of Related Factors on the Multi-Objective Minimisation of CLSC Inventory for the DNC HEKC-II Strategy with HV 90% Returns

ANOVA Results as in the Appendices E1 and E2, the p-value < 0.0001 indicates that the models can adequately be used to predict the minimisation of BL and WIP according to different levels of each parameter. Based on the ANOVA tables, it can be concluded that the factors and interactions included and reported in the analysis had significant effects on the inventory minimisation.

Table 6-14. RSM vs GA Optimised Results Comparison - DNC HEKC-II

DNC HEKC-II 90 HV		
	GA Solution	**RSM Solution**
CWn	7	7
CWr	84	80
CWe	14	15
CWf	12	12
Ks	5	5
Ksr	9	10
Kr	8	9
Ke	3	4
Kf	2	3
Km	13	13
Kmf	4	1
MP	10	12
DE	9	1
WIP	**89.27**	**89.21**
BL	**0.17**	**0.16**
Solutions Difference	**WIP**	**0.07%**
	BL	**4.94%**

The Design Experts software was asked to optimise it according to the responses provided. The resulting optimised parameter combinations are shown in Table 6-14. It is noteworthy that RSM found slightly better solutions than the genetic algorithm, with a similar response density input, as the evolutionary optimiser ran approximately 650 scenarios within this stretch of the Pareto (BL between 0.3 to 0.5), while the RSM 512.

6.2.2. Responses for HKC Strategy with Upper Processing Time Variability and 90% Recycled Supply

The boundaries of this experiment were based on the upper and lower limits of the card setting achieved by the optimised GA performance frontier within the range of 0.3 to 0.5 demand backlog. The following Table 6-15 shows those limits in which the design experts software sets the experiments to be carried out.

Table 6-15. Upper and Lower Parameters Limit for the Design of Experiment – HKC, BL Targeted to be within 0.3 and 0.5

HKC 90 HV		
CWn	6	7
CWr	97	110
CWe	10	17
CWf	15	17
Ks	3	6
Ksr	8	15
Kr	8	22
Ke	2	5
Kf	2	5
Km	12	20
Kmf	2	5

The model graphs in Figures 6-14 the effect of input factors on the minimisation of the two performance metrics. It is shown the importance of the increased CWn in achieving better results. The graph is based on the parameter optimisation provided by the RSM solutions.

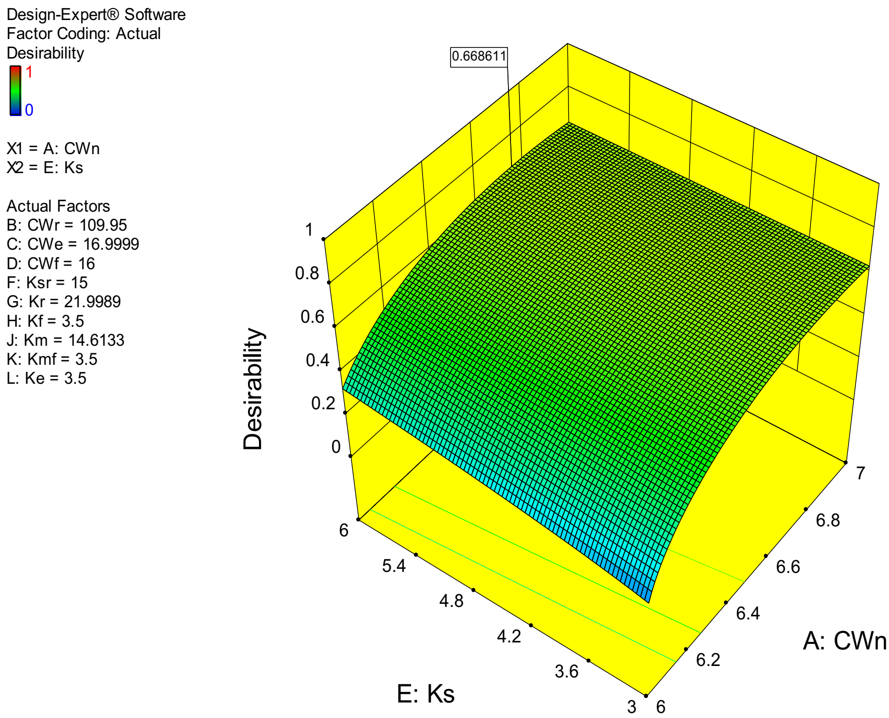

Figure 6-14. Response Surface Graph displaying the Impact of Related Factors on the Multi-Objective Minimisation of CLSC Inventory for the HKC Strategy with HV 90% Returns

ANOVA Results as in the Appendices E5 and E6, the p-value < 0.0001 indicates that the models can adequately be used to predict the minimisation of BL and WIP according to different levels of each factor. Based on the ANOVA tables, it can be concluded that the factors and interactions included and reported in the analysis had significant effects on the inventory minimisation.

Table 6-16. RSM vs GA Optimised Results Comparison – HKC

HKC 90 HV		
	GA Solution	**RSM Solution**
CWn	7	7
CWr	106	110
CWe	16	17
CWf	16	16
Ks	4	6
Ksr	15	15
Kr	21	21
Ke	2	4
Kf	2	4
Km	20	17
Kmf	2	4
WIP	**82.69**	**82.59**
BL	**0.34**	**0.33**
Solutions Difference	**WIP**	**0.12%**
	BL	**3.93%**

The Design Experts software was asked to optimise it according to the responses provided. The resulting optimised parameter combinations are shown in Table 6-16. It is noteworthy that RSM found slightly better results than the genetic algorithm, with a similar response density input, as the evolutionary optimiser ran approximately 650 scenarios within this stretch of the Pareto (BL between 0.3 to 0.5), while the RSM 512.

6.2.3. Responses for DNC HEKC-II Strategy with Upper Processing Time Variability and 40% Recycled Supply

The boundaries of this experiment were based on the upper and lower limits of the card setting achieved by the optimised GA performance frontier within the range of 0.3 to 0.5 demand backlog. The following Table 6-17 shows those limits in which the design experts software set the experiments to be carried out.

Table 6-17. Upper and Lower Parameters Limit for the Design of Experiment – DNC HEKC-II, BL Targeted to be within 0.3 and 0.5

DNC HEKC-II 40 HV		
CWn	25	27
CWr	20	48
CWe	4	7
CWf	3	7
Ks	7	14
Ksr	5	8
Kr	3	8
Ke	1	4
Kf	1	4
Km	10	16
Kmf	1	4
MP	2	8
DE	1	9

The model graphs in Figures 6-15 the effect of input factors on the minimisation of the two performance metrics. It is shown the importance of the MP high value in achieving better results. The graph is based on the parameter optimisation provided by the RSM solutions.

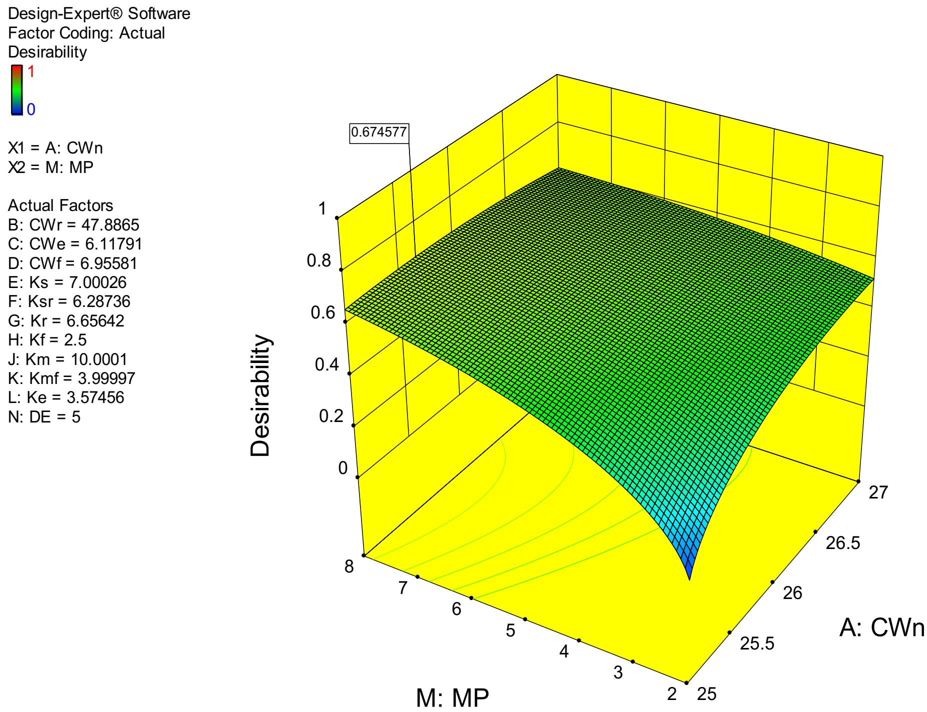

Figure 6-15 Response Surface Graph displaying the Impact of Related Factors on the Multi-Objective Minimisation of CLSC Inventory for the DNC HEKC-II Strategy with HV 40% Returns

ANOVA Results as in the Appendices E3 and E4, the p-value < 0.0001 indicates that the models can adequately be used to predict the minimisation of BL and WIP according to different levels of each factor. Based on the ANOVA tables, it can be concluded that the factors and interactions included and reported in the analysis had significant effects on the inventory minimisation.

Table 6-18. RSM vs GA Optimised Results Comparison - DNC HEKC-II

DNC HEKC-II 40 HV		
	GA Solution	**RSM Solution**
CWn	25	26
CWr	20	48
CWe	7	6
CWf	7	7
Ks	14	7
Ksr	6	6
Kr	6	7
Ke	2	3
Kf	1	4
Km	16	10
Kmf	3	4
MP	8	8
DE	7	5
WIP	**49.38**	**49.14**
BL	**0.51**	**0.49**
Solutions Difference	**WIP**	**0.48%**
	BL	**3.81%**

The Design Experts software was asked to optimise it according to the responses provided. The resulting optimised parameter combinations are shown in Table 6-18. It is noteworthy that RSM found slightly better results than the genetic algorithm, with a similar response density input, as the evolutionary optimiser ran approximately 650 scenarios within this stretch of the Pareto (BL between 0.3 to 0.5), while the RSM 512.

6.2.4. Responses for HKC Strategy with Upper Processing Time Variability and 40% Recycled Supply

The boundaries of this experiment were based on the upper and lower limits of the card setting achieved by the optimised GA performance frontier within the range of 0.3 to 0.5 demand backlog. The following Table 6-19 shows those limits in which the design experts software sets the experiments to be carried out.

Table 6-19. Upper and Lower Parameters Limit for the Design of Experiment – HKC, BL Targeted within 0.3 and 0.5

HKC 40 HV		
CWn	26	28
CWr	24	60
CWe	5	9
CWf	3	8
Ks	10	18
Ksr	4	10
Kr	4	10
Ke	1	4
Kf	1	4
Km	16	20
Kmf	1	4

The model graphs in Figures 6-16 the effect of input factors on the minimisation of the two performance metrics. It is shown the importance of the CWn increased value in achieving better results. The graph is based on the parameter optimisation provided by the RSM solutions.

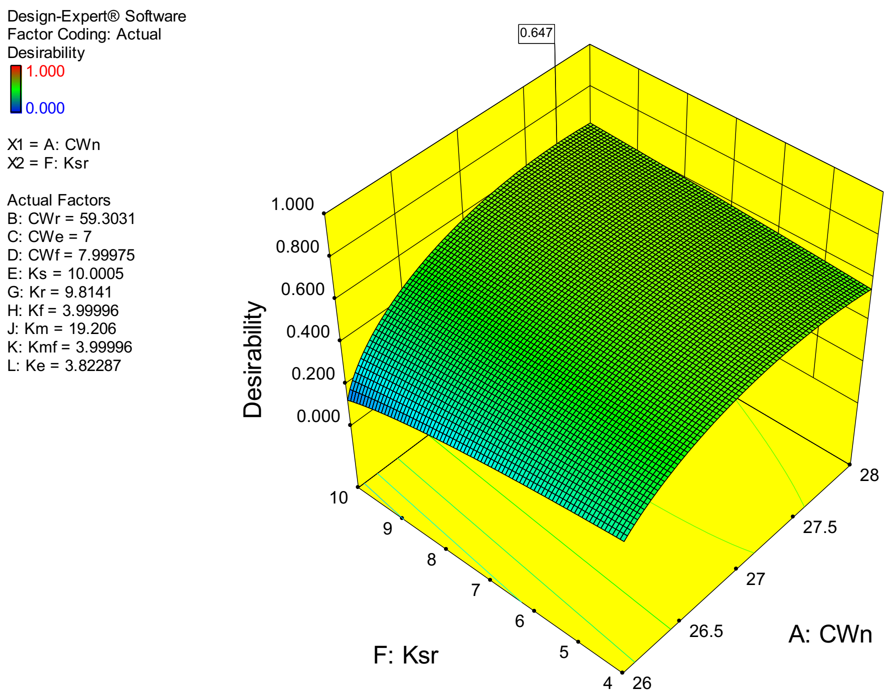

Figure 6-16 Response Surface Graph Displaying the Impact of Related Factors on the Multi-Objective Minimisation of CLSC Inventory for the HKC Strategy with HV 40% Returns

ANOVA Results as in the Appendices E7 and E8, the p-value < 0.0001 indicates that the models can adequately be used to predict the minimisation of BL and WIP according to different levels of each factor. Based on the ANOVA tables, it can be concluded that the factors and interactions included and reported in the analysis had significant effects on the inventory minimisation.

Table 6-20. RSM vs GA Optimised Results Comparison – HKC

HKC 40 HV		
	GA Solution	**RSM Solution**
CWn	28	28
CWr	47	59
CWe	7	7
CWf	7	8
Ks	10	10
Ksr	7	10
Kr	4	10
Ke	2	4
Kf	4	4
Km	17	19
Kmf	1	4
WIP	**52.51**	**52.40**
BL	**0.29**	**0.28**
Solutions Difference	**WIP**	**0.22%**
	BL	**3.63%**

The Design Experts software was asked to optimise it according to the responses provided. The resulting optimised parameter combinations are shown in Table 6-20. It is noteworthy that RSM found slightly better results than the genetic algorithm, with a similar response density input, as the evolutionary optimiser ran approximately 650 scenarios within this stretch of the Pareto (BL between 0.3 to 0.5), while the RSM 512.

6.2.5. Summary

These RSM experiments for the sensitivity analysis clearly proved that, on both dynamic allocation strategies tested, the major factor contributing for the minimisation of the BL and WIP simultaneously was the Master Pool parameter, which is the leading factor of the modification approach proposed in this research.

Secondarily, the results found by both research methodologies, namely RSM and GA, were also recorded as a referential that may be useful for other related studies [47, 51], although such comparison not objective of this research. RSM solutions found, approximately 4%, better solution than the evolutionary algorithm. Both had comparable input response density, as the genetic optimiser ran approximately 650 scenarios within the given stretch of the Pareto (BL between 0.3 to 0.5), while the ran RSM 512 combinations. Therefore, it is shown to be an effective method for researching the optimum parameter settings in multi-objective optimisations. That contrasts with a comparison experiment among multi-objective search algorithms by Smew [51] where that the genetic algorithm[60] found better and more precise solutions for Hybrid Kanban CONWIP systems.

CHAPTER 7. PERFORMANCE ASSESSMENT OF THE PROPOSED INTELLIGENT SELF-DESIGNING PRODUCTION CONTROL STRATEGY

7.1. DESCRIPTION AND SPECIFICATION OF THE SYSTEM

Based upon the experimental results found for the high performing DNC HEKC-II strategy as described in section 4.1, it is proposed here a new control mechanism: The Intelligent Self-Designing Production Control Strategy, which is designed to be a further development of optimum characteristics previously mentioned, with the following improvements:

I. Extensive increase of dynamically allocated authorisation cards, to a level that the number of Kanbans and CONWIPs initially assigned are considerably smaller than the number of cards available after the dynamic change;

II. Further anticipation of the time to trigger the change in the number of dynamically allocated production authorisation cards according to the finished goods buffer level. This is the TA parameter that also responds to the lag time the system has between the time of receiving additional cards and the actual increase in throughput and finished goods becoming available for delivery;

III. Addition of an acceleration and deceleration factor providing multi-level triggers at different points in order to scale up and down this dynamic change, aiming at minimising the backlog and maintaining the finished good buffer at the lowest possible level, so as to keep a low WIP. It was designed to have 2 levels of cards increase through the dynamic change, the full increase at TA and half of the increase at TA x 2. So, when TA=10, the full increase or decrease (MP number) when the finished goods buffer is at 10 and the half increase or decrease (MP / 2) when the finished goods buffer is at 20. It triggers in the same way independently of the final buffer being growing or reducing;

IV. The capability of downsizing itself to become similar to HKC, by Bonvik et al. [3], in an optimisation process if diverse production system conditions and variability would require the more streamlined approach, this would occur by the minimisation of MP and DE parameters.

The following Table 7-1 demonstrate the fourfold increase in the Master Pool, the time to trigger anticipation (TA) as a new optimisable parameter and all the other cards range on the research space. Table 7-2 details the logic of the dynamic change which was maintained the same as the one for the DNC HEKC-II, as described in section 4.2, with the high rate of recycled supply and the prioritisation of the local inventory, via Kanbans over CONWIPs. To simplify and try to keep the research space from being too large, the MP range ran by the previously described DNC HEKC-II was left out as results for them were already discussed in Chapter 5. All other ranges were kept equal. This strategy was run only with the high variability of processing time and 90% returned supply scenario because that was the situation where the greatest magnitude of improved performance was found, according to the previously described research results.

Table 7-1. Range of Parameters and Authorisation Cards for the Intelligent Self-Designing Production Control Strategy with 90% Returned Material.

Low and High Limits of Authorisation Cards			Range
MP	**150**	**480**	**34**
TA	**1**	**12**	**12**
CWn	2	9	**8**
CWr	40	85	**46**
CWe	7	15	**9**
CWf	6	14	**9**
Ks	2	6	**5**
Ksr	6	12	**7**
Kr	7	18	**12**
Kf	1	4	**4**
Ke	7	16	**10**
Km	1	4	**4**
Kmf	1	4	**4**
DE	**0**	**9**	**10**
Total Number of Scenarios			**2.72E+12**

Table 7-2. Formulas for the Dynamic Changes on the number of the Authorisation Cards for Intelligent Self-Designing Production Control Strategy with 90% Returned Material.

Initial Card Pool Size	Pool Size Change Triggered by Supply/Demand Queues			
Qfg >= TA - Standard 0	**Qfg < TA - Stand. 1 - Demand**	**Qr > 5 - Stand. 2**	**Qf > 5 - Stand. 3**	**Qe > 5- Stand. 4**
IP1	IP1+MPx0.5x3%			
IP2	IP2+MPx0.5x51%	IP2+MPx0.5x51%		
IP3	IP3+MPx0.5x6.6%		IP3+MPx0.5x6.6%	
IP4	IP4+MPx0.5x8.6%			IP4+MPx0.5x8.6%
IP5	IP5+MPx0.5x3%			
IP6	IP6+MPx0.5x3.6%	IP6+MPx0.5x3.6%		
IP7		**IP7+MPx9.6%**		
IP8			**IP8+MPx2%**	
IP9				**IP9+MPx2%**
IP10	**IP10+MPx8.6%**			
IP11			IP11+MPx0.5x2%	

7.2. EXPERIMENTAL RESULTS

The description of the percent-amount of the searched experimental space and the number of solutions found through the evolutionary optimisation process are displayed in Table 7-3 illustrated below.

Table 7-3. Solutions for Upper Processing Time Variability and 90% of Returned Materials

	INT. SELF DES. 90 HV
No. of Solutions on the Pareto	253
No. of Generations	1070
Percentage of Space Searched	2.98E-04 %

Concluding from Figures 7-1 to 7-3, the Intelligent Self-Designing Strategy achieved a significant shift forward of the entire performance frontier and very superior to the previously best-performing strategy, DNC HEKC-II, as it was displayed on the experimental results in Chapter 5.

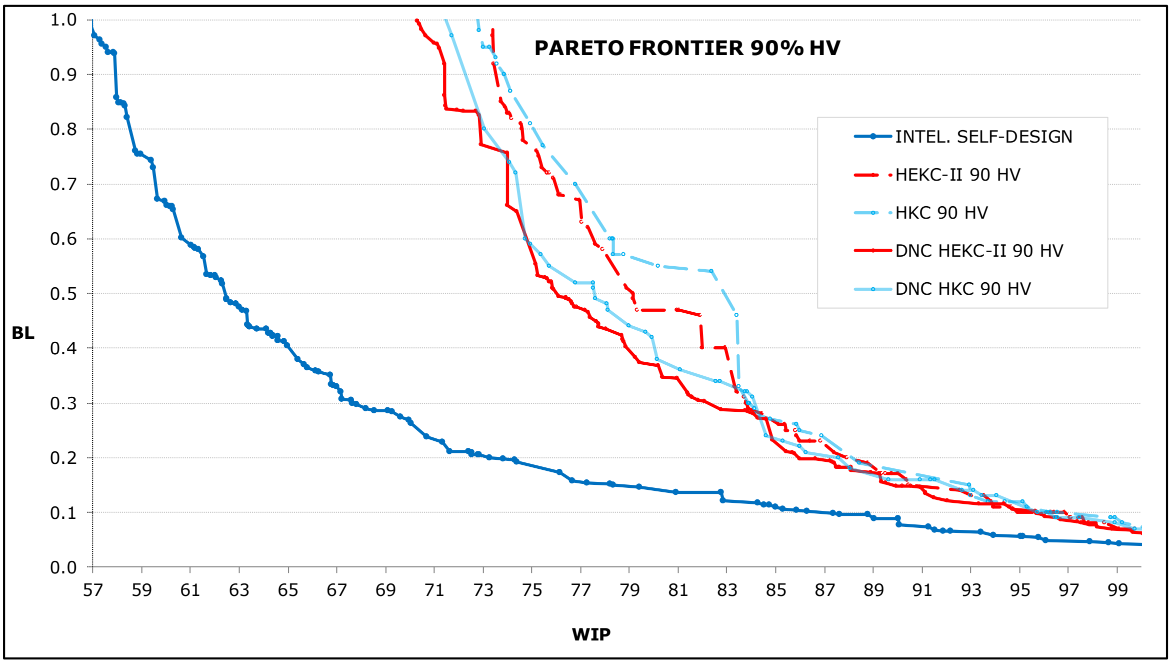

Figure 7-1. Pareto Optimum Performance Frontier, Upper Processing Time Variability and 90% of Returned Materials - Lower BL Range

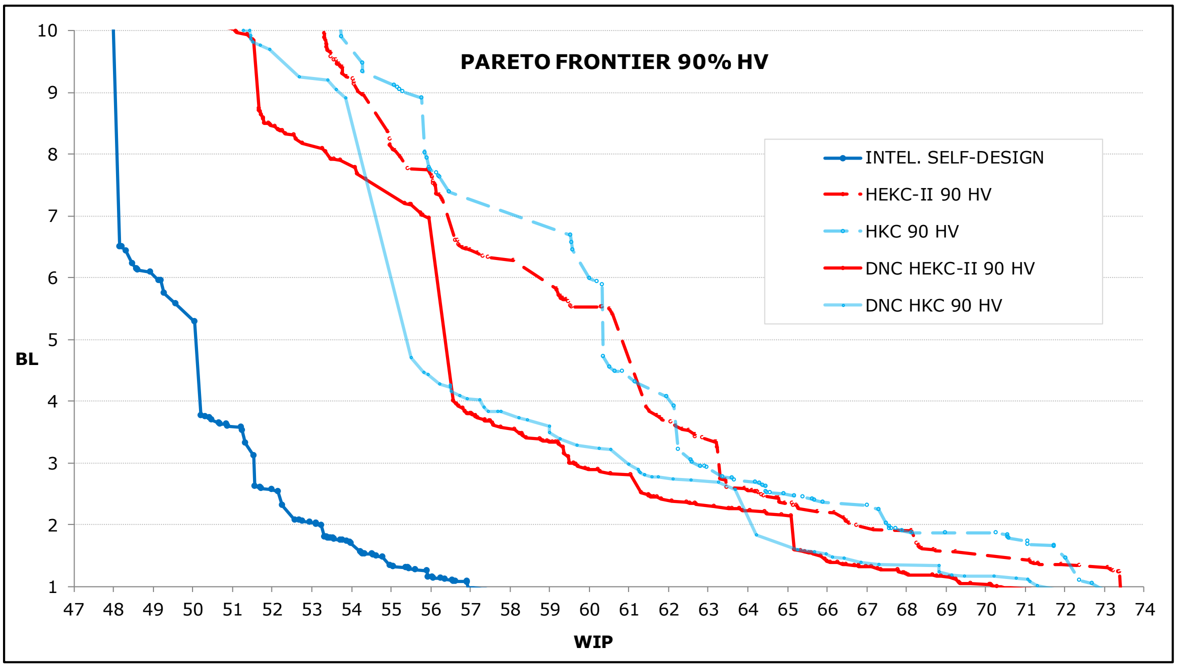

Figure 7-2. Pareto Optimum Performance Frontier, Upper Processing Time Variability and 90% of Returned Materials - Lower WIP Range

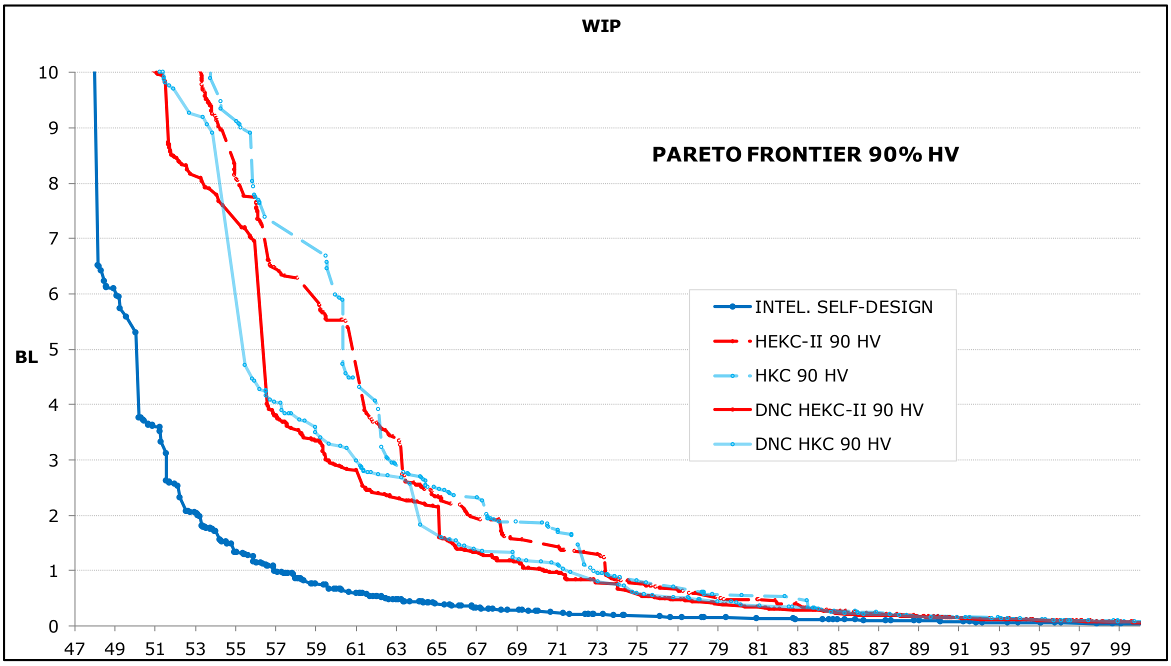

Figure 7-3. Pareto Optimum Performance Frontier, Upper Processing Time Variability and 90% of Returned Materials - Total Range

Similarly, from Figures 7-1 to 7-3 it is also proven that the Intelligent Self-Designing Strategy outperformed any other strategy under investigation, with up to 70% decrease in backlog for instance when BL=0.2 and WIP= 71 in comparison with the DNC HEKC-II. Additionally, in terms of WIP reduction, it can be observed that when BL=1 and WIP=57, a decrease of over 20% in WIP was recorded, also in comparison with the DNC HEKC-II. There was a major improvement for both metrics simultaneously.

The optimised number of authorisation cards for each of the non-dominated points on the frontier are provided in the Appendix B1. They detail the level of each parameter and the cards allocated at each of the Pareto-optimum solutions and how the most influential parameters for maximum performance are heavily used: The maximum limits of the master pool and the upper range of the TA, trigger anticipation, dominates the vast majority of the Pareto solutions.

7.3. SUMMARY

The considerable inventory management performance improvement provided by the Intelligent Self-Designing Strategy can also be visualised in Figures 7-4 to 7-6. They clearly display the highly positive impact of the increased MP and TA parameters in decreasing the backlog peaks on multiple instances, as well as the average backlog, the metric recorded by the genetic optimiser decision.

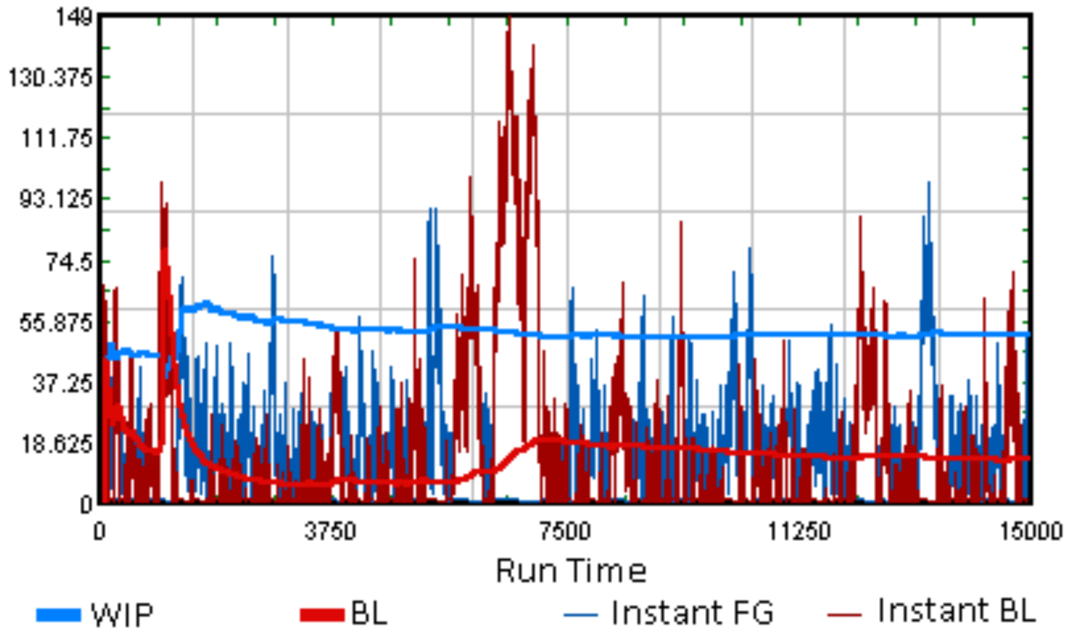

Figure 7-4. WIP and BL Plot Displaying Instant Variations of the Finished Goods Buffer (blue) and BL (red) for DNC HEKC-II. Pareto Optimum Settings with MP = 12

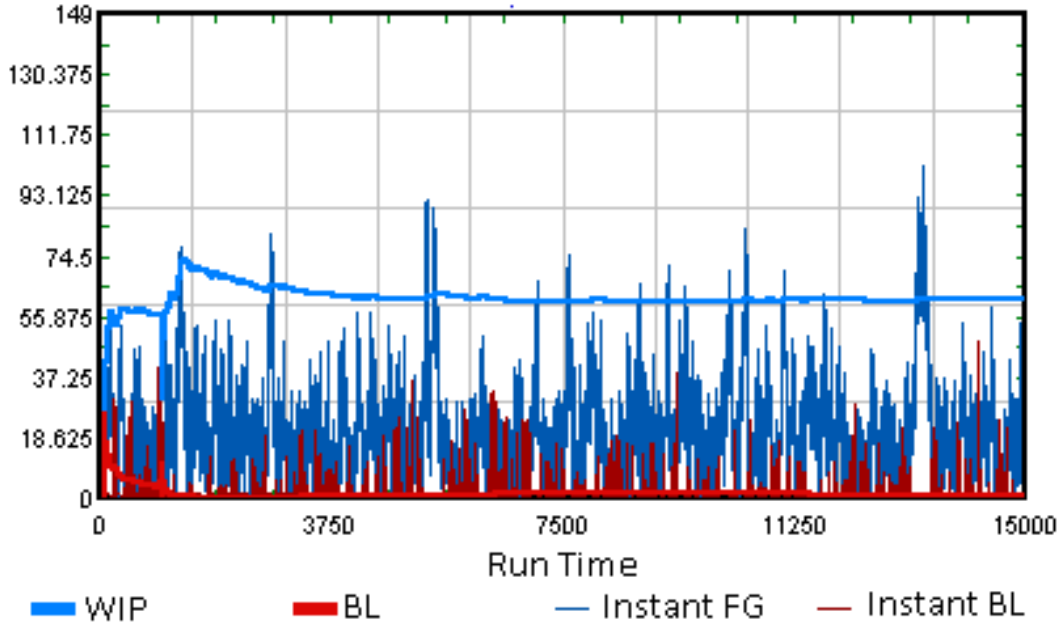

Figure 7-5. WIP and BL Plot Displaying Instant Variations of the Finished Goods Buffer (blue) and BL (red) on Intelligent Self-Designing PCS, modification of DNC HEKC-II. Changing only MP Setting to MP = 48

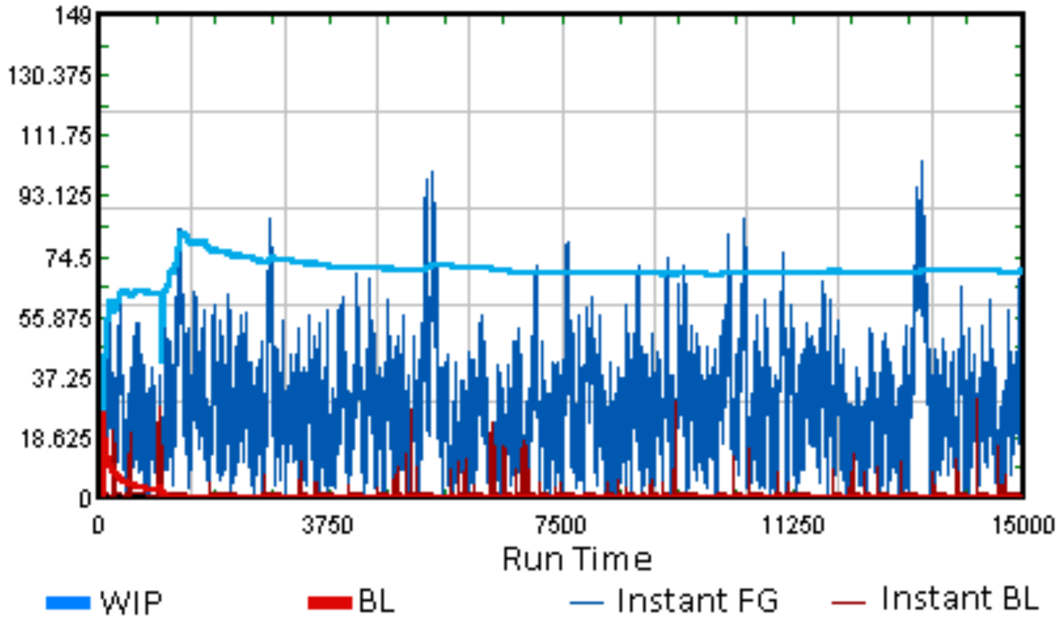

Figure 7-6. WIP and BL Plot Displaying Instant Variations of the Finished Goods Buffer (blue) and BL (red) on Intelligent Self-Designing PCS, modification of DNC HEKC-II. Changing only MP and TA Parameters to MP = 48 and TA = 12 with Acceleration/Deceleration enabled.

It is remarkable WIP reduction, as seen when BL=1 and WIP=57, a decrease from WIP=70 was achieved in comparison to the optimum DNC HEKC-II.

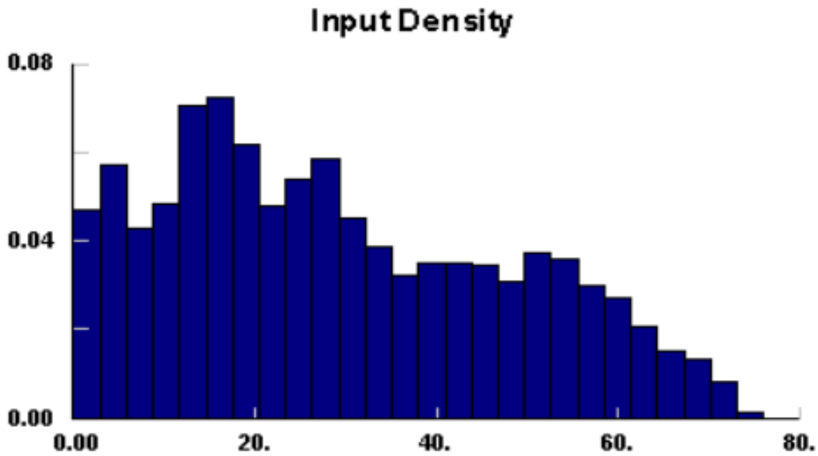

Figure 7-7. Frequency Interval Distribution of the Finished Goods Buffer for the DNC HEKC-II Optimised at BL = 1

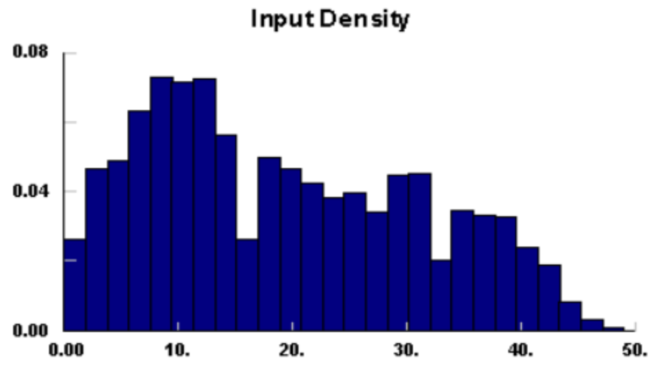

Figure 7-8. Frequency Interval Distribution of the Finished Goods Buffer for the DNC HEKC-II Optimised at BL = 1 (TA=5 and MP=48)

It is displayed in relation to the input density according to the frequency interval distribution level of the finished goods buffer on Figures 7-7 and 7-8. Maintaining the same demand backlog of 10 (BL=10) the DNC HEKC-II reached the maximum level of the finished goods buffer of 80, while the Intelligent Self-Designing Strategy was able the keep this maximum at only 50 parts.

CHAPTER 8. CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

8.1. SUMMARY OF CONTRIBUTIONS TO THE THEORY

This research project has experimentally proven, through scientific precision and due diligence that the development and the improved performance of production control strategies can be achieved, therefore, enabling better inventory management, lower backlogs of customer demands, and a higher cost-effectiveness of operations, so making the closed-loop supply chain implementation more feasible in technical and economic terms, even with the presence of more stochastic variables especially on the supply side of production systems.

The following contributions to the theory can be stated in reference to the performance of control production strategies implemented to the closed-loop supply chains design:

The successful implementation of the advanced control methodology named here: Intelligent Self-Designing Production Control Strategy, provided the maximum inventory management performance. This mechanism exerted a very significant shift on the performance frontier, essentially by using DNC HEKC-II with the extensive increase of dynamically allocated authorisation cards, the further anticipation of the time to trigger the card change according to the level of finished goods buffer and with an acceleration & deceleration factor of the dynamic change.

The proposed Intelligent Self-Designing Strategy demonstrated a higher performance at high variabilities of supply and processing time. Nevertheless, it can be reassembled or optimised for lower variabilities and can perform with similar improvements maintaining the same beneficial traits. It is totally flexible, being able to optimise all additional parameters to a very low range or even 0, therefore, redesigning itself to be converted to the standard HEKC-II or HKC or similar. So, it is applicable to a broad range of production systems even when detailed constraints of the system are not precisely measurable or foreseeable.

The design, optimisation of large research space and the computational efforts to implement the Intelligent Self-Designing Strategy can be higher than for other less complex strategies and, for some, it can be a limiting factor. Nevertheless, it is justifiable when the continuous performance improvement is delivered, as economies of scale in industrial production can exponentially maximise returns on investments. Moreover, the efficiency gains in productivity are continuous, long lasting and robust.

The Master Pool (MP), that defines by how much the dynamic changes of authorisation cards will be, during the optimisation, rapidly achieved the higher ranges of the allowed research space as the backlog started reaching lower values. The dynamic change was, by far, the strongest, most decisive parameter for the productivity improvement in all tested strategies, as it was also displayed on the RSM graphs.

The Intelligent Self-Designing Strategy had the MP increased by fourfold (up to 480) and the time to trigger (TA) also furthered to when the finished goods buffer had 24 parts. Still, both parameters, which are major factors, had their upper maximum range heavily utilised throughout the majority of the Pareto-frontier. This meant that further development in performance levels can still be achieved. It can be done by defining the limit of diminishing returns for the Master Pool (MP) and the anticipation of the time to trigger the dynamic allocation (TA).

The dynamic allocation methodological design of prioritising local inventory replenishment, with more kanbans at the point where higher throughput was expected due to increased queues, was beneficial. Furthermore, the fact of having the number of cards change based on the previous optimisation of HKC was also an advancement for the more precise balance of cards, according to the variability of supply sources.

All the three proposed modifications, alone, provided substantial performance improvement in comparison to the control group [3], namely: The Master Pool (MP) for the dynamic change, the multi-time to trigger (TA) accelerator and decelerator of the MP and the added demand to the HEKC-II strategy (DE) for the demand starvation avoidance.

The number of authorisation cards dynamically allocated for each cards pool were even higher than the original assigned number of Kanbans and CONWIPs, when the production system is at maximum performance.

The dynamic allocation enabled improved production performance by shifting the entire Pareto-frontier forward in all scenarios under investigation and for all production control strategies tested with significant advancements for the multi-objective metrics.

The modified HEKC-II, derived from Dallery and Liberopoulos [4], had better results than HKC in scenarios with higher variability of processing time and 90% returned material. It matched the HKC control group Bonvik et al. [3] results with lower variability of supply. It also provided grounds for the suggested improvements and flexibilisation of the HEKC Control Strategy.

The stochastic dominance test when analysed through the multi-objective plot and with the considerations for the termination mechanism that limits outlining performers, this can provide a more conclusive insight on the robustness test as proposed in this research.

DNC HEKC-II strategy had superior robustness to increased system workload and it was the strategy with the higher upper limit of maximum possible workload that the system can achieve during the robustness test.

RSM solutions found slightly, approximately 4%, better results than the evolutionary algorithm. Both had comparable input response density, as the genetic optimiser ran approximately 650 scenarios within the given stretch of the Pareto (BL between 0.3 to 0.5), while the RSM 512.

The termination mechanism to identify outlining performance with high values of WIP or BL improved the time effectiveness of the evolutionary optimisation process by decreasing the number of replications and the computational power dedicated to non-optimal system settings.

8.2. RECOMMENDATIONS FOR FUTURE RESEARCH AND DEVELOPMENT

It is recommended to further the development of the theoretical structure designed, proposed and experimented in this research:

The further use of multi-triggers mirroring multi-levels of the frequency interval distribution of the finished goods buffer for targeting response points of interest as appropriate for specific scenarios.

The test of the Intelligent Self-Designing Strategy with low and medium levels of processing time, supply and variabilities, in order to analyse its results while downsizing.

The base stock (S) optimisable parameter, by Dallery and Liberopoulos [4], needs to be tested in combination with the additional demand (DE) handler of the starvation avoidance. The DE parameter defines by how much the workstation slows down the processing speed and the base stock (S) parameter defines how often DE will happen. It would allow for the greater precision of results, lower level and lower range of these parameters, low research space and as a result, HEKC-II would be guaranteed to always outperform HKC by Bonvik et al. [3].

The added DE could be just temporary, being withdrawn from the system after a given time period, for example for 1% of the runtime. Thus, it avoids the momentary starvation of the shared demand, but by being withdrawn it would keep low base stock while increasing the likelihood of another slowdown occurrence.

Case studies with industry specific data and scenarios applicable to CLSC can be optimised for greater efficiency and further practical benefits from these technological advancements postulated here, especially regarding the Intelligent Self-designing PCS. Therefore, the productivity and profitability gains can be directly measured in practice and expandable to multiple related systems.

The number of demand backlogs could be added to the number of the finished goods buffer in the range of possibilities for the moment to trigger the dynamic change, so allowing for lower WIP.

The experiment with different ratios set on this research for the dynamic allocation of cards, namely: The Kanban over CONWIP prioritisation was in the order of 2 to 1 respectively and the proportionality of cards addition was based on the optimised setting for HKC with backlog of 0.5. Those could be changed according to specific objectives or interest of production system managers and practitioners.

The research space could be extended, in order to get a smoother Pareto line, specially by increasing the values of the parameters referent to the unlimited raw material supply, this would allow for a more detailed measure of the results, but heavily increasing the optimisation effort and likely justifiable for a case study.

One international body, like the International Organisation for Standardisation (ISO), should set norms, standards, and conventions for industrial engineering and production control strategies technical drawings, for the nomenclature and for standard tests.

REFERENCES

[1] V. D. R. Guide Jr. (2000). Production planning and control for remanufacturing: Industry practice and research needs. *Journal of Operations Management 18(4),* pp. 467-483.

[2] R. C. Gallego and E. P. Cueto (2010). A management model for closed-loop supply chains of reusable articles: Proposing solutions. Presented at XIV Congreso De Ingeniería De Organización: Donostia-San Sebastián.

[3] A. M. Bonvik, C. Couch and S. B. Gershwin (1997). A comparison of production-line control mechanisms. *International Journal of Production Research 35(3),* pp. 789-804.

[4] Y. Dallery and G. Liberopoulos. (2000). Extended kanban control system: Combining kanban and base stock. *IIE Transactions 32(4),* pp. 369-386.

[5] W. Hopp and M. Spearman. (1996). Factory physics foundations of manufacturing systems. *Irwin, Times Mirror, USA*

[6] M. H. Veatch and L. M. Wein. (1994) Optimal control of a two-station tandem production/inventory system. *Operations Research 42(2),* pp. 337-350.

[7] G. Liberopoulos and Y. Dallery. (2000). A unified framework for pull control mechanisms in multi-stage manufacturing systems. *Annals of Operations Research 93(1-4),* pp. 325-355.

[8] J. Geraghty and C. Heavey. (2005). A review and comparison of hybrid and pull-type production control strategies. *OR Spectrum 27(2-3),* pp. 435-457.

[9] K. Boonlertvanich. (2005). Extended -CONWIP -kanban system: Control and performance analysis. *ProQuest Dissertations and Theses* Available: http://search.proquest.com.dcu.idm.oclc.org/docview/305000575?accountid=15753

[10] K. Takahashi. (2003) Comparing reactive kanban systems. *International Journal of Production Research 41(18),* pp. 4317-4337.

[11] H. Groenevelt. (1993) The just-in-time system. *Handbooks in Operations Research and Management Science 4*pp. 629-670.

[12] T. Murino, G. Naviglio, E. Romano and P. Zoppoli (2009). Single stage multi product kanban system. optimization and parametric analysis.

[13] F. Karaesmen and Y. Dallery. (2000) A performance comparison of pull type control mechanisms for multi-stage manufacturing. *Int J Prod Econ 68(1),* pp. 59-71.

[14] J. A. Buzacott. (1989) Queueing models of kanban and MRP controlled production systems. *Engineering Costs and Production Economics 17(1-4),* pp. 3-20.

[15] T. J. Hodgson and D. Wang. (1991) Optimal hybrid push/pull control strategies for a parallel multistage system: Part I. *The International Journal of Production Research 29(6),* pp. 1279-1287.

[16] P. Y. Huang, L. P. Rees and B. W. Taylor. (1983). A simulation analysis of the Japanese just-in-time technique (with kanbans) for a multiline, multistage production system. *Decision Sciences 14(3),* pp. 326-344.

[17] M. L. Spearman, D. L. Woodruff and W. J. Hopp. (1990). CONWIP: A pull alternative to kanban. *The International Journal of Production Research 28(5),* pp. 879-894.

[18] R. P. Marek, D. A. Elkins and D. R. Smith. (2001) Manufacturing controls: Understanding the fundamentals of kanban and CONWIP pull systems using simulation. Presented at Proceedings of the 33nd Conference on Winter Simulation.

[19] J. E. Geraghty, (2003), *An Investigation of Pull-Type Production Control Mechanisms for Lean Manufacturing Environments in the Presence of Variability in the Demand Process* (Doctoral dissertation, University of Limerick).,

[20] A. Xanthopoulos and D. Koulouriotis. (2014) Multi-objective optimization of production control mechanisms for multi-stage serial manufacturing-inventory systems. *The International Journal of Advanced Manufacturing Technology 74(9-12),* pp. 1507-1519.

[21] P. Zipkin. (1989). A kanban-like production control system: Analysis of simple models. *Preprint*

[22] E. Gaury, J. Kleijnen and H. Pierreval. (2001). A methodology to customize pull control systems. *J. Oper. Res. Soc. 52(7),* pp. 789-799.

[23] B. Baynat, J. A. Buzacott and Y. Dallery. (2002). Multiproduct kanban-like control systems. *Int J Prod Res 40(16),* pp. 4225-4255.

[24] V. Tardif and L. Maaseidvaag. (2001). An adaptive approach to controlling kanban systems. *European Journal of Operational Research 132(2),* pp. 411-424.

[25] Takahashi, K., Nakamura, N., Koubeck, R.J. and Karwowski, W., (1996). A reactive ordering human-computer cooperation.

[26] R. Schonberger., (1982), *Japanese Manufacturing Techniques: Nine Hidden Lessons in Simplicity,*

[27] A. Xanthopoulos, D. E. Koulouriotis and A. Gasteratos. (2017). Adaptive card-based production control policies. *Comput. Ind. Eng. 103*pp. 131-144.

[28] J. M. Framinan, P. L. González and R. Ruiz-Usano. (2006). Dynamic card controlling in a conwip system. *International Journal of Production Economics 99(1),* pp. 102-116.

[29] T. Chang and Y. Yih. (1994) Generic kanban systems for dynamic environments. *The International Journal of Production Research 32(4),* pp. 889-902.

[30] Ohno, K., Boh, T., Nakade, K. and Tamura, T., (2016). New approximate dynamic programming algorithms for large-scale undiscounted markov decision processes and their application to optimize a production and distribution system. *European Journal of Operational Research 249(1),* pp. 22-31.

[31] G. Liberatore, S. Nicosia and P. Valigi. (1996). Dynamic scheduling and kanban allocation in manufacturing systems. *IFAC Proceedings Volumes 29(1),* pp. 589-594.

[32] J. M. Framinan, P. L. González and R. Ruiz-Usano. (2006). Dynamic card controlling in a conwip system. *International Journal of Production Economics 99(1),* pp. 102-116.

[33] H. Jodlbauer and A. Huber. (2008) Service-level performance of MRP, kanban, CONWIP and DBR due to parameter stability and environmental robustness. *Int J Prod Res 46(8),* pp. 2179-2195.

[34] O. A. Olaitan. (2016). A framework for creating production and inventory control strategies. (Doctoral dissertation, Dublin City University).

[35] G. Sivakumar and P. Shahabudeen. (2008) Design of multi-stage adaptive kanban system. *The International Journal of Advanced Manufacturing Technology 38(3-4),* pp. 321.

[36] Z. Li. (2013), *Design and Analysis of Robust Kanban System in an Uncertain Environment,* KIT Scientific Publishing.

[37] Finetto, C., Faccio, M., Rosati, G. and Rossi, A, (2014). Mixed-model sequencing optimization for an automated single-station fully flexible assembly system (F-FAS). *The International Journal of Advanced Manufacturing Technology 70(5-8),* pp. 797-812.

[38] M. L. Junior and M. Godinho Filho. (2010). Variations of the kanban system: Literature review and classification. *Int J Prod Econ 125(1),* pp. 13-21.

[39] E. Gaury, H. Pierreval and J. P. Kleijnen. (2000). An evolutionary approach to select a pull system among kanban, conwip and hybrid. *J. Intell. Manuf. 11(2),* pp. 157-167.

[40] S. M. Gupta, Y. A. Al-Turki and R. F. Perry. (1999). Flexible kanban system. *International Journal of Operations & Production Management 19(10),* pp. 1065-1093.

[41] A. Krishnamurthy, R. Suri and M. Vernon. (2004). Re-examining the performance of MRP and kanban material control strategies for multi-product flexible manufacturing systems. *International Journal of Flexible Manufacturing Systems 16(2),* pp. 123-150.

[42] S. Gstettner and H. Kuhn. (1996). Analysis of production control systems kanban and CONWIP. *Int J Prod Res 34(11),* pp. 3253-3273.

[43] P. Renna, L. Magrino and R. Zaffina. (2013). Dynamic card control strategy in pull manufacturing systems. *Int. J. Comput. Integr. Manuf. 26(9),* pp. 881-894.

[44] A. Xanthopoulos, D. E. Koulouriotis and A. Gasteratos. (2017). Adaptive card-based production control policies. *Comput. Ind. Eng. 103*pp. 131-144.

[45] T. Papadopoulou and A. Mousavi. (2007). Control of constant work-in-progress in dynamic lean job shops using a multi-agent system approach. *International Journal of Agile Manufacturing 10(2),* pp. 19-28.

[46] R. Iannone, S. Miranda and S. Riemma. (2009). The search for the optimal number of kanbans in unstable assembly-tree layout systems under intensive loading conditions. *Int. J. Comput. Integr. Manuf. 22(4),* pp. 315-324.

[47] J. Wang, J. R. Ebner Jr., O. Olaitan and J. Geraghty (2016). Characterization of multi-objective performance matrices in relation to inventory control policies, in *ICIL - International Conference in Industrial Logistics,* 2016,

[48] D. E. Koulouriotis, A. S. Xanthopoulos and V. D. Tourassis. (2010). Simulation optimisation of pull control policies for serial manufacturing lines and assembly manufacturing systems using genetic algorithms. *Int J Prod Res 48(10),* pp. 2887-2912.

[49] P. Shahabudeen, K. Krishnaiah and M. T. Narayanan. (2003). Design of a two-card dynamic kanban system using a simulated annealing algorithm. *The International Journal of Advanced Manufacturing Technology 21(10-11),* pp. 754-759.

[50] C. A. Coello. (2000). An updated survey of GA-based multiobjective optimization techniques. *ACM Computing Surveys (CSUR) 32(2),* pp. 109-143.

[51] W. Smew. (2012). *Evaluation of Production Control Strategies for the Co-Ordination of Work-Authorisations and Inventory Management in Lean Supply Chains.* (Doctoral dissertation, Dublin City University).

[52] J. A. Joines, D. Gupta, M. A. Gokce, R. E. King and M. G. Kay.(2002) Supply chain multi-objective simulation optimization. Presented at Simulation Conference. Proceedings of the Winter.

[53] M. A. Abido. Two-level of nondominated solutions approach to multiobjective particle swarm optimization (2008). Presented at Proceedings of the 9th Annual Conference on Genetic and Evolutionary Computation.

[54] Smew, W., Young, P. and Geraghty, J., (2013). Supply chain analysis using simulation, Gaussian process modelling and optimisation. *International Journal of Simulation Modelling*, *12*(3), pp.178-189.

[55] J. H. Holland and J. S. Reitman. (1977). Cognitive systems based on adaptive algorithms. *Acm Sigart Bulletin (63),* pp. 49-49.

[56] M. Pirlot. (1996). General local search methods. *European. Journal of Operations Research 92(3),* pp. 493-511.

[57] T. Yang, H. Fu and K. Yang. (2007). An evolutionary-simulation approach for the optimization of multi-constant work-in-process strategy—a case study. *Int J Prod Econ 107(1),* pp. 104-114.

[58] D. E. Goldberg and J. H. Holland. (1988). Genetic algorithms and machine learning. *Mach. Learning 3(2),* pp. 95-99.

[59] S. H. R. Pasandideh and S. T. A. Niaki. (2006). Multi-response simulation optimization using genetic algorithm within desirability function framework. *Applied Mathematics and Computation 175(1),* pp. 366-382.

[60] B. Kernan and J. Geraghty. (2004). A multi-objective genetic algorithm for extend. Presented at Proceedings of the First Irish Workshop on Simulation in Manufacturing, Services and Logistics.

[61] P. Shahabudeen, K. Krishnaiah and M. T. Narayanan. (2003) Design of a two-card dynamic kanban system using a simulated annealing algorithm. *The International Journal of Advanced Manufacturing Technology 21(10-11),* pp. 754-759.

[62] A. Maniezzo, (2012). Distributed optimization by ant colonies Presented at Toward a Practice of Autonomous Systems: Proceedings of the First European Conference on Artificial Life.

[63] M. Becker and H. Szczerbicka. (2005) Parameters influencing the performance of ant algorithms applied to optimisation of buffer size in manufacturing. *Industrial Engineering and Management Systems 4(2),* pp. 184-191.

[64] C. Alabas, F. Altiparmak and B. Dengiz. (2000) The optimization of number of kanbans with genetic algorithms, simulated annealing and tabu search. Presented at Evolutionary Computation, 2000. Proceedings of the Congress.

[65] R. O. Bowden, J. D. Hall and J. M. Usher. (1996) Integration of evolutionary programming and simulation to optimize a pull production system. *Comput. Ind. Eng. 31(1-2),* pp. 217-220.

[66] P. Picton. (1994), "What is a neural network?" in *Introduction to Neural Networks* Anonymous

[67] R. Bowden and J. D. Hall. (2006). Simulation optimization research and development Presented at Proceedings of the 30th Conference on Winter Simulation.

[68] F. Martinelli and P. Valigi (1998). A dynamic control problem for a two part-type pull manufacturing system. Presented at Robotics and Automation. Proceedings. 1998 IEEE International Conference On.

[69] J. Montgomery. (2005). Solution biases and pheromone representation selection in ant colony optimisation.

[70] Deb, K., Pratap, A., Agarwal, S. and Meyarivan, T.A.M.T., (2002). A fast and elitist multiobjective genetic algorithm: NSGA-II. *IEEE Transactions on Evolutionary Computation 6(2),* pp. 182-197.

[71] A. H. C. Ng, J. Bernedixen and A. Syberfeldt. (2012). A comparative study of production control mechanisms using simulation-based multi-objective optimisation. *Int J Prod Res 50(2),* pp. 359-377. Available: http://dx.doi.org/10.1080/00207543.2010.538741

[72] I. Lee. (2007). Evaluating artificial intelligence heuristics for a flexible kanban system: Simultaneous kanban controlling and scheduling. *Int J Prod Res 45(13),* pp. 2859-2873.

[73] A. M. Law (2011). Designing a simulation study: How to conduct a successful simulation study. Presented at Proceedings of the 35th Conference on Winter Simulation: Driving Innovation.

[74] M. R. Noraini and J. Geraghty. (2011) Genetic algorithm performance with different selection strategies in solving TSP. In *Proceedings of the world congress on engineering* (Vol. 2, pp. 1134-1139).

[75] Syberfeldt, A., Andersson, M., Ng, A. and Bengtsson, V., (2015) Multi-objective evolutionary simulation-optimization of personnel scheduling. *International Journal of Artificial Intelligence & Applications 6(1),* pp. 41.

[76] S. S. Deokar. (2004). Performance evaluation of multi-product kanban-like control systems.

[77] C. E. Onyeocha, J. Khoury and J. Geraghty. (2015). Evaluation of multi-product lean manufacturing systems with setup and erratic demand. *Comput. Ind. Eng. 87,* pp. 465-480.

[78] C. Duri, Y. Frein and M. Di Mascolo. (2000) Comparison among three pull control policies: Kanban, base stock, and generalized kanban. *Annals of Operations Research 93(1),* pp. 41-69.

[79] Deleersnyder, J.L., Hodgson, T.J., Muller-Malek, H. and O'Grady, P.J., (1989) Kanban controlled pull systems: An analytic approach. *Management Science 35(9),* pp. 1079-1091.

[80] K. K. Pochampally, S. M. Gupta and K. Govindan. (2009) Metrics for performance measurement of a reverse/closed-loop supply chain. *International Journal of Business Performance and Supply Chain Modelling 1(1),* pp. 8-32.

[81] C. A. Chung., (2003), *Simulation Modeling Handbook: A Practical Approach,*

[82] D. Goldsman and G. Tokol. (1997). Output analysis procedures for computer simulations. Presented at Systems, Man, and Cybernetics. Computational Cybernetics and Simulation., 1997 IEEE International Conference On.

[83] S. Robinson and A. Ioannou. (2007) The problem of the initial transient: Techniques for estimating the warm-up period for discrete-event simulation models. *Warwick Business School, University of Warwick, Coventry, UK*

[84] S. Umeda. (2015). Simulation analysis of supply chain systems with reverse logistics. Presented at Simulation Conference (WSC), 2013 Winter.

[85] J. R. Ebner Jr., J. Wang, O. Olaitan and J. Geraghty (2016). Discrete event simulation approach to closed loop supply chain optimisation: Conceptual design, control strategies and performance metrics. Presented at Eurosis - European Simulation Conference.

[86] Wolfstetter, E., Dulleck, U., Inderst, R., Kuhbier, P. and Lands-Berger, M., (1993), *Stochastic Dominance: Theory and Applications,* Humboldt-Univ., Wirtschaftswiss. Fak.

[87] J. P. Kleijnen and E. Gaury. (2003) Short-term robustness of production management systems: A case study. *Eur. J. Oper. Res. 148(2),* pp. 452-465.

[88] G. Taguchi., (1986), *Introduction to Quality Engineering: Designing Quality into Products and Processes,*

[89] N. Slack, S. Chambers and R. Johnston. (2010), *Operations Management,*

[90] T. W. Simpson, D. K. Lin and W. Chen. (2001). Sampling strategies for computer experiments: Design and analysis. *International Journal of Reliability and Applications 2(3),* pp. 209-240.

[91] M. D. McKay, R. J. Beckman and W. J. Conover. (2000). A comparison of three methods for selecting values of input variables in the analysis of output from a computer code. *Technometrics 42(1),* pp. 55-61.

[92] Vose Software.(2016) *ModelRisk Industrial User Manual,*

[93] Ferreira, S.C., Bruns, R.E., Ferreira, H.S., Matos, G.D., David, J.M., Brandao, G.C., da Silva, E.P., Portugal, L.A., Dos Reis, P.S., Souza, A.S. and Dos Santos, W.N.L., (2007) Box-behnken design: An alternative for the optimization of analytical methods. *Anal. Chim. Acta 597(2),* pp. 179-186.

[94] R. H. Myers, D. C. Montgomery and C. M. Anderson-Cook. (2016), *Response Surface Methodology: Process and Product Optimization using Designed Experiments,*

[95] T. Lindhqvist., (2000), *Extended Producer Responsibility in Cleaner Production: Policy Principle to Promote Environmental Improvements of Product Systems,*

[96] M. R. Johnson and I. P. McCarthy. (2014) October–December 2014). Product recovery decisions within the context of extended producer responsibility. *Journal of Engineering and Technology Management 34(Supplement C),* pp. 9-28.

[97] Thierry, M., Salomon, M., Van Nunen, J. and Van Wassenhove, L., (1995). Strategie issues in product recovery management. *Calif. Manage. Rev. 37(2),* pp. 114-135.

[98] A. Atasu, V. D. Guide and L. N. Van Wassenhove. (2008). Product reuse economics in closed-loop supply chain research. *Production & Operations Management 17(5),* pp. 483-496. Available:
http://search.ebscohost.com/login.aspx?direct=true&db=bth&AN=34614959&site=ehost-live

[99] Diabat, A., Abdallah, T., Al-Refaie, A., Svetinovic, D. and Govindan, K.. (2013) Strategic closed-loop facility location problem with carbon market trading. *Engineering Management, IEEE Transactions On 60(2),* pp. 398-408.

[100] H. L. Walker. (2009) Sustainable procurement: *A literature review. International Purchasing and Supply Education*

[101] Fleischmann, M., Bloemhof-Ruwaard, J.M., Dekker, R., Van der Laan, E., Van Nunen, J.A. and Van Wassenhove, L.N. (1997). Quantitative models for reverse logistics: A review. *Eur. J. Oper. Res. 103(1),* pp. 1-17.

[102] Coyle, J.J., Novack, R.A., Gibson, B. and Bardi, E.J., (2012), *Supply Chain Management: A Logistics Perspective,*

[103] Z. Tao. (2013). Carbon emission modeling in green supply chain management. *ProQuest Dissertations and Theses* Available: http://search.proquest.com.remote.library.dcu.ie/docview/1531329443?accountid=15753

[104] S. Krinke, B. Boßdorf-Zimmer and D. Goldmann (2006). The volkswagen-SiCon process: Eco-efficient solution for future end-of-life vehicle treatment. Presented at LCE, 13th CIRP International Conference on Life Cycle Engineering, Belgium.

[105] Schmidt, W.P., Dahlqvist, E., Finkbeiner, M., Krinke, S., Lazzari, S., Oschmann, D., Pichon, S. and Thiel, C., (2004). Life cycle assessment of lightweight and end-of-life scenarios for generic compact class passenger vehicles. *The International Journal of Life Cycle Assessment 9(6),* pp. 405-416.

[106] Sakai, S.I., Yoshida, H., Hiratsuka, J., Vandecasteele, C., Kohlmeyer, R., Rotter, V.S., Passarini, F., Santini, A., Peeler, M., Li, J. and Oh, G.J., (2014) An international comparative study of end-of-life vehicle (ELV) recycling systems. *Journal of Material Cycles and Waste Management 16(1),* pp. 1-20.

[107] S. Sakai, Y. Noma and A. Kida. (2007) End-of-life vehicle recycling and automobile shredder residue management in japan. *Journal of Material Cycles and Waste Management 9(2),* pp. 151-158.

[108] E. Ponce-Cueto, J. Á González Manteca and R. Carrasco-Gallego (2011). Reverse logistics practices for recovering mobile phones in Spain. Presented at Supply Chain Forum: An International Journal.

[109] Funazaki, A., Taneda, K., Tahara, K. and Inaba (2003). Automobile life cycle assessment issues at end-of-life and recycling. *JSAE Rev. 24(4),* pp. 381-386.

[110] K. Togawa. (2008 Japan's automotive recycling system: Evaluation three years after implementation. *Promoting 3Rs in Developing countries—Lessons from the Japanese Experience.IDE*

[111] K. Lai, S. J. Wu and C. W. Y. Wong. (2013). Did reverse logistics practices hit the triple bottom line of chinese manufacturers? *International Journal of Production Economics 146(1),* pp. 106-117.

[112] Q. Zhao and M. Chen. (2011) A comparison of ELV recycling system in china and japan and china's strategies. *Resour. Conserv. Recycling 57*pp. 15-21.

[113] W. Dalmijn and T. De Jong. (2007) The development of vehicle recycling in Europe: Sorting, shredding, and separation. *Jom 59(11),* pp. 52-56.

[114] Passarini, F., Ciacci, L., Santini, A., Vassura, I. and Morselli, L., (2012). Auto shredder residue LCA: Implications of ASR composition evolution. *J. Clean. Prod. 23(1),* pp. 28-36.

[115] N. Kanari, J. Pineau and S. Shallari. (2003) End-of-life vehicle recycling in the European union. *Jom 55(8),* pp. 15-19.

[116] V. D. Guide and L. N. Van Wassenhove. (2009). OR FORUM—The evolution of closed-loop supply chain research. *Oper. Res. 57(1),* pp. 10-18. Available: http://dx.doi.org/10.1287/opre.1080.0628

[117] H. Krikke. (2011). Impact of closed-loop network configurations on carbon footprints: A case study in copiers. *Resour. Conserv. Recycling 55(12),* pp. 1196-1205.

[118] H. Krikke, D. Hofenk and Y. Wang. (2013). Revealing an invisible giant: A comprehensive survey into return practices within original (closed-loop) supply chains. *Resour. Conserv. Recycling 73(0),* pp. 239-250.

[119] Y. Khojasteh-Ghamari. (2009) A performance comparison between kanban and CONWIP controlled assembly systems. *J. Intell. Manuf. 20(6),* pp. 751-760.

[120] O. A. Olaitan and J. Geraghty. (2013). Evaluation of production control strategies for negligible-setup, multi-product, serial lines with consideration for robustness. *Jnl of Manu Tech Mnagmnt 24(3),* pp. 331-357. Available: http://dx.doi.org/10.1108/17410381311318864

[121] Olaitan, O., Rotondo, A., Young, P. and Geraghty, J., (2014). Performance evaluation of production control strategies in a serial manufacturing system with two products having disparate demand profiles, with consideration for robustness.

[122] Onyeocha, C.E., Wang, J., Khoury, J. and Geraghty, J. (2015). A comparison of HK-CONWIP and BK-CONWIP control strategies in a multi-product manufacturing system. *Operations Research Perspectives 2*pp. 137-149.

[123] Olaitan, O., Rotondo, A., Young, P. and Geraghty, J (2014). Hybrid kanban allocation policy in pull control of multiproduct manufacturing systems.

[124] Onyeocha. C.E. (2014). *Robust Production & Inventory Control Systems for Multi-Product Manufacturing Flow Lines* (Doctoral dissertation, Dublin City University).

[125] G. N. Krieg and H. Kuhn. (2002). A decomposition method for multi-product kanban systems with setup times and lost sales. *Iie Transactions 34(7),* pp. 613-625.

LIST OF PUBLICATIONS AND OTHER WORKS

During the course of this work, other contributions were made in many areas. These contributions are listed below as follows:

[1] J. R. Ebner Jr., J. Wang, O. Olaitan and J. Geraghty. (2016) ”Discrete event simulation approach to closed loop supply chain optimisation: Conceptual design, control strategies and performance metrics”. Presented at Eurosis - European Simulation Conference.

[2] J. Wang, J. R. Ebner Jr. and J. Geraghty. (2016) "Characterization of multi-objective performance matrices in relation to inventory control policies," in ICIL - International Conference in Industrial Logistics.

[3] J. R. Ebner Jr., J. Geraghty and P. Young. (2018) “Intelligent Self-Designing Production Control Strategy: Advanced Dynamic Allocation Hybrid Pull-type Mechanism Applicable to Closed-Loop Supply Chains”. Journal of Computers & Industrial Engineering (currently under review)

[4] Symposium Presentation “Implementation and Performance Analysis for Production Control Strategies for Closed-Loop Supply Chain” 20th Sir Bernard Crossland Symposium, Dublin Institute of Technology (2017).

[5] Winter Simulation Conference (2015 and 2016).

[6] Tutor/Demonstrator, (2015 to 2017), “MM203 Mechanics of Machines” School of Mechanical and Manufacturing Engineering, Dublin City University (DCU), Ireland.

[7] Tutor/Demonstrator, (2016 and 2017), “MM485 Operations Research Methods Tutorial Class” School of Mechanical Engineering, Dublin City University (DCU), Ireland.

APPENDICES - TABLE OF CONTENTS

APPENDIX A. ROBUSTNESS TEST RESULTS FOR INCREASED SYSTEM WORKLOAD FROM 85% TO 95%.. A-1

A1. LHS RUNS - PCS WITH HIGHER VARIABILITY AND 90% RETURNED MATERIALS A-1

A2. LHS RUNS - PCS WITH LOWER VARIABILITY AND 90% RETURNED MATERIALS A-4

A3. LHS RUNS - PCS WITH HIGHER VARIABILITY AND 40% RETURNED MATERIALS A-6

A4. LHS RUNS - PCS WITH LOWER VARIABILITY AND 40% RETURNED MATERIALS A-8

APPENDIX B. EVOLUTIONARY OPTIMISATION RESULTS FOR ALL STRATEGIES WITH 90% RETURNED MATERIALS.. B-1

B1. INTELLIGENT SELF-DESIGNING STRATEGY – PAC OPTIMISED SETTINGS FOR UPPER PROCESSING TIME VARIABILITY B-1

B2. DNC HEKC-II - PAC OPTIMISED SETTINGS FOR UPPER PROCESSING TIME VARIABILITY..B-6

B3. DNC HKC - PAC OPTIMISED SETTINGS FOR UPPER PROCESSING TIME VARIABILITY..... B-11

B4. HEKC-II - PAC OPTIMISED SETTINGS FOR UPPER PROCESSING TIME VARIABILITY....... B-14

B5. HKC - PAC OPTIMISED SETTINGS FOR UPPER PROCESSING TIME VARIABILITY B-18

B6. DNC HEKC-II - PAC OPTIMISED SETTINGS FOR LOWER PROCESSING TIME VARIABILITB-21

B7. DNC HKC - PAC OPTIMISED SETTINGS FOR LOWER PROCESSING TIME VARIABILITY.... B-30

B8. HEKC-II – PAC OPTIMISED SETTINGS FOR LOWER PROCESSING TIME VARIABILITY B-34

B9. HKC - PAC OPTIMISED SETTINGS FOR LOWER PROCESSING TIME VARIABILITY B-42

APPENDIX C. EVOLUTIONARY OPTIMISATION RESULTS FOR ALL STRATEGIES WITH 40% RETURNED MATERIALS.. C-1

C1. DNC HEKC-II - PAC OPTIMISED SETTINGS FOR UPPER PROCESSING TIME VARIABILITY ...C-1

C2. DNC HKC - PAC OPTIMISED SETTINGS FOR UPPER PROCESSING TIME VARIABILITY C-6

C3. HEKC-II - PAC OPTIMISED SETTINGS FOR UPPER PROCESSING TIME VARIABILITY C-10

C4. HKC - PAC OPTIMISED SETTINGS FOR UPPER PROCESSING TIME VARIABILITY C-17

C5. DNC HEKC-II - PAC OPTIMISED SETTINGS FOR LOWER PROCESSING TIME VARIABILITY C-21

C6. DNC HKC - PAC OPTIMISED SETTINGS FOR LOWER PROCESSING TIME VARIABILITY C-28

C7. HEKC-II - PAC OPTIMISED SETTINGS FOR LOWER PROCESSING TIME VARIABILITY C-34

C8. HKC - PAC OPTIMISED SETTINGS FOR LOWER PROCESSING TIME VARIABILITY C-45

APPENDIX D. SERVICE LEVEL AND BACKLOG COMPARISON D-1

D1. DNC HKC 90 HV - RELATIONSHIP BETWEEN SL vs BL FOR EACH WIP VALUE D-1

D2. HKC 40 HV - RELANTIONSHIP BETWEEN SL vs BL FOR EACH WIP VALUE D-3

APPENDIX E. ANOVA REPORTS E-1

E1. DNC HEKC-II 90 HV - METAMODEL WIP REPORT E-1

E2. DNC HEKC-II 90 HV - METAMODEL BL REPORT E-3

E3. DNC HEKC-II 40 HV - METAMODEL WIP REPORT E-5

E4. DNC HEKC-II 40 HV - METAMODEL BL REPORT E-8

E5. HKC 90 HV - METAMODEL WIP REPORT E-11

E6. HKC 90 HV - METAMODEL BL REPORT E-13

E7. HKC 40 HV - METAMODEL WIP REPORT E-15

E8. HKC 40 HV - METAMODEL BL REPORT E-17

APPENDICES – LIST OF TABLES

TABLE A-1. LHS RUNS FOR DNC HEKC-II AND DNC HKC 90HV A-2

TABLE A-2. LHS RUNS FOR HEKC-II AND HKC 90HV A-3

TABLE A-3. LHS RUNS FOR DNC HEKC-II AND DNC HKC 90LV...A-4

TABLE A-4. LHS RUNS FOR HEKC-II AND HKC 90LV...A-5

TABLE A-5. LHS RUNS FOR DNC HEKC-II AND DNC HKC 40HV A-6

TABLE A-6. LHS RUNS FOR HEKC-II AND HKC 40HV A-7

TABLE A-7. LHS RUNS FOR DNC HEKC-II AND DNC HKC 40LV...A-8

TABLE A-8. LHS RUNS FOR HEKC-II AND HKC 40LV...A-9

TABLE B-1. PRODUCTION AUTHORISATION CARD SETTINGS FOR INTELLIGENT SELF-DESIGNING STRATEGY 90HV...B-1

TABLE B-2. PRODUCTION AUTHORISATION CARD SETTINGS FOR DNC HEKC-II STRATEGY 90HV.........B-6

TABLE B-3. PRODUCTION AUTHORISATION CARD SETTINGS FOR DNC HKC STRATEGY 90HV B-11

TABLE B-4. PRODUCTION AUTHORISATION CARD SETTINGS FOR HEKC-II STRATEGY 90HV..............B-14

TABLE B-5. PRODUCTION AUTHORISATION CARD SETTINGS FOR HKC STRATEGY 90HV B-18

TABLE B-6. PRODUCTION AUTHORISATION CARD SETTINGS FOR DNC HEKC-II STRATEGY 90LV B-21

TABLE B-7. PRODUCTION AUTHORISATION CARD SETTINGS FOR DNC HKC STRATEGY 90LV.............B-30

TABLE B-8. PRODUCTION AUTHORISATION CARD SETTINGS FOR HEKC-II STRATEGY 90LV B-34

TABLE B-9. PRODUCTION AUTHORISATION CARD SETTINGS FOR HKC STRATEGY 90LV....................B-42

TABLE C-1. PRODUCTION AUTHORISATION CARD SETTINGS FOR DNC HEKC-II STRATEGY 40HV........ C-1

TABLE C-2. PRODUCTION AUTHORISATION CARD SETTINGS FOR DNC HKC STRATEGY 40HV C-6

TABLE C-3. PRODUCTION AUTHORISATION CARD SETTINGS FOR HEKC-II STRATEGY 40HV..............C-10

TABLE C-4. PRODUCTION AUTHORISATION CARD SETTINGS FOR HKC STRATEGY 40HV C-17

TABLE C-5. PRODUCTION AUTHORISATION CARD SETTINGS FOR DNC HEKC-II STRATEGY 40LV C-21

TABLE C-6. PRODUCTION AUTHORISATION CARD SETTINGS FOR DNC HKC STRATEGY 40LV.............C-28

TABLE C-7. PRODUCTION AUTHORISATION CARD SETTINGS DNC HEKC-II STRATEGY 40LV C-34

TABLE C-8. PRODUCTION AUTHORISATION CARD SETTINGS FOR HKC STRATEGY 40LV....................C-45

TABLE D-1. SL TO BL RELATION - DNC HEKC-II STRATEGY 90HV – HIGHER WIP VALUE RANGE.......... D-1

TABLE D-2. SL TO BL RELATION - HKC STRATEGY 40HV – LOWER WIP VALUE RANGE D-3

TABLE E-1. ANOVA RESULTS FOR HV 90 DNC HEKC-II WIP RESPONSES...E-1

TABLE E-2. ANOVA WIP REPORT FOR THE DNC HEKC-II STRATEGY 90HV...E-1

TABLE E-3. ANOVA RESULTS FOR HV 90 DNC HEKC-II BL RESPONSES...E-3

TABLE E-4. ANOVA BL REPORT FOR THE DNC HEKC-II STRATEGY 90HV E-3

TABLE E-5. ANOVA RESULTS FOR 40 HV DNC HEKC-II WIP RESPONSES....E-5
TABLE E-6. ANOVA WIP REPORT FOR THE DNC HEKC-II STRATEGY 40HV....E-5
TABLE E-7. ANOVA RESULTS FOR 40 HV DNC HEKC-II BL RESPONSES....E-8
TABLE E-8. ANOVA BL REPORT FOR THE DNC HEKC-II STRATEGY 40HV....E-8
TABLE E-9. ANOVA RESULTS FOR 90 HV HKC WIP RESPONSES....E-11
TABLE E-10. ANOVA WIP REPORT FOR THE HKC STRATEGY 90HV....E-11
TABLE E-11. ANOVA RESULTS FOR 90 HV HKC BL RESPONSES....E-13
TABLE E-12. ANOVA BL REPORT FOR THE HKC STRATEGY 90HV....E-13
TABLE E-13. ANOVA RESULTS FOR 40 HV HKC WIP RESPONSES....E-15
TABLE E-14. ANOVA WIP REPORT FOR THE HKC STRATEGY 40HV....E-15
TABLE E-15. ANOVA RESULTS FOR 40 HV HKC BL RESPONSES....E-17
TABLE E-16. ANOVA BL REPORT FOR THE HKC STRATEGY 90HV....E-17

APPENDIX A. ROBUSTNESS TEST RESULTS FOR INCREASED SYSTEM WORKLOAD FROM 85% TO 95%

A1. LHS RUNS - PCS WITH HIGHER VARIABILITY AND 90% RETURNED MATERIALS

Table A-1. LHS Runs for DNC HEKC-II and DNC HKC 90HV

DNC HEKC-II			DNC HKC		
WORLOAD	**WIP**	**BL**	**WORLOAD**	**WIP**	**BL**
85.00%	76.503101	0.49642162	85.00%	77.604521	0.48855781
85.34%	76.566689	0.52375376	85.34%	77.698092	0.51244989
85.69%	76.611266	0.56207582	85.69%	77.859495	0.54542585
86.03%	76.663372	0.59794798	86.03%	77.892854	0.60250018
86.38%	76.729154	0.65500629	86.38%	78.020295	0.65063549
86.72%	76.694103	0.69548844	86.72%	78.146542	0.68540832
87.07%	76.798252	0.74343364	87.07%	78.259463	0.73918445
87.41%	76.797416	0.82592076	87.41%	78.502724	0.80860634
87.76%	76.846366	0.88411761	87.76%	78.624816	0.87845255
88.10%	76.843745	0.97369461	88.10%	78.794747	0.96503196
88.45%	76.917946	1.0832152	88.45%	78.918296	1.100225
88.79%	77.035375	1.1737655	88.79%	79.157933	1.1811315
89.14%	76.933533	1.3037612	89.14%	79.300091	1.2848296
89.48%	77.029611	1.4309605	89.48%	79.613393	1.470685
89.83%	77.018498	1.5750594	89.83%	79.901578	1.5817276
90.17%	77.187631	1.7282892	90.17%	80.405181	1.7313818
90.52%	77.279201	1.9207158	90.52%	80.690867	1.9439406
90.86%	77.286387	2.1081146	90.86%	81.10964	2.1914864
91.21%	77.23566	2.3874145	91.21%	81.649152	2.3851815
91.55%	77.412706	2.639072	91.55%	82.239294	2.750399
91.90%	77.481526	2.9877365	91.90%	83.532029	3.050159
92.24%	77.476495	3.3875029	92.24%	84.988173	3.562706
92.59%	77.631222	3.8229166	92.59%	86.656396	4.0441893
92.93%	77.778941	4.5312025	92.93%	88.937014	4.6865154
93.28%	77.910972	5.2803845	93.28%	92.450124	5.4298459
93.62%	78.278234	6.0427361	93.62%	95.326785	6.3860223
93.97%	78.754846	7.23074	93.97%	102.01725	7.7989464

Table A-2. LHS Runs for HEKC-II and HKC 90HV

HEKC-II			HKC		
WORLOAD	**WIP**	**BL**	**WORLOAD**	**WIP**	**BL**
85.00%	79.086113	0.50070362	85.00%	83.430316	0.4611759
85.34%	79.321356	0.51214694	85.34%	84.074742	0.47114025
85.69%	79.476886	0.56678692	85.69%	84.838183	0.50637836
86.03%	79.834385	0.58123049	86.03%	85.834859	0.54335205
86.38%	80.061043	0.61477768	86.38%	86.967789	0.59514515
86.72%	80.331659	0.65827309	86.72%	88.444432	0.61966927
87.07%	80.71417	0.67265933	87.07%	89.749056	0.65969101
87.41%	81.03939	0.74053191	87.41%	91.50694	0.74584456
87.76%	81.524932	0.78639517	87.76%	94.149657	0.76672994
88.10%	81.871823	0.83178357	88.10%	97.280559	0.83006941
88.45%	82.454129	0.89445417	88.45%	101.06308	0.92408015
88.79%	82.878797	0.9779559	88.79%	108.4672	1.0080226
89.14%	83.657777	1.0390759	89.14%	115.69811	1.1670338
89.48%	84.333402	1.1488503	89.48%	130.97769	1.2919753
89.83%	85.560011	1.2248513	89.83%	3000	1000
90.17%	86.641451	1.3565286	90.17%	3000	1000
90.52%	88.195356	1.5020018	90.52%	3000	1000
90.86%	89.651001	1.6682182	90.86%	3000	1000
91.21%	91.90648	1.797956	91.21%	3000	1000
91.55%	94.338881	1.9812476	91.55%	3000	1000
91.90%	98.420516	2.1336145	91.90%	3000	1000
92.24%	103.6611	2.376368	92.24%	3000	1000
92.59%	112.37357	2.643983	92.59%	3000	1000
92.93%	123.71325	3.1143967	92.93%	3000	1000
93.28%	140.45333	3.4850285	93.28%	3000	1000
93.62%	3000	1000	93.62%	3000	1000
93.97%	3000	1000	93.97%	3000	1000

A2. LHS RUNS - PCS WITH LOWER VARIABILITY AND 90% RETURNED MATERIALS

Table A-3. LHS Runs for DNC HEKC-II and DNC HKC 90LV

DNC HEKC-II			DNC HKC		
WORLOAD	WIP	BL	WORLOAD	WIP	BL
85.00%	69.325289	0.49660165	85.00%	71.330735	0.50808486
85.34%	69.476885	0.51328978	85.34%	71.516834	0.53520525
85.69%	69.662981	0.53370068	85.69%	71.756303	0.55296791
86.03%	69.832588	0.55175412	86.03%	71.980131	0.57312795
86.38%	70.01223	0.57394111	86.38%	72.180911	0.60321554
86.72%	70.193538	0.59426485	86.72%	72.422774	0.62926801
87.07%	70.401758	0.6190238	87.07%	72.675168	0.65740822
87.41%	70.621403	0.63783348	87.41%	72.891347	0.68611502
87.76%	70.837253	0.66623383	87.76%	73.175673	0.72749634
88.10%	71.073864	0.70016913	88.10%	73.451884	0.75936341
88.45%	71.340053	0.73286645	88.45%	73.691641	0.79933767
88.79%	71.603608	0.76768087	88.79%	73.9532	0.84361142
89.14%	71.902555	0.79995583	89.14%	74.228486	0.9006781
89.48%	72.194838	0.83879655	89.48%	74.410822	0.95604558
89.83%	72.511323	0.88057088	89.83%	74.718292	1.0038282
90.17%	72.87499	0.93010706	90.17%	75.038515	1.072577
90.52%	73.293112	0.97867566	90.52%	75.610673	1.1362561
90.86%	73.743471	1.0228038	90.86%	76.094962	1.1953251
91.21%	74.208371	1.0822908	91.21%	76.61261	1.2730615
91.55%	74.764048	1.1489777	91.55%	77.120423	1.3597824
91.90%	75.36423	1.2319118	91.90%	77.633607	1.4490384
92.24%	76.068008	1.3090224	92.24%	78.220187	1.5371979
92.59%	76.848335	1.4079091	92.59%	78.756571	1.6567358
92.93%	77.741747	1.5131631	92.93%	79.461518	1.7794465
93.28%	78.893347	1.6342219	93.28%	80.288936	1.93971
93.62%	80.133687	1.7598067	93.62%	81.20922	2.0926
93.97%	81.59688	1.8844083	93.97%	82.405648	2.2813328
94.31%	83.165247	1.9920011	94.31%	83.498704	2.503717
94.66%	84.859522	2.1381304	94.66%	84.980774	2.7932851
95.00%	87.318807	2.3282272	95.00%	86.789807	2.9517215

Table A-4. LHS Runs for HEKC-II and HKC 90LV

HEKC-II			HKC		
WORLOAD	**WIP**	**BL**	**WORLOAD**	**WIP**	**BL**
85.00%	73.905941	0.49030762	85.00%	73.499897	0.46704456
85.34%	73.806009	0.52113222	85.34%	73.35873	0.50435088
85.69%	73.716796	0.5572142	85.69%	73.230436	0.53842248
86.03%	73.630356	0.5956327	86.03%	73.103258	0.57707023
86.38%	73.500369	0.64052353	86.38%	72.95525	0.62567361
86.72%	73.366226	0.68474425	86.72%	72.792186	0.66869811
87.07%	73.238011	0.74765322	87.07%	72.587078	0.72799725
87.41%	73.102962	0.80520398	87.41%	72.419337	0.78946093
87.76%	72.916701	0.87859934	87.76%	72.193151	0.86724411
88.10%	72.722823	0.9578808	88.10%	71.986383	0.93875587
88.45%	72.515937	1.0428943	88.45%	71.743059	1.0252376
88.79%	72.307216	1.1426043	88.79%	71.480544	1.1328364
89.14%	72.071848	1.2379343	89.14%	71.229193	1.2376083
89.48%	71.779164	1.3682677	89.48%	70.919575	1.3646844
89.83%	71.534185	1.4896348	89.83%	70.625462	1.4921573
90.17%	71.247396	1.6406026	90.17%	70.293899	1.6439088
90.52%	70.897652	1.8143135	90.52%	69.936945	1.7993245
90.86%	70.571144	2.0222442	90.86%	69.522887	2.0180577
91.21%	70.166541	2.2497305	91.21%	69.096096	2.2259329
91.55%	69.770199	2.5101719	91.55%	68.627131	2.525191
91.90%	69.32023	2.8129851	91.90%	68.165909	2.8268357
92.24%	68.824312	3.1817009	92.24%	67.679566	3.1824046
92.59%	68.278452	3.629417	92.59%	67.098864	3.6508965
92.93%	67.638476	4.1844782	92.93%	66.502439	4.1771444
93.28%	66.952641	4.8426803	93.28%	65.866079	4.8342844
93.62%	66.253308	5.628995	93.62%	65.210255	5.6042332
93.97%	65.495023	6.7368797	93.97%	64.478939	6.6022409
94.31%	3000	1000	94.31%	3000	1000
94.66%	3000	1000	94.66%	3000	1000
95.00%	3000	1000	95.00%	3000	1000

A3. LHS RUNS - PCS WITH HIGHER VARIABILITY AND 40% RETURNED MATERIALS

Table A-5. LHS Runs for DNC HEKC-II and DNC HKC 40HV

DNC HEKC-II			DNC HKC		
WORLOAD	**WIP**	**BL**	**WORLOAD**	**WIP**	**BL**
85.00%	49.388988	0.47181962	85.00%	49.414897	0.4542133
85.34%	49.432189	0.51556182	85.34%	49.449512	0.49677824
85.69%	49.479627	0.56969081	85.69%	49.481632	0.54295931
86.03%	49.523761	0.61639375	86.03%	49.522635	0.59751467
86.38%	49.570389	0.68144165	86.38%	49.553516	0.65316117
86.72%	49.615689	0.74519351	86.72%	49.602811	0.71155181
87.07%	49.671084	0.81225982	87.07%	49.659313	0.78744027
87.41%	49.718561	0.90041158	87.41%	49.68795	0.86899264
87.76%	49.781181	0.98819982	87.76%	49.739557	0.9598703
88.10%	49.832842	1.0901071	88.10%	49.784113	1.0625599
88.45%	49.89809	1.1927515	88.45%	49.822367	1.1670429
88.79%	49.957475	1.3223386	88.79%	49.878883	1.2870236
89.14%	50.005077	1.4674207	89.14%	49.941116	1.4340502
89.48%	50.071495	1.6427003	89.48%	49.972222	1.5878639
89.83%	50.120647	1.8194412	89.83%	50.02807	1.7737256
90.17%	50.201873	2.0267008	90.17%	50.0801	1.9832685
90.52%	50.263251	2.2545116	90.52%	50.141144	2.2005326
90.86%	50.327642	2.5267323	90.86%	50.199289	2.4677306
91.21%	50.426495	2.8231229	91.21%	50.275589	2.7637917
91.55%	50.493898	3.1559135	91.55%	50.336731	3.0907106
91.90%	50.573132	3.5472383	91.90%	50.418586	3.4907947
92.24%	50.677892	4.0062413	92.24%	50.491838	3.9303728
92.59%	50.784016	4.480696	92.59%	50.571962	4.4703478
92.93%	50.897119	5.0944324	92.93%	50.667279	5.0109682
93.28%	51.018681	5.7887461	93.28%	50.77729	5.6865095
93.62%	51.153459	6.5815872	93.62%	50.885958	6.5002913
93.97%	51.292719	7.535029	93.97%	51.020297	7.3984737
94.31%	51.43372	8.6887635	94.31%	51.152299	8.5144083
94.66%	51.603983	10.069528	94.66%	51.306058	9.9293488
95.00%	3000	1000	95.00%	3000	1000

Table A-6. LHS Runs for HEKC-II and HKC 40HV

HEKC-II			HKC		
WORLOAD	WIP	BL	WORLOAD	WIP	BL
85.00%	49.645793	0.48005665	85.00%	49.820926	0.46726972
85.34%	49.67905	0.52374153	85.34%	49.887218	0.51276358
85.69%	49.710089	0.57498555	85.69%	49.909237	0.56929037
86.03%	49.739011	0.64040547	86.03%	49.971464	0.61653433
86.38%	49.75335	0.71153591	86.38%	50.01062	0.68509401
86.72%	49.79707	0.77525121	86.72%	50.100651	0.74412056
87.07%	49.823763	0.84862235	87.07%	50.126859	0.82223128
87.41%	49.858348	0.93544984	87.41%	50.200416	0.92244826
87.76%	49.890383	1.0329276	87.76%	50.237635	1.0112852
88.10%	49.901718	1.1533825	88.10%	50.3228	1.1230071
88.45%	49.935159	1.2859805	88.45%	50.41578	1.2411423
88.79%	49.954847	1.4288412	88.79%	50.497538	1.3853676
89.14%	49.952214	1.6082263	89.14%	50.57956	1.544924
89.48%	50.004665	1.7977183	89.48%	50.647525	1.7112633
89.83%	50.010914	2.0113792	89.83%	50.726803	1.9191613
90.17%	50.024496	2.2613346	90.17%	50.812526	2.1467519
90.52%	50.027441	2.5602947	90.52%	50.910952	2.397478
90.86%	50.058865	2.8726208	90.86%	51.008807	2.694304
91.21%	50.080227	3.2454182	91.21%	51.156357	3.0718844
91.55%	50.095787	3.6996117	91.55%	51.24	3.4446461
91.90%	50.134588	4.1763194	91.90%	51.420652	3.8758057
92.24%	50.107153	4.8278174	92.24%	51.559031	4.4180694
92.59%	50.136557	5.538044	92.59%	51.745196	5.1099509
92.93%	50.146902	6.3811941	92.93%	51.867956	5.7842362
93.28%	50.16387	7.443438	93.28%	52.105613	6.7014081
93.62%	50.17825	8.6387843	93.62%	52.291012	7.683652
93.97%	50.188499	10.272623	93.97%	52.555765	9.0332306
94.31%	3000	1000	94.31%	52.821154	10.565061
94.66%	3000	1000	94.66%	3000	1000
95.00%	3000	1000	95.00%	3000	1000

A4. LHS RUNS - PCS WITH LOWER VARIABILITY AND 40% RETURNED MATERIALS

Table A-7. LHS Runs for DNC HEKC-II and DNC HKC 40LV

DNC HEKC-II			DNC HKC		
WORLOAD	**WIP**	**BL**	**WORLOAD**	**WIP**	**BL**
85.00%	42.852711	0.52605592	85.00%	42.86896	0.50744223
85.34%	42.940947	0.5604323	85.34%	42.922992	0.54445108
85.69%	43.017354	0.60346055	85.69%	42.979817	0.58561966
86.03%	43.104516	0.64586774	86.03%	43.037466	0.6280678
86.38%	43.193331	0.68822126	86.38%	43.096653	0.674052
86.72%	43.283777	0.7357745	86.72%	43.157015	0.72552605
87.07%	43.375392	0.7887677	87.07%	43.212496	0.78072314
87.41%	43.462996	0.84569023	87.41%	43.277651	0.83593247
87.76%	43.551942	0.90716998	87.76%	43.338205	0.89943233
88.10%	43.644607	0.97793684	88.10%	43.395805	0.97123518
88.45%	43.737606	1.0552895	88.45%	43.459859	1.0507486
88.79%	43.833378	1.1418768	88.79%	43.527401	1.1379931
89.14%	43.933282	1.2382083	89.14%	43.59209	1.2310221
89.48%	44.034348	1.3364434	89.48%	43.665239	1.3349613
89.83%	44.144777	1.4473853	89.83%	43.733695	1.4441256
90.17%	44.251822	1.5660913	90.17%	43.806143	1.564521
90.52%	44.355285	1.7072371	90.52%	43.877275	1.7001955
90.86%	44.459184	1.8466284	90.86%	43.953602	1.8459142
91.21%	44.579027	2.0096311	91.21%	44.029756	2.0074749
91.55%	44.694328	2.1921909	91.55%	44.109728	2.1949546
91.90%	44.81384	2.3979933	91.90%	44.187107	2.4141532
92.24%	44.92893	2.6256884	92.24%	44.264859	2.6544049
92.59%	45.061748	2.8915153	92.59%	44.347548	2.9298044
92.93%	45.184125	3.1805016	92.93%	44.438577	3.2205193
93.28%	45.331094	3.4975779	93.28%	44.526634	3.5714516
93.62%	45.478094	3.8673778	93.62%	44.624881	3.9574986
93.97%	45.628479	4.2804514	93.97%	44.728913	4.4093777
94.31%	45.792098	4.7791163	94.31%	44.837814	4.9249076
94.66%	45.966215	5.3414462	94.66%	44.955182	5.5268893
95.00%	46.149803	5.9860413	95.00%	45.082206	6.2117505

Table A-8. LHS Runs for HEKC-II and HKC 40LV

HEKC-II			HKC		
WORLOAD	**WIP**	**BL**	**WORLOAD**	**WIP**	**BL**
85.00%	43.448605	0.51256888	85.00%	43.486752	0.52626238
85.34%	43.510286	0.55097537	85.34%	43.535166	0.56570038
85.69%	43.57333	0.59334124	85.69%	43.580394	0.60814774
86.03%	43.637629	0.63685226	86.03%	43.626786	0.65536759
86.38%	43.699211	0.68465814	86.38%	43.67569	0.70502894
86.72%	43.765174	0.73691826	86.72%	43.724915	0.7592992
87.07%	43.832074	0.79391945	87.07%	43.773511	0.82001411
87.41%	43.904293	0.85532708	87.41%	43.821782	0.88531871
87.76%	43.971883	0.92278851	87.76%	43.868991	0.95521905
88.10%	44.044057	0.99636711	88.10%	43.917132	1.0355563
88.45%	44.117164	1.0794021	88.45%	43.965497	1.1251291
88.79%	44.193496	1.1712905	88.79%	44.016344	1.2201911
89.14%	44.271191	1.2729046	89.14%	44.068399	1.3274952
89.48%	44.349867	1.3822391	89.48%	44.12434	1.4454653
89.83%	44.431966	1.5019786	89.83%	44.17694	1.568987
90.17%	44.516347	1.6306966	90.17%	44.236477	1.7085333
90.52%	44.604532	1.7741526	90.52%	44.291739	1.8572833
90.86%	44.690035	1.9292644	90.86%	44.350345	2.0250897
91.21%	44.778165	2.1111011	91.21%	44.410522	2.215278
91.55%	44.870029	2.3115885	91.55%	44.472371	2.4313254
91.90%	44.967231	2.5381514	91.90%	44.524935	2.6797725
92.24%	45.0659	2.7889252	92.24%	44.581502	2.9607039
92.59%	45.16336	3.0837935	92.59%	44.641276	3.2716667
92.93%	45.26655	3.413906	92.93%	44.701055	3.6284938
93.28%	45.385935	3.7857987	93.28%	44.767719	4.0221409
93.62%	45.492633	4.2107246	93.62%	44.832985	4.480435
93.97%	45.621568	4.6993205	93.97%	44.900592	5.0089965
94.31%	45.753517	5.255027	94.31%	44.970109	5.6357954
94.66%	45.899486	5.905528	94.66%	45.041262	6.33308
95.00%	46.040576	6.6946744	95.00%	45.118889	7.1787266

APPENDIX B. EVOLUTIONARY OPTIMISATION RESULTS FOR ALL STRATEGIES WITH 90% RETURNED MATERIALS

B1. INTELLIGENT SELF-DESIGNING STRATEGY – PAC OPTIMISED SETTINGS FOR UPPER PROCESSING TIME VARIABILITY

Table B-1. Production Authorisation Card Settings for Intelligent Self-Designing Strategy 90HV

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	MP	Kf	Km	Kmf	Ke	DE	TA	WIP	BL
2	48	12	6	2	12	13	18	2	12	4	1	1	1	44.91	16.14
2	68	12	10	5	11	15	15	1	16	2	4	4	2	45.28	15.84
2	59	13	10	2	10	8	19	4	11	4	2	7	2	45.35	15.74
2	51	12	6	2	11	8	15	3	10	2	1	7	2	45.47	15.31
2	50	11	11	4	9	7	15	2	9	1	3	1	1	45.83	15.04
2	81	11	10	3	9	15	15	2	9	1	2	8	1	45.83	14.95
2	78	7	8	2	8	7	15	4	13	4	1	2	1	45.84	14.73
2	48	9	8	6	8	11	15	4	15	1	4	2	1	46.17	14.43
2	42	12	11	6	8	16	15	4	16	1	3	3	1	46.20	14.32
2	85	12	14	6	12	16	15	4	7	2	1	7	5	46.49	14.24
2	78	11	12	4	10	18	15	2	9	1	2	3	5	46.76	13.96
2	85	11	6	5	10	7	15	4	13	4	3	9	6	46.83	13.68
2	64	12	7	6	7	13	15	4	10	3	4	7	1	46.87	12.70
2	72	12	7	6	7	8	15	1	10	3	1	7	2	47.19	12.28
2	72	12	7	6	7	7	15	1	8	3	1	8	2	47.55	11.92
2	45	12	6	6	7	11	15	2	16	1	2	4	2	47.69	11.92
2	50	11	6	4	7	9	15	4	15	1	4	2	3	47.91	11.78
2	85	7	11	3	12	9	24	1	16	4	1	1	1	48.15	6.51
2	42	11	9	2	12	17	25	1	14	4	4	6	1	48.21	6.50
2	81	12	13	2	10	14	23	2	8	3	1	8	1	48.31	6.43
2	85	14	9	6	12	14	25	3	15	4	2	9	2	48.46	6.22
2	67	10	6	5	12	12	26	1	15	4	4	3	2	48.58	6.14
2	67	10	6	6	12	17	25	1	15	4	1	6	2	48.58	6.13
2	58	7	10	2	12	15	26	4	15	4	1	7	2	48.60	6.12
2	51	12	7	6	8	8	20	4	9	4	4	7	1	48.93	6.09
2	79	8	8	2	8	17	23	1	9	3	4	8	2	49.13	5.96
2	48	8	14	2	8	18	25	1	9	2	2	7	2	49.18	5.95
2	68	10	13	2	12	18	24	4	8	1	3	1	3	49.28	5.74
2	68	12	9	6	12	17	22	1	8	3	2	1	4	49.57	5.58
2	85	12	14	6	10	12	25	4	15	4	3	5	5	50.04	5.29
2	51	15	7	5	11	13	30	4	14	4	4	1	1	50.21	3.76
2	85	14	6	6	12	8	30	1	16	4	1	9	1	50.30	3.75
2	57	14	6	3	10	10	27	1	13	4	1	9	1	50.42	3.72

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	MP	Kf	Km	Kmf	Ke	DE	TA	WIP	BL
2	52	7	14	6	10	8	27	1	11	2	3	4	1	50.48	3.70
2	85	14	6	2	9	9	28	1	15	4	1	9	1	50.64	3.65
2	70	10	10	6	8	13	27	4	16	2	4	9	1	50.69	3.63
2	44	15	6	6	8	17	30	3	10	4	2	8	1	50.86	3.62
2	69	11	6	6	8	18	33	1	13	2	1	6	1	50.88	3.60
2	85	12	9	2	11	12	28	2	14	1	1	9	1	51.23	3.58
2	80	8	8	6	9	7	29	4	13	1	2	2	1	51.24	3.52
2	82	7	8	2	12	9	33	1	11	1	3	8	2	51.32	3.32
2	49	15	14	4	12	11	33	4	16	4	1	1	3	51.54	3.11
2	76	12	7	6	12	9	36	3	9	4	4	8	1	51.57	2.62
2	64	12	7	2	12	13	39	4	8	3	1	8	1	51.69	2.61
2	84	9	6	4	12	13	37	4	8	4	3	3	1	51.73	2.58
2	60	12	7	6	8	16	37	4	9	4	1	8	1	51.99	2.57
2	76	12	7	6	11	8	36	1	9	1	4	8	1	52.15	2.53
2	82	14	9	3	11	10	34	1	13	4	1	9	2	52.26	2.32
2	78	9	10	3	12	18	44	1	10	3	2	5	1	52.57	2.08
2	75	13	14	2	10	16	44	2	9	3	4	2	1	52.68	2.07
2	47	14	6	6	11	13	44	4	10	3	1	1	1	52.77	2.05
2	84	12	6	4	10	17	43	4	8	3	2	8	1	52.95	2.04
2	84	9	14	4	8	8	42	3	16	4	3	4	1	53.10	2.02
2	82	9	11	4	11	9	45	1	11	1	3	8	1	53.11	2.02
2	82	11	6	5	12	9	45	4	11	1	3	8	1	53.11	2.00
2	82	11	14	5	12	7	45	1	15	1	4	3	1	53.24	1.98
2	81	12	10	3	12	18	48	1	11	4	1	2	1	53.33	1.80
2	75	14	10	2	10	16	47	2	14	4	3	1	1	53.34	1.79
2	74	10	9	6	12	17	43	4	16	4	1	8	2	53.36	1.79
2	78	12	10	2	11	14	47	1	15	3	1	1	1	53.40	1.79
2	83	13	6	2	11	14	47	4	15	2	3	1	1	53.42	1.78
2	85	13	10	2	10	15	47	1	13	4	1	4	1	53.44	1.78
2	72	7	8	3	12	18	47	2	10	3	1	6	1	53.48	1.77
2	55	10	12	3	12	18	47	4	8	2	4	1	1	53.52	1.77
2	82	7	7	3	11	9	48	2	15	4	3	1	1	53.55	1.77
2	78	7	6	2	11	14	47	3	15	4	3	2	1	53.55	1.76
2	85	10	6	6	12	13	47	2	8	2	1	2	1	53.73	1.76
2	46	7	14	6	12	18	47	1	8	3	2	5	1	53.76	1.75
2	47	7	8	2	9	13	48	3	13	3	1	8	1	53.87	1.74
2	78	14	10	3	12	7	47	4	10	1	4	2	1	53.97	1.71
2	84	13	11	2	11	7	47	4	15	1	4	1	1	53.99	1.70
2	79	9	11	4	12	13	44	1	12	4	4	1	3	54.22	1.56
2	51	10	14	3	12	9	47	2	16	4	1	8	2	54.26	1.54
2	58	7	10	6	11	18	47	2	15	4	3	9	2	54.29	1.53
2	82	14	6	4	10	16	47	2	16	2	4	9	2	54.33	1.52
2	77	10	10	4	8	16	48	1	15	3	4	7	2	54.52	1.52
2	59	14	10	4	8	18	48	1	13	4	1	1	2	54.56	1.52
2	81	7	7	3	9	17	47	1	12	3	3	7	2	54.62	1.49
2	85	12	11	6	12	18	47	1	9	1	2	1	2	54.78	1.48
2	82	12	10	2	12	16	48	3	15	3	2	6	3	54.97	1.33
2	57	14	10	6	12	8	47	4	14	2	2	2	3	55.06	1.33
2	50	11	9	6	12	13	48	4	15	4	2	2	3	55.06	1.33
2	83	10	11	3	10	13	47	1	8	4	1	9	3	55.36	1.31
2	81	12	10	2	12	18	48	4	16	1	4	5	3	55.43	1.30
2	66	8	7	2	12	7	47	1	8	2	2	8	3	55.46	1.29
2	52	12	14	3	10	13	48	1	16	1	4	5	3	55.62	1.26
2	64	15	6	6	10	9	48	1	11	1	2	9	3	55.89	1.26
2	68	10	9	2	12	18	48	2	12	4	1	9	4	55.92	1.15
2	54	12	10	5	10	9	47	1	16	3	4	5	4	56.04	1.15
2	62	14	14	2	12	11	48	4	8	2	3	7	4	56.05	1.14
2	60	8	13	4	11	9	47	1	8	2	4	1	4	56.26	1.13
2	64	10	13	4	8	8	48	1	15	3	4	9	4	56.34	1.12
2	67	12	8	2	12	15	48	1	10	1	2	1	4	56.55	1.10
2	82	7	8	2	11	18	48	4	13	1	4	2	4	56.56	1.09
2	82	13	8	3	10	8	47	1	11	1	2	9	4	56.64	1.08
2	82	11	6	5	8	18	48	4	15	1	4	2	4	56.91	1.08
2	79	13	14	2	12	16	44	2	16	2	2	1	6	56.91	1.06
2	85	8	12	2	12	9	48	4	16	2	2	1	5	56.95	0.99
2	72	12	6	4	12	8	48	1	10	4	3	9	5	57.08	0.97
2	85	9	10	4	12	12	47	4	13	1	3	2	5	57.29	0.96
2	83	13	6	6	12	10	47	3	11	1	4	2	5	57.39	0.95
2	85	11	6	6	12	18	48	3	13	1	2	4	5	57.54	0.95
2	84	7	6	4	12	15	47	4	10	1	3	9	5	57.61	0.94
2	82	10	14	3	12	9	47	4	7	4	4	8	5	57.83	0.94
2	74	9	11	6	7	15	48	4	16	1	4	9	5	57.88	0.94

INTELLIGENT SELF-DESIGNING STRATEGY – PAC OPTIMISED SETTINGS FOR UPPER PROCESSING TIME VARIABILITY

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	MP	Kf	Km	Kmf	Ke	DE	TA	WIP	BL
2	70	14	11	2	9	16	48	4	12	3	3	6	6	57.98	0.86
2	84	7	11	3	12	18	48	2	10	3	2	8	6	58.07	0.85
2	85	7	13	2	12	9	48	2	12	2	1	9	6	58.15	0.85
2	78	7	8	3	11	7	48	4	10	4	1	2	6	58.25	0.85
2	73	10	10	4	8	8	48	1	15	2	1	4	6	58.31	0.84
2	67	7	12	2	12	11	48	2	10	1	4	1	6	58.39	0.82
2	79	14	10	5	11	18	48	2	13	4	1	8	7	58.76	0.76
2	79	14	10	2	10	11	48	3	9	3	1	2	7	58.85	0.75
2	74	10	9	4	9	13	47	4	11	4	1	1	7	58.97	0.75
2	55	9	13	5	7	9	48	2	16	4	1	2	7	59.40	0.74
2	85	13	7	2	8	18	48	1	15	1	4	5	7	59.49	0.73
2	84	15	10	4	12	15	47	2	10	2	2	8	8	59.66	0.67
2	82	13	6	2	12	18	48	4	15	3	1	5	8	59.94	0.67
2	78	7	13	2	12	16	47	2	9	4	2	8	8	60.02	0.66
2	50	13	6	2	12	18	48	3	8	2	4	1	8	60.18	0.66
2	85	12	10	5	7	17	47	4	12	4	4	2	8	60.26	0.66
2	85	8	7	2	8	8	48	4	14	2	4	9	8	60.30	0.65
2	79	14	13	2	12	14	48	2	8	3	3	8	9	60.65	0.60
2	67	13	7	2	12	18	47	4	9	1	4	6	9	61.01	0.59
2	60	15	13	2	8	18	47	1	9	1	4	1	9	61.16	0.58
2	74	14	9	2	8	15	48	4	12	1	3	8	9	61.21	0.58
2	82	7	6	2	10	12	47	4	10	4	1	9	9	61.33	0.58
2	46	13	7	6	10	9	47	3	11	1	2	1	9	61.53	0.57
2	66	15	7	2	12	18	47	1	16	4	1	1	10	61.69	0.53
2	78	12	7	6	10	17	47	2	8	4	4	2	10	61.86	0.53
2	57	7	14	2	12	18	47	2	8	4	3	2	10	62.03	0.53
2	46	11	10	2	10	13	48	1	11	4	4	1	10	62.06	0.53
2	72	15	6	4	8	7	48	1	10	3	3	5	10	62.29	0.52
2	75	7	8	2	10	16	48	3	15	1	3	9	10	62.30	0.52
2	75	13	14	5	10	17	47	2	13	4	4	1	11	62.48	0.49
2	81	13	10	4	12	17	47	4	14	2	1	2	11	62.49	0.49
2	72	14	14	5	12	17	47	4	10	1	4	2	11	62.66	0.48
2	82	8	7	4	12	7	47	3	16	3	1	9	11	62.85	0.48
2	75	7	12	2	12	7	48	4	11	2	1	2	11	62.99	0.47
2	51	12	6	2	11	15	48	2	13	2	1	1	11	63.12	0.47
2	85	11	10	6	10	13	47	1	8	1	1	9	11	63.29	0.47
2	82	14	13	5	12	18	47	2	11	2	4	8	12	63.35	0.44
2	61	13	10	4	12	17	47	2	15	2	3	2	12	63.39	0.44
2	72	9	11	2	12	16	47	4	16	4	2	6	12	63.44	0.44
2	85	12	11	6	11	9	47	1	16	1	3	1	12	63.71	0.43
2	73	9	7	5	7	15	48	2	11	2	4	1	12	64.13	0.43
2	85	11	6	2	8	12	48	4	16	2	1	6	12	64.19	0.43
2	82	12	7	6	11	11	48	2	7	1	3	9	12	64.30	0.43
2	77	8	6	3	8	16	48	4	8	3	1	7	12	64.36	0.42
2	66	9	11	2	8	17	47	1	16	1	1	3	12	64.39	0.42
2	54	12	13	2	6	9	47	4	8	2	2	5	12	64.58	0.42
2	48	11	14	2	6	7	47	2	14	2	4	1	12	64.60	0.41
2	76	15	6	6	11	7	48	1	9	1	1	1	12	64.61	0.41
3	78	9	7	5	11	8	48	1	16	2	3	2	9	64.85	0.41
3	82	10	8	6	11	14	47	2	13	1	3	1	9	64.97	0.40
3	78	15	14	3	10	18	48	4	15	4	1	8	10	65.41	0.38
3	79	14	10	5	11	17	48	1	8	2	1	7	10	65.67	0.37
3	84	11	7	3	12	8	47	4	8	3	2	3	10	65.78	0.36
3	81	10	6	3	11	7	47	1	15	2	1	9	10	66.15	0.36
3	79	14	12	6	11	17	47	4	12	1	1	1	10	66.27	0.36
3	79	9	6	4	7	18	48	4	15	2	4	7	10	66.76	0.35
3	82	15	9	2	8	10	48	4	10	4	1	8	11	66.79	0.33
3	49	13	13	2	10	7	47	4	15	4	4	6	11	66.87	0.33
3	79	7	11	6	12	8	48	2	13	2	1	1	11	67.00	0.33
3	76	7	7	5	12	13	47	4	12	2	1	1	11	67.18	0.32
3	85	12	14	5	11	15	47	4	16	4	1	1	12	67.23	0.31
3	82	15	8	2	11	7	48	4	8	4	1	1	12	67.58	0.31
3	69	14	10	6	11	13	48	4	13	1	4	8	12	67.62	0.30
3	83	11	6	5	12	14	47	3	11	3	4	2	12	67.82	0.30
3	63	14	12	4	11	11	48	3	15	1	1	1	12	68.21	0.29
3	82	7	8	2	9	7	48	4	16	1	4	2	12	68.55	0.29
3	40	11	10	2	10	7	48	2	7	3	4	6	12	69.12	0.29
3	78	9	10	6	6	18	48	3	10	2	1	9	12	69.26	0.28
3	84	12	6	3	6	7	48	2	14	1	4	9	12	69.60	0.27
4	60	15	14	2	10	15	47	1	15	4	3	1	10	69.98	0.27
4	62	15	14	4	10	16	47	3	15	4	2	4	10	70.07	0.26
4	85	13	14	2	11	9	47	2	15	4	4	4	11	70.69	0.24

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	MP	Kf	Km	Kmf	Ke	DE	TA	WIP	BL
4	70	14	9	6	10	17	48	1	8	2	1	1	11	71.33	0.23
4	82	15	12	4	11	17	47	1	12	3	1	9	12	71.63	0.21
4	85	7	14	3	12	18	47	2	15	4	1	4	12	72.39	0.21
4	85	7	9	3	12	11	48	2	10	4	3	4	12	72.55	0.21
4	81	15	6	4	12	7	47	4	9	4	3	8	12	72.56	0.21
4	44	12	14	4	12	18	47	4	10	2	1	5	12	72.80	0.21
4	74	8	14	2	12	15	47	3	15	1	1	8	12	72.83	0.20
4	85	13	8	2	12	7	48	1	7	1	4	7	12	73.29	0.20
4	74	7	6	2	11	14	47	1	14	1	1	2	12	73.83	0.20
4	44	12	7	6	11	11	48	1	16	1	1	1	12	74.28	0.20
4	83	13	6	6	6	7	47	2	11	4	3	1	12	74.37	0.19
5	72	9	12	2	12	12	47	4	9	4	3	1	11	76.13	0.17
5	83	13	12	6	12	18	48	2	16	3	4	6	12	76.67	0.16
5	82	8	12	2	12	18	48	2	9	3	1	5	12	77.25	0.15
5	72	15	13	5	8	16	48	1	8	2	4	1	12	78.22	0.15
5	84	8	9	6	10	10	48	2	13	1	2	4	12	78.35	0.15
5	48	12	14	2	7	9	47	4	8	1	4	9	12	79.41	0.15
5	46	9	6	2	6	7	47	2	16	4	3	6	12	80.92	0.14
5	48	11	10	5	6	9	47	2	7	2	1	9	12	82.76	0.14
6	78	14	10	6	12	10	47	1	13	2	4	1	12	82.86	0.12
6	76	14	8	3	9	9	48	2	15	3	3	9	12	84.25	0.12
6	85	14	13	5	9	12	48	1	9	1	3	9	12	84.54	0.11
6	82	8	10	5	8	9	44	4	14	2	1	1	11	84.73	0.11
6	67	14	6	6	12	11	45	4	12	1	4	5	12	84.99	0.11
6	67	14	6	4	11	11	48	4	13	1	4	2	12	85.32	0.11
6	84	7	10	5	8	8	45	2	14	2	1	4	12	85.86	0.10
6	75	12	8	2	7	7	40	1	14	1	3	9	12	86.29	0.10
6	85	7	7	5	7	9	46	1	9	3	2	8	12	87.38	0.10
6	85	7	13	5	6	7	48	2	15	2	1	7	12	87.64	0.10
6	59	13	7	6	6	10	48	3	16	1	1	1	12	88.77	0.10
7	62	13	13	2	11	17	48	4	9	4	1	9	10	89.06	0.09
6	45	7	6	6	7	8	48	2	8	1	1	5	12	90.04	0.09
7	78	12	10	4	12	18	45	4	10	3	1	5	12	90.08	0.08
7	85	12	14	4	8	9	48	1	12	3	2	9	11	91.26	0.07
7	82	15	14	4	8	9	48	4	13	3	2	1	12	91.55	0.07
7	48	15	12	2	9	18	48	4	16	3	1	8	12	91.89	0.07
7	72	14	11	4	8	18	40	4	10	3	1	1	12	92.19	0.06
7	85	14	8	6	7	11	48	4	15	3	1	8	12	93.44	0.06
7	82	7	14	4	8	11	46	4	10	1	1	3	11	93.96	0.06
7	46	14	6	6	7	10	38	1	12	3	2	9	12	95.07	0.06
7	82	11	8	6	6	8	48	1	14	4	3	1	12	95.12	0.06
7	46	12	6	6	7	17	46	2	11	2	2	6	12	95.79	0.05
7	50	11	11	6	6	7	40	4	8	3	4	8	12	96.09	0.05
7	85	7	10	6	6	9	44	4	9	1	1	9	12	97.89	0.05
7	84	11	11	4	6	15	40	1	8	1	4	3	11	98.65	0.05
7	66	9	6	4	6	15	40	2	16	1	4	2	12	99.08	0.04
8	80	12	13	2	8	7	31	1	8	2	3	2	12	100.48	0.04
8	81	15	13	4	8	16	47	2	9	1	3	8	8	101.27	0.04
8	82	15	8	2	7	8	47	4	8	3	1	2	9	101.42	0.04
8	84	14	14	4	8	15	48	2	9	1	4	4	11	101.44	0.04
8	79	10	10	2	7	16	48	3	12	3	1	6	12	102.15	0.03
8	84	10	11	4	6	7	48	3	12	4	1	9	11	103.56	0.03
8	82	8	11	2	7	16	44	4	11	1	4	5	12	103.62	0.03
8	82	12	10	4	6	8	29	1	9	2	1	8	10	104.60	0.03
8	48	8	11	2	7	15	43	2	8	1	4	1	12	104.66	0.03
8	58	9	12	4	6	13	46	3	9	1	4	7	10	105.53	0.03
8	84	14	10	6	6	10	44	1	8	4	1	6	12	105.67	0.02
8	45	12	6	6	7	8	46	2	8	1	4	6	12	106.93	0.02
8	84	7	7	5	6	10	45	4	10	1	4	7	12	108.18	0.02
8	82	7	6	3	6	8	28	1	15	1	4	1	12	109.26	0.02
9	81	15	13	3	8	16	47	4	12	1	4	8	12	111.02	0.02
9	54	14	9	3	8	9	47	3	16	4	3	4	10	111.92	0.02
9	79	15	10	2	6	9	48	3	10	3	1	2	12	111.93	0.02
9	59	13	14	4	8	12	48	1	13	1	3	2	10	112.07	0.02
9	82	13	14	2	6	8	33	4	9	4	1	2	11	112.41	0.02
9	85	14	8	6	7	9	48	1	13	3	3	4	12	112.70	0.02
9	82	14	13	2	6	17	47	4	9	4	1	4	11	113.34	0.01
9	62	7	6	4	11	17	48	1	8	3	3	7	12	115.49	0.01
9	84	11	13	3	6	18	47	1	9	2	2	4	12	116.16	0.01
9	58	8	14	4	6	9	47	4	8	1	4	8	12	116.62	0.01
9	84	11	11	4	6	18	48	4	9	4	1	1	12	117.01	0.01
9	82	7	8	2	6	17	48	3	10	2	1	1	11	117.83	0.01

INTELLIGENT SELF-DESIGNING STRATEGY – PAC OPTIMISED SETTINGS FOR UPPER PROCESSING TIME VARIABILITY

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	MP	Kf	Km	Kmf	Ke	DE	TA	WIP	BL
9	82	7	7	6	6	7	45	4	11	3	4	1	11	117.91	0.01
9	82	12	11	4	6	16	43	4	8	1	2	4	11	118.99	0.01
9	58	9	7	4	6	13	25	4	8	4	4	5	11	122.59	0.01
9	84	8	8	6	6	18	23	4	8	1	1	8	12	127.48	0.00

B2. DNC HEKC-II - PAC OPTIMISED SETTINGS FOR UPPER PROCESSING TIME VARIABILITY

Table B-2. Production Authorisation Card Settings for DNC HEKC-II Strategy 90HV

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	MP	Kf	Km	Kmf	Ke	DE	WIP	BL
3	83	15	14	2	8	15	8	4	13	4	1	1	50.07	10.64
3	82	14	14	6	8	17	8	1	16	3	4	6	50.11	10.57
3	85	14	14	6	8	16	9	3	16	2	4	6	50.13	10.54
3	85	11	14	6	8	10	11	4	14	3	3	1	50.13	10.53
3	81	14	14	4	8	7	7	4	16	4	4	3	50.14	10.44
3	81	15	8	4	8	12	9	2	12	2	2	3	50.18	10.41
3	83	9	14	3	8	7	11	2	14	2	3	8	50.22	10.37
3	68	15	13	6	8	7	11	4	15	3	2	8	50.23	10.34
3	84	13	10	6	8	12	7	1	10	2	1	3	50.38	10.30
3	84	7	12	4	8	12	10	1	14	2	1	5	50.47	10.29
3	84	15	8	5	7	10	12	2	15	4	4	2	50.52	10.26
3	72	15	9	6	7	14	12	1	13	4	4	8	50.54	10.24
3	85	9	11	6	7	8	12	1	10	4	1	6	50.58	10.20
3	81	15	8	3	7	14	12	1	16	3	4	4	50.63	10.14
3	60	9	14	5	8	14	11	4	14	1	3	9	50.76	10.06
3	68	15	7	6	8	7	10	4	14	1	2	7	50.94	10.03
3	85	15	9	5	7	8	12	1	13	1	3	1	51.02	10.03
3	83	13	11	6	8	7	10	3	8	1	4	8	51.07	9.98
3	82	13	8	4	8	18	11	4	8	1	2	7	51.12	9.97
3	41	15	10	6	7	14	12	1	15	1	3	2	51.37	9.94
3	65	12	9	5	7	12	12	1	15	1	1	1	51.51	9.84
3	85	10	8	6	7	9	12	1	13	1	1	5	51.53	9.83
3	76	14	8	4	7	7	12	3	8	1	3	9	51.53	9.82
3	84	14	14	2	7	7	10	2	15	4	1	4	51.66	8.74
3	85	12	11	2	7	9	11	4	16	2	4	2	51.68	8.71
3	85	14	14	6	7	8	11	1	16	2	3	6	51.71	8.69
3	85	12	12	3	7	9	8	1	13	4	4	5	51.72	8.64
3	84	11	12	2	7	12	7	1	15	2	2	4	51.76	8.59
3	82	15	14	3	7	8	8	3	13	3	2	4	51.77	8.56
3	84	9	13	5	7	9	11	3	12	4	1	9	51.81	8.50
3	85	8	11	5	7	8	8	1	12	4	4	2	51.90	8.50
3	85	15	7	5	7	10	9	1	15	2	3	5	51.93	8.49
3	74	14	7	6	7	7	7	2	12	4	1	2	51.95	8.48
3	74	10	8	6	7	7	7	1	12	4	1	4	51.96	8.46
3	84	7	12	6	7	7	7	1	16	2	4	2	52.07	8.45
3	84	14	9	5	7	9	11	3	15	1	4	1	52.16	8.40
3	78	11	10	5	7	9	11	1	16	1	4	2	52.21	8.38
3	85	10	14	2	7	10	11	1	15	1	4	1	52.25	8.38
3	72	11	14	4	7	17	10	3	15	1	4	1	52.34	8.33
3	57	9	11	3	7	8	11	1	9	1	4	2	52.56	8.31
3	60	15	6	5	7	8	10	1	16	1	2	4	52.60	8.24
3	85	15	8	5	7	8	11	3	8	3	2	1	52.77	8.17
3	55	13	12	6	6	8	12	1	16	1	4	1	53.27	8.09
3	56	13	13	6	6	8	12	1	16	1	4	6	53.34	8.04
3	83	11	6	3	6	7	12	3	14	1	3	6	53.47	7.93
3	65	12	11	6	6	10	12	1	12	1	4	7	53.56	7.91
3	85	10	8	4	6	8	12	4	9	1	3	5	53.73	7.91
3	54	14	8	2	6	13	12	2	13	1	2	1	54.09	7.79
3	83	10	10	6	6	10	12	4	9	1	2	1	54.15	7.68
3	69	15	13	3	6	7	12	3	8	1	3	8	54.37	7.59
3	63	13	14	4	6	7	7	1	16	4	2	7	55.33	7.20
3	68	14	11	6	6	7	8	1	16	3	4	1	55.48	7.19
3	85	15	9	3	6	8	7	4	12	4	1	7	55.50	7.18
3	76	7	11	6	6	8	8	1	16	3	1	2	55.73	7.04

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	MP	Kf	Km	Kmf	Ke	DE	WIP	BL
3	76	15	6	6	6	8	10	3	15	2	4	4	55.76	7.02
3	56	12	12	4	6	7	11	1	14	3	3	7	55.80	7.01
3	83	15	14	2	6	7	10	4	15	1	4	2	55.95	6.96
3	66	15	14	6	6	7	11	2	10	1	4	6	56.28	6.94
3	69	11	6	5	6	10	11	4	16	4	2	6	56.34	6.89
3	72	13	6	3	6	8	11	3	15	1	3	4	56.42	6.87
3	73	12	12	5	6	13	8	1	13	3	4	6	56.57	6.86
4	75	10	14	2	12	13	8	2	16	2	2	1	56.58	4.00
4	69	14	11	2	11	18	12	2	16	3	2	1	56.64	3.96
4	84	12	12	6	12	15	12	4	11	4	4	2	56.70	3.91
4	83	15	14	2	11	11	7	1	13	2	4	3	56.82	3.89
4	83	12	14	4	12	13	9	4	14	4	2	7	56.87	3.84
4	84	14	8	5	12	14	12	4	13	3	3	7	56.92	3.80
4	85	11	14	5	12	15	12	4	9	2	4	9	57.00	3.80
4	85	14	12	5	11	14	12	4	13	3	3	7	57.01	3.79
4	69	13	10	6	12	10	10	1	13	3	4	9	57.04	3.79
4	83	14	11	5	12	9	8	1	16	4	4	7	57.06	3.78
4	85	12	13	4	12	8	11	1	12	3	2	7	57.12	3.76
4	83	12	10	5	11	13	8	4	14	4	4	6	57.12	3.74
4	81	15	8	6	11	17	12	4	15	4	1	2	57.18	3.73
4	71	12	10	4	11	8	11	4	13	3	2	6	57.38	3.69
4	70	12	10	4	12	7	11	4	14	3	2	6	57.38	3.69
4	71	13	13	4	11	8	10	3	16	4	1	7	57.38	3.68
4	85	15	13	6	12	7	11	3	14	2	1	4	57.47	3.68
4	72	15	11	6	10	14	11	1	16	2	2	6	57.51	3.67
4	85	14	11	5	10	9	10	3	12	3	1	4	57.56	3.64
4	85	13	9	6	11	7	10	3	12	3	1	4	57.57	3.61
4	85	10	11	6	10	7	7	4	16	2	3	1	57.77	3.58
4	77	14	11	4	9	18	12	4	16	3	2	1	58.13	3.54
4	85	15	14	4	9	9	7	2	12	3	4	8	58.26	3.47
4	85	13	13	4	9	9	11	4	16	2	4	6	58.30	3.47
4	84	15	14	6	9	8	10	3	15	4	3	5	58.31	3.46
4	83	14	14	5	9	8	10	4	13	3	3	7	58.33	3.43
4	84	15	14	4	9	9	11	1	13	3	1	2	58.41	3.40
4	83	10	12	5	9	14	7	1	9	4	4	7	58.75	3.38
4	54	10	14	6	9	7	11	2	11	4	2	9	58.78	3.37
4	84	14	9	3	8	11	12	1	11	3	3	5	58.85	3.36
4	64	15	12	5	8	18	12	4	11	3	1	5	58.94	3.36
4	84	12	7	6	8	10	12	4	13	3	4	6	58.98	3.34
4	83	9	13	3	8	7	12	2	14	2	1	7	59.08	3.34
4	46	12	13	6	9	12	11	1	11	2	1	8	59.17	3.34
4	85	11	10	5	9	9	8	1	8	2	4	8	59.20	3.34
4	84	15	14	4	9	9	11	3	16	1	4	7	59.22	3.31
4	85	8	9	4	8	8	12	3	15	2	4	2	59.22	3.30
4	68	12	7	6	8	7	12	4	16	2	1	7	59.35	3.25
4	75	10	11	2	8	18	8	3	12	4	4	9	59.37	3.15
4	83	14	8	2	8	16	10	2	12	4	4	2	59.46	3.10
4	85	13	14	5	8	14	10	4	15	3	2	2	59.50	2.99
4	71	12	14	4	8	8	10	4	16	3	1	6	59.62	2.99
4	85	14	12	6	8	16	10	4	15	2	3	5	59.64	2.98
4	83	13	13	5	8	12	7	1	10	2	4	6	59.66	2.97
4	85	12	13	4	8	7	11	2	16	3	2	1	59.71	2.95
4	84	11	10	5	8	16	7	4	13	2	1	8	59.90	2.92
4	71	12	7	6	8	12	10	1	12	3	2	3	59.97	2.90
4	53	13	7	5	8	8	11	3	13	3	2	6	60.21	2.89
4	85	15	10	4	7	8	12	1	16	4	2	2	60.27	2.86
4	85	12	9	5	7	12	12	4	13	2	1	7	60.54	2.83
4	63	12	7	4	7	7	12	4	9	2	2	2	61.04	2.81
4	79	14	14	2	7	7	7	4	13	4	3	7	61.31	2.52
4	83	15	12	3	7	9	8	2	14	3	3	8	61.49	2.49
4	85	14	14	3	7	9	11	4	15	2	4	2	61.49	2.46
4	84	14	14	4	7	8	7	1	13	3	1	4	61.51	2.46
4	85	12	14	6	7	8	7	4	13	4	1	9	61.54	2.45
4	84	13	11	6	7	8	10	3	15	4	4	5	61.56	2.45
4	85	14	14	6	7	7	11	3	16	2	2	2	61.62	2.45
4	84	10	12	6	7	8	11	2	15	4	1	2	61.63	2.44
4	71	14	14	4	7	8	11	4	16	2	1	6	61.72	2.44
4	80	10	14	6	7	11	9	3	10	2	4	5	61.83	2.41
4	85	8	9	3	7	7	8	1	15	4	4	5	62.09	2.38
4	77	12	14	5	7	9	11	1	16	1	3	2	62.45	2.37
4	85	12	14	4	7	7	11	1	16	1	4	9	62.55	2.35
4	85	9	8	5	7	10	11	1	13	1	4	2	62.67	2.35

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	MP	Kf	Km	Kmf	Ke	DE	WIP	BL
4	83	14	8	4	7	7	10	1	13	1	3	9	62.71	2.33
4	85	15	11	4	7	10	11	3	13	1	1	7	63.14	2.29
4	83	7	12	4	7	10	11	3	13	1	1	1	63.53	2.27
4	85	8	11	6	6	7	12	3	15	3	3	2	63.61	2.26
4	63	11	6	5	6	7	12	4	16	3	4	2	63.78	2.26
4	56	11	6	3	7	8	11	2	15	1	1	4	63.88	2.23
4	84	8	6	3	6	7	12	2	15	3	1	5	64.06	2.23
4	58	7	6	4	6	7	12	1	13	4	2	9	64.42	2.21
4	85	8	13	3	6	8	12	1	15	1	3	6	64.49	2.18
4	78	9	13	4	6	10	12	4	11	1	2	2	64.85	2.16
4	84	9	12	6	6	14	12	1	15	4	3	8	65.10	2.14
5	81	14	13	2	12	12	7	4	13	3	3	3	65.16	1.59
5	80	11	12	2	12	15	11	4	15	3	1	2	65.32	1.58
5	79	14	11	2	11	11	9	2	11	3	3	1	65.43	1.57
5	79	14	9	2	11	15	10	4	11	3	4	7	65.55	1.54
5	80	10	14	2	11	14	7	4	11	2	2	6	65.60	1.54
5	79	15	12	2	11	9	10	1	13	3	2	5	65.65	1.52
5	84	15	14	2	12	7	11	3	11	2	2	6	65.83	1.49
5	84	13	12	5	12	18	12	4	15	2	2	7	65.96	1.44
5	85	14	12	6	12	13	11	1	15	4	2	1	65.99	1.40
5	85	14	12	6	12	14	11	4	13	4	1	9	66.06	1.39
5	84	11	13	6	11	15	12	4	15	2	2	4	66.27	1.38
5	85	14	12	6	12	8	7	3	14	4	1	2	66.39	1.36
5	85	15	14	6	12	8	10	3	15	3	1	5	66.47	1.36
5	85	13	14	5	10	17	11	3	15	4	1	2	66.70	1.34
5	84	15	13	6	10	8	12	4	13	2	2	4	66.80	1.34
5	85	14	11	4	10	14	7	1	16	2	2	6	66.80	1.32
5	84	9	14	5	10	12	12	1	15	4	1	9	66.99	1.32
5	84	14	13	5	11	7	9	1	9	3	3	2	67.12	1.31
5	84	12	13	5	10	7	9	1	14	4	3	4	67.27	1.29
5	85	13	14	5	10	7	8	2	15	2	1	4	67.35	1.27
5	84	15	14	5	12	7	12	4	12	1	4	6	67.78	1.27
5	84	15	14	5	9	10	10	3	12	3	2	6	67.81	1.23
5	84	15	13	5	9	8	10	3	13	4	2	6	67.91	1.22
5	77	14	14	6	9	10	10	1	15	4	4	6	67.95	1.21
5	77	15	14	5	9	8	10	4	15	3	1	6	68.01	1.21
5	84	14	12	6	9	7	8	3	13	4	4	6	68.05	1.18
5	83	10	11	5	9	8	11	1	9	2	4	9	68.67	1.18
5	84	10	14	3	8	8	12	2	16	2	4	1	68.78	1.17
5	82	11	14	3	8	18	12	1	16	3	1	7	68.88	1.16
5	85	12	8	3	8	14	12	1	13	3	3	9	69.10	1.16
5	85	9	13	4	8	7	12	1	16	3	4	2	69.17	1.13
5	73	9	12	5	8	7	12	3	14	2	3	1	69.25	1.12
5	83	15	14	5	8	9	10	2	12	3	4	2	69.32	1.07
5	84	15	14	3	8	17	10	1	15	3	3	8	69.35	1.05
5	84	13	12	6	8	7	8	1	13	2	3	5	69.61	1.04
5	68	9	10	5	8	7	10	1	13	2	4	2	70.10	1.03
5	84	15	7	5	8	7	11	2	15	4	3	8	70.12	1.03
5	84	10	8	5	8	7	11	4	13	2	1	9	70.16	1.02
5	84	12	11	4	7	10	12	2	14	3	3	5	70.29	1.00
5	83	15	9	3	7	9	12	4	16	4	4	9	70.32	1.00
5	85	11	12	4	7	10	12	3	16	3	4	5	70.38	0.99
5	85	14	13	6	7	15	12	3	16	2	2	4	70.48	0.98
5	85	15	14	6	8	13	11	4	15	1	2	9	70.63	0.97
5	64	12	8	5	7	7	12	4	15	2	1	6	70.99	0.96
5	53	15	13	5	7	8	12	3	10	4	2	1	71.13	0.96
5	69	12	12	2	7	11	7	4	15	2	4	9	71.21	0.95
5	69	10	14	2	7	11	7	4	15	2	2	9	71.40	0.92
5	83	15	14	6	7	10	10	1	16	3	4	1	71.42	0.86
5	84	15	14	5	7	8	11	4	16	2	3	6	71.46	0.84
5	85	15	14	5	7	9	10	1	15	3	1	2	71.52	0.84
5	76	15	10	4	7	14	10	1	16	2	1	3	71.96	0.83
5	85	10	8	5	7	14	11	4	13	2	4	9	72.21	0.83
5	59	15	8	6	7	12	7	4	13	4	4	5	72.70	0.83
5	85	14	6	6	7	10	11	2	12	3	2	2	72.86	0.83
5	76	14	14	6	7	14	10	1	15	1	2	3	72.93	0.77
5	83	8	10	4	7	8	10	2	13	1	1	9	74.00	0.76
6	76	15	14	2	12	14	10	3	15	4	4	3	74.02	0.66
6	84	15	12	2	11	11	8	4	13	4	4	2	74.40	0.65
6	85	15	14	3	12	10	10	1	15	3	4	9	75.18	0.55
6	77	15	14	5	12	18	12	4	15	4	3	4	75.25	0.53
6	82	15	10	5	12	18	12	1	16	3	1	5	75.54	0.53

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	MP	Kf	Km	Kmf	Ke	DE	WIP	BL
6	83	12	12	4	12	18	12	2	14	2	1	8	75.63	0.53
6	84	14	11	4	12	10	12	4	9	3	2	9	75.73	0.52
6	85	15	14	4	12	9	12	4	9	3	2	9	75.78	0.52
6	84	15	12	6	12	8	10	2	16	3	1	1	75.87	0.51
6	80	14	14	6	11	9	10	1	16	4	4	2	75.89	0.51
6	85	15	12	4	12	7	12	4	12	3	1	2	76.11	0.49
6	85	14	14	6	10	8	12	1	14	2	3	6	76.40	0.49
6	84	15	14	6	11	8	8	4	13	2	1	8	76.40	0.49
6	85	10	14	6	12	7	12	2	12	3	1	9	76.55	0.49
6	85	10	12	6	11	8	11	1	14	2	2	6	76.64	0.49
6	85	15	14	4	10	7	11	2	15	2	3	8	76.64	0.48
6	79	11	12	6	10	10	7	1	15	3	1	5	76.77	0.48
6	84	15	10	6	10	7	11	2	15	4	4	6	76.82	0.47
6	85	9	10	5	10	10	10	3	13	4	1	6	77.18	0.47
6	75	13	10	5	10	7	7	4	13	4	2	2	77.32	0.47
6	85	12	12	6	12	8	12	4	14	1	3	6	77.38	0.46
6	85	15	14	6	9	10	11	4	12	3	1	9	77.65	0.45
6	83	14	11	6	9	10	8	1	16	3	2	2	77.73	0.44
6	84	14	12	6	9	9	11	1	15	4	1	9	77.74	0.44
6	84	14	10	4	9	7	11	4	11	3	1	7	78.05	0.44
6	84	12	10	6	9	8	10	1	9	3	1	6	78.69	0.42
6	84	12	14	6	9	7	10	1	9	2	1	8	78.74	0.42
6	83	11	14	6	9	7	10	1	9	2	1	8	78.79	0.41
6	84	12	13	5	8	9	12	1	13	3	1	9	78.87	0.40
6	83	15	14	4	8	9	10	1	16	3	4	9	79.25	0.38
6	84	13	14	6	8	7	10	2	12	3	1	9	79.42	0.37
6	82	10	10	6	8	7	7	4	13	3	1	1	80.20	0.37
6	81	14	12	4	7	8	12	2	12	3	3	9	80.35	0.35
6	81	15	11	3	8	7	11	4	15	1	2	7	80.97	0.35
6	85	14	14	5	7	10	10	4	16	3	3	1	81.37	0.32
6	85	14	14	6	7	10	10	1	16	2	2	5	81.41	0.31
6	84	15	14	4	7	10	11	4	16	2	1	9	81.54	0.31
6	84	15	14	4	7	7	10	1	13	2	2	2	81.58	0.31
6	80	13	14	6	7	7	9	1	13	2	1	5	81.84	0.30
6	85	10	12	4	7	12	11	1	15	2	2	6	82.09	0.30
6	84	14	14	4	7	7	10	3	16	1	4	3	82.78	0.29
6	85	14	11	4	7	8	10	4	13	1	1	9	83.76	0.29
6	72	14	12	6	6	7	12	4	12	2	3	8	84.08	0.28
7	84	14	12	2	10	15	10	2	15	4	3	9	84.29	0.27
6	65	13	9	5	6	7	12	1	16	3	3	8	84.61	0.27
7	80	15	13	3	12	10	12	1	15	3	2	6	84.88	0.23
7	85	11	13	6	12	18	10	4	15	2	2	7	85.45	0.21
7	84	15	14	6	12	8	8	2	15	2	4	4	85.69	0.21
7	83	14	14	6	11	10	8	1	13	4	3	9	85.78	0.21
7	85	14	14	6	12	7	11	1	16	3	4	2	85.99	0.20
7	83	10	11	6	12	8	11	2	13	4	4	3	86.62	0.20
7	80	10	12	6	11	7	12	2	12	3	2	7	87.22	0.19
7	83	15	9	5	10	8	10	4	16	2	1	9	87.33	0.19
7	83	14	14	3	9	10	10	1	13	3	3	9	87.42	0.19
7	83	15	14	6	9	12	12	4	12	4	1	9	87.49	0.18
7	83	14	14	4	9	10	10	1	13	3	3	1	87.56	0.18
7	83	14	14	6	9	10	10	4	13	3	3	5	87.61	0.18
7	83	12	11	6	9	10	12	4	13	2	1	5	88.08	0.18
7	83	14	11	5	9	7	9	4	16	4	3	9	88.10	0.18
7	83	14	10	4	9	7	12	1	13	2	2	2	88.14	0.18
7	83	10	12	6	9	7	12	2	10	3	4	7	88.90	0.17
7	78	11	9	5	9	10	10	3	10	4	2	7	89.27	0.17
7	74	14	14	5	8	8	12	1	12	3	1	6	89.34	0.15
7	85	15	13	6	8	8	10	3	16	2	1	3	89.53	0.15
7	85	13	11	5	8	8	8	1	16	3	1	2	89.92	0.15
7	84	10	13	5	8	7	12	1	13	2	1	3	90.20	0.15
7	74	11	11	5	8	12	10	3	16	2	2	6	90.54	0.15
7	74	11	9	5	8	10	10	3	16	4	2	9	90.92	0.15
7	83	11	14	4	7	10	12	4	14	3	3	5	91.13	0.14
7	84	11	13	6	7	10	12	4	15	3	4	4	91.16	0.13
7	83	15	12	3	7	8	11	4	16	4	1	9	91.51	0.13
7	84	11	12	6	7	8	11	2	15	4	4	3	92.07	0.12
7	83	15	10	4	7	8	11	4	15	1	4	4	93.35	0.12
7	85	15	7	5	7	8	10	2	13	4	2	6	94.36	0.12
7	85	11	13	4	6	7	12	4	14	4	1	4	94.58	0.11
7	85	9	12	3	7	8	10	3	12	1	2	5	94.70	0.11
8	79	15	11	3	12	10	11	1	14	4	4	6	95.66	0.10

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	MP	Kf	Km	Kmf	Ke	DE	WIP	BL
8	83	15	14	6	11	10	11	4	13	3	2	9	95.70	0.10
8	85	12	11	5	12	10	12	2	16	3	1	2	95.90	0.10
8	80	15	10	4	12	10	12	1	15	3	1	8	96.05	0.09
8	78	15	12	6	12	10	8	1	13	2	3	9	96.53	0.09
8	85	15	14	6	12	7	11	1	9	3	3	2	96.70	0.09
8	75	12	11	5	10	17	12	1	16	4	1	6	97.36	0.08
8	84	13	10	4	10	7	12	4	16	4	1	6	97.55	0.08
8	85	14	14	6	9	13	10	3	15	3	3	2	97.89	0.08
8	85	15	13	5	9	10	10	3	14	2	1	6	98.15	0.08
8	82	14	14	6	9	10	10	4	13	3	3	5	98.17	0.07
8	84	14	11	5	9	7	10	1	13	3	1	4	98.81	0.07
8	84	13	13	5	9	10	12	2	13	1	4	6	99.59	0.07
8	85	14	14	4	8	7	11	3	16	3	3	1	99.67	0.06
8	84	10	13	6	8	10	12	1	15	3	3	5	101.22	0.06
8	84	14	14	6	7	7	11	3	16	2	3	2	102.04	0.05
8	85	14	13	5	7	7	11	3	16	4	1	3	102.06	0.05
8	83	13	13	3	7	16	9	4	13	4	1	4	102.78	0.05
8	85	13	13	6	7	12	10	1	10	2	4	8	102.99	0.05
8	85	10	10	6	7	7	12	4	14	2	2	2	103.65	0.05
8	85	11	9	6	7	10	11	2	15	3	4	2	104.39	0.05
8	84	15	7	5	7	8	12	4	16	2	2	1	104.49	0.04
8	83	15	8	3	7	12	11	2	16	2	3	2	104.88	0.04
8	84	9	8	6	8	7	11	3	14	2	1	1	105.87	0.04
8	84	10	7	4	7	9	12	4	15	3	1	5	106.27	0.04
8	64	15	6	5	9	14	12	4	12	1	3	6	106.39	0.04
8	84	14	7	6	7	10	12	4	14	1	4	4	106.41	0.04
8	85	13	14	6	6	12	12	1	11	4	4	9	106.46	0.03
8	77	14	6	5	7	10	12	3	12	3	1	2	107.78	0.03
9	82	12	11	4	10	8	12	4	16	4	3	6	108.32	0.03
9	83	15	14	6	9	10	10	1	12	3	2	1	108.93	0.03
9	84	14	14	3	9	7	10	1	13	3	4	2	109.10	0.03
9	81	14	11	4	9	14	12	3	13	3	2	1	109.35	0.03
9	84	13	13	3	9	7	9	4	16	4	1	3	109.69	0.03
9	84	15	8	6	12	7	12	2	15	3	1	3	109.92	0.02
9	75	15	8	5	12	7	12	1	13	4	1	2	110.66	0.02
9	83	14	13	4	8	9	10	1	12	3	1	2	111.37	0.02
9	85	14	14	4	7	10	12	2	14	3	2	8	111.90	0.02
9	85	15	13	6	7	18	10	2	16	4	1	6	113.30	0.02
9	79	14	14	3	7	9	11	1	16	2	3	2	113.55	0.02
9	85	15	9	4	7	7	12	3	13	2	1	2	114.08	0.02
9	84	12	13	4	7	10	9	4	16	3	4	3	114.59	0.02
9	85	11	13	6	7	10	10	1	15	3	4	2	114.91	0.02
9	85	9	13	6	10	7	12	4	9	1	3	4	115.83	0.01
9	80	10	8	4	8	10	12	1	16	3	1	9	116.77	0.01
9	77	11	7	5	8	10	12	3	14	2	4	1	117.84	0.01
9	85	14	9	4	7	18	7	3	15	4	2	7	118.65	0.01
9	68	11	7	6	8	7	12	1	13	3	1	9	118.80	0.01
9	84	9	14	5	7	8	12	3	13	4	3	8	119.44	0.01
9	76	9	9	4	7	10	12	4	16	2	4	9	121.31	0.01
9	84	14	6	5	8	7	12	3	13	3	1	9	121.76	0.01
9	79	14	7	6	8	8	11	4	9	2	1	1	123.02	0.01
9	85	14	6	3	7	10	12	4	13	3	3	8	123.52	0.01
9	83	15	7	6	7	9	10	4	16	3	3	1	123.94	0.01
9	73	14	7	6	6	10	12	1	13	1	1	1	125.60	0.01
9	84	9	14	5	6	18	12	4	12	1	3	1	128.01	0.00
9	83	9	14	5	6	8	9	2	14	4	3	3	134.83	0.00
9	83	10	13	4	6	9	6	2	13	2	1	2	135.39	0.00
9	85	8	6	4	7	7	10	2	10	4	1	9	145.27	0.00
9	76	10	6	6	6	10	10	4	16	4	4	5	145.56	0.00
9	84	9	6	6	6	10	10	3	16	2	4	1	146.90	0.00

B3. DNC HKC - PAC OPTIMISED SETTINGS FOR UPPER PROCESSING TIME VARIABILITY

Table B-3. Production Authorisation Card Settings for DNC HKC Strategy 90HV

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	MP	Kf	Km	Kmf	Ke	WIP	BL
3	78	13	13	4	7	9	10	3	15	3	3	51.26	10.00
3	85	10	13	6	7	11	11	1	16	3	3	51.42	10.00
3	67	14	7	5	7	9	7	2	16	3	4	51.45	9.92
3	62	15	14	5	7	7	9	3	16	2	4	51.45	9.87
3	52	8	14	4	7	10	11	3	16	4	4	51.51	9.82
3	80	14	14	4	7	7	11	3	9	3	1	51.69	9.76
3	83	9	10	6	7	17	11	1	9	4	1	51.93	9.70
3	63	14	14	3	7	18	11	3	9	1	1	52.69	9.26
3	70	15	14	4	6	14	12	3	11	2	4	53.40	9.20
3	62	15	12	4	6	7	12	3	8	3	4	53.60	9.05
3	83	15	11	3	6	11	12	3	12	1	1	53.85	8.91
4	75	9	13	2	12	17	12	3	16	2	2	55.50	4.71
4	82	12	14	2	11	11	12	1	12	4	1	55.82	4.47
4	84	13	14	3	12	15	12	1	16	2	3	55.94	4.43
4	78	13	13	4	11	10	12	3	15	4	3	56.22	4.27
4	84	12	7	6	11	17	12	3	16	2	1	56.50	4.23
4	73	8	7	6	12	10	11	3	16	4	4	56.50	4.26
4	78	15	14	6	11	10	11	3	16	2	1	56.52	4.16
4	85	10	11	6	10	13	10	3	16	2	4	56.73	4.09
4	78	11	14	6	10	9	8	4	12	4	1	56.92	4.04
4	62	14	10	5	10	12	11	2	9	2	1	57.23	4.03
4	81	11	9	4	9	8	12	3	12	3	1	57.33	3.90
4	81	12	9	5	9	11	11	4	15	4	1	57.44	3.84
4	78	9	13	5	9	8	8	1	15	3	3	57.68	3.84
4	78	14	14	4	9	9	11	1	9	4	3	57.78	3.83
4	84	15	13	6	8	8	12	4	12	4	4	58.21	3.73
4	84	13	8	6	8	12	12	3	16	2	1	58.44	3.70
4	85	14	6	2	8	18	10	2	16	4	1	58.99	3.59
4	82	8	14	3	8	10	7	3	14	4	4	59.00	3.50
4	79	13	12	5	8	12	7	1	9	2	4	59.26	3.39
4	85	10	10	6	8	13	10	3	16	1	3	59.68	3.29
4	85	15	9	4	7	7	12	1	9	4	1	60.25	3.24
4	79	13	6	6	7	12	12	4	10	2	2	60.55	3.21
4	85	14	13	2	7	8	8	1	12	4	4	61.00	2.98
4	84	12	13	2	7	16	10	3	13	4	1	61.23	2.89
4	72	9	14	2	7	16	11	3	16	2	2	61.27	2.86
4	83	15	14	6	7	7	7	4	12	4	1	61.29	2.85
4	84	13	9	3	7	15	10	4	15	3	4	61.40	2.81
4	78	15	13	6	7	12	8	4	11	4	1	61.40	2.80
4	81	13	11	5	7	13	8	1	16	2	1	61.57	2.77
4	81	15	8	3	7	16	8	4	11	4	4	61.73	2.77
4	84	12	6	4	7	18	10	3	16	4	1	62.10	2.74
4	46	15	13	5	7	12	10	3	9	4	3	62.57	2.72
4	81	7	12	2	6	7	12	3	16	3	1	63.26	2.68
4	82	10	8	3	6	10	12	4	16	2	4	63.67	2.57
5	81	11	14	2	12	17	12	3	10	4	1	64.21	1.83
5	84	15	14	5	11	13	12	3	16	2	4	65.26	1.59
5	69	13	14	3	12	8	11	1	16	4	3	65.67	1.56
5	59	14	14	5	11	10	11	4	12	4	4	65.98	1.53
5	84	15	10	5	10	13	8	1	12	4	4	66.13	1.47
5	84	13	9	6	10	9	9	1	15	4	1	66.42	1.45
5	81	12	9	5	9	12	11	4	15	4	1	66.85	1.39
5	82	15	8	6	9	8	11	4	16	3	1	67.30	1.35
5	51	13	13	4	9	10	8	2	9	4	2	68.81	1.33
5	82	14	8	6	8	12	11	2	16	2	4	68.83	1.24
5	82	12	14	5	8	13	7	1	10	2	1	69.13	1.19
5	58	14	12	4	8	7	11	1	12	2	1	69.47	1.17
5	82	8	6	6	8	10	10	4	15	2	4	70.21	1.16
5	72	9	6	6	8	13	10	4	9	2	2	70.76	1.13
5	73	15	9	3	7	13	12	1	9	4	3	71.07	1.11

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	MP	Kf	Km	Kmf	Ke	WIP	BL
5	77	14	7	6	7	17	12	1	12	2	4	71.11	1.08
5	83	14	13	6	7	11	12	1	13	1	3	71.30	1.02
5	69	15	14	4	7	14	9	4	12	2	4	71.71	0.97
6	84	13	13	2	12	17	7	1	12	4	1	73.05	0.80
6	81	14	8	2	11	12	11	4	10	4	4	74.09	0.74
6	81	9	13	2	11	9	10	1	12	4	2	74.34	0.72
6	85	13	13	3	11	15	8	3	16	2	1	74.75	0.60
6	82	15	13	6	11	10	12	3	10	3	3	74.96	0.59
6	85	15	11	4	10	15	8	2	16	2	3	75.37	0.57
6	75	15	13	4	11	8	10	1	11	3	1	75.74	0.55
6	85	15	13	6	12	9	12	4	15	1	1	76.80	0.52
6	84	14	10	3	10	9	8	4	8	3	1	77.52	0.52
6	61	14	13	6	9	11	11	4	10	2	3	77.54	0.51
6	70	13	13	4	9	7	12	1	9	3	4	77.60	0.49
6	73	12	9	5	9	8	10	3	9	4	1	78.08	0.48
6	84	10	13	4	9	7	8	4	9	2	2	78.14	0.47
6	83	15	13	6	8	7	12	2	9	3	1	78.98	0.44
6	84	9	13	3	8	7	12	2	9	4	2	79.69	0.43
6	69	14	8	5	8	13	8	3	13	2	1	79.93	0.42
6	82	15	13	6	7	11	12	3	16	2	4	80.14	0.38
6	83	13	14	6	7	13	12	4	10	3	1	81.08	0.36
6	85	10	11	3	7	12	7	3	11	2	1	82.56	0.34
6	70	15	13	4	7	11	12	3	12	1	1	82.74	0.34
6	83	8	12	6	7	7	12	3	9	1	4	83.74	0.32
6	72	9	14	5	7	13	11	4	13	1	2	83.82	0.32
6	84	8	14	3	7	10	11	3	16	1	4	84.04	0.31
7	78	15	13	6	11	10	12	3	16	2	3	84.63	0.24
7	85	14	8	6	11	12	12	4	14	3	3	85.31	0.23
7	85	11	9	3	12	7	10	3	13	4	4	85.99	0.22
7	81	12	14	3	10	7	12	1	12	3	2	86.01	0.22
7	79	15	14	6	9	10	11	3	16	3	1	86.25	0.21
7	75	11	9	4	9	12	10	3	13	3	1	87.57	0.20
7	82	15	13	6	9	7	12	2	16	1	4	88.06	0.18
7	84	13	8	6	8	12	12	3	16	2	1	89.63	0.16
7	84	13	8	6	8	8	9	2	11	2	4	90.91	0.16
7	84	13	8	5	8	7	7	3	11	2	1	91.35	0.16
7	80	12	6	3	8	7	12	4	15	2	4	91.55	0.16
7	82	14	7	6	7	7	12	3	13	4	4	92.64	0.14
7	62	12	8	4	7	7	12	1	11	2	2	93.12	0.14
7	84	12	7	5	7	14	12	3	15	2	1	93.46	0.13
7	80	15	14	4	7	9	10	3	12	1	1	94.07	0.13
8	78	13	13	4	11	8	10	3	15	3	3	95.74	0.10
8	78	13	13	4	10	10	10	2	11	3	3	96.12	0.10
8	84	14	13	6	11	17	11	1	12	1	2	96.49	0.09
8	82	11	14	5	12	7	12	1	16	2	1	96.56	0.09
8	81	15	9	4	10	7	12	1	12	3	4	97.45	0.09
8	81	15	9	5	9	8	8	2	16	2	4	98.93	0.08
8	81	15	9	5	8	11	12	3	15	3	1	99.75	0.07
8	81	14	9	5	8	12	11	4	12	4	1	100.70	0.07
8	82	12	6	2	8	9	12	4	9	1	3	104.83	0.07
8	62	12	8	3	7	7	12	2	16	4	3	104.94	0.06
8	81	14	6	6	8	10	12	4	10	3	2	104.95	0.05
9	84	12	13	5	12	8	12	4	16	3	2	105.91	0.04
9	82	15	14	6	11	7	12	1	15	4	4	106.29	0.04
8	81	13	11	6	6	12	12	1	10	4	1	108.57	0.04
9	81	15	9	3	12	8	8	3	16	4	1	108.99	0.03
9	81	11	13	3	10	8	8	4	12	4	1	109.28	0.03
9	85	15	10	4	10	7	8	4	9	4	4	109.86	0.03
9	81	15	9	5	8	7	12	2	13	4	1	111.51	0.02
9	81	15	11	5	8	9	8	3	16	2	4	111.51	0.03
9	84	11	7	6	11	7	12	3	16	2	2	112.41	0.02
9	85	15	9	4	7	7	12	3	11	4	3	113.78	0.02
9	84	14	8	6	7	12	12	3	14	3	1	115.62	0.01
9	81	10	8	4	8	13	11	4	16	4	4	117.05	0.01
9	81	15	9	6	6	7	12	2	15	1	3	119.10	0.01
9	84	9	14	3	7	16	12	4	16	1	3	120.65	0.01
9	84	9	8	6	7	12	11	3	12	2	1	124.64	0.01
9	84	13	8	6	6	12	10	2	16	2	1	128.22	0.01
9	81	9	9	3	6	16	12	4	16	4	1	128.37	0.01
9	85	8	10	4	7	9	11	1	16	2	1	130.06	0.01
9	85	8	8	6	7	17	12	1	11	1	1	132.54	0.01
9	84	9	13	3	6	16	7	2	13	3	1	139.91	0.00

DNC HKC - PAC OPTIMISED SETTINGS FOR UPPER PROCESSING TIME VARIABILITY

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	MP	Kf	Km	Kmf	Ke	WIP	BL
9	84	11	7	4	6	18	9	1	16	2	2	148.95	0.00

B4. HEKC-II - PAC OPTIMISED SETTINGS FOR UPPER PROCESSING TIME VARIABILITY

Table B-4. Production Authorisation Card Settings for HEKC-II Strategy 90HV

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	Kf	Km	Kmf	Ke	DE	WIP	BL
5	87	8	17	2	15	15	3	20	5	3	0	51.58	73.41
4	98	18	17	6	12	16	3	12	4	4	1	52.49	10.61
4	88	11	16	5	12	11	3	20	3	2	2	52.73	10.51
4	77	13	17	6	12	22	2	18	2	2	3	52.78	10.51
4	99	17	14	4	12	10	2	17	4	2	2	52.80	10.42
4	108	18	14	4	14	9	2	11	5	2	3	52.82	10.36
4	110	18	17	6	11	22	3	14	4	5	8	52.86	10.33
4	98	17	17	5	15	9	4	13	2	2	1	52.94	10.14
4	110	17	13	3	12	9	4	19	3	5	5	52.99	10.09
4	97	17	15	5	13	9	5	20	3	2	2	52.99	10.11
4	110	13	17	5	10	16	3	20	3	2	1	53.23	10.03
4	109	15	14	3	15	8	5	19	4	3	1	53.31	9.96
4	110	17	17	5	10	18	3	20	3	2	3	53.32	9.89
4	106	17	14	6	10	17	2	17	4	3	4	53.34	9.85
4	109	13	17	4	10	22	4	16	3	4	9	53.36	9.79
4	110	16	16	4	15	8	4	19	5	4	1	53.37	9.73
4	104	16	17	4	15	8	5	20	3	2	1	53.39	9.70
4	110	18	16	5	15	8	2	20	5	2	1	53.40	9.68
4	88	13	17	6	14	8	5	13	5	2	1	53.47	9.65
4	107	16	12	6	15	8	2	17	4	5	2	53.48	9.57
4	95	18	14	4	14	8	4	13	2	5	2	53.56	9.52
4	98	18	10	6	15	8	2	20	2	5	4	53.60	9.52
4	110	16	13	5	13	8	5	13	2	2	5	53.63	9.45
4	110	16	17	6	12	8	5	20	4	4	3	53.70	9.45
4	110	13	17	5	10	9	5	18	2	3	1	53.72	9.43
4	109	10	16	6	12	8	3	18	4	5	1	53.74	9.41
4	78	12	17	6	12	8	2	19	4	4	1	53.77	9.40
4	109	15	17	6	12	8	2	18	2	2	1	53.78	9.40
4	93	13	17	5	10	9	2	18	2	4	1	53.78	9.31
4	96	10	12	3	11	8	3	20	5	2	3	53.88	9.26
4	110	15	14	5	11	8	2	19	2	4	6	53.88	9.25
4	105	10	17	5	11	8	2	19	2	5	3	54.03	9.21
4	109	17	15	4	10	8	2	12	3	3	1	54.07	9.17
4	110	12	14	5	10	8	2	20	5	5	2	54.07	9.14
4	90	13	13	6	10	8	2	16	5	5	3	54.16	9.02
4	106	12	12	4	10	8	3	13	2	2	7	54.27	8.96
4	98	10	16	5	10	8	5	19	2	5	9	54.31	8.96
4	110	18	13	3	9	17	5	14	5	2	8	54.93	8.36
4	110	16	16	4	9	22	5	19	2	4	2	54.96	8.25
4	97	17	17	6	9	18	3	15	3	3	6	54.98	8.14
4	107	11	17	6	9	21	2	17	3	5	4	55.05	8.08
4	110	16	16	4	9	9	2	13	4	4	2	55.10	8.06
4	99	10	15	4	9	17	3	13	4	5	1	55.23	7.96
4	96	14	13	5	9	8	5	14	3	4	6	55.43	7.76
4	74	9	16	6	9	8	5	17	4	2	7	55.93	7.74
4	99	18	17	2	8	11	5	16	4	3	9	56.03	7.63
4	109	15	14	2	8	22	2	18	5	2	1	56.03	7.65
4	109	17	15	2	8	22	5	20	3	3	1	56.05	7.56
4	94	18	17	2	8	22	2	14	3	5	1	56.06	7.53
4	105	12	17	2	8	21	2	16	3	5	1	56.12	7.51
4	96	12	16	2	8	21	2	19	3	5	1	56.12	7.49
4	110	17	16	2	8	22	3	19	2	5	5	56.13	7.35
4	110	18	12	2	8	15	4	16	2	2	2	56.21	7.34
4	110	10	16	2	8	21	3	20	2	4	1	56.28	7.29
4	78	15	17	2	8	10	3	20	5	2	7	56.31	7.25
4	110	17	13	3	8	21	4	20	3	5	5	56.63	6.61
4	107	18	16	3	8	21	2	19	3	5	1	56.67	6.61
4	102	13	12	6	8	22	5	20	5	2	4	56.71	6.53
4	105	14	16	4	8	20	2	20	3	3	3	56.72	6.52
4	103	12	13	6	8	20	3	14	5	4	1	56.80	6.49

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	Kf	Km	Kmf	Ke	DE	WIP	BL
4	99	10	12	4	8	18	4	17	4	2	4	56.88	6.47
4	98	10	10	6	8	15	5	18	4	4	9	56.92	6.47
4	74	13	17	4	8	21	5	14	3	4	4	56.99	6.45
4	87	12	17	5	8	8	4	13	5	4	6	57.19	6.40
4	88	10	16	6	8	8	2	15	2	4	3	57.32	6.35
4	103	16	8	6	8	9	2	16	4	2	2	57.45	6.33
4	108	18	7	4	8	9	3	14	2	5	2	58.09	6.28
4	110	18	14	6	7	21	2	16	4	2	4	59.19	5.81
4	109	18	15	3	7	19	5	17	2	3	3	59.19	5.80
4	110	14	17	4	7	21	4	20	5	3	4	59.22	5.72
4	110	18	15	5	7	21	5	20	2	3	4	59.25	5.70
4	110	17	14	6	7	17	3	18	5	3	2	59.28	5.69
4	94	13	16	4	7	22	4	19	3	5	3	59.29	5.67
4	105	15	14	6	7	14	5	19	2	3	7	59.34	5.66
4	105	13	15	6	7	20	3	17	2	4	1	59.35	5.65
4	106	17	17	6	7	10	5	16	5	4	1	59.41	5.65
4	88	17	17	5	7	18	2	19	2	5	1	59.48	5.61
4	110	10	16	3	7	22	2	17	2	5	1	59.53	5.55
4	80	17	16	6	7	12	5	16	5	3	5	59.54	5.53
4	109	8	13	6	7	17	2	19	3	3	1	60.30	5.52
4	110	8	14	4	7	21	2	18	5	5	5	60.32	5.52
4	91	8	17	4	7	10	2	12	3	5	3	60.52	5.50
4	91	18	7	6	7	20	5	18	3	3	8	60.60	5.40
5	110	18	16	2	15	16	5	11	5	5	1	61.43	3.90
5	99	12	14	2	15	21	2	11	5	5	1	61.53	3.84
5	108	12	17	2	15	21	4	12	4	5	3	61.71	3.76
5	98	17	14	2	15	21	4	19	3	2	6	61.79	3.73
5	103	12	15	2	15	22	5	16	4	5	1	61.84	3.69
5	110	12	16	2	13	18	5	19	3	2	2	62.05	3.67
5	96	13	10	2	15	22	4	19	3	3	6	62.20	3.59
5	110	12	17	2	13	10	2	20	3	2	1	62.35	3.55
5	91	17	12	2	12	11	2	17	3	2	2	62.51	3.53
5	108	13	17	2	11	13	4	17	5	5	7	62.66	3.45
5	96	14	15	2	11	17	3	12	3	3	9	62.68	3.43
5	101	15	15	2	11	10	2	16	3	4	1	62.85	3.41
5	107	17	14	2	10	21	2	18	3	3	5	63.18	3.34
5	110	13	17	2	13	8	2	10	5	5	3	63.19	3.34
5	110	13	17	2	10	19	3	14	4	5	1	63.22	3.26
5	103	13	17	3	15	16	3	18	5	5	1	63.30	2.74
5	105	12	15	3	15	21	2	18	2	2	1	63.43	2.72
5	110	18	17	6	15	22	2	18	3	3	1	63.47	2.60
5	110	13	12	5	13	20	2	20	4	5	4	63.91	2.58
5	109	17	14	5	12	18	2	15	4	2	2	64.00	2.55
5	93	18	16	4	12	11	2	20	3	4	4	64.10	2.55
5	107	17	16	4	11	16	3	20	3	5	9	64.19	2.54
5	106	13	14	5	11	16	2	20	5	2	1	64.25	2.53
5	95	13	17	4	15	9	3	20	5	2	3	64.26	2.51
5	110	14	17	6	11	13	2	12	3	5	7	64.35	2.48
5	94	18	13	6	11	22	5	13	4	4	2	64.40	2.46
5	89	13	13	5	11	10	3	14	4	2	5	64.71	2.44
5	108	14	14	5	11	9	5	16	5	4	7	64.77	2.43
5	110	18	16	6	15	8	4	13	4	2	1	64.79	2.37
5	110	17	13	6	14	8	4	13	5	3	7	64.94	2.34
5	97	12	14	5	14	8	2	20	2	3	2	65.11	2.34
5	103	17	14	4	12	8	2	18	4	5	8	65.14	2.32
5	95	12	14	6	12	8	3	19	5	2	2	65.23	2.32
5	110	12	12	4	12	8	2	20	5	4	1	65.24	2.29
5	106	15	16	6	11	8	5	17	5	2	1	65.27	2.26
5	99	12	17	5	10	8	2	19	5	3	4	65.75	2.21
5	110	10	16	4	10	8	4	13	4	2	6	66.19	2.19
5	107	17	16	3	9	17	5	13	4	3	8	66.43	2.10
5	105	18	17	4	9	22	2	18	4	4	2	66.47	2.06
5	110	18	13	6	9	14	2	16	3	4	7	66.50	2.05
5	106	12	15	6	9	15	3	19	5	2	3	66.55	2.02
5	93	12	15	5	9	17	3	13	3	2	5	66.74	1.98
5	110	11	13	4	9	8	2	16	5	3	2	67.18	1.92
5	102	9	17	4	9	8	5	17	4	2	7	68.14	1.91
5	106	16	14	3	8	20	3	19	4	2	3	68.25	1.70
5	105	18	17	5	8	17	3	16	5	2	2	68.31	1.66
5	95	18	17	3	8	17	3	15	2	5	1	68.31	1.67
5	110	17	14	6	8	22	2	19	4	5	2	68.32	1.65
5	107	16	14	4	8	21	3	18	3	2	5	68.33	1.63

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	Kf	Km	Kmf	Ke	DE	WIP	BL
5	110	17	17	6	8	21	4	17	2	2	2	68.39	1.61
5	96	12	17	4	8	17	3	12	3	2	1	68.69	1.59
5	87	18	17	6	8	9	4	19	2	5	8	68.73	1.58
5	110	10	15	4	8	9	5	16	2	2	2	69.26	1.56
5	109	14	14	3	7	14	3	20	3	4	6	71.11	1.42
5	109	18	16	6	7	22	5	17	2	2	8	71.15	1.39
5	105	12	14	5	7	21	5	17	2	2	3	71.23	1.37
5	109	17	15	5	7	10	5	15	5	2	2	71.33	1.37
5	108	17	17	6	7	13	5	13	5	3	4	71.36	1.36
5	110	17	17	6	7	8	5	19	2	2	3	71.90	1.35
5	87	11	14	5	7	8	2	19	4	5	6	72.37	1.33
6	99	12	17	2	12	9	2	13	4	3	3	73.07	1.30
6	103	17	15	2	10	14	3	20	5	2	3	73.16	1.27
6	110	17	17	2	15	8	5	20	3	3	9	73.21	1.26
6	109	18	13	2	14	8	4	15	5	5	1	73.35	1.24
6	110	14	16	2	14	8	5	18	2	5	4	73.38	1.24
6	110	15	17	3	15	21	3	10	2	5	4	73.40	0.97
6	110	17	15	3	15	21	5	13	3	4	2	73.44	0.92
6	110	18	17	6	15	22	2	18	4	4	1	73.73	0.85
6	104	17	16	4	14	17	2	19	2	3	1	73.90	0.84
6	103	13	17	6	15	16	3	18	3	2	7	74.02	0.83
6	106	15	17	6	15	14	4	12	2	2	9	74.02	0.84
6	110	12	16	6	15	13	2	18	4	3	1	74.10	0.83
6	110	13	12	6	15	21	4	19	4	2	2	74.19	0.82
6	110	18	15	6	15	9	2	10	3	2	8	74.56	0.81
6	109	17	16	5	11	18	5	18	5	2	2	74.62	0.80
6	110	17	16	4	11	18	5	15	2	4	1	74.63	0.78
6	106	17	15	4	10	19	5	15	3	2	2	75.21	0.76
6	102	15	16	5	10	21	5	19	5	2	9	75.29	0.75
6	106	15	16	4	13	8	4	20	4	3	3	75.43	0.73
6	110	16	13	5	13	8	4	14	2	3	5	75.65	0.72
6	110	17	14	6	12	8	3	13	5	2	2	75.65	0.72
6	109	14	14	6	12	8	2	18	4	2	4	75.72	0.72
6	109	14	16	5	11	8	3	19	5	2	1	75.90	0.71
6	110	16	11	5	14	8	4	20	4	3	2	75.91	0.71
6	110	17	15	5	10	8	5	20	4	2	6	76.11	0.68
6	106	18	17	5	10	8	4	20	4	3	2	76.19	0.68
6	110	16	17	3	9	13	3	12	5	5	9	76.95	0.67
6	107	18	16	5	9	14	2	19	5	3	1	77.06	0.63
6	108	18	13	5	9	10	5	14	3	2	5	77.30	0.62
6	110	18	15	4	9	8	5	16	2	3	2	77.59	0.59
6	110	12	17	4	9	8	4	14	5	2	2	77.89	0.58
6	110	17	16	3	8	22	5	16	3	2	1	78.90	0.51
6	108	18	14	3	8	22	2	20	3	2	3	78.90	0.52
6	99	17	17	4	8	21	5	16	2	2	1	79.14	0.50
6	108	18	14	5	8	16	2	16	3	2	7	79.15	0.49
6	110	18	16	5	8	8	2	20	5	3	2	79.31	0.47
6	89	10	15	6	8	18	5	17	4	5	1	80.98	0.47
6	110	10	16	6	8	21	2	19	2	5	6	81.04	0.47
6	110	10	10	6	8	8	3	20	2	4	1	81.89	0.46
6	110	18	14	6	7	22	2	19	5	3	2	81.98	0.40
6	109	16	13	6	7	8	2	20	3	4	2	82.95	0.40
7	110	17	17	3	15	22	5	15	3	4	1	83.31	0.33
6	110	12	14	5	7	8	2	20	2	5	1	83.31	0.39
7	110	17	17	3	15	22	5	13	2	3	1	83.39	0.32
7	109	17	17	4	15	16	5	11	3	3	4	83.71	0.31
7	109	17	15	4	15	16	5	15	3	2	2	83.78	0.30
7	110	17	14	4	14	19	3	16	4	5	2	83.89	0.29
7	103	13	14	6	14	12	2	14	4	4	2	84.46	0.28
7	101	12	17	6	12	16	2	17	4	3	1	85.13	0.26
7	97	14	13	6	11	12	5	17	4	3	1	85.38	0.26
7	110	17	17	5	10	22	3	12	3	3	1	85.41	0.25
7	97	18	14	6	10	21	3	19	2	5	1	85.81	0.25
7	101	14	17	5	10	11	2	17	2	2	1	85.84	0.24
7	109	15	15	6	12	8	2	18	2	2	1	85.97	0.23
7	106	18	17	4	10	8	4	16	5	3	2	86.44	0.23
7	110	13	17	6	10	8	2	16	2	5	7	86.85	0.23
7	105	18	15	6	9	18	5	16	5	5	1	87.41	0.21
7	101	14	13	6	9	11	5	17	3	2	7	87.92	0.20
7	108	12	15	5	9	8	2	20	4	2	6	88.77	0.19
7	110	18	17	4	8	19	3	16	2	3	3	89.33	0.17
7	108	18	17	5	8	9	3	14	4	3	2	89.50	0.17

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	Kf	Km	Kmf	Ke	DE	WIP	BL
7	105	18	13	5	8	18	2	20	5	4	1	89.78	0.17
7	109	14	13	3	8	8	5	18	3	2	4	90.01	0.17
7	105	12	15	5	8	21	4	17	5	2	1	90.37	0.16
7	110	13	13	5	8	8	3	14	2	4	5	90.44	0.15
7	110	18	16	4	7	15	2	15	2	4	1	92.57	0.14
7	102	14	13	4	7	20	5	19	4	2	4	93.05	0.13
7	102	12	17	4	7	20	2	18	4	3	8	93.54	0.13
8	109	17	15	4	15	21	4	12	4	5	3	93.84	0.12
8	110	17	16	6	14	17	2	17	5	2	1	93.92	0.11
8	110	16	14	5	12	20	2	15	4	2	2	94.69	0.11
8	107	17	17	5	12	10	2	19	3	5	1	94.91	0.10
8	110	13	13	4	13	10	4	12	3	5	2	95.69	0.10
8	110	17	14	5	10	17	5	20	5	5	1	95.72	0.10
8	109	18	14	4	10	22	4	10	2	5	1	96.30	0.10
8	106	17	17	4	11	8	5	18	3	2	2	96.41	0.10
8	110	17	12	6	11	9	4	13	3	3	1	96.86	0.10
8	96	16	13	5	14	8	5	20	5	2	2	97.09	0.09
8	99	15	14	6	10	9	5	17	2	2	6	97.13	0.09
8	101	14	13	5	11	8	5	13	3	3	4	97.57	0.09
8	106	18	17	4	9	21	5	19	3	5	1	97.66	0.08
8	107	16	15	5	9	19	3	20	5	5	1	97.86	0.08
8	110	14	16	6	9	8	5	18	5	5	7	98.51	0.08
8	110	13	15	4	9	8	2	20	4	3	6	99.10	0.07
8	110	17	16	4	8	22	3	20	2	2	1	99.72	0.07
8	110	14	16	6	8	11	5	18	4	5	2	100.07	0.06
8	106	17	13	4	8	8	3	18	2	2	1	100.87	0.06
8	110	12	17	6	8	20	5	17	3	2	4	102.18	0.06
8	106	12	17	4	8	9	5	17	3	3	2	102.30	0.05
8	106	17	15	4	7	10	5	15	2	2	1	103.41	0.05
8	103	13	14	3	7	21	2	19	5	4	5	104.09	0.05
8	110	13	15	4	7	10	4	17	3	4	2	104.10	0.05
9	110	17	17	6	14	17	4	13	2	4	7	104.51	0.05
9	110	17	14	5	15	22	2	16	3	3	2	104.66	0.05
9	107	18	17	6	15	10	4	13	2	2	3	105.09	0.05
9	110	17	14	6	13	22	2	10	4	3	2	105.29	0.05
9	110	16	13	5	13	18	3	19	3	4	2	105.68	0.04
9	110	14	13	5	15	20	5	17	2	2	9	106.02	0.04
9	108	14	16	6	10	16	3	20	3	2	4	106.88	0.04
9	106	15	12	6	14	22	5	18	3	4	6	107.43	0.03
9	103	13	13	5	13	13	2	14	5	3	2	107.45	0.03
9	110	14	14	5	10	9	2	14	2	5	3	107.95	0.03
9	110	17	13	5	9	10	2	14	5	2	5	109.75	0.03
9	110	12	16	6	15	8	2	15	4	2	1	110.79	0.03
9	106	12	17	4	14	8	5	18	4	2	2	110.89	0.02
9	110	12	14	5	15	8	2	14	4	4	9	111.10	0.02
9	110	15	14	5	8	18	5	14	2	5	8	111.42	0.02
9	110	17	13	4	8	9	5	18	5	2	6	111.96	0.02
9	110	17	17	6	7	17	2	17	5	5	3	113.75	0.02
9	110	12	14	6	9	11	3	19	3	2	2	113.77	0.02
9	110	12	14	6	9	22	3	14	5	2	4	113.88	0.02
9	107	18	12	5	8	18	4	20	2	4	1	114.12	0.02
9	109	17	14	5	7	21	2	19	5	2	5	114.20	0.02
9	104	15	17	5	7	8	2	19	3	2	2	115.91	0.02
9	110	13	17	6	7	15	4	17	3	2	4	116.04	0.02
9	109	17	13	6	7	8	3	17	5	3	6	116.07	0.02
9	110	12	17	6	8	22	4	14	3	2	6	116.31	0.02
9	108	12	17	5	8	21	3	17	2	5	4	116.67	0.01
9	110	12	16	6	7	14	5	18	2	3	1	120.08	0.01
9	110	12	15	4	7	9	5	15	3	2	8	120.16	0.01
9	94	11	16	6	8	11	3	20	4	4	1	125.66	0.01
9	88	17	17	6	7	8	2	20	5	5	4	128.63	0.01
9	107	11	14	4	7	20	4	19	5	5	8	128.71	0.01
9	110	11	13	3	7	18	3	14	5	5	7	128.86	0.01
9	110	11	15	4	7	9	4	13	2	4	2	129.33	0.01
9	110	11	13	6	7	8	5	17	5	2	1	129.89	0.01
9	98	11	13	5	7	8	3	14	3	3	5	130.19	0.01

B5. HKC - PAC OPTIMISED SETTINGS FOR UPPER PROCESSING TIME VARIABILITY

Table B-5. Production Authorisation Card Settings for HKC Strategy 90HV

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	Kf	Km	Kmf	Ke	WIP	BL
4	99	16	13	4	12	8	2	19	2	3	53.11	10.54
4	102	10	17	4	12	8	5	18	4	2	53.14	10.52
4	95	14	17	6	9	20	5	20	3	3	53.44	10.25
4	88	17	10	5	11	8	5	12	2	4	53.55	10.20
4	107	9	16	3	9	12	5	13	5	5	53.65	10.09
4	104	15	16	6	10	8	3	20	2	2	53.73	10.08
4	102	16	16	3	9	9	4	19	3	4	53.74	9.90
4	99	9	12	5	10	8	2	11	2	2	54.28	9.48
4	110	17	12	4	9	8	4	19	5	3	54.28	9.34
4	107	18	15	2	8	20	5	20	5	5	55.07	9.12
4	101	18	16	2	8	21	3	19	2	5	55.15	9.08
4	107	18	16	2	8	14	2	19	2	4	55.2	9.05
4	84	11	16	2	8	11	5	18	3	2	55.21	9.05
4	99	12	12	2	8	10	2	19	2	5	55.28	9.01
4	110	13	8	2	8	12	2	13	2	5	55.76	8.91
4	96	11	12	6	8	22	5	20	5	2	55.84	8.03
4	94	18	15	6	8	20	5	20	4	5	55.89	7.93
4	110	18	12	6	8	12	5	18	5	2	55.95	7.78
4	92	17	17	5	8	15	2	20	2	4	55.98	7.75
4	107	12	17	5	8	10	2	14	2	5	56.14	7.70
4	106	17	17	5	8	9	3	20	3	3	56.19	7.65
4	94	16	15	5	8	9	5	20	2	5	56.22	7.63
4	107	15	17	4	8	8	3	20	3	2	56.47	7.39
4	110	16	11	2	7	18	5	16	2	2	59.52	6.69
4	107	17	16	2	7	21	4	20	2	5	59.55	6.57
4	87	11	17	2	7	19	5	19	4	2	59.57	6.45
4	107	18	16	4	7	18	2	18	2	4	60	5.99
4	83	17	17	4	7	21	4	20	2	3	60.18	5.93
4	84	11	14	3	7	14	2	17	5	2	60.33	5.88
5	85	18	16	2	15	20	5	10	2	2	60.34	4.73
5	84	16	16	2	14	19	5	20	5	3	60.52	4.56
5	107	10	16	2	14	21	2	12	5	2	60.65	4.49
5	102	17	14	2	12	20	2	12	4	5	60.84	4.48
5	78	12	14	2	14	10	2	13	5	2	61.16	4.31
5	75	12	11	2	11	22	4	18	3	4	61.94	4.07
5	103	16	15	2	10	22	5	13	5	3	62.14	3.92
5	108	17	17	3	14	22	2	15	5	3	62.25	3.22
5	107	17	17	5	14	15	5	11	5	3	62.55	3.04
5	106	14	16	6	14	19	4	13	2	3	62.6	3.01
5	98	13	17	4	13	20	2	13	2	5	62.81	2.95
5	102	12	16	4	15	10	5	20	5	5	62.91	2.94
5	103	13	13	6	13	11	5	13	3	2	62.96	2.92
5	107	18	16	5	11	20	2	19	2	4	63.35	2.77
5	110	14	16	5	13	9	5	18	3	3	63.59	2.75
5	84	17	16	4	14	9	2	20	4	5	63.65	2.73
5	107	16	15	3	14	8	3	12	2	2	64.19	2.69
5	107	16	16	3	12	8	2	19	4	5	64.28	2.67
5	85	15	14	5	15	8	2	17	4	5	64.37	2.64
5	92	13	12	6	14	8	2	14	5	2	64.45	2.62
5	102	13	14	6	14	8	3	13	2	2	64.45	2.54
5	102	16	16	4	12	8	3	19	5	2	64.49	2.52
5	102	18	17	5	12	8	5	20	3	2	64.55	2.51
5	110	18	13	5	9	15	5	18	2	3	64.91	2.50
5	85	18	16	5	9	11	5	19	5	3	65.17	2.46
5	86	13	10	6	9	19	4	19	4	2	65.39	2.45
5	110	18	11	5	9	9	3	18	2	2	65.62	2.42
5	85	10	16	6	9	10	2	16	3	3	65.68	2.40
5	107	12	17	3	9	8	4	20	5	5	65.88	2.36
5	110	16	8	5	9	9	4	19	2	2	67.02	2.31
5	69	13	10	6	9	8	2	19	5	2	67.3	2.25

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	Kf	Km	Kmf	Ke	WIP	BL
5	94	14	16	6	8	13	3	20	3	3	67.5	2.02
5	108	17	17	4	8	15	2	15	5	5	67.56	1.97
5	106	15	17	4	8	13	2	20	4	2	67.57	1.94
5	109	13	15	4	8	20	5	15	2	3	67.61	1.93
5	107	15	14	6	8	10	5	15	2	2	67.73	1.93
5	93	16	15	4	8	9	3	14	2	4	67.88	1.91
5	94	18	15	6	8	8	3	20	5	5	68.14	1.87
5	76	12	15	6	8	8	3	14	2	5	68.97	1.87
6	102	13	16	2	14	21	2	13	2	4	70.25	1.86
6	84	14	15	2	15	18	5	18	5	5	70.54	1.84
5	104	8	17	6	8	12	3	20	4	2	70.56	1.80
6	107	17	16	2	12	18	2	18	5	2	70.57	1.78
6	97	16	16	2	15	9	5	10	2	5	71.05	1.73
6	106	15	16	2	14	9	2	13	3	5	71.07	1.68
6	110	11	15	2	15	9	5	13	2	5	71.73	1.66
6	108	15	11	2	14	9	2	14	2	5	71.73	1.64
5	98	13	17	4	7	19	2	20	2	4	72.03	1.46
6	107	17	16	3	14	21	3	18	2	3	72.36	1.10
6	97	12	15	3	14	15	3	17	5	3	72.69	1.04
6	106	17	17	5	14	14	5	11	5	4	72.86	0.98
6	107	17	16	5	13	18	2	18	2	2	73.03	0.95
6	103	17	16	6	12	14	2	13	4	3	73.26	0.95
6	102	13	14	6	12	18	3	12	5	3	73.52	0.93
6	108	14	15	4	11	18	4	19	3	2	73.56	0.92
6	107	13	15	6	14	9	5	18	5	3	73.89	0.90
6	107	13	15	6	14	9	2	18	5	3	73.89	0.90
6	107	15	15	6	12	9	5	18	5	3	74.12	0.87
6	107	12	15	6	14	9	2	13	2	3	74.15	0.87
6	103	12	15	4	14	8	2	13	5	2	74.96	0.81
6	109	17	14	5	9	18	4	19	5	2	75.47	0.77
6	92	17	17	4	9	8	2	16	3	4	76.8	0.70
6	106	14	15	5	8	15	2	20	5	2	78.22	0.60
6	104	17	17	5	8	14	2	13	3	4	78.29	0.60
6	107	17	16	6	8	14	5	13	2	4	78.35	0.60
6	103	17	17	4	8	9	2	20	5	3	78.35	0.57
6	102	12	15	6	8	12	2	13	2	3	78.77	0.57
6	103	10	15	4	8	20	2	13	2	5	80.2	0.55
6	110	9	15	5	8	11	2	14	5	4	82.37	0.54
6	104	12	17	6	7	12	2	13	3	3	83.43	0.46
7	107	13	17	3	11	18	4	19	3	5	83.49	0.33
7	102	13	12	6	13	12	2	18	2	2	83.89	0.30
7	109	14	15	6	14	9	2	14	5	3	83.93	0.30
7	97	14	17	5	11	17	2	19	5	2	84.13	0.29
7	102	13	16	5	11	17	5	19	2	2	84.16	0.28
7	109	15	14	5	10	12	3	13	5	2	84.8	0.27
7	102	15	16	6	11	8	3	13	2	2	85.88	0.26
7	107	14	14	5	9	17	5	19	5	2	85.97	0.25
7	110	14	12	6	9	9	2	18	5	2	86.91	0.24
7	110	16	17	5	8	21	4	18	5	2	88.42	0.19
8	98	15	15	3	14	21	3	20	2	4	92.96	0.15
8	106	15	17	6	14	22	2	18	3	3	93.01	0.13
8	107	17	15	6	12	21	3	12	2	5	93.71	0.12
8	108	15	15	6	12	12	3	13	2	5	93.73	0.12
8	110	18	12	5	12	18	5	20	2	5	94.39	0.12
8	93	18	17	4	11	17	5	19	5	2	95.14	0.12
8	108	14	17	4	10	21	2	11	4	2	95.33	0.11
8	110	18	13	4	9	21	3	18	2	4	96.25	0.10
8	107	18	16	4	9	9	3	20	2	3	96.55	0.10
8	104	12	15	5	9	15	3	10	3	3	98.74	0.09
8	104	12	15	6	9	21	3	10	3	4	98.92	0.09
8	106	15	17	6	8	22	2	13	3	2	99.23	0.08
8	106	15	13	6	8	8	3	13	5	5	100.46	0.07
9	102	16	17	3	14	19	4	19	2	5	103.36	0.06
9	102	15	16	3	14	18	2	13	2	3	103.42	0.06
9	106	17	16	4	12	14	2	13	3	5	103.98	0.06
9	103	18	13	4	14	18	3	17	2	4	104.32	0.05
9	99	18	15	4	14	18	2	20	2	3	104.41	0.05
9	107	15	17	6	15	9	5	10	4	5	104.88	0.05
9	106	17	15	4	12	9	2	19	3	2	105.09	0.05
9	109	14	15	6	14	9	3	15	3	3	105.16	0.04
9	109	15	15	5	13	8	2	13	5	2	106.14	0.04
9	104	16	12	6	11	16	2	12	2	2	107.27	0.04

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	Kf	Km	Kmf	Ke	WIP	BL
9	108	12	15	6	11	18	2	18	5	5	108.29	0.04
9	98	13	17	4	14	8	2	20	5	3	108.31	0.03
9	110	18	17	6	8	22	5	18	5	5	109.45	0.03
9	109	16	15	5	8	22	3	15	3	5	109.91	0.03
9	107	15	16	6	8	11	5	12	2	2	110.65	0.03
9	105	16	15	5	8	16	2	12	5	3	110.7	0.02
9	102	13	16	6	8	12	3	20	2	2	112.47	0.02
9	108	12	15	6	9	8	4	13	3	2	112.79	0.02
9	102	12	15	5	8	10	4	18	2	3	115.68	0.02
9	104	17	12	5	7	17	3	19	2	2	118.54	0.02
9	93	14	13	5	7	18	2	19	3	3	122.26	0.02
9	110	11	14	4	8	22	5	10	5	2	124.31	0.01
9	81	11	11	5	7	18	2	12	4	2	153.36	0.01
9	80	12	17	4	7	17	2	17	2	2	157.68	0.01
9	79	17	10	6	7	12	2	12	4	2	170.41	0.01
9	84	12	9	5	8	18	2	12	2	2	171.07	0.01

B6. DNC HEKC-II - PAC OPTIMISED SETTINGS FOR LOWER PROCESSING TIME VARIABILITY

Table B-6. Production Authorisation Card Settings for DNC HEKC-II Strategy 90LV

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	MP	Kf	Km	Kmf	Ke	DE	WIP	BL
3	58	14	11	4	12	14	12	4	14	3	2	0	44.01	73.22
3	84	12	9	6	12	15	7	4	15	3	4	0	44.16	73.20
3	62	7	11	6	12	11	12	1	14	2	1	0	44.18	73.17
3	40	12	12	5	12	7	12	1	12	4	4	0	44.51	73.12
3	85	10	11	6	12	7	8	1	11	4	3	0	44.92	73.08
3	57	15	14	4	12	9	11	1	14	1	4	0	44.97	73.03
3	44	12	14	6	11	9	12	4	12	1	4	0	45.20	73.03
3	79	10	11	2	11	7	11	4	16	1	1	0	45.28	72.98
3	82	13	7	4	9	7	12	3	15	1	1	0	46.17	72.87
3	84	15	9	6	9	7	11	2	16	1	1	0	46.99	72.76
3	84	15	14	2	12	11	12	1	13	2	1	1	47.66	7.25
3	85	14	11	2	12	14	7	1	16	2	3	6	47.70	7.23
3	79	14	12	4	12	10	12	1	16	4	2	1	47.72	7.23
3	79	15	13	2	12	17	11	1	8	2	2	5	47.72	7.23
3	81	13	12	3	11	14	12	4	9	3	1	1	47.73	7.23
3	84	15	13	6	12	10	11	4	8	4	1	1	47.74	7.22
3	85	11	13	5	10	18	11	4	16	4	2	1	47.74	7.22
3	85	11	13	6	12	15	8	2	13	3	4	3	47.75	7.21
3	78	15	13	4	12	12	7	4	13	2	4	7	47.75	7.21
3	83	14	9	5	12	18	8	3	14	3	4	7	47.76	7.21
3	81	13	9	4	12	17	7	3	12	4	3	9	47.77	7.21
3	85	10	11	3	12	9	7	1	14	4	4	6	47.77	7.21
3	85	15	14	5	12	9	12	4	8	2	2	6	47.77	7.21
3	79	13	11	4	10	17	10	4	11	3	3	5	47.77	7.21
3	83	15	8	6	12	17	12	3	14	3	4	4	47.78	7.21
3	80	13	8	3	12	11	10	4	15	3	1	4	47.78	7.21
3	84	13	8	5	12	16	7	4	15	3	1	4	47.78	7.21
3	85	11	8	5	12	12	11	2	15	3	3	9	47.78	7.21
3	81	10	9	3	12	17	12	1	8	2	2	3	47.79	7.21
3	81	15	8	6	11	9	11	1	11	3	4	3	47.79	7.20
3	78	15	13	5	10	8	8	4	15	4	4	1	47.79	7.20
3	85	14	8	5	10	16	7	3	12	4	2	9	47.80	7.20
3	85	14	12	5	10	8	10	1	13	4	4	7	47.80	7.20
3	85	14	7	4	12	14	9	4	8	4	3	3	47.83	7.20
3	64	10	10	3	11	8	7	1	9	4	1	1	47.84	7.20
3	81	13	7	3	12	8	10	4	10	2	4	1	47.84	7.20
3	85	11	12	6	11	15	7	3	8	4	1	8	47.84	7.19
3	78	12	8	4	10	17	7	4	9	2	1	2	47.85	7.19
3	78	13	10	2	12	7	8	1	16	4	4	8	47.86	7.19
3	73	15	6	5	12	14	12	4	13	3	3	2	47.87	7.19
3	76	13	6	5	12	12	12	1	16	3	4	3	47.87	7.18
3	72	10	9	6	11	9	7	3	8	4	2	5	47.88	7.18
3	81	15	14	4	12	7	12	1	15	3	2	1	47.88	7.18
3	79	10	14	3	12	7	7	4	16	3	3	1	47.89	7.18
3	84	12	12	4	10	7	10	3	13	2	2	1	47.89	7.17
3	85	15	13	4	11	7	8	4	15	4	3	6	47.89	7.17
3	85	14	13	6	10	7	11	4	13	4	4	5	47.90	7.17
3	85	14	14	4	10	7	10	4	11	4	1	6	47.90	7.17
3	85	13	14	4	10	7	10	4	11	4	1	6	47.90	7.17
3	82	15	11	6	10	7	10	1	16	2	2	3	47.90	7.17
3	81	14	14	5	12	14	12	1	16	1	4	1	47.91	7.14
3	81	10	14	6	12	11	11	1	14	1	3	1	47.92	7.14
3	80	14	13	2	9	12	11	4	13	2	4	8	47.95	7.14
3	82	14	14	2	9	16	8	1	10	4	2	5	47.95	7.14
3	85	15	14	2	10	8	10	2	14	1	4	7	47.95	7.13
3	79	15	12	5	10	15	12	4	16	1	4	4	47.96	7.12
3	84	9	9	3	12	15	12	4	14	1	3	4	47.97	7.12
3	83	8	14	3	12	10	12	4	14	1	3	3	47.98	7.12
3	77	14	13	5	9	12	11	1	13	3	4	7	47.99	7.12
3	81	8	14	4	10	16	12	2	14	1	4	9	48.00	7.12

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	MP	Kf	Km	Kmf	Ke	DE	WIP	BL
3	85	10	10	5	9	12	7	1	10	4	3	7	48.00	7.11
3	66	15	9	3	9	8	10	2	15	4	4	7	48.02	7.11
3	78	14	9	2	9	18	7	2	8	4	1	5	48.04	7.11
3	85	10	10	3	9	7	8	1	13	3	3	3	48.05	7.09
3	85	15	11	6	12	9	12	3	10	1	1	9	48.06	7.09
3	85	14	7	3	9	7	10	4	10	3	3	1	48.09	7.09
3	85	11	12	5	8	16	12	2	15	2	3	2	48.09	7.08
3	84	12	14	4	8	16	12	4	10	4	1	8	48.09	7.08
3	83	13	14	5	12	7	11	3	14	1	2	5	48.10	7.08
3	80	9	11	3	12	7	12	1	9	1	4	9	48.12	7.08
3	85	9	14	5	12	7	12	4	12	1	2	3	48.12	7.07
3	84	15	11	4	8	7	12	3	15	4	2	2	48.14	7.07
3	85	8	13	6	10	7	11	4	14	1	4	2	48.16	7.06
3	85	15	14	4	9	8	11	4	12	1	2	1	48.18	7.03
3	82	15	11	6	9	7	11	3	9	1	2	8	48.24	7.00
3	85	15	14	6	8	12	12	2	16	1	3	1	48.29	6.99
3	85	12	11	6	8	12	12	1	15	1	2	1	48.30	6.99
3	81	11	7	4	9	17	10	1	11	1	1	4	48.36	6.98
3	78	8	9	6	8	17	12	1	9	1	3	8	48.37	6.98
3	58	15	9	6	8	8	12	4	9	1	3	3	48.37	6.97
3	82	13	14	5	8	18	12	4	15	1	1	9	48.41	6.97
3	84	15	12	5	8	17	12	1	9	1	1	9	48.41	6.96
3	83	13	10	5	8	12	12	1	9	1	1	1	48.42	6.96
3	81	10	10	5	8	8	12	1	11	1	1	1	48.43	6.96
3	83	12	8	6	8	10	12	2	16	1	1	1	48.44	6.96
3	82	7	11	5	8	8	12	2	8	1	3	1	48.44	6.95
3	83	14	6	6	8	17	12	2	13	1	1	1	48.53	6.94
3	84	7	8	6	8	15	12	1	9	1	1	5	48.55	6.94
3	79	15	10	2	8	8	8	4	15	4	1	1	48.58	6.49
3	85	15	13	6	8	16	7	4	11	3	3	1	48.58	6.49
3	84	15	12	3	8	16	7	4	15	4	2	4	48.59	6.47
3	83	13	13	3	8	16	8	4	9	4	3	2	48.59	6.47
3	79	14	14	5	8	12	7	3	15	4	3	2	48.59	6.47
3	83	15	9	3	8	16	11	1	15	4	3	3	48.61	6.47
3	81	15	9	4	8	11	11	2	16	4	2	2	48.61	6.47
3	84	14	14	6	8	7	8	3	12	3	4	5	48.61	6.47
3	80	14	9	5	8	7	7	1	14	4	1	8	48.63	6.46
3	66	15	10	5	8	7	9	3	15	4	2	4	48.65	6.46
3	83	9	12	5	8	7	11	3	8	2	4	5	48.67	6.46
3	82	14	7	4	8	7	8	4	13	4	2	5	48.69	6.46
3	80	11	6	2	8	18	10	3	9	4	1	5	48.71	6.45
3	85	14	6	2	8	8	9	2	9	4	1	2	48.73	6.45
3	76	7	11	3	8	11	10	1	16	2	3	4	48.73	6.45
3	85	14	6	5	8	9	7	1	14	4	1	5	48.74	6.44
3	85	12	11	6	8	12	10	3	15	1	2	3	48.80	6.39
3	74	15	9	3	8	15	11	1	15	1	2	3	48.82	6.39
3	68	15	11	3	8	7	11	1	13	1	3	2	48.85	6.38
3	81	12	11	6	8	8	11	1	15	1	1	8	48.91	6.36
3	79	15	6	3	8	10	10	3	15	1	2	4	48.93	6.36
3	84	8	6	3	8	15	11	4	16	1	3	4	48.98	6.35
3	47	15	9	3	7	7	12	3	15	4	2	2	49.04	6.35
3	85	7	11	3	7	7	12	3	8	3	2	3	49.04	6.34
3	64	15	6	5	8	18	11	4	11	1	1	1	49.06	6.34
3	73	8	6	5	8	8	10	1	16	1	1	1	49.08	6.34
3	83	15	13	2	7	15	12	2	13	1	2	2	49.09	6.31
3	76	9	13	5	7	7	12	1	11	1	2	5	49.10	6.28
3	67	15	6	4	7	10	12	2	9	1	4	5	49.21	6.28
3	77	14	7	3	7	9	12	2	14	1	1	1	49.24	6.27
3	83	13	9	5	7	15	12	4	11	1	1	2	49.25	6.27
3	58	11	6	3	7	17	12	2	9	1	2	3	49.28	6.26
3	51	10	7	2	7	17	12	2	13	1	1	5	49.34	6.26
3	82	15	10	6	8	9	8	2	7	4	1	3	49.55	6.25
3	76	13	9	6	8	11	10	4	7	4	4	4	49.57	6.24
3	84	14	8	4	8	10	8	4	7	4	2	8	49.58	6.23
3	85	13	13	4	8	7	8	1	7	4	4	3	49.59	6.23
3	80	14	10	5	8	7	8	2	7	4	1	8	49.60	6.22
3	81	8	8	5	8	8	10	1	7	2	3	9	49.63	6.22
3	62	9	13	4	8	7	11	4	7	2	2	8	49.63	6.21
3	81	15	14	2	7	7	10	3	13	4	1	3	49.64	5.52
3	81	15	14	3	7	7	7	4	13	4	1	9	49.66	5.51
3	79	12	14	4	7	7	7	4	9	4	1	8	49.66	5.50
3	76	13	9	6	7	7	7	4	15	4	1	7	49.68	5.50

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	MP	Kf	Km	Kmf	Ke	DE	WIP	BL
3	85	14	8	5	7	7	8	4	13	4	4	7	49.70	5.50
3	82	15	8	2	7	16	9	1	9	4	3	5	49.74	5.50
3	85	12	8	6	7	9	10	1	8	4	2	4	49.74	5.50
3	81	14	7	6	7	7	7	3	10	4	1	1	49.75	5.49
3	85	15	7	6	7	11	11	3	13	4	4	1	49.78	5.48
3	85	15	6	6	7	7	11	3	16	3	1	1	49.81	5.47
3	83	12	6	6	7	7	8	4	11	4	1	4	49.82	5.47
3	67	9	6	4	7	7	10	2	8	2	3	9	49.86	5.46
3	85	14	8	2	7	7	10	3	13	1	3	4	49.90	5.44
3	65	12	12	3	7	7	11	4	8	1	2	8	49.93	5.42
3	74	9	10	4	7	7	11	4	8	1	2	5	49.94	5.42
3	57	13	10	4	7	9	11	1	10	1	3	1	49.97	5.42
3	54	15	14	3	7	11	10	3	13	1	3	4	50.00	5.42
3	54	12	11	5	7	15	11	1	15	1	3	6	50.01	5.41
3	54	15	14	6	7	14	10	1	13	1	4	4	50.02	5.41
3	78	14	6	6	7	9	11	1	16	1	2	8	50.03	5.40
3	80	14	14	6	7	11	10	1	15	1	1	4	50.03	5.39
3	84	8	9	3	7	7	10	2	10	1	1	4	50.06	5.39
3	54	15	14	2	7	16	10	1	14	1	1	9	50.11	5.38
3	57	11	7	3	7	8	11	1	13	1	1	1	50.13	5.38
3	54	14	9	6	7	13	10	1	13	1	1	4	50.14	5.38
3	41	7	10	6	7	14	7	4	8	2	2	9	50.44	5.37
3	40	9	6	4	7	11	7	1	11	4	1	9	50.46	5.36
3	83	12	14	3	6	7	12	4	16	4	4	4	50.66	5.20
3	47	13	13	2	6	7	12	2	15	4	4	2	50.72	5.20
3	85	11	9	6	6	7	12	1	8	4	4	3	50.73	5.18
3	85	14	9	5	6	7	12	2	8	4	1	1	50.76	5.18
3	77	15	6	5	6	7	12	2	16	3	1	8	50.78	5.17
3	82	15	6	3	6	7	12	2	13	4	1	2	50.79	5.17
3	47	11	6	2	6	7	12	3	16	4	4	1	50.86	5.16
3	66	8	8	6	6	8	12	4	8	3	2	2	50.91	5.16
3	77	13	12	2	6	7	12	2	8	1	4	1	50.97	5.11
3	85	12	7	4	6	7	12	3	12	1	2	2	50.97	5.11
3	85	15	11	4	6	8	12	2	13	1	2	9	50.99	5.10
3	82	9	12	6	6	8	12	1	15	1	2	5	51.01	5.10
3	61	12	10	4	6	7	12	2	11	1	1	9	51.03	5.09
3	79	14	10	6	6	7	12	4	8	1	1	4	51.06	5.09
3	56	14	8	5	6	7	12	3	11	1	1	1	51.09	5.08
3	84	14	14	2	6	9	12	3	13	1	4	4	51.17	5.07
3	41	15	8	6	6	11	12	3	16	4	4	4	51.23	5.06
3	81	10	7	6	6	9	12	4	10	1	4	1	51.27	5.03
3	77	7	10	2	6	10	12	3	16	1	2	2	51.48	5.00
3	41	14	7	4	6	11	12	3	11	1	2	9	51.49	4.99
3	77	15	6	5	6	10	12	1	14	1	4	1	51.53	4.99
3	85	12	7	2	6	11	12	3	16	1	3	3	51.61	4.96
3	54	11	8	3	6	11	12	3	16	1	1	1	51.71	4.95
3	52	12	8	2	6	12	12	3	12	1	1	3	51.81	4.92
3	65	15	14	3	6	7	7	4	13	3	4	8	51.82	4.69
3	59	11	9	2	6	7	7	1	14	4	1	8	51.84	4.68
3	82	10	9	6	6	7	8	1	15	4	4	3	51.87	4.68
3	62	8	14	2	6	7	8	4	13	4	3	9	51.91	4.67
3	85	12	6	2	6	7	7	2	16	3	2	9	51.92	4.67
3	83	7	14	5	6	7	7	4	9	2	1	4	51.96	4.66
3	82	8	6	6	6	7	7	4	16	4	1	1	52.03	4.65
3	71	14	14	2	6	8	8	2	13	3	3	2	52.04	4.63
3	83	8	10	4	6	8	7	2	15	3	1	6	52.07	4.62
3	76	15	14	2	6	8	11	1	10	2	2	9	52.14	4.62
3	64	12	14	5	6	8	11	1	11	4	4	9	52.19	4.61
3	81	9	10	2	6	9	7	1	11	4	4	9	52.20	4.61
3	85	14	10	5	6	9	7	1	10	4	1	6	52.22	4.60
3	75	15	8	2	6	7	11	2	9	1	4	8	52.23	4.60
3	85	14	7	6	6	8	9	2	8	4	4	8	52.23	4.59
3	85	12	6	3	6	8	10	3	16	3	2	3	52.27	4.59
3	82	15	13	6	6	7	11	1	12	1	2	1	52.28	4.58
3	64	8	9	6	6	9	7	2	9	4	2	4	52.31	4.58
3	85	14	14	5	6	7	11	3	10	1	1	6	52.36	4.56
3	64	11	7	2	6	8	11	4	15	1	4	3	52.47	4.55
3	84	15	9	6	6	10	8	1	14	4	4	9	52.48	4.54
3	43	11	8	2	6	8	11	2	16	1	2	4	52.55	4.54
3	70	14	6	4	6	8	11	3	12	1	4	3	52.58	4.52
3	85	12	9	6	6	8	10	1	8	1	1	2	52.60	4.52
3	40	8	6	3	6	7	11	3	15	1	2	1	52.64	4.52

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	MP	Kf	Km	Kmf	Ke	DE	WIP	BL
3	83	7	13	6	6	8	11	2	8	1	4	1	52.67	4.51
3	80	9	6	4	6	8	11	3	11	1	1	1	52.77	4.49
3	79	9	9	5	6	12	7	3	15	3	1	2	52.87	4.49
3	79	12	12	6	6	12	7	2	8	4	3	1	52.93	4.48
3	84	10	9	2	6	12	11	1	14	3	1	8	52.93	4.48
3	52	13	8	6	6	12	11	4	14	3	1	2	52.95	4.48
3	81	14	8	4	6	12	11	4	13	2	3	4	52.99	4.46
3	52	12	14	3	6	13	10	2	14	4	4	4	53.04	4.46
3	62	14	9	5	6	11	10	1	9	1	3	1	53.04	4.44
3	76	14	6	5	6	10	11	4	8	1	3	1	53.07	4.44
3	47	7	7	3	6	10	10	3	16	1	1	4	53.09	4.43
3	81	9	8	3	6	14	7	3	14	4	2	3	53.25	4.42
3	67	7	12	2	6	14	7	1	11	3	4	1	53.33	4.40
3	79	11	6	2	6	14	10	2	13	3	1	3	53.38	4.39
3	53	8	13	3	6	15	10	4	9	4	2	9	53.41	4.39
3	66	14	11	6	6	15	8	1	9	4	4	2	53.42	4.39
3	60	15	7	3	6	15	8	4	9	4	2	7	53.44	4.38
3	54	14	12	6	6	14	10	1	13	1	3	2	53.47	4.36
3	80	13	13	2	6	13	10	2	15	1	1	1	53.52	4.36
3	78	11	6	4	6	15	10	2	12	3	1	9	53.62	4.35
3	79	11	11	5	6	17	7	3	10	2	1	7	53.74	4.34
3	79	10	6	2	6	16	10	2	14	3	1	3	53.76	4.33
3	49	13	6	2	6	15	11	1	8	1	2	1	53.77	4.30
3	84	15	6	3	6	16	11	4	8	4	1	1	53.99	4.30
3	84	8	8	6	6	16	11	1	11	1	4	3	54.03	4.28
3	80	13	13	2	6	17	11	1	15	1	4	1	54.14	4.26
3	79	13	10	2	6	17	11	3	15	1	4	1	54.15	4.26
3	83	9	7	6	6	7	11	1	7	1	4	3	54.37	4.24
3	74	15	11	3	6	7	11	1	7	1	1	8	54.40	4.24
3	65	14	6	5	6	7	11	4	7	1	3	1	54.49	4.22
3	58	7	8	2	6	11	7	1	7	3	3	9	54.59	4.22
3	84	7	9	2	6	10	11	2	7	2	1	6	54.73	4.19
3	64	7	10	4	6	11	9	1	7	3	2	8	54.83	4.17
3	85	11	10	5	6	18	7	4	11	1	2	4	55.05	4.17
3	42	7	6	2	6	8	7	1	7	1	3	1	55.49	4.17
3	70	14	7	4	6	12	11	2	7	1	4	9	55.50	4.05
4	78	13	11	2	12	11	12	1	13	4	1	1	56.50	2.17
4	85	14	14	2	12	11	11	1	13	2	4	4	56.51	2.17
4	83	13	9	2	10	17	11	3	14	2	2	1	56.58	2.17
4	78	10	14	2	12	17	10	1	9	3	3	9	56.58	2.17
4	83	13	8	2	12	17	12	4	15	4	4	2	56.60	2.17
4	83	14	14	6	12	16	12	4	13	3	1	1	56.63	2.14
4	85	13	13	5	12	10	7	4	13	3	1	1	56.64	2.14
4	84	15	14	4	12	10	11	4	9	4	1	3	56.67	2.14
4	82	15	14	4	11	11	10	4	15	4	1	5	56.69	2.14
4	84	11	9	6	12	15	10	4	15	3	4	1	56.70	2.14
4	79	13	11	5	12	16	12	1	16	3	1	4	56.70	2.14
4	82	11	14	4	10	14	12	3	10	4	1	2	56.72	2.14
4	81	11	10	6	12	17	11	4	11	3	1	6	56.73	2.13
4	78	12	8	4	12	11	11	1	15	3	3	1	56.75	2.13
4	81	11	13	6	12	8	11	4	11	3	1	1	56.76	2.13
4	83	12	8	6	11	18	11	4	12	2	2	5	56.79	2.13
4	78	15	8	6	11	14	8	1	15	4	3	7	56.82	2.13
4	79	10	8	5	12	17	11	2	15	3	3	5	56.82	2.13
4	85	15	7	6	12	18	11	4	9	4	3	1	56.83	2.13
4	77	14	11	4	12	8	12	2	8	2	2	5	56.83	2.13
4	85	10	7	5	10	11	12	4	14	2	4	1	56.89	2.13
4	66	14	14	5	12	8	8	1	10	2	4	7	56.89	2.12
4	84	11	8	6	12	8	11	4	15	3	4	5	56.89	2.12
4	84	15	10	5	11	8	10	1	8	4	3	9	56.93	2.12
4	85	9	11	4	10	15	7	2	9	3	2	3	56.95	2.12
4	85	8	14	5	10	16	12	3	9	3	1	1	56.98	2.12
4	85	15	11	4	12	7	7	1	16	3	2	6	57.02	2.10
4	84	15	12	4	10	7	10	3	13	4	1	3	57.02	2.10
4	85	15	13	6	11	12	11	3	15	1	4	6	57.04	2.09
4	79	13	14	4	12	17	11	3	14	1	2	5	57.04	2.09
4	85	14	9	6	12	16	11	1	13	1	3	4	57.08	2.09
4	73	9	14	4	12	17	12	4	8	1	4	2	57.14	2.09
4	85	12	14	5	10	8	10	2	14	1	4	7	57.14	2.08
4	85	14	10	3	9	7	11	4	13	3	4	1	57.22	2.07
4	79	11	14	4	9	7	10	2	16	4	3	1	57.23	2.07
4	78	9	14	5	9	7	9	1	11	4	2	3	57.34	2.07

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	MP	Kf	Km	Kmf	Ke	DE	WIP	BL
4	85	15	13	3	9	17	8	1	8	3	4	8	57.35	2.06
4	85	15	10	3	10	7	12	2	15	1	3	2	57.37	2.05
4	84	13	10	6	12	7	12	1	10	1	2	4	57.39	2.05
4	85	13	12	3	8	17	12	2	15	2	3	1	57.43	2.05
4	76	15	14	5	9	18	12	4	15	1	4	8	57.49	2.04
4	84	14	8	3	8	16	12	4	15	4	1	2	57.52	2.04
4	85	14	8	3	12	7	12	1	9	1	1	1	57.53	2.04
4	85	12	8	4	11	7	12	1	13	1	1	1	57.55	2.03
4	78	15	9	5	9	7	12	4	15	1	2	2	57.59	2.03
4	85	10	9	6	9	7	10	1	16	1	2	1	57.63	2.02
4	85	15	11	5	9	7	12	2	8	1	4	4	57.68	2.01
4	85	14	12	2	8	17	9	1	13	4	3	3	57.75	1.93
4	73	14	13	2	8	17	8	4	16	2	1	5	57.80	1.93
4	79	11	11	2	8	7	11	4	14	4	2	5	57.81	1.93
4	85	13	14	3	8	17	10	1	14	2	1	3	57.82	1.91
4	84	14	14	4	8	12	7	4	15	4	3	1	57.83	1.91
4	80	12	14	6	8	9	9	3	13	4	4	1	57.84	1.91
4	84	11	11	4	8	12	7	4	14	3	2	1	57.86	1.91
4	82	14	11	6	8	7	10	1	14	2	2	3	57.87	1.91
4	82	15	14	6	8	18	8	4	8	2	4	1	57.90	1.91
4	82	12	11	6	8	18	8	4	8	2	3	1	57.93	1.91
4	73	14	10	3	8	17	8	4	8	2	2	2	57.96	1.91
4	70	14	10	3	8	17	7	4	8	2	2	1	58.00	1.91
4	79	9	13	3	8	17	11	2	8	2	2	5	58.00	1.90
4	83	15	8	6	8	16	7	4	8	4	1	1	58.02	1.90
4	85	14	7	3	8	7	9	1	13	4	3	1	58.10	1.90
4	75	14	7	6	8	7	7	4	15	4	3	4	58.12	1.90
4	70	8	11	3	8	7	8	3	16	4	1	8	58.15	1.90
4	83	15	14	6	8	13	10	4	16	1	4	7	58.20	1.86
4	85	13	9	6	8	13	11	2	16	1	3	3	58.25	1.86
4	61	13	10	4	8	7	10	2	15	1	3	4	58.39	1.85
4	57	12	11	4	8	14	11	4	13	1	2	4	58.42	1.85
4	79	8	12	4	8	17	11	3	8	1	4	5	58.42	1.85
4	54	11	14	5	7	7	12	3	14	4	4	2	58.53	1.84
4	72	12	9	2	7	7	12	3	14	1	2	4	58.62	1.83
4	82	13	11	5	7	7	12	3	14	1	2	8	58.64	1.81
4	83	14	7	5	7	16	12	3	9	1	4	8	58.92	1.80
4	79	15	14	2	7	7	10	2	14	4	3	5	59.21	1.57
4	75	11	14	2	7	7	7	4	14	2	1	4	59.26	1.57
4	85	14	9	6	7	7	7	1	11	4	4	5	59.31	1.56
4	84	10	13	5	7	7	8	3	8	3	4	2	59.38	1.55
4	84	12	8	5	7	10	7	1	16	2	3	1	59.43	1.55
4	77	11	8	6	7	7	9	1	8	4	4	5	59.48	1.55
4	68	11	11	5	7	10	8	4	8	4	1	1	59.49	1.55
4	71	14	7	5	7	11	10	1	16	4	1	1	59.57	1.55
4	67	11	9	4	7	17	8	4	8	4	1	2	59.58	1.54
4	85	15	13	6	7	18	11	1	16	1	4	6	59.72	1.52
4	79	15	14	3	7	17	10	2	13	1	3	5	59.72	1.52
4	85	15	8	3	7	16	10	3	13	1	3	4	59.82	1.51
4	84	11	7	6	7	7	10	4	11	1	1	1	59.97	1.50
4	70	7	14	5	7	7	11	1	16	1	2	9	60.03	1.50
4	85	11	7	3	7	16	10	4	14	1	1	1	60.07	1.50
4	54	14	9	3	7	13	10	4	15	1	1	2	60.14	1.50
4	85	14	6	6	7	11	10	2	15	1	1	2	60.24	1.49
4	73	10	12	6	7	17	9	4	10	1	4	3	60.51	1.49
4	85	9	14	3	7	17	7	2	16	1	2	2	60.55	1.49
4	70	10	14	5	7	17	7	4	13	1	4	1	60.55	1.49
4	66	9	14	6	7	14	8	4	14	1	1	2	60.61	1.49
4	65	15	7	4	7	15	7	1	16	1	1	1	60.79	1.48
4	62	14	14	6	6	7	12	1	13	4	4	9	60.85	1.42
4	78	15	8	5	6	7	12	2	10	2	3	1	60.93	1.42
4	54	12	9	3	6	7	12	1	11	3	4	2	60.97	1.42
4	85	11	14	5	6	7	12	3	10	1	2	9	61.17	1.39
4	85	15	11	3	6	7	12	1	8	1	2	9	61.25	1.38
4	84	14	9	4	6	7	12	1	11	1	1	9	61.34	1.38
4	46	11	10	4	6	7	12	3	13	1	4	6	61.52	1.37
4	85	8	9	3	6	8	12	2	10	1	4	8	61.54	1.37
4	81	9	9	5	6	10	12	4	15	4	2	9	61.66	1.37
4	85	14	7	5	6	10	12	3	15	4	1	1	61.73	1.36
4	45	7	6	2	6	7	12	4	13	1	2	4	62.07	1.36
4	54	11	10	2	6	11	12	1	16	1	4	1	62.10	1.33
4	85	15	14	6	6	7	7	1	9	4	3	9	62.13	1.26

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	MP	Kf	Km	Kmf	Ke	DE	WIP	BL
4	80	13	14	3	6	7	8	2	10	3	4	7	62.21	1.25
4	85	15	9	6	6	7	8	4	14	4	4	7	62.25	1.25
4	66	14	14	3	6	7	8	1	14	3	4	9	62.27	1.25
4	79	14	10	2	6	7	8	4	8	4	1	1	62.30	1.25
4	81	14	12	4	6	7	10	3	9	3	2	5	62.36	1.25
4	85	15	10	3	6	7	11	1	10	4	1	9	62.43	1.24
4	67	15	14	5	6	8	8	2	16	4	1	7	62.55	1.24
4	85	15	7	3	6	7	11	4	13	4	1	8	62.62	1.24
4	77	8	14	6	6	7	11	2	14	4	1	4	62.64	1.24
4	81	14	7	6	6	7	10	3	8	2	2	7	62.71	1.23
4	84	14	10	5	6	7	10	3	11	1	3	9	62.76	1.22
4	80	9	14	3	6	7	10	1	11	1	4	3	62.82	1.22
4	85	14	14	5	6	7	10	1	14	1	1	1	62.88	1.21
4	57	9	10	4	6	7	11	1	10	1	4	4	62.99	1.21
4	79	11	7	2	6	8	11	4	16	1	4	1	63.20	1.20
4	64	8	12	6	6	8	10	2	16	1	2	9	63.22	1.20
4	74	15	14	3	6	10	10	4	11	3	4	1	63.25	1.20
4	79	14	13	2	6	9	10	2	13	1	1	4	63.31	1.19
4	85	7	12	5	6	8	10	2	9	1	4	1	63.42	1.19
4	71	12	13	5	6	11	10	2	10	4	2	7	63.49	1.18
4	84	14	7	6	6	9	11	4	9	1	4	8	63.57	1.18
4	76	13	14	3	6	10	10	1	11	1	4	4	63.60	1.17
4	60	15	7	3	6	12	10	1	14	2	2	3	63.97	1.17
4	52	12	11	3	6	13	11	2	9	3	1	8	63.98	1.16
4	78	15	12	2	6	11	11	2	8	1	4	1	64.00	1.15
4	85	13	10	2	6	14	8	4	13	2	2	3	64.13	1.15
4	84	14	14	6	6	14	7	2	16	2	4	4	64.18	1.15
4	85	13	14	3	6	14	8	4	11	3	4	1	64.29	1.14
4	51	11	10	6	6	15	10	2	14	3	2	1	64.40	1.14
4	80	12	13	2	6	13	11	4	13	1	1	1	64.53	1.12
4	66	11	8	6	6	16	7	2	9	3	1	1	64.85	1.11
4	49	7	14	3	6	16	10	2	8	4	2	1	64.99	1.11
4	79	13	14	3	6	17	7	4	14	2	4	6	65.03	1.11
4	85	8	10	4	6	16	11	2	10	4	2	2	65.19	1.10
4	79	11	10	3	6	17	11	2	11	2	1	5	65.25	1.09
4	75	15	12	6	6	18	7	1	10	4	4	8	65.28	1.09
4	69	7	11	6	6	14	10	4	8	1	1	6	65.30	1.09
4	69	15	6	3	6	15	10	4	13	1	2	3	65.39	1.09
4	78	15	14	5	6	18	8	1	16	3	4	1	65.41	1.09
4	82	13	8	6	6	18	8	4	12	2	1	1	65.55	1.09
5	83	15	10	2	10	12	11	3	16	3	1	1	65.61	0.76
5	85	13	11	2	10	17	12	2	9	2	3	1	65.76	0.75
5	85	15	14	5	11	15	7	4	16	2	4	5	65.80	0.73
5	73	14	12	4	11	14	12	2	10	4	2	6	65.90	0.73
5	83	11	14	6	12	9	8	1	14	4	4	7	65.91	0.73
5	79	12	13	5	11	8	12	3	12	4	1	1	65.97	0.72
5	72	15	11	6	12	8	12	2	8	4	2	6	66.10	0.72
5	83	9	14	6	12	9	7	2	8	4	1	7	66.22	0.72
5	83	10	13	6	11	8	8	3	8	3	1	1	66.29	0.71
5	85	11	9	3	12	10	10	4	8	1	2	1	66.33	0.71
5	85	15	11	6	11	7	10	4	16	4	1	1	66.35	0.70
5	84	15	11	4	11	7	12	4	16	4	3	2	66.36	0.70
5	83	13	11	4	12	7	8	3	14	4	2	7	66.41	0.70
5	84	13	11	5	12	7	10	3	8	2	3	5	66.41	0.70
5	84	10	14	6	12	8	10	4	9	1	4	1	66.45	0.70
5	77	15	10	4	10	7	12	4	16	4	3	2	66.46	0.70
5	73	14	13	6	10	8	10	1	15	1	3	4	66.52	0.70
5	81	14	13	4	10	9	11	3	8	3	3	9	66.58	0.69
5	85	13	11	4	9	18	12	2	9	2	3	1	66.62	0.69
5	74	14	13	6	9	16	12	2	9	3	1	3	66.68	0.69
5	67	15	9	5	9	17	12	3	9	4	1	9	66.90	0.68
5	68	14	12	5	10	7	7	1	8	2	1	1	66.97	0.68
5	85	11	12	3	9	18	10	4	10	1	3	1	66.98	0.67
5	85	14	9	4	11	7	11	1	15	1	1	8	67.06	0.67
5	78	13	10	6	9	10	10	4	14	1	1	1	67.15	0.67
5	84	11	10	4	8	7	12	4	14	3	2	3	67.25	0.66
5	79	15	10	5	9	7	12	3	14	1	1	4	67.26	0.66
5	84	15	13	2	8	17	8	4	8	4	3	1	67.37	0.64
5	85	14	14	3	8	10	10	4	15	4	3	1	67.38	0.63
5	83	14	14	6	8	7	11	4	12	2	3	3	67.43	0.62
5	81	15	14	6	8	7	7	4	13	3	4	8	67.47	0.62
5	82	13	11	6	8	7	10	4	9	2	2	3	67.50	0.62

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	MP	Kf	Km	Kmf	Ke	DE	WIP	BL
5	85	15	14	5	8	10	8	4	8	2	4	9	67.52	0.62
5	78	11	9	6	8	10	10	4	8	2	1	1	67.76	0.62
5	74	8	11	3	8	17	11	3	10	4	3	1	68.03	0.62
5	85	10	9	3	8	16	10	1	16	1	3	1	68.11	0.60
5	85	15	11	3	8	14	8	4	16	1	2	8	68.48	0.60
5	67	9	9	3	7	7	12	4	14	3	2	3	68.52	0.60
5	76	15	14	5	7	7	12	1	9	1	1	8	68.62	0.58
5	79	14	14	2	7	7	7	1	14	4	1	5	68.68	0.53
5	83	14	13	2	7	17	10	4	15	2	2	5	68.76	0.52
5	79	13	12	6	7	7	10	4	9	4	3	2	68.83	0.51
5	85	14	9	6	7	7	10	1	8	4	1	1	69.02	0.51
5	81	11	13	6	7	9	10	2	13	1	2	3	69.33	0.50
5	66	15	14	6	7	11	10	1	14	1	4	2	69.52	0.50
5	77	14	11	4	7	18	10	3	14	1	1	1	69.54	0.50
5	82	11	11	6	7	7	7	2	9	1	1	6	69.94	0.49
5	83	7	13	3	7	12	10	4	10	1	1	7	70.40	0.48
5	51	8	14	3	7	14	10	4	10	1	3	2	70.73	0.48
5	84	14	13	2	6	8	12	4	15	4	4	1	70.75	0.47
5	71	13	11	3	6	7	12	1	15	4	3	2	70.77	0.46
5	71	15	10	5	6	7	12	1	9	4	1	8	70.81	0.46
5	81	15	11	3	6	8	12	2	11	3	1	5	70.89	0.46
5	85	9	10	3	6	7	12	1	16	1	3	9	71.43	0.44
5	85	14	9	5	6	10	12	4	15	4	1	9	71.70	0.44
5	52	13	8	5	6	7	12	3	11	1	4	1	71.88	0.44
5	85	9	9	3	6	11	12	1	16	2	3	1	72.33	0.43
5	76	15	14	6	6	7	7	4	15	4	3	9	72.34	0.39
5	85	14	10	5	6	7	9	2	11	4	2	4	72.56	0.39
5	73	15	12	6	6	7	8	3	8	3	1	1	72.65	0.39
5	80	8	14	6	6	7	7	2	10	4	1	1	73.02	0.38
5	81	7	13	2	6	7	10	4	16	2	1	1	73.48	0.38
5	79	11	10	6	6	7	11	4	8	1	1	1	73.51	0.36
5	81	15	11	3	6	10	11	1	8	2	3	1	73.88	0.36
5	67	15	12	3	6	10	10	1	10	1	3	2	74.10	0.35
5	85	14	9	5	6	13	7	4	15	4	1	1	74.56	0.35
6	83	15	9	2	12	12	11	3	15	3	4	1	75.06	0.29
6	75	13	10	2	12	9	11	2	16	3	4	1	75.14	0.28
6	85	15	12	2	12	17	12	4	12	1	3	8	75.34	0.27
6	81	15	14	3	11	8	11	1	9	3	3	1	75.36	0.26
6	84	15	12	6	10	17	11	3	9	4	3	1	75.52	0.26
6	81	14	13	4	11	9	12	1	8	3	4	9	75.71	0.26
6	79	14	9	6	10	17	8	2	11	4	1	5	75.84	0.26
6	83	9	10	5	12	11	11	4	9	3	2	2	75.96	0.26
6	78	9	13	4	12	8	12	3	12	4	4	1	76.05	0.26
6	84	14	11	6	11	7	10	3	11	4	1	1	76.06	0.25
6	76	15	14	5	11	7	12	4	8	2	3	9	76.23	0.25
6	85	10	14	5	12	7	7	4	9	3	1	1	76.42	0.25
6	85	15	11	4	9	7	9	2	16	4	1	8	76.45	0.25
6	82	14	13	3	12	7	11	3	11	1	4	2	76.55	0.24
6	75	14	11	6	12	7	10	2	8	1	3	6	76.80	0.24
6	82	15	14	3	9	7	10	4	8	4	4	6	76.97	0.24
6	84	15	14	6	8	7	8	3	16	3	1	1	77.29	0.22
6	80	11	10	6	8	7	7	4	9	2	4	4	77.82	0.22
6	85	15	13	2	7	7	8	1	15	4	2	1	78.29	0.20
6	85	13	13	6	7	17	10	3	15	3	4	5	78.68	0.19
6	84	14	14	5	7	15	8	3	15	4	1	1	78.69	0.19
6	85	14	9	5	7	10	7	1	9	3	1	4	79.04	0.19
6	79	14	8	3	7	8	7	4	9	3	4	1	79.47	0.19
6	66	15	14	3	7	7	10	1	13	1	3	2	79.60	0.18
6	84	9	12	3	7	14	10	4	15	1	4	3	79.77	0.18
6	85	15	9	3	7	17	7	2	16	1	1	1	80.21	0.18
6	85	15	14	5	6	8	12	2	16	3	1	1	80.89	0.16
6	79	13	14	6	6	10	12	1	10	4	4	8	81.64	0.16
6	85	15	11	5	6	8	7	3	15	4	3	8	82.69	0.14
6	85	14	10	6	6	8	10	2	16	2	1	4	83.06	0.14
6	79	15	9	3	6	7	10	4	15	1	1	2	83.49	0.13
6	79	11	14	5	6	7	11	4	8	1	1	1	83.57	0.13
6	83	14	11	5	6	10	11	4	11	2	4	6	83.75	0.13
7	85	14	11	2	12	10	11	4	13	3	3	2	84.63	0.13
7	80	11	11	2	12	15	10	4	14	3	4	3	85.12	0.12
7	79	15	14	6	12	8	12	2	14	3	4	9	85.42	0.11
7	83	15	9	6	12	10	12	3	15	4	1	7	85.68	0.11
7	83	15	9	6	10	16	11	4	16	3	1	1	85.83	0.11

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	MP	Kf	Km	Kmf	Ke	DE	WIP	BL
7	79	10	14	4	12	12	11	3	15	3	2	1	85.84	0.11
7	84	15	11	6	11	12	7	1	8	4	2	5	86.08	0.11
7	84	15	11	6	12	7	12	4	16	4	3	8	86.11	0.11
7	85	14	11	4	11	8	10	1	8	1	1	6	86.27	0.10
7	85	15	13	6	9	16	12	3	9	3	1	1	86.34	0.10
7	84	12	12	5	11	7	12	3	8	4	1	8	86.34	0.10
7	83	15	11	4	9	17	8	4	9	4	1	3	86.79	0.10
7	82	10	11	4	12	7	11	4	15	4	3	1	86.81	0.10
7	83	11	10	4	10	12	9	4	10	1	2	3	87.05	0.10
7	84	15	8	5	12	7	11	4	10	2	4	1	87.23	0.10
7	80	15	8	6	12	7	10	1	9	2	1	1	87.36	0.10
7	82	15	14	4	9	9	8	2	8	4	1	5	87.38	0.10
7	85	14	14	4	8	7	11	2	15	4	3	1	87.39	0.10
7	81	15	12	5	8	10	11	3	15	3	2	2	87.56	0.10
7	81	15	13	6	8	8	9	3	15	4	2	8	87.62	0.10
7	85	11	14	4	8	17	11	2	15	2	4	1	87.75	0.09
7	85	11	14	4	8	11	12	1	8	2	3	7	87.91	0.09
7	81	14	12	5	8	11	10	4	9	1	3	3	88.25	0.09
7	79	14	11	3	8	8	11	4	16	1	1	9	88.36	0.09
7	82	11	13	6	8	10	7	1	8	3	3	3	88.44	0.09
7	83	9	11	5	12	17	7	1	9	1	1	9	88.55	0.09
7	76	10	13	6	8	7	10	3	9	1	3	9	88.96	0.09
7	83	12	10	6	7	7	11	3	10	3	3	3	89.12	0.08
7	85	13	10	6	7	7	8	4	8	4	4	7	89.32	0.08
7	76	13	9	4	7	8	10	1	12	2	4	2	89.62	0.08
7	85	14	9	6	7	8	7	2	11	2	4	6	89.64	0.08
7	77	15	10	5	7	7	10	2	13	1	1	4	89.84	0.08
7	83	12	13	4	7	17	8	4	13	1	4	3	90.18	0.08
7	68	15	14	6	7	7	10	2	13	1	3	4	90.20	0.08
7	85	15	8	3	7	7	11	4	9	1	2	7	90.46	0.08
7	82	15	12	4	6	7	12	3	9	4	2	8	90.86	0.07
7	79	11	8	4	7	13	11	4	13	1	3	1	90.96	0.07
7	85	9	9	6	7	7	11	2	10	1	1	9	91.01	0.07
7	85	10	13	6	7	16	7	2	9	1	2	2	91.02	0.07
7	77	15	7	4	7	18	10	2	13	3	1	2	91.24	0.07
7	85	13	7	4	7	7	7	2	15	2	1	2	91.97	0.07
7	85	10	10	4	6	7	12	2	16	1	2	1	92.29	0.07
7	83	15	12	4	6	7	8	4	15	4	4	3	92.59	0.07
7	80	12	13	3	6	7	7	1	15	2	4	1	92.86	0.06
7	82	12	14	5	6	14	12	4	11	2	4	5	93.26	0.06
7	85	14	12	5	6	9	9	2	11	4	1	5	93.32	0.06
7	75	15	12	3	6	9	11	3	15	4	1	9	93.60	0.06
7	79	14	14	4	6	7	7	4	8	1	1	8	94.00	0.06
7	79	7	10	6	7	11	11	4	8	2	1	9	94.16	0.06
7	85	14	8	6	6	8	7	2	15	2	3	6	94.47	0.06
7	85	15	14	3	6	14	11	1	9	4	1	9	94.96	0.06
7	85	11	14	3	6	14	7	2	11	4	3	8	95.32	0.06
7	85	13	8	4	6	12	10	3	16	4	1	3	95.77	0.06
7	73	13	7	3	6	17	12	1	8	4	1	8	95.80	0.06
7	79	13	7	2	6	9	10	4	14	1	4	1	95.80	0.06
7	79	9	13	5	6	11	8	2	16	4	4	5	95.99	0.05
7	75	7	12	3	6	8	12	1	15	4	2	9	96.19	0.05
8	83	15	9	5	12	16	12	3	15	3	1	1	96.29	0.05
8	81	14	14	4	11	8	12	4	8	1	1	9	96.50	0.05
8	78	15	13	3	11	18	10	1	11	1	3	4	96.51	0.05
8	85	15	13	6	9	16	12	3	9	3	1	1	96.60	0.05
8	77	15	14	6	11	9	11	2	9	1	1	9	96.69	0.05
7	82	15	7	2	6	8	8	1	15	1	3	3	96.76	0.05
7	84	13	6	3	6	7	11	4	15	2	2	1	96.81	0.05
7	80	15	6	4	6	8	10	4	12	4	1	1	97.09	0.05
7	84	9	10	6	6	10	9	1	15	1	1	1	97.38	0.04
8	83	9	14	3	12	10	12	1	16	4	1	5	97.77	0.04
8	84	13	14	4	8	17	11	3	16	2	3	9	97.98	0.04
8	85	15	10	4	8	8	12	4	15	4	4	4	98.04	0.04
8	85	15	8	3	11	8	11	4	11	1	1	9	98.34	0.04
8	82	14	9	6	11	18	9	1	16	1	4	3	98.41	0.04
8	77	15	7	5	10	16	12	1	13	4	1	9	98.68	0.04
7	77	7	14	4	6	10	10	3	10	3	3	5	98.82	0.04
7	84	8	14	6	6	7	9	4	9	1	2	9	99.20	0.04
8	84	15	7	5	11	17	11	3	9	4	4	3	99.35	0.04
8	85	15	7	5	11	8	10	2	8	3	1	1	99.85	0.03
8	85	14	9	3	7	15	8	4	14	3	2	1	101.06	0.03

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	MP	Kf	Km	Kmf	Ke	DE	WIP	BL
8	76	8	13	6	11	7	12	4	8	4	3	5	101.71	0.03
8	82	9	13	6	7	16	12	1	8	4	4	5	101.92	0.03
8	85	11	6	5	11	7	12	1	8	1	4	5	102.05	0.03
8	79	9	14	5	7	17	12	2	13	1	4	1	102.09	0.03
8	75	14	7	5	8	8	10	4	15	2	1	8	102.36	0.03
8	76	14	7	6	8	7	10	3	16	1	2	1	102.89	0.03
8	82	8	14	6	8	7	12	2	8	4	1	2	103.27	0.02
8	81	14	8	6	7	18	9	4	13	1	4	2	103.89	0.02
8	85	14	8	5	6	7	9	2	11	2	1	9	106.38	0.02
8	79	8	13	5	6	7	12	2	10	4	1	1	106.57	0.02
8	85	15	7	5	7	7	8	1	8	2	1	9	106.60	0.02
8	84	15	6	6	7	8	10	1	8	4	3	1	107.48	0.02
8	85	14	7	2	6	9	10	3	16	1	3	2	107.87	0.02
8	79	8	10	5	7	7	7	3	13	4	4	3	109.57	0.01
8	79	15	7	6	6	15	10	1	15	4	4	6	109.60	0.01
8	84	13	7	6	6	14	10	1	15	1	4	7	110.09	0.01
8	82	9	9	3	6	8	7	4	11	1	4	2	110.45	0.01
9	84	14	8	5	11	8	10	1	8	4	1	8	110.73	0.01
9	85	14	8	5	12	7	11	3	13	2	1	3	110.99	0.01
8	72	9	10	2	6	13	8	1	9	1	3	3	111.23	0.01
9	85	15	8	5	8	13	12	3	12	1	2	9	111.72	0.01
8	76	14	6	3	6	10	10	2	11	2	1	6	112.08	0.01
9	80	10	11	6	8	7	10	1	8	4	2	9	112.53	0.01
9	84	9	12	6	9	7	11	1	15	4	1	1	112.63	0.01
9	84	9	10	5	9	12	11	1	15	4	1	3	113.12	0.01
9	83	11	7	4	9	7	12	4	9	4	1	8	113.29	0.01
9	77	9	14	5	9	7	10	4	9	2	4	5	113.39	0.01
9	85	15	7	3	8	7	12	1	13	1	1	1	113.77	0.01
9	77	13	8	6	7	7	10	4	14	3	4	1	114.81	0.01
9	85	11	8	5	7	7	10	4	15	2	2	1	114.87	0.01
9	78	9	8	6	8	16	12	2	11	3	4	1	116.09	0.01
9	85	9	9	5	7	10	12	1	13	3	1	2	116.13	0.01
9	84	14	7	4	9	8	10	1	8	2	1	8	116.55	0.01
9	83	9	9	3	7	10	10	4	9	1	2	1	117.13	0.01
9	85	14	9	6	7	13	6	4	8	2	2	7	117.33	0.01
9	77	15	6	4	8	8	12	1	16	4	1	1	117.46	0.01
9	85	13	7	5	7	7	10	1	15	3	2	7	118.29	0.00
9	66	8	11	4	8	8	12	3	15	2	4	6	120.67	0.00
9	85	10	11	6	6	7	8	3	8	1	1	5	120.70	0.00
9	72	8	14	4	7	14	11	4	9	3	2	1	121.94	0.00
9	85	8	11	4	6	7	12	2	10	4	4	3	123.48	0.00
9	85	9	9	6	6	7	8	2	15	3	1	4	125.64	0.00
9	69	8	10	5	6	8	11	1	11	3	4	9	126.92	0.00
9	77	8	14	5	6	15	10	4	9	2	2	5	127.40	0.00
9	85	8	6	6	6	15	12	3	16	2	3	5	131.36	0.00
9	81	9	6	5	6	17	11	1	15	1	1	1	136.24	0.00
9	85	8	7	5	7	10	8	2	15	2	4	1	142.88	0.00
9	78	7	14	4	6	18	12	3	15	3	4	1	143.10	0.00
9	54	7	8	3	6	13	12	3	11	3	4	4	144.51	0.00
9	84	8	8	6	6	16	7	4	9	3	1	4	145.30	0.00
9	77	7	6	3	6	8	11	3	9	4	4	1	148.70	0.00
9	85	7	6	6	6	10	11	2	16	4	2	1	149.69	0.00

B7. DNC HKC - PAC OPTIMISED SETTINGS FOR LOWER PROCESSING TIME VARIABILITY

Table B-7. Production Authorisation Card Settings for DNC HKC Strategy 90LV

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	MP	Kf	Km	Kmf	Ke	WIP	BL
3	74	14	13	2	10	11	9	4	14	4	1	46.98	8.14
3	84	9	12	2	10	16	11	3	10	4	2	46.99	8.13
3	74	12	10	3	10	15	12	2	14	3	4	47.02	8.12
3	78	10	14	4	10	12	7	1	9	4	4	47.03	8.10
3	85	11	9	3	11	8	12	4	14	2	4	47.07	8.10
3	74	8	7	4	12	12	7	2	10	3	1	47.11	8.10
3	68	14	6	6	12	16	12	3	14	2	4	47.11	8.09
3	67	10	6	3	12	16	11	3	10	2	1	47.14	8.08
3	60	7	14	5	11	9	12	4	10	2	1	47.18	8.08
3	54	14	14	3	11	8	10	4	8	4	1	47.19	8.08
3	52	14	9	6	11	8	11	4	12	2	4	47.20	8.07
3	65	15	13	6	9	10	11	1	9	4	1	47.23	7.99
3	58	9	12	5	9	17	11	4	10	4	1	47.27	7.98
3	57	10	9	5	9	14	10	4	14	4	4	47.28	7.98
3	82	12	14	2	9	7	11	4	13	4	4	47.34	7.95
3	80	13	9	2	9	17	9	4	8	4	4	47.38	7.95
3	78	14	14	2	8	8	12	3	10	2	4	47.44	7.92
3	57	13	11	4	9	8	11	2	11	1	4	47.45	7.90
3	74	11	14	3	8	16	12	3	8	2	2	47.53	7.89
3	78	12	7	5	8	8	12	4	8	2	2	47.59	7.87
3	74	9	6	6	12	7	10	3	11	1	1	47.71	7.83
3	85	13	14	4	8	17	10	1	15	2	3	47.76	7.55
3	84	15	9	3	8	8	11	1	9	2	2	47.77	7.54
3	85	10	9	5	8	8	8	2	16	4	4	47.78	7.54
3	72	10	8	4	8	10	10	3	13	3	1	47.81	7.53
3	74	13	7	5	8	9	10	4	11	4	1	47.83	7.53
3	58	9	14	2	8	7	10	4	9	3	4	47.87	7.53
3	84	11	6	2	8	9	11	1	13	4	1	47.87	7.53
3	79	15	7	6	8	7	10	2	8	4	1	47.94	7.46
3	85	10	13	6	7	9	12	2	9	3	1	48.07	7.43
3	57	15	7	5	8	9	11	1	14	1	4	48.08	7.40
3	57	8	7	4	8	16	10	1	11	1	3	48.13	7.39
3	42	15	13	2	8	8	11	1	9	1	3	48.28	7.38
3	64	15	10	6	7	8	12	2	10	1	1	48.39	7.30
3	67	13	7	3	7	16	12	3	12	1	1	48.49	7.28
3	74	10	6	2	7	7	12	1	9	1	1	48.54	7.24
3	80	10	12	4	7	15	12	4	7	4	3	48.97	7.20
3	85	8	14	4	7	9	11	4	9	2	1	49.09	6.20
3	85	12	6	5	7	8	10	4	16	2	4	49.14	6.19
3	85	10	6	6	7	8	9	3	16	2	1	49.17	6.18
3	74	12	6	3	7	7	9	4	15	4	1	49.18	6.17
3	64	12	13	5	7	8	11	2	9	1	3	49.25	6.14
3	85	11	14	3	7	7	11	1	9	1	1	49.35	6.10
3	84	10	13	5	6	7	12	3	11	3	4	49.96	5.92
3	59	15	8	2	6	7	12	3	8	2	1	50.05	5.91
3	83	10	6	3	6	7	12	1	11	3	1	50.09	5.90
3	78	15	6	5	6	7	12	1	8	2	1	50.13	5.89
3	74	15	7	6	6	7	12	1	9	1	2	50.26	5.82
3	62	15	8	5	6	11	12	4	8	3	1	50.54	5.82
3	72	8	14	4	6	12	12	4	12	3	2	50.69	5.78
3	78	10	13	4	6	12	12	1	16	1	4	50.88	5.71
3	72	15	13	4	6	13	12	2	9	1	4	51.02	5.70
3	84	10	8	6	6	14	12	3	10	1	2	51.21	5.67
3	85	14	9	4	6	17	12	1	10	2	2	51.37	5.66
3	81	15	6	3	6	18	12	4	11	2	4	51.59	5.63
3	84	14	7	2	6	16	12	3	15	1	1	51.60	5.60
3	72	15	14	5	6	7	7	1	13	4	1	51.71	4.70
3	56	9	14	3	6	7	11	2	10	3	4	51.96	4.67
3	82	7	13	4	6	8	7	2	12	3	1	52.09	4.63
3	72	15	6	5	6	8	7	1	8	3	2	52.12	4.62

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	MP	Kf	Km	Kmf	Ke	WIP	BL
3	84	14	12	5	6	9	8	1	15	4	4	52.16	4.61
3	72	14	14	2	6	9	7	3	8	2	1	52.16	4.61
3	64	12	6	4	6	7	10	1	9	1	2	52.24	4.59
3	46	12	13	4	6	7	10	1	8	1	2	52.28	4.59
3	44	10	14	3	6	9	9	2	9	3	2	52.36	4.59
3	72	8	14	6	6	10	10	4	14	3	1	52.50	4.56
3	49	7	6	3	6	9	8	1	8	4	4	52.54	4.55
3	80	13	9	5	6	11	8	1	9	4	4	52.56	4.54
3	65	8	6	6	6	9	10	3	14	1	4	52.67	4.51
3	81	7	7	2	6	9	10	3	8	1	3	52.70	4.51
3	72	9	14	6	6	12	11	4	14	2	2	52.86	4.49
3	58	14	9	6	6	12	11	3	8	2	4	52.90	4.48
3	84	11	6	4	6	13	11	3	10	2	4	53.17	4.44
3	85	9	12	4	6	15	8	3	9	4	4	53.34	4.41
3	81	9	7	3	6	16	7	1	14	3	4	53.53	4.37
3	72	12	14	3	6	17	7	3	9	4	1	53.60	4.36
3	62	11	6	4	6	18	9	1	9	2	3	53.93	4.32
3	49	7	6	4	6	9	10	1	7	4	4	54.43	4.27
3	80	14	13	5	6	18	8	3	14	1	1	54.93	4.22
4	82	10	9	2	11	14	10	2	9	3	1	55.76	2.47
4	81	14	12	4	10	15	12	4	15	2	4	55.85	2.44
4	81	9	12	6	11	9	10	2	15	2	1	55.91	2.44
4	73	13	9	6	11	11	11	4	8	4	4	55.94	2.43
4	69	12	7	6	12	9	10	1	11	3	3	56.06	2.43
4	57	13	14	6	10	12	10	1	12	3	1	56.14	2.42
4	63	12	7	6	11	11	12	1	8	3	1	56.15	2.42
4	81	13	12	5	10	12	12	3	16	1	2	56.16	2.39
4	81	10	11	5	12	18	12	2	16	1	2	56.17	2.39
4	71	10	12	6	12	15	11	2	9	1	3	56.21	2.39
4	63	11	14	4	11	11	12	4	16	1	2	56.27	2.38
4	62	11	11	4	11	11	12	4	14	1	2	56.30	2.38
4	73	11	7	4	9	11	10	3	11	2	2	56.35	2.38
4	73	11	14	4	9	11	10	4	11	1	2	56.39	2.35
4	74	11	12	6	12	7	8	2	13	3	4	56.47	2.35
4	75	15	6	4	9	8	7	1	12	2	1	56.70	2.35
4	57	13	14	2	9	12	11	1	8	3	2	56.75	2.35
4	52	13	10	6	10	9	12	1	15	1	1	56.78	2.34
4	85	12	9	4	8	13	12	4	15	4	4	56.79	2.32
4	73	13	12	5	8	8	10	2	11	3	4	56.99	2.24
4	74	13	14	6	8	7	11	3	12	4	4	57.06	2.22
4	69	9	10	4	8	7	8	3	16	3	1	57.23	2.21
4	73	12	6	3	8	10	10	2	11	2	3	57.39	2.21
4	73	12	6	4	8	9	10	1	11	2	3	57.40	2.21
4	69	8	11	5	8	10	10	4	8	3	3	57.44	2.17
4	80	11	8	5	7	12	12	3	15	4	1	57.74	2.14
4	80	15	6	4	7	9	12	1	14	4	3	57.93	2.13
4	80	14	14	5	7	10	10	4	12	4	1	58.41	1.85
4	84	14	13	6	7	14	8	3	15	4	1	58.44	1.85
4	85	12	13	6	7	18	8	3	15	4	1	58.46	1.85
4	69	14	6	6	7	18	7	1	11	2	2	59.01	1.82
4	67	7	6	2	7	7	10	3	11	2	4	59.15	1.82
4	70	12	6	4	7	8	10	3	8	1	4	59.26	1.79
4	44	10	13	3	7	13	11	2	8	1	1	59.75	1.75
4	65	12	7	4	6	7	12	1	8	2	1	60.17	1.70
4	69	7	8	2	6	7	12	4	11	1	4	60.57	1.66
4	69	15	6	3	6	8	12	1	11	1	4	60.70	1.66
4	77	7	13	3	6	9	12	1	13	1	2	60.94	1.63
4	58	15	14	6	6	12	12	2	10	1	2	61.28	1.61
4	85	14	7	2	6	16	12	3	9	2	1	62.04	1.59
4	84	14	7	3	6	16	12	1	9	2	1	62.15	1.58
4	85	10	9	4	6	8	8	1	16	3	4	62.43	1.26
4	73	7	7	3	6	7	10	3	9	3	4	62.78	1.25
4	77	9	6	3	6	8	8	4	8	2	1	63.04	1.24
4	56	15	10	6	6	10	10	2	8	4	4	63.23	1.22
4	85	13	9	4	6	12	7	4	12	2	4	63.47	1.20
4	65	11	9	4	6	12	7	4	9	3	4	63.51	1.20
4	58	14	6	2	6	12	11	3	13	3	2	63.88	1.19
4	82	7	12	6	6	12	8	3	15	2	1	64.01	1.18
4	70	7	7	6	6	9	7	3	11	1	1	64.33	1.18
4	81	13	10	3	6	13	11	3	11	1	1	64.42	1.14
5	81	14	12	2	10	15	12	2	16	2	1	64.61	0.88
5	72	11	12	2	10	10	11	2	12	3	1	64.79	0.87

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	MP	Kf	Km	Kmf	Ke	WIP	BL
5	84	12	13	6	11	13	12	4	13	4	4	64.80	0.84
5	81	11	13	6	11	14	10	1	13	2	3	64.87	0.84
5	72	10	12	6	12	12	10	2	10	4	2	65.03	0.83
5	80	15	12	6	12	8	12	3	16	4	1	65.08	0.83
5	76	14	8	6	11	8	11	3	9	2	3	65.35	0.82
5	84	15	7	6	12	8	12	4	14	2	1	65.48	0.82
5	76	13	11	6	10	16	10	3	15	1	1	65.48	0.80
5	75	10	10	6	10	14	12	1	13	1	1	65.59	0.80
5	85	15	12	6	12	7	11	2	12	2	1	65.77	0.79
5	85	15	12	5	10	7	12	2	9	4	4	65.78	0.79
5	82	15	9	6	11	7	10	4	10	2	4	65.90	0.79
5	58	14	13	5	11	8	12	3	11	1	1	66.19	0.78
5	84	15	12	2	8	7	9	2	15	4	1	66.44	0.76
5	85	12	12	5	8	8	10	4	9	4	1	66.52	0.74
5	80	11	8	5	8	12	11	4	15	4	1	66.82	0.74
5	80	10	8	5	8	10	11	4	9	4	1	66.91	0.73
5	73	11	12	2	8	11	11	2	8	1	4	67.36	0.71
5	85	15	13	2	7	8	12	4	8	2	4	67.40	0.71
5	56	14	14	2	7	18	12	4	13	4	1	67.88	0.70
5	83	13	7	6	7	12	12	3	14	2	4	68.00	0.68
5	81	14	12	5	7	9	8	1	16	4	4	68.10	0.61
5	74	14	7	6	7	17	11	3	10	4	4	68.77	0.60
5	83	14	8	6	7	12	10	1	14	1	4	68.89	0.59
5	74	10	6	3	7	7	11	3	11	1	2	69.66	0.57
5	84	12	6	3	7	13	10	3	15	1	4	69.71	0.57
5	85	13	14	4	6	9	12	4	16	2	2	70.43	0.53
5	62	7	12	6	6	7	12	3	14	4	3	71.13	0.52
5	80	15	12	6	6	7	7	1	14	4	3	72.02	0.41
5	64	12	10	6	6	7	8	2	13	4	1	72.46	0.41
5	83	11	7	5	6	7	11	2	14	1	4	73.41	0.39
5	74	11	12	6	6	9	10	4	16	1	1	73.57	0.37
6	85	15	13	2	12	13	12	3	11	2	3	73.72	0.33
6	77	11	11	2	11	13	12	1	15	4	2	74.08	0.33
6	73	12	14	2	10	12	12	2	11	3	4	74.15	0.33
6	85	15	14	5	12	18	8	4	12	2	4	74.18	0.30
6	77	11	11	6	12	13	12	2	16	4	2	74.49	0.30
6	81	11	13	3	11	13	10	1	9	1	1	74.92	0.29
6	80	10	13	3	10	18	12	1	14	1	1	75.06	0.29
6	84	9	14	4	9	16	8	2	12	3	1	75.66	0.28
6	77	15	7	4	9	9	12	4	15	2	4	75.80	0.28
6	64	10	14	6	9	15	12	2	10	1	4	75.95	0.28
6	76	15	14	5	9	7	12	2	8	2	4	76.20	0.26
6	85	11	13	3	8	7	10	4	12	2	2	76.53	0.26
6	73	14	12	4	8	10	11	4	11	1	3	76.88	0.25
6	85	9	10	3	8	16	10	1	14	1	4	77.32	0.25
6	84	13	12	2	7	7	12	3	16	2	4	77.41	0.25
6	71	13	13	6	8	9	12	1	8	1	2	77.54	0.24
6	76	13	14	6	8	12	10	1	8	1	1	77.76	0.23
6	65	9	14	3	7	15	12	3	11	4	4	78.71	0.22
6	72	10	8	4	7	10	10	3	12	3	1	79.19	0.21
6	83	14	8	4	7	12	11	3	8	1	1	79.63	0.20
6	84	7	6	6	7	7	12	1	15	1	4	81.68	0.19
6	72	8	8	4	7	13	7	3	12	1	1	81.78	0.19
6	63	15	7	2	6	7	12	3	12	1	1	81.80	0.18
6	83	11	7	4	6	7	12	1	8	1	2	82.11	0.17
6	83	12	11	6	6	16	12	4	15	3	3	83.38	0.16
6	73	15	13	3	6	9	10	2	15	1	3	83.57	0.14
6	82	12	9	4	6	12	9	4	8	4	1	84.60	0.13
7	81	11	13	3	11	13	10	3	12	1	2	84.78	0.12
7	80	9	14	3	12	18	11	3	15	2	1	85.15	0.12
7	80	10	8	5	11	15	11	3	9	3	1	85.73	0.12
7	80	10	8	5	11	12	11	2	8	3	1	85.90	0.11
7	75	11	9	4	9	12	10	3	13	3	1	85.97	0.11
7	72	14	14	4	9	10	8	3	10	1	3	86.35	0.11
7	80	10	7	5	11	17	11	3	15	3	1	86.57	0.11
7	80	15	10	3	9	18	11	1	8	2	1	86.62	0.11
7	77	10	13	4	10	7	10	1	11	1	1	86.89	0.11
7	65	14	12	6	12	7	11	1	9	1	3	87.27	0.11
7	80	15	7	4	12	8	7	2	14	4	1	87.35	0.10
7	73	14	9	6	8	7	11	3	12	3	1	87.57	0.10
7	73	10	13	3	8	9	10	2	11	1	3	87.71	0.10
7	85	11	6	5	9	16	12	1	9	4	3	87.80	0.10

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	MP	Kf	Km	Kmf	Ke	WIP	BL
7	73	11	13	4	8	11	11	3	8	2	4	88.13	0.10
7	85	13	14	6	7	9	10	4	9	1	3	88.82	0.09
7	84	10	14	6	7	9	12	4	8	1	3	89.33	0.09
7	80	11	8	5	7	12	11	2	14	3	1	90.02	0.08
7	67	8	14	6	7	9	11	3	8	2	4	91.67	0.07
7	73	14	7	5	7	9	11	1	8	1	1	91.68	0.07
7	73	11	6	3	7	8	10	1	12	1	1	93.18	0.07
8	85	15	14	5	12	12	12	4	11	2	3	93.93	0.06
8	84	15	13	6	9	8	12	3	15	1	1	95.30	0.05
8	73	12	11	6	11	16	11	4	15	2	3	95.87	0.05
8	73	12	13	4	10	11	10	4	15	1	1	96.40	0.05
8	85	14	13	5	8	14	12	3	10	3	1	96.61	0.05
8	82	10	13	6	11	7	12	2	9	4	4	97.07	0.05
8	76	9	12	6	11	18	12	1	15	1	1	97.55	0.05
8	80	15	8	6	11	8	10	1	11	1	4	97.55	0.05
8	85	9	9	6	11	16	11	4	8	2	3	97.59	0.05
8	81	15	7	6	11	16	11	1	8	4	3	98.25	0.04
8	85	8	12	3	11	18	10	2	14	1	1	98.95	0.04
8	68	14	6	5	12	16	12	1	9	2	2	99.89	0.04
8	85	8	8	6	12	18	12	2	15	1	3	100.17	0.04
8	85	14	6	3	11	9	11	3	14	1	3	101.64	0.03
8	84	15	7	6	10	7	9	1	16	2	4	102.35	0.03
8	85	14	6	3	7	8	12	1	9	2	3	103.24	0.03
8	71	8	11	6	7	7	10	1	10	1	1	104.97	0.02
8	80	14	8	5	6	10	11	3	8	3	1	106.50	0.02
8	84	10	8	6	6	14	12	1	14	1	1	106.72	0.02
8	83	14	7	3	6	16	12	1	13	2	2	106.79	0.02
9	77	11	12	3	11	13	12	1	14	4	4	106.89	0.02
9	82	11	12	3	9	16	12	2	15	4	1	107.03	0.02
8	85	8	6	4	7	7	12	4	9	1	1	107.35	0.02
9	68	12	14	3	12	16	12	4	9	1	2	108.87	0.02
9	85	10	14	3	12	13	7	1	10	4	4	109.00	0.02
8	72	8	9	6	6	7	11	4	14	3	1	109.16	0.02
9	84	15	7	6	12	15	12	2	14	2	3	109.28	0.02
9	82	11	10	4	8	11	12	2	8	4	2	110.66	0.01
9	80	12	7	3	9	13	12	2	14	4	1	110.74	0.01
9	77	9	12	4	10	9	11	1	9	1	1	110.85	0.01
9	84	10	14	3	7	17	12	3	15	2	3	111.77	0.01
9	75	12	14	3	7	16	9	1	15	1	1	113.81	0.01
8	84	15	6	2	6	18	10	3	13	4	1	113.85	0.01
9	72	9	14	4	8	11	10	2	12	1	3	114.07	0.01
9	84	15	11	5	6	18	12	1	13	3	1	114.86	0.01
9	73	14	7	6	7	18	12	3	15	3	2	114.87	0.01
9	80	15	8	5	6	17	12	1	13	3	1	117.02	0.01
9	85	12	11	6	6	18	9	3	14	1	2	119.23	0.01
9	66	15	7	4	7	16	11	1	9	2	3	119.99	0.01
9	84	9	12	2	6	17	10	1	14	2	2	121.22	0.01
9	80	8	9	2	7	17	12	1	15	1	3	121.33	0.01
9	80	9	8	5	6	11	11	3	15	3	1	123.06	0.00
9	63	8	7	6	8	9	12	4	8	3	1	123.92	0.00
9	81	8	7	3	7	16	10	3	10	1	1	125.81	0.00
9	80	8	8	5	6	7	11	2	9	3	1	127.28	0.00
9	81	8	14	3	6	16	10	2	11	4	1	127.38	0.00
9	85	8	7	3	6	17	7	3	12	4	1	149.11	0.00
9	85	7	6	4	6	18	10	1	12	1	2	151.80	0.00
9	60	9	6	3	6	8	8	4	10	1	3	167.83	0.00

B8. HEKC-II – PAC OPTIMISED SETTINGS FOR LOWER PROCESSING TIME VARIABILITY

Table B-8. Production Authorisation Card Settings for HEKC-II Strategy 90LV

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	Kf	Km	Kmf	Ke	DE	WIP	BL
4	102	17	13	2	15	22	5	20	4	3	0	45.23	73.02
4	62	17	17	2	14	13	3	20	5	3	0	45.53	72.95
4	106	8	11	6	15	15	4	20	3	5	0	45.76	72.73
4	80	17	7	6	14	20	3	20	4	5	0	45.96	72.69
4	108	9	13	6	14	13	2	20	3	5	0	46.05	72.69
4	79	12	13	6	14	11	4	20	3	2	0	46.10	72.66
4	75	12	9	3	13	21	2	19	5	5	0	46.50	72.65
4	77	17	16	6	13	21	4	19	5	2	0	46.55	72.64
4	62	17	9	6	14	10	4	18	5	4	0	46.57	72.56
4	95	8	17	5	15	15	2	18	2	5	0	47.09	72.56
4	110	14	15	5	15	9	4	17	4	4	0	47.36	72.19
4	109	8	12	3	15	9	3	14	5	4	0	48.13	72.16
4	86	18	10	5	15	9	2	13	5	5	0	48.63	72.10
4	110	12	17	3	13	9	5	15	3	3	0	49.04	72.05
4	76	18	17	2	15	8	3	18	5	3	0	49.20	71.66
4	74	9	14	2	14	8	4	18	4	2	0	49.63	71.58
4	104	17	17	5	15	8	2	19	5	2	0	49.80	71.38
4	72	9	16	6	14	8	2	20	5	4	0	50.08	71.35
4	79	14	9	5	15	8	3	16	4	2	0	50.47	71.34
4	60	10	17	5	13	8	4	19	3	4	0	50.95	71.27
4	82	17	8	3	15	8	2	18	2	3	0	51.03	71.23
4	73	12	17	3	12	8	3	18	5	2	0	51.99	71.21
4	81	11	8	5	11	8	4	20	3	5	0	52.60	71.17
4	106	11	15	2	14	15	5	8	3	2	1	53.22	5.56
4	107	18	17	2	14	18	2	19	5	4	1	53.22	5.50
4	109	17	15	2	13	19	5	13	2	5	1	53.23	5.50
4	102	17	16	2	13	19	3	10	4	4	1	53.23	5.50
4	109	13	15	2	15	11	5	12	4	4	1	53.23	5.49
4	99	13	17	2	12	12	5	14	5	3	1	53.24	5.49
4	93	12	14	2	15	20	4	14	2	4	1	53.25	5.49
4	90	13	13	2	14	17	2	19	2	5	1	53.26	5.49
4	100	14	11	2	14	10	2	13	3	4	1	53.27	5.49
4	110	18	15	2	11	10	3	9	3	2	1	53.30	5.47
4	99	17	17	2	12	22	4	20	2	3	2	53.30	5.47
4	108	18	17	2	14	12	3	17	4	3	4	53.30	5.47
4	109	17	17	2	14	19	2	14	3	3	8	53.30	5.47
4	108	17	15	2	13	14	5	18	4	5	6	53.30	5.47
4	109	16	14	2	13	11	2	12	3	5	8	53.30	5.47
4	107	14	17	2	15	14	5	10	5	5	4	53.30	5.46
4	110	13	15	2	14	21	5	14	3	2	7	53.31	5.46
4	99	13	17	2	14	19	4	15	5	4	7	53.32	5.46
4	110	12	14	2	13	18	2	10	5	2	4	53.32	5.46
4	98	12	15	2	12	11	4	12	3	5	4	53.33	5.46
4	93	12	16	2	15	21	4	16	4	2	6	53.34	5.46
4	103	11	16	2	15	19	5	13	2	3	3	53.34	5.46
4	110	11	17	2	14	14	2	20	4	4	5	53.34	5.46
4	97	11	15	2	15	21	5	12	3	4	7	53.35	5.46
4	110	18	14	2	14	9	2	9	4	4	2	53.35	5.44
4	110	13	17	2	10	11	5	16	3	2	5	53.39	5.43
4	107	16	15	6	14	16	5	8	2	2	1	53.39	5.41
4	109	16	14	3	15	12	3	11	2	5	1	53.40	5.34
4	110	18	15	3	14	17	2	9	5	4	1	53.40	5.34
4	110	17	16	3	14	22	5	13	2	3	1	53.40	5.34
4	103	15	17	3	14	11	3	20	3	5	1	53.41	5.34
4	110	18	16	5	14	21	5	9	3	2	1	53.41	5.34
4	110	14	16	5	14	22	2	19	2	5	1	53.41	5.34
4	107	17	17	6	14	21	2	20	3	5	1	53.41	5.34
4	110	18	13	6	13	13	4	11	2	3	1	53.42	5.34
4	100	14	17	6	14	16	5	9	3	4	1	53.42	5.34
4	98	16	13	5	15	13	2	9	3	3	1	53.42	5.34

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	Kf	Km	Kmf	Ke	DE	WIP	BL
4	110	12	17	6	14	22	2	14	5	2	1	53.43	5.34
4	99	13	17	6	13	16	3	9	3	4	1	53.43	5.34
4	109	15	17	4	11	15	2	20	2	5	1	53.43	5.33
4	101	15	17	6	11	12	2	10	3	5	1	53.44	5.33
4	110	11	17	6	14	11	4	18	5	5	1	53.45	5.33
4	99	11	17	6	13	16	4	11	3	4	1	53.46	5.33
4	106	15	11	6	11	16	3	11	3	2	1	53.46	5.33
4	110	17	14	3	13	22	2	9	2	3	3	53.47	5.32
4	110	16	16	3	15	13	4	17	5	3	8	53.47	5.32
4	104	16	15	3	14	13	2	12	4	5	9	53.48	5.32
4	103	14	17	3	14	11	3	20	2	2	4	53.48	5.32
4	106	16	16	3	14	10	5	16	5	2	8	53.48	5.32
4	100	17	17	3	14	10	5	19	2	5	3	53.48	5.32
4	109	15	16	6	15	20	3	13	5	2	4	53.48	5.31
4	107	16	15	6	15	13	5	13	2	4	4	53.48	5.31
4	109	17	16	4	15	14	5	20	4	2	9	53.48	5.31
4	109	15	15	6	14	19	2	13	2	3	9	53.49	5.31
4	106	18	14	3	10	11	2	11	5	3	1	53.51	5.30
4	110	17	15	6	10	19	3	11	4	5	1	53.52	5.29
4	110	18	14	6	10	11	5	19	4	2	1	53.52	5.29
4	108	16	14	4	10	11	3	17	2	5	1	53.52	5.29
4	109	15	14	6	10	19	3	10	4	3	1	53.52	5.29
4	107	18	15	3	11	22	3	9	5	5	7	53.53	5.29
4	109	13	15	3	11	16	3	9	2	5	7	53.53	5.29
4	108	11	17	5	10	15	4	11	3	5	1	53.55	5.28
4	101	11	17	6	10	12	3	10	4	5	1	53.56	5.28
4	110	18	13	3	10	16	2	11	2	3	8	53.56	5.27
4	110	18	15	6	10	11	3	13	5	2	7	53.57	5.26
4	97	12	13	5	10	18	5	13	5	5	7	53.60	5.26
4	97	12	13	5	10	18	5	10	5	4	9	53.60	5.26
4	110	11	16	6	10	17	5	16	5	2	3	53.60	5.26
4	110	18	15	6	10	9	3	20	5	3	3	53.61	5.25
4	110	13	17	6	10	9	3	20	2	4	5	53.61	5.24
4	104	13	17	2	10	9	5	9	5	2	1	53.69	5.23
4	107	13	17	2	10	15	4	9	4	4	4	53.71	5.22
4	106	16	17	2	11	13	2	8	5	3	1	53.79	5.22
4	104	17	15	3	14	8	5	19	3	2	6	53.81	5.16
4	110	13	17	5	14	8	3	11	5	2	7	53.82	5.15
4	109	13	16	6	12	8	2	9	4	4	8	53.82	5.15
4	110	11	14	4	10	15	5	9	4	5	1	53.83	5.15
4	108	16	14	4	10	8	4	18	5	2	4	53.86	5.13
4	107	12	11	4	10	8	3	16	2	5	2	53.90	5.13
4	106	15	11	6	11	9	3	8	3	5	1	54.03	5.07
4	98	14	17	3	11	8	4	8	5	5	4	54.08	5.04
4	110	17	15	2	9	14	4	15	3	5	1	54.43	4.78
4	109	14	17	2	9	9	3	14	2	3	1	54.43	4.78
4	109	17	13	2	9	17	4	20	4	5	1	54.43	4.78
4	109	18	14	2	9	21	3	10	5	3	1	54.43	4.78
4	108	14	17	2	9	9	3	14	4	2	2	54.44	4.78
4	109	15	17	2	9	8	3	18	5	4	3	54.45	4.78
4	109	18	13	2	9	17	2	17	4	2	8	54.45	4.78
4	96	16	17	2	9	12	3	17	5	2	2	54.46	4.78
4	102	18	12	2	9	10	2	19	5	4	7	54.46	4.77
4	107	18	11	2	9	18	2	20	4	2	2	54.48	4.77
4	108	18	11	2	9	18	2	20	5	5	2	54.48	4.77
4	104	17	11	2	9	19	5	12	2	5	5	54.48	4.77
4	91	11	12	2	9	17	5	18	4	4	3	54.52	4.77
4	109	13	15	4	9	15	5	14	4	5	1	54.55	4.71
4	110	16	15	3	9	13	3	17	2	5	2	54.55	4.70
4	110	12	16	6	9	9	4	15	3	5	1	54.55	4.70
4	110	18	17	4	9	11	2	20	2	2	3	54.56	4.70
4	109	18	16	6	9	14	2	20	4	2	7	54.56	4.70
4	107	17	15	6	9	14	4	14	2	4	4	54.56	4.70
4	108	14	16	6	9	12	5	19	2	3	6	54.56	4.70
4	106	18	14	4	9	14	4	11	3	4	3	54.56	4.70
4	109	18	16	6	9	8	2	12	4	5	4	54.56	4.70
4	104	18	15	4	9	8	5	10	5	5	1	54.57	4.69
4	100	14	17	4	9	12	5	10	3	3	2	54.57	4.69
4	92	11	14	6	9	8	2	19	4	4	3	54.63	4.69
4	83	17	16	4	9	22	5	10	2	5	7	54.64	4.68
4	106	10	15	5	9	17	5	10	5	2	1	54.65	4.68
4	110	14	16	2	9	16	5	9	5	5	2	54.66	4.62

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	Kf	Km	Kmf	Ke	DE	WIP	BL
4	102	18	17	2	9	16	4	9	3	4	7	54.67	4.62
4	107	17	17	6	10	11	3	8	4	4	1	54.68	4.61
4	106	11	13	6	10	22	2	8	5	2	1	54.72	4.61
4	107	12	12	3	10	8	2	8	4	5	1	54.73	4.60
4	101	18	16	6	9	14	5	9	3	5	1	54.74	4.57
4	108	11	17	3	9	8	2	9	2	5	2	54.80	4.55
4	91	11	17	3	9	8	2	9	5	4	3	54.82	4.55
4	83	11	17	3	9	8	2	9	3	5	3	54.86	4.55
4	96	17	9	6	9	9	2	9	3	5	1	54.93	4.54
4	74	15	15	6	9	16	5	9	5	5	9	54.98	4.54
4	74	18	10	4	9	10	5	9	5	5	2	55.00	4.54
4	110	17	16	6	9	16	3	8	4	2	1	55.29	4.23
4	101	18	16	6	9	14	4	8	4	4	1	55.29	4.23
4	103	17	13	6	9	16	3	8	4	2	1	55.30	4.23
4	107	18	14	6	9	8	3	8	3	5	1	55.30	4.23
4	99	16	14	3	9	18	2	8	5	5	2	55.31	4.22
4	110	14	12	3	9	18	2	8	4	5	8	55.32	4.22
4	91	16	17	6	9	12	5	8	3	4	2	55.32	4.22
4	110	11	12	4	9	17	3	8	5	4	2	55.35	4.22
4	101	10	10	6	9	10	2	8	2	5	1	55.46	4.22
4	99	10	10	6	9	10	2	8	5	2	2	55.47	4.21
4	110	17	9	6	9	9	3	8	2	5	1	55.50	4.21
4	100	9	16	6	9	14	3	8	5	5	1	55.54	4.21
4	91	9	17	5	9	8	2	8	2	4	6	55.56	4.20
4	109	17	16	2	8	19	4	15	4	3	7	55.58	3.99
4	106	13	17	2	8	10	4	11	3	4	8	55.59	3.99
4	110	18	14	2	8	19	5	10	4	5	1	55.59	3.99
4	110	17	13	2	8	21	3	18	2	3	1	55.59	3.99
4	110	18	13	2	8	20	5	15	5	2	1	55.59	3.99
4	106	13	17	2	8	15	3	14	2	4	1	55.60	3.99
4	110	12	16	2	8	15	2	17	5	5	1	55.61	3.99
4	110	12	16	2	8	8	2	16	4	5	1	55.61	3.99
4	110	11	17	2	8	16	4	13	4	5	5	55.62	3.99
4	110	11	16	2	8	17	2	16	4	5	3	55.62	3.99
4	110	17	16	4	8	21	4	14	2	3	3	55.63	3.97
4	110	17	17	5	8	8	5	13	2	5	2	55.63	3.97
4	107	18	17	6	8	14	4	11	5	5	2	55.63	3.97
4	104	18	17	4	8	10	2	19	3	4	2	55.64	3.97
4	109	18	14	6	8	22	5	11	4	3	1	55.64	3.97
4	110	13	17	4	8	11	4	11	2	4	1	55.64	3.97
4	100	16	16	6	8	16	3	11	3	2	1	55.64	3.97
4	110	17	17	4	8	22	2	9	3	2	8	55.65	3.97
4	109	15	13	4	8	14	2	9	4	5	1	55.66	3.96
4	105	18	12	3	8	22	2	9	4	5	1	55.67	3.96
4	109	12	14	6	8	17	2	9	5	5	2	55.67	3.96
4	92	12	14	6	8	21	3	9	4	5	3	55.69	3.96
4	92	12	17	4	8	21	4	9	2	5	1	55.69	3.96
4	100	11	15	6	8	10	3	9	3	4	4	55.70	3.96
4	109	10	17	6	8	13	5	9	4	2	5	55.75	3.95
4	107	12	10	6	8	8	2	9	4	3	4	55.76	3.95
4	105	17	13	4	8	16	5	8	2	2	3	55.80	3.93
4	106	15	13	6	8	15	5	8	5	5	1	55.81	3.93
4	100	12	17	6	8	10	5	8	5	5	2	55.82	3.93
4	97	18	12	4	8	8	3	8	2	2	1	55.83	3.93
4	100	12	14	6	8	8	3	8	4	4	1	55.83	3.93
4	89	12	17	4	8	11	4	8	2	3	3	55.84	3.93
4	103	11	15	4	8	15	5	8	5	2	1	55.84	3.93
4	108	11	13	5	8	14	3	8	3	4	1	55.84	3.93
4	96	11	12	4	8	17	3	8	3	4	1	55.86	3.93
4	110	10	13	4	8	14	3	8	2	5	7	55.90	3.92
4	95	10	10	6	8	15	4	8	2	5	2	55.97	3.92
4	77	11	17	4	8	9	5	8	2	2	1	55.99	3.92
4	106	9	17	5	8	15	2	8	4	4	4	56.05	3.91
4	73	9	17	3	8	14	2	8	2	3	3	56.19	3.91
4	95	12	8	6	8	22	4	8	2	3	3	56.26	3.89
4	99	8	9	2	8	8	4	8	5	3	8	56.43	3.89
4	109	18	7	6	8	22	4	13	3	2	6	56.57	3.89
4	110	18	17	2	7	8	2	10	3	3	8	56.58	3.61
4	110	18	17	2	7	8	2	12	5	5	3	56.59	3.61
4	95	17	17	2	7	19	4	13	2	4	7	56.60	3.61
4	110	15	16	2	7	15	3	18	5	3	1	56.60	3.60
4	107	17	12	2	7	8	2	18	2	2	1	56.62	3.60

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	Kf	Km	Kmf	Ke	DE	WIP	BL
4	104	15	11	2	7	17	2	9	4	4	2	56.65	3.60
4	110	17	17	5	7	10	2	17	5	3	9	56.66	3.59
4	110	18	17	6	7	10	2	15	2	3	7	56.66	3.59
4	109	17	17	5	7	14	3	18	5	5	7	56.66	3.59
4	110	18	15	3	7	12	3	10	2	2	2	56.66	3.59
4	100	18	14	4	7	21	2	10	3	3	4	56.67	3.59
4	107	13	17	3	7	18	4	11	2	5	2	56.67	3.59
4	104	13	17	6	7	19	3	17	2	5	2	56.67	3.59
4	110	17	15	3	7	9	5	20	5	2	1	56.68	3.58
4	110	17	17	6	7	21	5	19	5	5	1	56.68	3.58
4	110	18	17	5	7	12	3	10	3	5	1	56.68	3.58
4	110	14	15	4	7	11	4	10	2	5	1	56.68	3.58
4	109	13	16	4	7	9	2	15	2	5	1	56.68	3.58
4	107	13	17	6	7	22	4	13	2	3	1	56.69	3.58
4	101	15	17	6	7	17	4	9	2	2	8	56.69	3.58
4	99	16	17	5	7	11	5	9	2	4	8	56.70	3.58
4	101	13	17	5	7	10	4	9	4	4	1	56.72	3.57
4	95	11	15	6	7	8	4	9	2	3	3	56.74	3.57
4	109	11	16	5	7	13	5	9	2	5	1	56.75	3.57
4	110	18	17	2	7	8	5	8	3	5	7	56.77	3.57
4	106	13	17	2	7	16	5	8	3	5	1	56.81	3.57
4	110	11	16	2	7	15	2	8	3	2	2	56.82	3.56
4	97	11	17	2	7	18	4	8	2	4	2	56.83	3.56
4	110	16	17	5	7	8	2	8	4	2	9	56.85	3.55
4	106	17	15	6	7	21	2	8	2	2	3	56.86	3.55
4	108	17	12	6	7	14	2	8	4	2	4	56.87	3.55
4	96	17	17	5	7	14	2	8	2	5	8	56.87	3.55
4	108	15	16	6	7	21	3	8	5	2	1	56.89	3.55
4	100	16	16	5	7	22	3	8	5	3	1	56.89	3.55
4	96	17	16	4	7	12	5	8	4	4	1	56.90	3.54
4	107	11	12	4	7	18	3	8	2	3	7	56.90	3.54
4	109	11	12	4	7	8	3	8	5	5	1	56.93	3.54
4	102	11	12	4	7	9	3	8	3	5	1	56.93	3.54
4	98	15	10	3	7	10	2	8	4	2	4	56.95	3.54
4	110	10	17	3	7	14	4	8	5	2	2	56.96	3.54
4	84	11	13	6	7	8	3	8	2	5	1	56.99	3.54
4	84	11	13	6	7	18	4	8	4	5	1	56.99	3.54
4	101	10	14	3	7	8	2	8	4	5	1	56.99	3.54
4	101	10	14	6	7	19	4	8	3	5	1	56.99	3.54
4	88	10	10	6	7	16	5	8	5	3	3	57.04	3.54
4	83	12	9	4	7	9	3	8	4	2	7	57.09	3.53
4	82	11	9	6	7	8	4	8	3	5	2	57.11	3.53
4	90	9	17	3	7	9	2	8	2	5	3	57.13	3.53
4	104	12	8	3	7	8	3	8	5	5	5	57.32	3.51
4	97	11	8	5	7	13	3	8	2	2	4	57.33	3.51
4	104	8	17	3	7	14	5	8	2	4	1	57.51	3.50
4	84	8	10	3	7	9	3	8	3	4	7	57.52	3.50
4	82	8	10	3	7	17	4	8	2	5	8	57.53	3.50
4	107	8	10	3	7	17	4	8	3	3	1	57.53	3.50
4	76	8	10	3	7	17	4	8	4	2	8	57.55	3.49
4	109	11	7	3	7	10	2	8	5	2	6	57.81	3.48
4	81	13	7	5	7	9	4	8	5	4	1	57.83	3.48
4	64	8	15	5	7	19	4	8	3	4	1	57.92	3.47
4	100	8	7	6	7	15	2	8	2	4	1	58.05	3.46
5	108	18	17	2	15	17	5	20	5	3	1	63.94	1.46
5	109	17	17	2	14	13	2	12	2	3	8	64.03	1.45
5	108	18	16	2	14	16	3	10	3	3	9	64.03	1.45
5	109	14	16	2	15	17	3	19	2	5	8	64.04	1.45
5	101	17	16	2	14	22	5	10	3	3	7	64.05	1.45
5	97	18	15	2	11	14	3	18	5	5	7	64.10	1.45
5	88	12	14	2	14	16	5	10	4	4	4	64.24	1.45
5	107	11	11	2	11	15	5	17	3	4	7	64.32	1.45
5	107	16	13	3	14	16	5	8	5	3	1	64.32	1.36
5	101	18	13	3	12	19	2	9	5	2	1	64.37	1.35
5	106	18	15	4	13	18	5	14	5	2	1	64.38	1.34
5	107	18	13	5	15	16	4	20	3	3	1	64.40	1.34
5	110	18	15	6	14	20	2	19	2	2	2	64.43	1.33
5	110	17	14	5	11	13	3	17	5	3	2	64.46	1.33
5	107	18	17	5	15	19	2	12	2	2	7	64.46	1.33
5	103	17	14	6	14	20	5	16	2	5	7	64.48	1.33
5	108	13	17	6	14	11	5	15	5	3	6	64.49	1.33
5	105	16	17	5	15	9	3	11	2	2	8	64.52	1.32

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	Kf	Km	Kmf	Ke	DE	WIP	BL
5	107	17	16	5	10	16	2	13	2	2	9	64.57	1.32
5	106	13	13	6	10	21	2	13	4	2	7	64.62	1.32
5	107	18	11	6	10	15	3	20	2	5	8	64.71	1.32
5	99	18	16	4	13	8	2	20	2	5	1	64.84	1.29
5	107	18	16	6	10	8	3	10	3	2	1	64.85	1.28
5	104	18	14	4	10	14	5	9	2	3	3	64.87	1.28
5	85	11	17	5	10	22	5	9	3	4	4	65.19	1.27
5	98	11	16	5	10	8	5	9	4	4	8	65.21	1.26
5	85	11	17	5	10	8	5	9	2	4	2	65.34	1.25
5	108	15	17	2	10	11	2	8	2	2	1	65.44	1.25
5	107	16	14	3	9	14	4	12	2	4	1	65.57	1.19
5	110	17	16	4	9	14	2	19	2	2	7	65.59	1.19
5	110	18	14	4	9	19	3	10	5	5	8	65.61	1.19
5	109	13	17	4	9	14	4	16	4	5	9	65.63	1.18
5	94	12	17	4	9	15	3	11	2	5	1	65.71	1.18
5	107	11	14	6	9	11	4	20	5	2	7	65.78	1.18
5	106	17	16	6	10	22	2	8	2	2	2	65.83	1.15
5	103	17	16	5	9	8	2	9	2	5	9	65.85	1.14
5	98	18	17	4	9	8	5	9	4	4	1	65.87	1.14
5	103	17	10	6	9	19	5	9	3	4	1	66.14	1.14
5	94	13	10	6	9	10	3	9	5	5	1	66.17	1.14
5	86	17	10	6	9	19	5	9	2	3	1	66.22	1.14
5	104	13	17	2	9	10	5	8	2	2	8	66.39	1.07
5	107	17	16	6	9	22	2	8	5	5	1	66.59	1.02
5	108	18	17	3	9	18	4	8	5	5	4	66.59	1.02
5	110	17	15	6	9	16	2	8	3	5	3	66.60	1.01
5	110	18	15	6	9	10	2	8	5	5	9	66.60	1.01
5	104	18	17	4	9	16	3	8	5	3	7	66.61	1.01
5	88	16	17	6	9	11	4	8	5	5	9	66.77	1.01
5	109	12	17	2	8	14	2	15	2	5	1	66.91	0.97
5	107	12	14	2	8	16	2	15	5	3	3	66.92	0.97
5	109	17	16	6	8	13	5	10	3	2	1	66.94	0.94
5	107	18	17	5	8	14	2	19	2	5	7	66.94	0.94
5	107	18	17	5	8	19	2	14	2	5	7	66.94	0.94
5	103	18	15	6	8	15	2	16	5	2	6	66.96	0.94
5	110	16	13	5	8	13	2	20	2	4	9	66.97	0.94
5	109	18	14	5	8	8	5	9	4	5	1	66.98	0.94
5	105	11	17	3	8	10	5	9	2	5	4	67.15	0.94
5	106	18	17	3	8	16	2	8	4	4	1	67.15	0.93
5	99	18	17	3	8	16	2	8	3	5	2	67.18	0.93
5	94	12	17	4	8	15	2	8	4	5	1	67.28	0.93
5	110	15	11	4	8	10	3	8	2	4	8	67.31	0.93
5	100	11	14	5	8	14	2	8	2	5	3	67.35	0.93
5	109	11	13	6	8	22	2	8	3	5	1	67.35	0.93
5	108	11	12	4	8	8	3	8	2	4	1	67.38	0.93
5	94	10	17	4	8	8	3	8	2	2	1	67.60	0.92
5	89	10	17	6	8	14	3	8	5	2	3	67.63	0.92
5	99	17	9	6	8	10	3	8	5	2	8	67.83	0.92
5	110	18	16	2	7	14	2	11	5	4	7	67.88	0.87
5	109	17	15	2	7	14	5	18	5	4	3	67.89	0.87
5	99	18	16	2	7	8	2	18	4	5	1	67.94	0.87
5	110	11	16	2	7	10	5	16	3	4	3	68.06	0.87
5	110	18	16	3	7	12	2	10	3	5	7	68.08	0.84
5	107	16	17	3	7	14	3	11	5	2	3	68.09	0.84
5	108	18	17	3	7	14	3	17	2	4	2	68.09	0.84
5	109	17	17	3	7	14	3	16	4	5	1	68.10	0.84
5	106	17	17	4	7	14	4	14	2	3	2	68.10	0.84
5	110	17	14	5	7	16	4	15	5	5	2	68.11	0.84
5	110	18	14	3	7	12	3	10	2	5	1	68.11	0.84
5	110	18	15	4	7	8	5	9	4	5	3	68.12	0.84
5	99	18	16	5	7	8	5	9	2	3	5	68.15	0.84
5	104	17	13	4	7	15	2	9	5	2	3	68.16	0.84
5	97	14	14	3	7	21	3	9	2	4	1	68.19	0.84
5	93	15	17	3	7	14	2	9	2	4	1	68.23	0.84
5	107	18	17	3	7	15	2	8	3	2	5	68.30	0.84
5	109	16	17	4	7	11	5	8	2	3	8	68.31	0.84
5	110	15	14	6	7	14	3	8	2	2	8	68.33	0.83
5	93	13	15	4	7	14	5	8	2	2	2	68.43	0.83
5	110	11	16	6	7	19	4	8	2	2	2	68.48	0.83
5	88	11	17	6	7	8	5	8	3	4	5	68.60	0.83
5	100	17	10	6	7	8	2	8	2	5	4	68.66	0.83
5	94	11	10	4	7	15	2	8	5	5	7	68.75	0.83

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	Kf	Km	Kmf	Ke	DE	WIP	BL
5	100	10	10	5	7	11	3	8	5	5	1	68.93	0.83
5	106	11	9	6	7	21	5	8	2	4	2	69.06	0.83
5	105	9	17	4	7	11	5	9	2	5	2	69.11	0.83
5	109	9	17	3	7	8	5	8	2	5	7	69.29	0.82
5	109	9	17	5	7	8	2	8	4	5	6	69.30	0.82
5	103	17	8	4	7	8	5	14	2	2	3	69.51	0.82
5	110	13	8	4	7	22	2	8	5	2	1	69.74	0.81
5	103	8	17	3	7	12	5	20	2	3	5	70.37	0.80
5	109	8	14	5	7	16	3	18	5	2	2	70.38	0.80
5	97	8	16	5	7	22	3	10	3	3	3	70.39	0.80
5	104	8	11	4	7	8	3	18	4	3	4	70.39	0.80
5	83	8	16	3	7	13	5	8	3	4	9	70.59	0.79
5	72	8	10	3	7	17	4	8	2	5	2	70.78	0.79
5	110	18	7	3	7	11	3	12	3	5	1	71.27	0.79
5	105	17	7	5	7	17	4	20	3	4	1	71.30	0.79
5	91	17	7	5	7	14	5	9	4	2	3	71.31	0.79
5	92	12	7	6	7	9	2	8	2	2	4	71.50	0.78
6	107	17	17	2	14	16	2	8	4	2	2	73.90	0.50
6	107	17	17	2	14	18	4	20	2	3	1	73.91	0.49
6	109	18	14	2	14	22	2	10	3	2	6	74.03	0.49
6	110	13	17	2	13	11	5	18	4	3	3	74.07	0.49
6	110	13	17	2	13	9	2	18	5	3	1	74.11	0.48
6	99	12	17	2	11	10	4	19	3	3	2	74.27	0.48
6	100	18	11	2	15	21	2	14	2	2	8	74.45	0.48
6	110	17	16	4	14	12	3	9	4	3	1	74.51	0.39
6	110	18	16	6	13	15	3	16	4	5	1	74.52	0.39
6	110	17	15	6	12	10	3	15	4	2	1	74.56	0.39
6	110	16	17	5	13	14	4	10	3	4	3	74.61	0.39
6	110	16	16	6	13	15	2	15	2	2	8	74.62	0.39
6	108	15	17	6	14	9	4	15	2	2	1	74.65	0.39
6	108	15	16	6	13	9	5	19	3	2	8	74.71	0.39
6	109	18	15	6	10	9	3	12	5	3	5	74.79	0.38
6	110	17	14	5	13	8	3	9	2	2	1	75.03	0.38
6	100	12	12	6	11	8	5	9	4	3	2	75.42	0.37
6	102	11	15	6	10	8	5	20	2	3	5	75.61	0.37
6	107	17	17	5	9	18	3	12	4	2	9	75.86	0.35
6	110	15	14	6	10	8	4	8	4	2	1	76.21	0.34
6	101	11	11	4	10	10	5	8	4	4	1	76.91	0.33
6	110	18	15	3	9	19	4	8	4	4	1	76.98	0.29
6	110	17	16	5	9	8	3	8	3	3	1	77.01	0.29
6	105	16	16	5	9	8	4	8	4	2	1	77.06	0.29
6	104	13	16	4	9	14	3	8	5	3	4	77.15	0.29
6	107	17	17	3	8	21	3	15	2	5	9	77.27	0.28
6	110	18	15	4	8	11	2	17	4	4	1	77.27	0.28
6	99	12	16	4	8	14	3	17	4	4	6	77.57	0.28
6	110	18	15	3	8	19	3	8	4	4	4	77.60	0.26
6	110	17	17	6	7	21	2	15	5	3	1	78.60	0.23
6	106	18	14	5	7	22	4	13	4	2	3	78.65	0.23
6	110	13	17	4	7	11	3	16	2	3	3	78.70	0.23
6	106	15	12	5	7	22	4	9	4	4	1	78.87	0.23
6	102	12	13	3	7	22	2	19	2	2	1	78.93	0.23
6	100	12	14	6	7	8	3	10	4	3	1	78.93	0.23
6	110	11	16	5	7	13	4	19	5	2	3	79.18	0.23
6	110	11	17	5	7	14	5	9	4	2	5	79.19	0.23
6	107	11	16	5	7	11	2	9	5	5	7	79.20	0.23
6	100	11	14	6	7	8	3	8	4	4	1	79.46	0.23
6	99	18	10	6	7	8	2	18	5	2	5	79.51	0.23
6	110	10	15	5	7	8	5	16	3	5	1	79.89	0.22
6	101	10	10	6	7	10	3	9	3	5	1	80.29	0.22
6	110	17	9	3	7	20	5	18	4	5	6	80.43	0.22
6	110	9	16	3	7	14	4	11	4	5	2	81.49	0.21
6	109	9	15	6	7	8	5	12	5	5	1	81.51	0.21
6	110	9	10	4	7	22	4	8	2	2	3	81.92	0.21
6	101	16	8	3	7	22	4	9	5	2	1	82.89	0.20
6	107	16	8	5	7	8	5	8	3	4	1	83.15	0.20
7	110	16	16	4	13	12	5	20	2	4	4	84.66	0.13
7	107	18	17	5	12	14	3	12	5	4	4	84.72	0.13
7	110	15	15	5	13	10	5	19	2	5	7	84.73	0.13
7	109	18	13	6	15	11	5	12	5	2	7	84.89	0.13
7	108	13	15	5	13	14	5	19	5	3	4	84.94	0.13
7	109	13	13	6	15	11	4	10	3	2	1	84.98	0.13
7	109	13	13	6	15	9	2	10	2	5	1	85.09	0.13

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	Kf	Km	Kmf	Ke	DE	WIP	BL
7	110	12	15	5	14	14	5	11	2	4	1	85.15	0.13
7	110	12	15	5	14	8	4	17	3	5	1	85.69	0.12
7	104	12	16	6	10	9	4	9	3	5	3	85.88	0.12
7	110	12	17	5	9	22	3	15	4	4	2	86.61	0.12
7	97	17	10	5	14	8	4	9	3	3	1	87.09	0.12
7	110	17	17	4	8	12	4	13	2	3	3	87.37	0.10
7	109	18	17	5	8	10	2	20	5	5	1	87.39	0.10
7	105	17	14	6	8	17	5	8	5	5	9	87.98	0.10
7	106	13	16	6	8	22	4	8	4	5	1	88.13	0.09
7	99	13	14	6	8	16	2	8	5	5	8	88.35	0.09
7	96	13	13	6	8	22	5	8	3	5	4	88.54	0.09
7	110	18	17	4	7	12	3	12	3	3	3	88.80	0.09
7	109	16	14	4	7	11	3	17	3	5	1	88.92	0.09
7	106	17	14	6	7	8	4	11	5	5	7	88.96	0.09
7	106	17	14	6	7	9	5	16	5	2	1	88.97	0.09
7	110	13	15	4	7	8	5	20	3	5	5	89.09	0.08
7	110	12	17	3	7	8	4	14	3	4	9	89.48	0.08
7	109	12	17	3	7	8	2	14	2	2	7	89.49	0.08
7	105	12	17	4	7	8	5	11	2	3	1	89.55	0.08
7	100	12	14	6	7	9	3	8	4	3	1	89.88	0.08
7	102	17	11	3	7	8	5	20	2	5	7	89.91	0.08
7	104	12	11	3	7	12	3	13	4	3	4	90.22	0.08
7	110	11	15	4	7	8	5	12	3	5	3	90.31	0.08
7	110	11	15	4	7	10	4	17	3	5	3	90.31	0.08
7	110	11	17	6	7	11	3	11	3	5	1	90.31	0.08
7	110	11	16	4	7	8	5	9	3	2	5	90.32	0.08
7	107	11	17	5	7	8	5	9	3	5	1	90.35	0.08
7	99	11	15	5	7	12	5	9	3	3	5	90.41	0.08
7	94	11	17	4	7	22	2	9	3	5	1	90.55	0.08
7	109	11	15	5	7	18	5	8	3	3	4	90.58	0.08
7	106	11	15	4	7	15	5	8	2	4	1	90.59	0.08
7	104	11	11	3	7	14	4	12	4	4	4	90.79	0.08
7	102	14	10	4	7	8	2	10	5	2	2	91.06	0.08
7	100	17	10	6	7	22	4	9	4	2	8	91.08	0.07
7	109	10	15	3	7	10	2	15	4	4	1	92.24	0.07
7	110	10	15	4	7	9	3	11	3	4	3	92.25	0.07
7	100	13	9	5	7	22	3	15	4	3	8	94.06	0.07
7	99	17	9	6	7	10	5	8	3	3	1	94.24	0.06
8	110	18	15	3	14	14	2	13	4	4	1	94.63	0.06
8	110	16	17	3	13	18	2	9	4	2	4	94.70	0.06
8	110	17	17	4	14	14	2	17	3	2	3	94.77	0.06
8	110	14	17	5	14	13	4	8	4	2	1	94.89	0.06
8	110	14	15	6	10	20	4	13	4	2	9	95.23	0.06
8	109	13	16	6	14	13	4	20	5	5	1	95.28	0.06
8	110	13	16	6	15	22	4	9	2	2	4	95.35	0.06
8	99	13	15	4	14	22	2	11	4	3	1	95.79	0.05
8	110	13	16	5	12	8	4	9	3	2	4	95.83	0.05
8	110	12	17	6	14	22	4	16	2	5	4	96.13	0.05
8	110	12	17	6	12	8	4	14	5	2	5	96.66	0.05
8	110	12	13	5	10	8	4	15	3	5	6	96.94	0.05
8	99	16	11	4	14	21	2	15	4	2	7	97.06	0.05
8	110	16	17	6	8	15	4	10	4	2	1	97.67	0.05
8	108	14	16	4	9	22	4	8	2	5	1	97.74	0.05
8	110	11	15	6	14	18	2	8	2	2	1	97.74	0.04
8	110	11	16	5	11	12	2	15	2	4	7	97.92	0.04
8	109	11	17	6	13	10	4	10	2	3	5	97.92	0.04
8	110	11	15	5	10	8	4	16	3	5	4	98.59	0.04
8	110	17	16	4	7	14	2	19	2	2	2	99.14	0.04
8	110	12	16	5	8	22	3	13	2	5	3	99.19	0.04
8	110	12	14	6	8	14	2	13	4	5	2	99.26	0.04
8	103	12	16	6	8	8	4	20	3	2	2	99.34	0.04
8	105	14	15	4	7	11	4	10	5	2	1	99.63	0.04
8	101	18	10	6	13	10	5	20	3	2	1	99.69	0.04
8	109	13	15	4	7	9	2	10	4	2	1	99.82	0.04
8	105	13	17	4	7	8	2	8	2	3	1	100.18	0.04
8	110	18	12	3	7	22	4	9	4	2	1	100.18	0.04
8	110	16	12	6	7	18	2	8	4	3	3	100.41	0.04
8	107	12	17	6	7	14	2	18	4	2	1	100.76	0.03
8	104	12	15	5	7	13	2	12	3	2	8	100.83	0.03
8	101	12	15	4	7	20	5	15	3	2	1	100.99	0.03
8	110	11	15	6	8	9	3	13	3	4	3	101.28	0.03
8	110	11	15	4	8	8	2	17	3	5	2	101.29	0.03

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	Kf	Km	Kmf	Ke	DE	WIP	BL
8	110	11	15	5	8	14	4	9	4	4	1	101.39	0.03
8	110	11	12	4	8	21	4	8	4	3	5	102.20	0.03
8	110	11	16	5	7	10	4	10	3	4	2	102.90	0.03
8	109	11	13	6	7	20	4	8	2	4	6	103.28	0.03
8	110	17	10	6	7	12	5	10	5	2	1	104.96	0.02
8	93	10	17	4	8	14	2	15	4	5	3	106.56	0.02
9	101	17	13	4	12	11	3	9	4	3	1	106.88	0.02
9	110	14	16	5	9	22	3	18	2	2	1	107.20	0.02
9	106	13	15	6	15	8	4	8	2	5	6	107.28	0.02
9	102	17	12	6	15	20	5	19	2	5	9	107.78	0.02
9	110	17	12	6	15	8	4	8	2	5	8	107.78	0.02
9	109	12	17	3	15	22	2	13	5	2	6	108.25	0.02
9	107	12	17	6	14	22	2	18	4	2	1	108.37	0.02
9	102	12	15	4	14	22	5	12	4	5	1	108.75	0.02
9	110	13	17	6	8	15	3	9	4	2	1	109.76	0.01
9	110	12	16	4	9	11	3	20	2	3	3	110.21	0.01
9	108	12	15	4	9	19	5	17	3	5	2	110.25	0.01
9	110	13	17	6	7	10	2	17	5	5	1	111.21	0.01
9	110	12	17	6	8	9	3	20	5	4	1	111.90	0.01
9	109	12	17	3	7	14	3	13	5	2	7	113.50	0.01
9	110	12	15	5	7	10	4	15	3	4	1	113.58	0.01
9	107	12	11	5	7	9	5	17	2	2	1	117.51	0.01
9	99	11	17	5	8	8	4	12	4	4	8	117.70	0.01
9	110	11	16	4	7	9	4	12	4	2	1	119.10	0.00
9	109	11	16	5	7	10	4	10	5	2	2	119.12	0.00
9	105	11	15	6	7	22	2	9	3	3	3	119.23	0.00
9	110	11	12	5	7	8	5	20	3	2	1	119.82	0.00
9	101	17	10	6	7	8	5	9	3	3	5	124.08	0.00
9	110	13	10	6	7	12	2	13	5	5	1	124.32	0.00
9	99	12	10	4	7	9	5	12	2	4	1	124.79	0.00
9	99	11	10	4	7	9	4	12	2	4	1	127.09	0.00
9	101	10	12	3	7	20	5	9	5	2	6	136.09	0.00
9	89	10	16	5	7	8	4	11	5	3	1	136.88	0.00
9	89	10	14	6	7	18	5	17	5	2	3	136.96	0.00
9	87	10	17	3	7	21	2	8	3	3	2	137.64	0.00
9	110	10	9	5	9	13	5	19	2	2	1	151.13	0.00
9	76	11	9	6	7	10	4	20	2	3	2	167.86	0.00

B9. HKC - PAC OPTIMISED SETTINGS FOR LOWER PROCESSING TIME VARIABILITY

Table B-9. Production Authorisation Card Settings for HKC Strategy 90LV

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	Kf	Km	Kmf	Ke	WIP	BL
4	105	15	17	2	15	10	2	8	2	5	52.25	6.37
4	97	12	17	2	14	10	3	8	5	3	52.27	6.37
4	101	15	17	2	14	19	2	20	2	5	52.29	6.30
4	108	14	17	2	11	18	5	15	5	2	52.29	6.29
4	100	11	11	2	15	22	2	10	5	2	52.34	6.29
4	108	16	10	2	11	17	3	10	2	3	52.36	6.28
4	104	15	15	2	10	20	5	11	5	3	52.39	6.23
4	109	15	15	2	10	15	5	20	4	3	52.39	6.23
4	110	17	15	5	13	20	3	8	2	2	52.44	6.20
4	104	15	15	3	15	21	4	11	3	4	52.45	6.14
4	102	16	16	3	12	19	3	15	2	3	52.45	6.14
4	108	16	17	3	13	10	2	9	5	5	52.45	6.14
4	105	15	17	3	13	10	2	9	2	5	52.46	6.13
4	107	15	17	4	15	17	4	20	5	3	52.46	6.13
4	105	16	14	5	14	19	5	15	5	4	52.46	6.13
4	106	14	14	4	11	11	3	10	2	3	52.47	6.12
4	108	16	17	6	13	10	2	10	3	3	52.47	6.13
4	108	14	16	5	13	10	2	20	4	4	52.47	6.13
4	108	14	11	4	11	16	4	10	2	2	52.49	6.12
4	109	11	15	5	11	10	4	9	3	5	52.50	6.12
4	102	10	14	3	15	11	2	19	5	3	52.53	6.12
4	100	10	16	3	12	17	3	16	2	5	52.53	6.12
4	108	16	10	5	13	18	3	9	5	3	52.53	6.12
4	110	10	17	3	12	10	2	16	2	3	52.54	6.12
4	107	10	16	6	12	12	2	18	4	5	52.54	6.11
4	109	12	17	5	13	9	2	16	5	2	52.55	6.09
4	100	17	16	4	13	9	3	19	5	2	52.55	6.09
4	103	16	16	4	14	9	3	17	2	5	52.55	6.09
4	102	12	15	3	10	14	3	20	2	3	52.57	6.08
4	97	16	17	6	10	22	3	13	2	3	52.57	6.08
4	98	13	17	5	10	16	5	20	4	2	52.57	6.07
4	98	13	17	6	10	18	2	20	5	4	52.57	6.07
4	94	13	17	5	10	21	2	16	4	4	52.58	6.07
4	103	14	11	5	10	22	5	19	5	2	52.58	6.07
4	99	13	17	3	10	10	3	9	2	4	52.60	6.07
4	99	14	10	6	10	20	3	18	5	2	52.63	6.07
4	98	18	14	3	10	9	3	10	5	4	52.63	6.04
4	92	9	17	6	10	9	5	19	2	5	52.84	6.01
4	108	14	17	2	15	8	3	15	2	2	52.86	5.93
4	106	14	13	6	15	8	2	17	2	2	53.01	5.80
4	97	16	17	5	14	8	2	20	5	2	53.01	5.80
4	105	12	17	5	15	8	5	14	2	4	53.02	5.80
4	92	16	11	6	15	8	2	9	4	2	53.05	5.79
4	104	10	17	3	15	8	5	10	4	4	53.09	5.79
4	77	18	15	5	14	8	2	20	4	5	53.14	5.79
4	110	17	17	4	9	22	5	17	2	2	53.18	5.68
4	102	14	14	4	9	11	3	10	5	4	53.19	5.68
4	108	16	13	5	9	17	2	10	4	3	53.19	5.68
4	88	15	15	4	9	20	3	18	5	5	53.22	5.68
4	102	13	14	4	9	9	2	12	2	4	53.22	5.66
4	100	14	13	6	9	18	2	9	3	2	53.30	5.57
4	100	13	17	6	9	15	5	9	2	2	53.30	5.57
4	82	16	13	3	9	12	2	9	4	2	53.36	5.57
4	94	18	12	4	9	8	4	18	3	2	53.46	5.53
4	88	18	7	5	10	8	2	8	5	2	54.33	5.40
4	104	12	17	6	9	21	3	8	3	2	54.60	4.74
4	92	14	13	6	9	10	5	8	2	4	54.61	4.74
4	90	11	16	3	9	8	3	8	2	5	54.66	4.73
4	110	15	9	4	9	9	2	8	5	3	54.79	4.72
4	105	13	13	2	8	22	5	12	3	3	54.84	4.57

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	Kf	Km	Kmf	Ke	WIP	BL
4	106	17	16	4	8	17	2	20	5	2	54.87	4.54
4	106	16	17	6	8	8	2	18	5	2	54.87	4.54
4	95	13	15	6	8	21	4	12	5	3	54.89	4.53
4	107	12	14	6	8	19	3	20	2	2	54.89	4.54
4	94	13	12	5	8	21	3	11	5	2	54.90	4.53
4	89	16	16	4	8	20	5	18	3	5	54.90	4.53
4	88	14	15	6	8	20	4	11	3	5	54.91	4.53
4	99	15	14	6	8	21	3	9	5	5	54.93	4.51
4	96	15	12	5	8	22	5	9	5	2	54.94	4.51
4	108	14	9	4	8	10	2	13	5	2	55.07	4.51
4	108	14	9	6	8	11	5	12	4	2	55.07	4.51
4	96	10	9	6	8	12	2	17	4	2	55.13	4.51
4	107	9	10	6	8	19	3	20	3	2	55.16	4.50
4	68	9	10	5	8	10	5	13	5	2	55.44	4.49
4	67	9	16	3	8	18	2	20	3	2	55.47	4.48
4	105	8	17	6	8	22	5	18	5	2	55.49	4.46
4	101	8	14	5	8	10	4	10	5	2	55.50	4.46
4	66	12	15	4	8	13	2	9	5	2	55.52	4.46
4	108	16	14	3	8	20	5	8	4	4	55.63	4.04
4	98	18	14	4	8	8	4	8	2	2	55.64	4.04
4	106	12	15	3	8	21	2	8	2	2	55.65	4.04
4	95	12	15	3	8	10	2	8	5	5	55.66	4.04
4	104	11	12	6	8	8	3	8	5	3	55.68	4.03
4	66	16	15	6	8	20	3	8	5	5	56.24	3.99
4	104	18	17	2	7	8	3	10	5	2	56.61	3.60
4	102	14	17	2	7	11	2	9	2	4	56.62	3.59
4	99	17	17	2	7	22	5	18	2	5	56.62	3.60
4	103	16	17	2	7	18	5	16	5	2	56.62	3.60
4	106	13	17	6	7	15	3	18	2	2	56.64	3.59
4	110	15	15	5	7	17	2	19	5	2	56.64	3.59
4	105	16	15	6	7	22	2	20	5	3	56.64	3.59
4	98	16	16	6	7	17	5	9	4	2	56.65	3.59
4	88	13	16	4	7	8	5	17	2	5	56.68	3.59
4	97	11	17	6	7	12	2	15	2	2	56.69	3.59
4	95	11	16	6	7	14	2	12	2	4	56.69	3.59
4	102	14	10	5	7	8	2	14	2	4	56.73	3.58
4	106	16	10	5	7	8	4	9	2	3	56.74	3.58
4	97	16	17	2	7	21	2	8	5	5	56.80	3.56
4	109	14	16	4	7	16	4	8	3	2	56.82	3.55
4	99	17	17	5	7	19	5	8	3	3	56.83	3.55
4	97	14	17	4	7	20	5	8	3	3	56.84	3.55
4	104	11	17	5	7	8	4	8	5	5	56.86	3.55
4	99	14	10	3	7	17	2	8	4	2	56.91	3.55
4	99	14	10	6	7	9	3	8	4	4	56.92	3.55
4	97	10	17	6	7	22	3	8	3	3	56.93	3.54
4	105	10	16	5	7	19	2	8	5	3	56.93	3.54
4	99	10	15	4	7	11	4	8	5	2	56.93	3.54
4	97	10	17	4	7	20	5	8	5	2	56.93	3.54
4	95	10	17	5	7	12	2	8	2	3	56.94	3.54
4	75	13	17	5	7	11	4	8	5	2	57.06	3.53
4	88	9	17	4	7	14	4	8	2	5	57.09	3.53
4	87	9	17	4	7	12	3	8	3	3	57.10	3.53
4	67	13	17	2	7	12	3	8	3	2	57.39	3.52
4	109	8	15	2	7	8	3	8	5	5	57.41	3.52
4	110	8	17	2	7	8	3	8	3	5	57.41	3.52
4	88	8	16	2	7	20	4	8	5	2	57.41	3.52
4	67	11	15	4	7	17	5	8	5	5	57.43	3.51
4	105	8	16	5	7	8	2	8	5	3	57.45	3.51
4	96	8	17	4	7	21	3	8	5	3	57.45	3.51
4	92	17	7	6	7	20	2	8	2	5	57.78	3.48
4	102	13	7	6	7	12	5	8	2	5	57.78	3.49
4	64	8	9	3	7	10	4	8	2	2	57.87	3.48
4	107	8	7	3	7	20	2	8	5	2	58.00	3.47
4	60	8	7	2	7	8	2	8	2	2	58.40	3.46
5	105	14	17	2	13	13	2	9	2	2	62.94	1.70
5	106	16	15	2	11	20	3	10	2	4	62.94	1.70
5	104	18	17	2	11	10	2	16	3	2	62.96	1.70
5	104	18	17	2	11	10	3	9	5	2	62.97	1.70
5	106	18	16	2	11	9	3	10	2	5	63.04	1.68
5	99	12	15	2	10	20	2	10	5	2	63.18	1.67
5	99	12	17	2	10	17	5	9	5	2	63.19	1.67
5	109	16	17	6	13	13	3	9	4	5	63.32	1.55

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	Kf	Km	Kmf	Ke	WIP	BL
5	101	15	14	5	11	20	5	10	2	4	63.37	1.55
5	95	17	13	4	13	17	5	17	3	2	63.40	1.55
5	109	12	16	6	11	14	5	20	2	4	63.40	1.55
5	101	14	15	3	10	10	3	10	5	2	63.45	1.55
5	109	12	17	6	11	9	5	20	2	3	63.49	1.54
5	101	15	16	5	10	19	3	9	3	2	63.50	1.54
5	99	12	10	4	10	13	4	10	3	2	63.79	1.52
5	101	18	16	6	15	8	3	9	2	3	63.91	1.47
5	101	14	13	6	10	8	4	11	2	4	64.00	1.46
5	105	16	17	4	9	22	3	10	2	2	64.12	1.44
5	81	13	15	5	9	14	3	18	4	5	64.48	1.43
5	92	10	13	6	10	9	4	8	2	2	64.70	1.42
5	92	17	9	5	9	8	4	14	2	2	64.98	1.39
5	106	18	15	2	8	9	3	10	2	2	65.71	1.23
5	99	18	17	5	8	12	3	18	3	4	65.92	1.16
5	108	16	13	5	8	18	2	16	5	3	65.92	1.16
5	101	16	17	6	8	8	3	18	4	5	65.92	1.16
5	103	14	12	6	8	16	5	9	2	2	66.04	1.15
5	105	13	17	3	8	16	2	8	5	4	66.94	0.97
5	102	13	13	3	8	17	2	8	4	2	66.97	0.97
5	108	12	17	6	8	11	2	8	3	2	66.98	0.97
5	96	11	13	6	8	11	5	8	5	2	67.12	0.97
5	90	11	16	6	8	9	5	8	5	3	67.16	0.97
5	82	11	17	3	8	8	2	8	3	2	67.33	0.97
5	108	17	15	6	7	17	3	13	4	2	67.99	0.85
5	110	14	15	4	7	10	4	11	3	5	68.00	0.85
5	103	14	12	5	7	18	2	17	3	3	68.07	0.85
5	96	11	17	6	7	12	4	10	4	3	68.20	0.85
5	99	16	12	6	7	17	4	8	2	4	68.29	0.84
5	108	11	17	6	7	22	4	8	3	2	68.39	0.84
5	109	11	15	5	7	19	2	8	5	5	68.39	0.84
5	92	11	17	6	7	9	3	8	2	2	68.45	0.84
5	95	9	13	4	7	8	2	11	2	2	68.99	0.83
5	103	13	8	6	7	22	3	13	5	2	69.39	0.83
5	82	16	8	5	7	9	2	9	3	5	69.45	0.83
5	71	9	14	4	7	11	2	11	4	2	69.58	0.83
5	88	9	8	3	7	19	2	15	3	3	69.75	0.83
5	68	9	13	6	7	10	2	15	5	2	69.99	0.83
5	68	9	16	5	7	11	5	10	4	2	69.99	0.83
5	89	8	14	4	7	13	4	20	3	2	70.26	0.81
5	106	8	14	6	7	8	2	8	5	3	70.50	0.80
5	82	15	7	6	7	19	4	15	3	3	71.15	0.80
6	94	14	17	2	11	22	3	8	5	4	73.25	0.59
6	108	13	16	3	13	21	2	18	2	5	73.50	0.47
6	106	13	14	3	15	14	4	18	3	3	73.54	0.47
6	105	14	16	5	13	19	3	9	3	2	73.56	0.46
6	110	13	14	6	13	12	2	18	4	5	73.59	0.46
6	98	14	14	6	11	19	3	12	2	5	73.68	0.46
6	96	13	17	6	12	11	2	15	2	3	73.74	0.46
6	98	13	17	6	10	17	2	18	3	2	73.83	0.45
6	83	14	12	6	15	9	4	13	5	4	74.43	0.45
6	110	11	17	3	12	8	3	13	5	5	74.51	0.44
6	106	11	12	3	9	14	4	18	2	3	74.87	0.43
6	85	16	17	4	9	9	2	10	2	3	75.04	0.42
6	106	16	17	6	9	22	2	8	5	2	76.00	0.36
6	106	13	13	5	8	17	5	10	3	2	76.34	0.35
6	109	12	16	6	8	10	5	10	2	3	76.40	0.35
6	98	15	13	4	8	9	2	9	4	2	76.42	0.34
6	102	12	12	6	8	14	5	9	3	5	76.61	0.34
6	100	11	17	5	8	10	2	9	3	3	76.81	0.34
6	94	10	15	2	8	9	2	8	5	5	78.26	0.33
6	100	17	14	2	7	8	2	11	3	3	78.37	0.26
6	101	13	17	3	7	8	2	20	5	5	78.54	0.24
6	109	16	16	3	7	17	2	8	2	2	78.69	0.24
6	109	13	16	3	7	20	2	8	2	2	78.79	0.24
6	106	12	17	4	7	15	5	8	3	2	78.94	0.24
6	103	11	17	6	7	22	5	8	3	2	79.28	0.23
6	106	11	12	3	7	22	2	8	2	3	79.35	0.23
6	102	10	17	6	7	16	3	8	5	3	80.00	0.23
6	97	10	16	4	7	13	2	8	2	4	80.01	0.23
6	86	14	9	4	7	9	3	8	2	2	80.62	0.23
6	86	11	8	6	7	9	2	19	4	3	82.69	0.22

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	Kf	Km	Kmf	Ke	WIP	BL
7	98	14	17	6	12	17	4	9	2	4	83.85	0.15
7	108	12	15	5	15	9	4	9	5	4	84.11	0.15
7	84	12	17	5	10	10	2	20	3	4	85.53	0.14
7	82	18	17	4	9	22	2	12	5	2	86.63	0.14
7	108	13	14	6	8	9	4	10	3	2	86.66	0.12
7	100	16	17	6	8	13	3	8	2	3	87.77	0.10
7	106	13	17	6	7	8	5	18	2	2	88.83	0.09
7	88	11	13	6	7	18	2	17	2	2	90.65	0.09
7	110	14	10	6	7	13	2	8	5	3	91.13	0.08
8	108	17	17	5	13	21	2	19	3	2	93.56	0.06
8	108	15	16	6	15	17	5	15	5	2	93.65	0.06
8	110	14	13	5	13	13	4	8	3	3	94.04	0.06
8	103	13	17	4	15	14	2	13	2	4	94.19	0.06
8	106	12	17	5	12	17	5	9	5	5	94.82	0.06
8	108	12	16	6	10	18	4	20	3	5	94.96	0.06
8	92	12	14	4	14	11	3	20	2	2	95.78	0.06
8	108	12	17	4	9	10	5	15	2	3	95.85	0.06
8	97	15	11	4	10	21	5	20	3	2	95.90	0.05
8	103	11	17	6	11	20	2	11	2	5	96.52	0.05
8	101	11	17	5	15	13	4	13	2	5	96.56	0.05
8	106	11	17	6	10	21	2	18	2	2	96.67	0.05
8	104	13	10	6	11	20	5	18	5	2	98.24	0.05
8	99	12	17	4	8	18	4	9	2	2	98.44	0.05
8	107	17	17	5	7	9	5	20	2	3	98.96	0.04
8	108	16	15	6	7	17	5	15	2	2	98.98	0.04
8	105	15	17	6	7	8	5	15	2	2	99.15	0.04
8	107	14	17	6	7	14	3	9	2	4	99.18	0.04
8	107	14	17	6	7	22	5	9	5	2	99.18	0.04
8	108	16	13	6	7	9	5	15	5	2	99.32	0.04
8	106	13	17	6	7	20	2	9	5	2	99.56	0.04
8	104	13	13	6	7	10	3	16	2	5	99.86	0.04
8	110	12	17	6	7	18	4	16	5	5	100.36	0.04
8	105	12	16	4	7	8	5	15	5	5	100.45	0.04
8	104	12	17	6	7	19	2	20	5	3	100.48	0.04
8	104	12	12	6	7	10	3	20	2	2	100.98	0.03
8	104	11	16	6	8	8	3	8	2	4	101.45	0.03
8	108	11	15	6	7	8	2	16	2	5	102.51	0.03
8	103	11	15	4	7	20	4	18	3	3	102.56	0.03
9	108	15	17	6	10	22	4	19	2	3	104.37	0.03
9	103	14	17	5	11	21	2	10	5	2	105.01	0.03
9	100	14	16	6	11	15	3	16	2	2	105.54	0.03
9	108	17	12	4	15	13	4	9	4	3	105.85	0.02
9	102	14	12	4	12	8	5	15	5	2	107.29	0.02
8	89	10	17	6	7	16	3	9	4	2	108.30	0.02
9	95	12	13	6	10	14	4	20	3	4	108.69	0.02
9	109	18	16	5	7	9	4	9	4	3	109.56	0.02
9	108	13	15	5	8	17	4	8	2	2	109.88	0.02
9	108	18	13	6	7	9	4	15	4	2	110.45	0.01
9	107	11	17	3	11	12	3	18	2	5	110.74	0.01
9	103	11	16	6	15	14	5	9	3	4	111.06	0.01
9	103	13	17	4	7	20	2	17	2	2	111.46	0.01
9	104	13	12	6	8	15	2	8	3	3	111.58	0.01
9	107	14	12	6	7	8	3	9	5	3	112.20	0.01
9	110	12	17	6	7	19	4	10	5	2	113.17	0.01
9	106	11	15	4	7	21	2	9	3	2	118.78	0.01
9	107	11	15	5	7	20	5	8	4	2	119.25	0.01
9	106	10	12	4	7	21	2	9	3	2	135.67	0.00
9	96	10	14	4	7	9	5	8	2	2	136.21	0.00
9	85	10	10	6	7	22	2	10	2	5	139.61	0.00
9	92	10	9	2	7	18	2	8	3	2	159.47	0.00

APPENDIX C. EVOLUTIONARY OPTIMISATION RESULTS FOR ALL STRATEGIES WITH 40% RETURNED MATERIALS

C1. DNC HEKC-II - PAC OPTIMISED SETTINGS FOR UPPER PROCESSING TIME VARIABILITY

Table C-1. Production Authorisation Card Settings for DNC HEKC-II Strategy 40HV

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	MP	Kf	Km	Kmf	Ke	DE	WIP	BL
14	32	5	7	4	6	6	6	3	15	4	4	4	35.91	13.53
14	32	5	7	4	8	3	6	3	16	4	4	4	35.91	13.32
14	27	7	7	4	5	7	6	4	16	1	2	4	35.98	13.22
15	34	7	4	4	6	5	5	1	16	1	1	1	36.15	12.77
11	48	6	7	4	6	7	8	2	12	3	1	2	36.17	11.81
11	41	6	3	4	5	3	8	1	16	2	2	5	36.20	11.70
11	48	6	5	4	4	5	8	1	16	3	3	1	36.21	11.66
12	21	7	5	4	8	3	7	4	8	2	4	4	36.25	11.61
13	36	5	4	5	7	6	6	3	15	4	4	10	36.32	11.18
13	46	7	6	5	8	3	6	4	9	2	1	5	36.33	11.16
13	41	3	6	5	5	6	6	2	12	1	4	1	36.45	11.02
15	28	5	2	4	5	8	6	1	10	4	4	7	36.52	10.63
11	40	7	5	5	6	4	8	2	10	4	3	3	36.56	10.57
11	47	5	7	5	6	3	8	2	8	4	3	1	36.61	10.41
11	40	5	7	5	6	5	8	4	7	1	2	2	36.67	10.31
13	30	4	4	6	5	6	6	4	16	4	3	1	36.74	9.89
16	28	3	7	4	8	6	6	1	7	4	2	10	36.74	9.44
12	23	5	4	4	8	5	8	3	9	4	4	7	36.82	8.13
12	44	5	7	4	5	4	8	2	12	3	1	3	36.83	8.11
12	35	6	5	4	5	3	8	1	13	3	3	2	36.84	8.07
13	35	5	7	4	6	3	7	1	15	3	2	8	36.90	7.88
13	29	6	7	4	8	7	7	2	9	4	1	1	36.90	7.85
13	35	7	7	4	6	8	7	1	8	3	4	2	36.93	7.81
13	47	5	3	4	6	4	7	2	8	2	4	2	36.95	7.77
14	48	5	7	5	6	3	6	4	12	3	4	2	37.05	7.47
14	47	5	6	5	5	5	6	3	13	3	1	1	37.08	7.40
14	21	4	6	5	7	6	6	2	13	1	2	1	37.12	7.40
15	30	4	3	5	8	8	5	4	15	2	1	1	37.21	7.17
15	30	5	6	5	7	6	5	3	8	3	3	2	37.24	7.14
12	28	4	6	5	5	3	8	4	15	2	2	10	37.37	7.06
13	48	4	4	4	5	7	8	1	15	1	1	3	37.49	6.30
14	46	5	4	4	5	4	7	4	15	1	3	1	37.57	6.07
14	45	6	3	4	5	4	7	4	11	1	4	2	37.57	6.07

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	MP	Kf	Km	Kmf	Ke	DE	WIP	BL
14	45	6	3	4	5	7	7	4	11	1	1	2	37.62	6.05
15	44	5	4	5	8	6	6	2	16	2	2	8	37.73	5.61
15	44	6	5	5	6	6	6	2	15	2	2	8	37.74	5.59
15	46	5	4	5	5	4	6	2	16	1	4	8	37.81	5.55
14	28	4	6	4	5	4	8	3	15	3	4	3	37.90	5.26
14	48	3	7	4	5	4	8	1	9	2	2	1	38.01	5.25
14	17	5	3	4	4	7	8	2	13	3	4	4	38.06	5.24
14	20	6	2	4	5	8	8	1	16	2	4	3	38.13	5.20
15	48	6	3	4	7	3	7	4	7	4	2	1	38.13	5.04
15	48	4	5	4	4	4	7	4	12	4	2	6	38.19	5.00
17	47	5	5	6	5	6	4	2	10	4	3	4	38.33	4.86
15	48	4	7	4	4	7	8	1	13	3	1	2	38.36	4.61
15	42	5	6	4	5	5	8	2	8	2	1	1	38.37	4.60
16	25	5	4	5	8	7	6	4	8	1	2	1	38.43	4.55
16	35	7	7	4	6	5	7	4	13	3	4	2	38.45	4.40
16	35	6	6	4	5	5	7	4	15	3	4	2	38.48	4.37
17	47	5	4	5	5	6	5	2	10	2	3	9	38.63	4.23
16	35	4	3	4	6	5	8	4	12	1	3	1	38.73	4.16
17	21	6	6	4	8	3	7	4	8	2	2	1	38.87	4.04
17	21	6	7	4	6	3	7	4	16	2	4	1	38.87	3.95
17	28	5	7	4	4	7	7	3	14	1	4	4	39.06	3.90
17	44	4	3	4	4	7	8	1	8	2	1	3	39.11	3.88
17	47	6	6	4	8	3	8	3	16	1	1	5	39.12	3.83
15	23	4	7	5	6	6	8	4	14	3	1	7	39.25	3.70
18	48	6	4	4	5	6	7	1	9	1	1	8	39.32	3.67
15	34	7	7	5	4	5	8	1	16	1	2	5	39.37	3.67
19	39	5	3	4	6	5	7	3	8	2	2	2	39.40	3.58
16	44	6	6	5	8	3	7	3	12	3	2	1	39.45	3.46
18	44	5	3	5	5	8	6	4	12	2	4	3	39.50	3.35
20	48	6	5	4	7	3	7	1	10	4	2	4	39.75	3.30
16	29	7	6	5	6	8	8	4	16	3	3	5	39.77	3.22
16	29	7	5	5	7	7	8	1	16	2	2	7	39.77	3.19
16	38	4	3	5	4	4	8	1	12	3	2	10	39.92	3.18
17	36	6	6	5	8	7	7	2	15	2	4	9	40.01	2.99
17	21	6	4	5	5	7	7	4	11	3	4	1	40.08	2.98
18	48	5	3	6	8	8	5	3	12	4	1	4	40.22	2.83
18	36	5	3	6	8	6	6	3	11	3	4	1	40.53	2.60
18	22	5	3	6	4	7	6	4	11	3	4	4	40.77	2.56
18	29	7	5	5	6	6	8	2	13	1	1	1	40.90	2.54
19	27	7	6	7	5	3	4	3	12	3	1	4	40.93	2.49
21	48	4	7	5	7	8	5	3	12	2	1	2	41.10	2.48
21	37	7	6	5	5	8	6	2	12	3	2	1	41.17	2.44
19	48	5	5	5	6	5	8	4	12	3	1	2	41.23	2.28
20	42	4	5	7	6	5	3	1	10	3	2	4	41.50	2.22
20	45	7	6	5	6	6	7	3	13	3	3	3	41.67	2.10
20	46	7	3	5	6	3	7	4	11	2	4	3	41.73	2.09
19	46	7	4	7	7	8	6	3	11	4	4	2	41.80	2.04
19	29	6	3	7	6	8	6	4	9	3	1	2	41.88	2.04
20	45	5	7	6	7	6	6	3	11	3	4	3	41.94	1.90
20	47	6	6	6	6	6	6	2	12	3	1	5	41.96	1.89
20	47	7	5	6	5	6	6	1	13	2	2	8	42.05	1.89
21	48	7	4	8	8	6	2	3	15	3	1	4	42.35	1.88
20	29	7	5	7	8	5	5	3	15	3	2	3	42.39	1.78
21	24	5	4	7	7	3	3	3	12	2	3	3	42.59	1.71
21	46	7	5	7	6	3	4	3	12	4	4	1	42.76	1.62
21	47	7	6	7	5	8	4	1	13	1	4	2	42.89	1.61
20	47	7	6	9	6	3	6	2	15	2	1	3	43.21	1.59
21	21	7	6	9	8	8	3	4	16	1	4	3	43.24	1.58
21	36	7	4	12	6	5	3	2	16	2	2	3	43.26	1.57
20	43	6	5	7	6	8	8	3	11	3	3	10	43.26	1.56
20	31	7	6	8	7	7	7	4	15	2	4	3	43.35	1.56
21	40	7	4	13	6	3	3	2	12	3	3	3	43.40	1.56
21	30	7	7	9	8	7	4	4	14	3	4	4	43.43	1.47
22	43	7	6	6	8	8	6	3	13	4	2	7	43.58	1.38
21	47	5	6	8	7	6	6	2	12	3	4	5	43.86	1.36
21	28	5	5	8	7	6	6	3	14	3	4	5	43.87	1.35
21	47	5	7	8	8	7	6	1	16	4	4	3	43.92	1.34
21	46	6	7	7	7	3	7	2	12	2	4	3	43.96	1.34
22	25	7	5	6	8	5	8	3	9	1	3	9	44.05	1.32
21	30	7	7	7	5	8	8	1	15	3	4	1	44.09	1.31
22	45	6	3	6	8	8	7	3	12	3	1	7	44.27	1.24
22	41	7	6	13	6	5	3	2	14	3	2	1	44.51	1.22

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	MP	Kf	Km	Kmf	Ke	DE	WIP	BL
23	45	5	6	6	6	6	6	4	13	2	4	2	44.55	1.17
23	47	6	6	6	6	6	6	2	12	4	2	6	44.55	1.16
23	48	5	3	6	7	7	6	1	16	4	1	1	44.74	1.16
22	41	5	7	13	6	5	4	4	14	1	4	4	44.85	1.14
22	37	7	6	8	6	4	6	3	15	3	2	3	44.87	1.09
23	48	7	4	7	5	7	3	4	12	4	3	10	45.00	1.07
22	27	4	3	11	6	4	6	3	13	4	2	1	45.41	1.06
22	39	5	4	14	6	6	7	1	16	4	4	5	45.47	1.04
22	40	7	5	13	6	3	7	2	14	4	3	4	45.52	1.03
22	36	5	4	12	6	8	8	4	15	3	2	8	45.57	1.02
22	40	7	5	13	8	6	8	1	13	2	2	4	45.58	1.02
24	30	7	5	6	7	7	6	4	15	2	1	3	45.58	0.99
24	47	5	7	6	6	6	5	4	13	1	3	4	45.61	0.98
24	26	6	3	6	6	6	5	3	16	4	1	9	45.74	0.97
23	30	7	6	9	6	5	4	4	16	3	4	2	45.79	0.92
24	42	7	6	6	6	8	7	3	13	4	4	3	46.05	0.89
23	48	5	6	9	8	8	5	1	13	4	1	2	46.12	0.88
24	41	6	5	7	6	7	3	3	16	2	2	3	46.13	0.87
23	47	5	5	8	6	7	8	1	12	3	1	7	46.27	0.85
23	23	4	5	8	7	6	8	3	12	1	3	1	46.40	0.85
23	45	7	5	9	6	6	8	3	13	3	2	7	46.41	0.84
23	48	5	6	9	6	6	8	4	12	3	2	7	46.42	0.84
23	35	7	6	11	8	5	8	2	15	3	4	4	46.54	0.83
24	28	6	4	7	6	3	5	3	13	3	1	3	46.68	0.77
24	36	7	5	8	7	5	3	4	15	3	1	1	46.74	0.77
24	23	7	6	8	5	4	5	3	10	3	1	3	47.20	0.72
24	46	5	6	8	8	8	8	4	13	3	1	3	47.35	0.68
24	40	5	6	8	6	3	8	1	12	2	1	4	47.49	0.68
24	33	5	4	9	6	8	7	4	15	3	3	3	47.53	0.67
25	28	7	7	7	5	7	4	1	16	4	2	3	47.62	0.67
24	47	7	3	8	5	8	7	1	13	4	1	7	47.64	0.67
24	47	7	6	13	8	5	7	3	14	4	2	7	47.65	0.67
24	42	7	6	12	7	7	7	3	14	3	1	3	47.68	0.67
24	40	5	5	11	8	6	8	2	12	3	2	7	47.68	0.66
24	48	4	5	12	7	8	8	3	16	2	3	2	47.80	0.66
24	40	5	6	12	5	6	7	1	16	3	4	1	47.81	0.66
25	35	7	6	7	8	4	5	1	12	3	4	1	47.86	0.62
25	31	5	6	8	6	8	3	4	15	3	4	3	48.10	0.59
25	44	5	4	8	7	8	8	4	12	3	2	3	48.55	0.55
25	34	7	7	12	5	6	3	4	14	4	2	9	48.80	0.55
25	48	4	6	13	8	8	5	4	10	4	2	5	48.90	0.54
25	48	7	7	14	8	8	6	1	15	4	2	3	48.93	0.53
25	47	7	7	14	6	7	6	1	16	4	4	9	48.97	0.53
25	48	4	6	9	5	4	8	1	12	2	1	1	49.06	0.53
25	21	5	5	10	8	6	8	3	12	2	4	3	49.10	0.52
25	41	4	6	13	8	4	8	4	15	3	1	6	49.16	0.52
25	48	7	7	13	6	3	8	1	16	3	4	1	49.18	0.52
25	44	5	5	12	7	3	8	4	16	1	2	5	49.19	0.52
25	20	7	7	14	6	6	8	1	16	3	2	7	49.38	0.51
26	47	6	7	7	6	8	7	4	16	3	2	2	49.39	0.47
26	29	7	4	8	8	6	8	4	10	2	1	8	49.75	0.44
26	29	7	6	8	8	3	8	4	10	4	1	4	49.84	0.44
26	35	6	6	11	6	5	4	3	13	3	1	2	50.13	0.42
26	31	4	6	8	5	7	7	1	13	2	4	3	50.16	0.42
26	26	7	6	13	8	8	5	4	14	2	3	2	50.23	0.41
26	41	5	4	12	6	6	7	4	15	4	3	2	50.35	0.41
26	47	7	6	12	5	6	6	3	12	3	1	2	50.39	0.41
26	34	7	5	14	5	6	6	4	13	3	2	9	50.41	0.41
26	30	6	5	12	6	3	6	3	12	3	3	6	50.44	0.41
26	26	7	7	12	5	7	8	4	15	4	1	2	50.47	0.41
26	48	6	7	14	8	3	8	4	12	3	2	3	50.50	0.41
26	22	7	6	11	5	8	8	1	16	4	4	1	50.59	0.40
26	30	6	3	13	7	3	6	4	16	3	2	6	50.72	0.40
27	41	5	4	7	6	8	8	3	14	3	2	6	50.77	0.38
27	24	7	4	9	6	8	2	3	13	3	2	8	51.30	0.35
27	46	5	6	8	6	5	8	1	15	2	2	4	51.33	0.34
27	40	5	7	9	8	7	8	1	10	4	1	9	51.42	0.34
27	30	5	6	11	6	7	4	3	15	1	2	1	51.64	0.33
27	40	5	7	13	6	6	4	4	15	4	4	1	51.65	0.33
27	35	6	7	12	6	8	4	3	13	3	1	4	51.66	0.33
27	31	7	4	12	6	6	6	3	13	3	3	2	51.72	0.32
27	40	5	5	12	6	8	8	2	15	3	3	3	51.76	0.32

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	MP	Kf	Km	Kmf	Ke	DE	WIP	BL
27	30	6	5	13	7	5	8	4	16	3	2	1	51.76	0.32
27	48	5	7	13	5	7	7	1	15	4	4	6	51.93	0.31
27	48	7	3	12	8	8	8	1	16	3	2	3	52.15	0.31
27	40	7	3	13	6	3	6	1	14	3	3	6	52.40	0.31
27	26	7	7	12	4	3	8	1	12	3	2	6	52.69	0.30
28	47	6	6	8	6	8	7	4	16	4	2	7	52.73	0.26
28	48	7	7	8	6	3	7	1	13	1	2	4	52.97	0.26
28	48	6	7	9	6	6	8	2	15	4	3	2	53.00	0.25
28	48	7	7	10	7	7	7	1	14	4	2	3	53.12	0.25
28	46	5	7	9	5	4	7	2	14	3	1	1	53.24	0.25
28	48	5	7	14	7	8	6	2	13	3	1	9	53.25	0.25
28	40	7	7	12	5	6	6	3	13	3	3	2	53.32	0.24
28	36	6	6	11	5	3	8	3	14	2	1	1	53.60	0.24
28	40	7	6	10	4	8	7	1	13	4	1	4	53.81	0.24
28	48	4	6	12	5	3	7	1	12	4	1	1	54.00	0.23
28	36	4	7	12	4	5	8	3	14	3	3	1	54.02	0.23
29	35	7	5	8	6	3	8	3	16	4	4	8	54.42	0.20
29	29	7	5	10	8	6	8	4	10	4	1	3	54.53	0.20
29	29	7	5	12	8	4	8	4	10	4	1	6	54.76	0.20
29	48	6	7	13	8	8	8	1	14	2	3	1	54.79	0.19
29	28	7	6	13	6	4	7	3	14	4	2	6	54.86	0.19
29	48	6	7	13	6	5	6	1	16	1	4	2	54.90	0.19
29	28	7	6	11	6	3	8	3	14	4	1	2	55.01	0.19
29	23	6	7	11	5	5	6	3	16	3	4	2	55.11	0.19
29	35	4	5	10	6	3	8	4	12	3	3	1	55.20	0.19
29	47	5	3	11	5	7	4	2	13	4	2	3	55.50	0.18
30	48	7	6	7	4	8	8	3	16	4	4	10	55.59	0.18
30	33	5	7	8	6	5	6	2	11	3	1	2	55.64	0.17
30	48	7	7	8	6	8	6	1	16	3	1	2	55.83	0.16
30	48	6	7	8	6	3	7	3	13	1	2	4	56.01	0.16
30	48	6	7	9	6	6	6	1	16	3	3	1	56.12	0.15
30	47	6	7	9	6	4	7	4	16	4	2	2	56.14	0.15
30	47	6	7	13	8	7	6	3	14	4	1	3	56.32	0.15
30	29	7	6	12	6	6	6	4	15	4	4	7	56.35	0.15
30	48	7	5	12	6	6	6	3	14	3	1	1	56.37	0.15
30	28	7	6	13	6	6	6	3	14	4	2	7	56.39	0.15
30	41	4	7	12	6	6	8	4	13	3	4	3	56.71	0.14
30	34	6	7	11	5	3	6	2	13	4	4	8	56.73	0.14
30	47	5	4	14	8	3	8	4	14	1	1	7	56.94	0.14
30	48	7	7	13	4	7	8	1	16	3	2	1	56.99	0.14
30	48	6	7	14	4	6	6	1	15	3	2	4	57.18	0.14
30	32	7	3	13	6	3	6	1	15	2	1	6	57.49	0.14
31	48	7	7	8	6	3	6	1	16	3	2	1	57.57	0.12
31	48	7	5	11	6	6	3	2	11	2	1	1	57.87	0.12
31	25	6	5	9	8	4	8	2	16	2	4	1	57.89	0.12
31	47	5	7	11	6	4	2	4	16	4	1	2	58.03	0.12
31	48	5	7	9	6	3	6	1	14	1	2	4	58.08	0.11
31	48	7	7	13	7	3	6	4	16	4	4	3	58.15	0.11
31	48	6	5	12	5	4	8	1	15	3	4	3	58.21	0.11
31	48	4	7	13	7	6	6	3	12	3	2	6	58.37	0.11
31	37	7	4	13	6	3	7	1	15	3	1	1	58.43	0.11
31	28	6	6	13	5	3	7	2	15	3	4	1	58.52	0.11
31	48	7	4	14	7	3	7	2	16	1	1	7	58.59	0.11
31	48	7	7	13	4	7	8	1	13	4	1	6	58.70	0.11
32	36	5	6	8	8	8	8	3	12	2	1	3	58.93	0.10
32	31	7	6	8	7	8	6	4	15	2	1	1	58.95	0.10
32	48	6	6	9	6	6	7	1	14	1	4	5	59.37	0.09
32	30	6	6	11	6	8	8	4	16	3	1	3	59.60	0.09
32	33	5	7	14	6	7	8	2	16	4	2	1	59.69	0.08
32	48	5	7	13	6	8	6	1	16	3	4	1	59.72	0.08
32	35	6	5	12	5	7	8	4	15	3	1	3	59.75	0.08
32	48	7	5	13	5	6	5	1	12	3	4	1	59.86	0.08
32	27	7	7	13	6	3	5	3	15	4	4	4	59.95	0.08
32	28	7	7	13	5	3	5	2	15	3	4	1	60.15	0.08
32	48	6	4	14	5	3	5	2	12	4	4	1	60.32	0.08
33	28	5	5	8	6	7	3	3	14	3	2	3	60.73	0.07
33	26	6	6	8	7	4	8	3	15	1	2	9	60.83	0.07
33	48	5	7	9	6	4	6	1	14	3	1	3	61.10	0.07
33	48	5	6	10	6	4	3	2	12	3	4	10	61.20	0.07
33	47	6	7	12	6	8	7	4	16	3	2	1	61.21	0.07
33	32	6	7	13	6	8	6	2	14	4	3	8	61.25	0.06
33	48	7	6	14	5	6	7	1	14	3	4	3	61.46	0.06

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	MP	Kf	Km	Kmf	Ke	DE	WIP	BL
33	37	7	7	13	6	3	7	2	13	3	4	1	61.51	0.06
33	36	7	7	13	6	3	7	1	16	2	4	3	61.55	0.06
33	32	7	7	13	5	3	6	2	13	3	1	2	61.78	0.06
33	29	6	6	14	5	3	6	2	15	3	1	7	61.85	0.06
33	25	7	7	13	5	3	8	2	15	3	4	1	61.99	0.06
33	35	7	4	12	4	7	2	2	16	4	2	3	62.43	0.06
34	47	6	7	12	6	8	7	4	16	1	2	4	62.89	0.05
34	34	7	7	14	6	6	7	1	15	4	1	4	62.97	0.05
34	38	7	7	13	4	6	6	1	16	4	3	8	63.68	0.04
35	48	7	7	8	8	8	6	2	16	2	1	1	63.77	0.04
35	36	7	6	8	6	5	7	4	15	3	3	2	63.77	0.04
35	41	7	7	14	8	4	2	3	12	2	4	5	64.46	0.04
35	32	7	7	13	6	8	6	2	14	2	2	8	64.53	0.04
35	41	6	7	13	7	8	4	4	16	1	2	4	64.53	0.04
35	48	6	5	12	5	4	8	1	15	3	4	3	64.81	0.03
35	48	7	6	14	7	3	7	1	14	1	3	7	64.84	0.03
35	41	5	7	13	6	5	4	1	15	1	2	4	64.89	0.03
35	48	7	7	13	5	3	5	1	15	2	2	3	65.09	0.03
36	34	5	6	8	7	7	3	3	14	2	3	10	65.62	0.03
36	48	7	7	13	6	8	6	1	16	3	3	1	66.20	0.03
36	46	5	6	12	6	4	6	3	14	3	2	4	66.36	0.03
36	48	6	5	12	5	7	8	1	14	1	2	4	66.44	0.02
36	48	7	4	12	5	3	4	4	16	1	2	2	67.08	0.02
36	28	6	4	13	5	3	8	4	12	4	1	10	67.32	0.02
37	30	6	6	9	6	5	4	3	15	3	4	1	67.56	0.02
37	45	7	7	13	6	6	6	1	15	3	1	2	67.90	0.02
37	48	7	7	13	6	3	7	2	16	4	2	6	68.11	0.02
37	30	6	4	14	7	8	6	3	16	4	1	1	68.45	0.02
37	30	7	5	10	4	8	7	4	14	2	1	4	68.63	0.02
37	24	6	6	14	5	8	8	4	16	3	1	5	69.02	0.02
38	39	7	5	9	6	8	4	1	14	1	4	6	69.22	0.01
38	48	7	6	12	5	8	7	3	12	3	1	2	69.66	0.01
38	29	6	5	13	4	6	6	1	16	3	2	3	70.71	0.01
39	42	7	5	12	8	6	5	2	16	4	2	2	71.12	0.01
39	48	7	7	13	6	7	5	1	15	1	3	1	71.19	0.01
39	48	5	7	13	6	5	7	4	14	1	4	4	71.57	0.01
39	48	7	5	13	6	3	8	1	15	2	3	4	71.57	0.01
39	39	5	6	14	6	3	8	3	15	4	2	5	71.82	0.01
39	47	5	7	13	4	7	7	4	15	1	2	4	72.39	0.01
40	48	6	6	13	6	7	8	3	15	4	2	3	72.85	0.01
40	48	7	6	13	5	8	6	1	13	3	4	7	73.06	0.01
40	48	7	5	12	6	7	8	1	15	1	1	3	73.17	0.01
40	47	7	4	12	5	4	8	4	16	4	4	3	73.73	0.01
40	31	5	6	12	6	3	5	1	13	3	1	2	73.76	0.01
41	48	5	7	8	6	4	6	3	12	3	2	1	74.00	0.01
40	25	7	6	14	6	3	5	3	14	1	2	1	74.35	0.01
41	48	7	7	13	6	7	6	1	13	1	4	1	74.52	0.00
41	36	7	7	13	6	6	6	1	15	4	4	1	74.53	0.00
41	48	6	7	14	8	6	4	2	13	1	4	2	74.56	0.00
41	48	7	7	14	6	6	6	1	16	1	3	1	74.58	0.00
41	48	7	6	13	6	3	5	1	15	2	4	1	74.85	0.00
41	36	6	5	13	4	6	2	4	15	4	1	6	76.02	0.00
42	46	6	6	12	6	8	6	2	12	3	4	2	76.15	0.00
42	48	7	6	14	6	6	3	4	16	2	4	1	76.17	0.00
42	48	6	7	12	6	3	6	3	13	1	1	6	76.68	0.00
43	31	7	7	8	7	4	7	4	15	3	1	1	77.29	0.00
43	39	7	6	12	6	4	7	3	12	4	1	3	77.84	0.00
43	46	7	7	14	6	6	7	4	14	1	2	2	77.85	0.00
43	48	7	7	14	6	6	6	1	15	4	4	2	77.86	0.00
43	31	7	5	12	6	8	7	1	14	1	2	1	78.37	0.00
43	48	7	7	14	4	6	6	1	12	4	1	2	78.94	0.00
43	47	7	4	14	6	6	6	3	14	1	2	2	78.97	0.00
44	48	7	7	13	5	8	5	1	15	3	3	1	79.71	0.00
45	37	7	7	12	6	8	8	4	15	4	2	7	81.11	0.00
46	45	7	6	8	7	6	8	3	13	3	2	3	81.87	0.00
45	47	7	7	12	4	7	6	3	13	3	1	2	82.01	0.00
45	48	5	7	13	4	7	6	1	16	4	1	4	83.00	0.00
47	47	6	5	8	6	8	3	1	13	3	4	8	84.45	0.00
47	48	6	7	13	6	3	6	1	12	3	2	1	85.08	0.00
47	48	6	4	13	5	4	8	1	15	3	4	3	86.66	0.00
48	34	7	7	12	4	6	6	1	14	3	2	7	87.35	0.00
48	28	5	4	14	4	4	8	1	16	3	3	1	91.68	0.00

C2. DNC HKC - PAC OPTIMISED SETTINGS FOR UPPER PROCESSING TIME VARIABILITY

Table C-2. Production Authorisation Card Settings for DNC HKC Strategy 40HV

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	MP	Kf	Km	Kmf	Ke	WIP	BL
11	41	7	7	4	7	3	8	1	13	3	4	35.97	12.70
11	48	7	4	4	6	8	8	2	14	4	4	35.97	12.43
12	39	6	7	4	8	4	7	2	13	3	3	36.02	12.24
11	43	6	4	4	4	8	8	2	9	4	2	36.02	12.34
12	30	6	4	4	7	3	7	2	15	4	4	36.02	12.39
12	38	6	7	4	7	3	7	1	8	3	2	36.05	12.18
13	48	6	5	5	6	5	6	3	15	4	2	36.12	11.95
12	30	6	4	5	7	3	7	3	13	4	4	36.41	10.74
12	45	3	5	5	8	5	7	4	9	1	2	36.51	10.68
11	34	6	7	6	8	7	8	2	16	1	4	36.53	10.56
11	46	7	5	13	8	6	8	4	15	2	3	36.54	10.47
11	42	7	6	9	8	8	8	3	14	4	2	36.54	10.52
12	32	6	3	4	7	3	8	2	9	4	2	36.58	8.63
13	43	6	6	4	6	8	7	4	15	3	1	36.66	8.39
13	40	6	6	4	4	8	7	4	15	4	2	36.77	8.23
14	40	6	6	5	7	7	6	3	10	3	1	36.80	7.93
14	29	5	6	5	8	8	6	3	8	4	4	36.84	7.91
15	29	5	6	5	6	5	5	2	13	4	2	36.95	7.68
15	43	5	6	5	7	4	5	4	9	3	4	36.96	7.61
12	43	6	7	5	7	4	8	1	9	3	1	37.08	7.42
13	41	7	3	4	4	6	8	3	10	3	1	37.13	6.80
14	29	4	5	4	8	8	7	3	12	3	4	37.18	6.60
14	45	4	5	4	6	8	7	3	13	3	4	37.19	6.52
14	33	3	5	4	5	8	7	1	14	2	4	37.30	6.50
14	48	3	3	4	5	3	7	2	16	4	1	37.33	6.45
14	48	4	6	4	6	5	8	3	8	4	2	37.57	5.70
15	42	6	4	4	6	7	7	2	11	4	1	37.65	5.50
15	42	4	7	4	7	3	7	2	16	3	4	37.65	5.53
15	34	4	4	4	7	8	7	3	13	3	1	37.65	5.50
15	48	7	5	4	5	8	7	4	15	3	2	37.67	5.46
15	47	4	5	4	6	3	8	1	15	3	3	37.90	5.06
15	39	6	7	4	5	3	8	1	15	4	3	37.90	5.05
15	39	6	7	4	7	6	8	1	13	1	3	37.92	5.04
15	39	6	7	4	3	5	8	4	13	4	2	38.15	5.04
17	35	7	6	5	7	6	5	4	16	2	4	38.23	4.67
14	46	4	5	5	8	8	8	3	14	3	2	38.30	4.56
14	41	7	6	5	6	8	8	2	11	2	4	38.30	4.58
17	28	7	6	4	8	8	7	1	13	2	4	38.37	4.42
17	29	6	6	4	6	4	7	3	15	4	2	38.39	4.41
15	39	6	7	5	5	5	7	2	13	4	4	38.49	4.33
17	48	7	3	4	6	6	8	4	15	4	1	38.50	4.33
17	26	5	7	4	4	6	8	2	16	2	4	38.51	4.32
17	48	7	5	4	5	6	8	3	14	1	2	38.54	4.28
18	25	7	7	4	8	8	7	3	16	2	3	38.67	4.16
18	36	5	7	4	8	5	7	2	14	3	2	38.67	4.15
18	46	6	4	4	6	8	7	2	15	4	1	38.69	4.14
18	40	6	4	4	6	3	7	2	15	2	4	38.70	4.12
18	38	7	4	4	8	5	8	4	13	2	3	38.73	4.09
18	48	7	3	4	6	5	8	4	9	3	1	38.74	4.09
18	38	7	4	4	8	5	8	1	15	2	4	38.75	4.05
15	47	4	4	5	7	8	8	3	14	3	4	38.81	3.89
15	37	6	3	5	8	4	8	2	15	1	1	38.96	3.87
16	27	6	3	5	8	8	7	4	10	3	1	39.04	3.66
15	46	7	5	6	8	4	8	4	11	3	1	39.29	3.58

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	MP	Kf	Km	Kmf	Ke	WIP	BL
16	47	7	5	5	8	7	8	3	11	2	3	39.30	3.39
17	30	7	5	6	5	3	6	3	8	2	4	39.61	3.30
17	41	6	7	5	8	5	7	2	8	1	4	39.64	3.22
16	31	7	3	7	8	6	7	2	11	4	3	39.75	3.21
17	48	3	7	5	5	5	7	4	9	3	1	39.76	3.17
16	31	7	7	7	7	3	7	1	16	4	3	39.76	3.21
17	38	7	7	5	8	3	8	4	9	4	4	39.77	3.04
17	25	6	4	5	7	3	8	2	9	1	1	39.91	3.02
18	42	6	7	5	7	3	7	3	15	2	4	40.08	2.81
18	37	7	3	5	8	5	7	3	15	1	4	40.14	2.80
18	18	5	3	6	8	4	6	3	10	4	1	40.20	2.77
18	34	7	3	5	7	3	8	3	16	4	1	40.25	2.72
17	41	4	3	6	8	8	8	1	8	4	2	40.58	2.68
17	47	7	6	8	6	3	7	3	14	3	2	40.60	2.67
17	34	6	6	14	8	8	7	1	10	4	4	40.63	2.66
17	32	6	6	14	6	4	7	4	15	1	2	40.67	2.66
17	18	7	5	6	7	7	8	2	16	1	1	40.68	2.63
18	39	6	6	6	6	4	7	1	16	4	4	40.79	2.43
18	29	6	3	6	6	3	8	1	15	3	2	41.06	2.30
18	41	7	7	7	5	6	7	3	10	4	3	41.17	2.29
18	39	7	7	8	7	8	7	3	15	4	3	41.26	2.25
20	32	7	6	5	4	7	7	1	11	3	4	41.31	2.24
20	26	5	3	7	8	8	4	2	13	1	4	41.41	2.14
21	47	7	7	5	5	8	7	1	9	3	1	41.56	2.12
21	47	7	6	5	7	4	7	3	10	3	1	41.62	2.08
21	46	4	7	5	8	6	8	1	10	4	2	41.67	2.06
20	31	7	7	6	4	8	6	3	13	2	1	41.68	2.03
19	46	6	6	7	7	5	7	2	14	3	3	41.81	1.97
20	39	7	5	9	7	8	4	3	10	4	3	41.95	1.93
20	34	6	3	6	6	6	7	3	13	4	4	42.15	1.82
20	40	6	5	6	6	6	8	3	10	3	2	42.17	1.79
20	31	5	7	8	7	5	5	1	10	3	3	42.33	1.79
20	31	6	5	6	4	5	7	2	16	1	3	42.39	1.78
21	46	4	5	7	7	4	4	3	13	3	1	42.41	1.75
20	31	7	7	7	7	8	7	4	13	2	3	42.55	1.66
20	31	6	5	7	5	8	7	1	13	1	4	42.71	1.64
21	48	7	7	8	6	6	4	1	10	2	3	42.86	1.60
21	47	6	6	6	7	5	8	3	13	2	1	42.90	1.55
21	45	5	4	6	5	3	8	3	15	4	2	43.02	1.54
21	46	7	7	6	5	8	8	1	13	1	1	43.13	1.52
21	48	5	4	9	5	7	4	1	13	1	3	43.24	1.51
21	40	7	7	8	5	7	5	2	12	4	4	43.26	1.44
21	46	7	6	9	8	4	5	2	12	4	4	43.37	1.41
22	36	6	6	6	7	8	7	1	14	2	4	43.66	1.33
22	37	7	3	6	6	5	8	1	11	3	2	43.79	1.32
22	47	7	3	6	8	3	8	4	14	1	3	43.89	1.31
22	25	7	7	7	5	5	5	2	14	4	4	43.93	1.26
22	26	7	7	8	5	6	4	2	13	4	1	44.03	1.26
22	28	7	7	10	5	7	3	2	11	4	1	44.34	1.25
22	45	4	6	7	8	7	8	2	16	4	4	44.39	1.15
22	26	4	4	8	8	8	8	1	13	4	1	44.80	1.08
22	28	7	7	9	5	8	8	2	16	3	4	44.91	1.07
22	48	4	5	9	5	5	8	4	15	1	2	45.04	1.06
22	48	4	5	10	6	4	8	4	15	3	1	45.08	1.06
23	45	7	6	8	7	5	5	4	10	2	3	45.33	0.96
23	41	4	6	7	8	6	7	4	14	4	1	45.39	0.96
23	48	7	4	9	5	8	7	3	10	3	1	45.98	0.88
23	42	6	6	11	5	7	6	3	15	4	1	45.98	0.88
23	45	5	3	9	5	5	7	3	15	3	4	46.10	0.87
23	45	7	3	11	5	4	6	4	15	3	4	46.16	0.86
23	41	6	7	10	8	3	8	1	11	1	3	46.23	0.85
23	42	6	7	12	5	7	8	1	11	3	4	46.24	0.85
23	41	5	7	10	4	6	8	1	10	4	1	46.41	0.84
24	47	6	5	7	4	7	5	4	10	4	3	46.46	0.83
25	34	7	7	6	8	8	7	4	11	3	1	46.49	0.82
24	38	7	5	7	5	5	7	1	10	1	4	46.52	0.79
24	48	7	6	14	7	7	2	1	14	2	1	46.79	0.78
24	46	7	6	8	8	8	7	3	11	2	4	46.81	0.72
24	29	4	3	10	5	5	4	4	15	2	4	47.19	0.71
24	45	5	4	13	8	8	6	4	11	4	1	47.21	0.70
24	42	7	6	12	7	7	7	3	14	3	1	47.25	0.69
24	48	4	6	10	6	5	8	4	15	4	1	47.29	0.68

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	MP	Kf	Km	Kmf	Ke	WIP	BL
24	48	4	6	10	6	3	7	4	16	4	3	47.41	0.68
24	40	4	6	12	6	7	8	1	14	1	4	47.49	0.68
24	44	4	5	14	5	5	8	3	11	3	1	47.56	0.67
24	48	7	3	14	6	3	8	4	14	2	1	47.73	0.67
25	42	6	6	7	5	7	7	2	14	1	3	47.76	0.62
25	20	7	7	7	7	5	7	3	12	4	1	47.95	0.62
25	42	7	6	12	6	4	2	3	14	2	1	48.21	0.59
25	31	6	6	8	5	8	7	4	14	1	4	48.22	0.57
25	26	5	7	9	5	4	6	2	14	3	1	48.38	0.56
25	33	5	6	8	4	5	8	3	15	1	4	48.53	0.55
25	20	5	6	10	7	7	6	3	12	3	4	48.65	0.54
25	47	7	5	13	5	8	7	1	15	4	2	48.70	0.54
25	31	6	4	14	8	3	7	1	15	4	2	48.77	0.53
25	29	4	4	12	5	7	7	3	14	1	1	48.99	0.53
25	44	4	3	14	5	4	8	2	13	1	2	49.14	0.53
25	22	7	5	13	4	8	7	4	11	3	3	49.35	0.52
26	39	6	5	8	7	7	7	4	16	2	4	49.41	0.45
26	38	6	4	8	5	4	8	3	14	4	1	49.62	0.45
26	44	7	6	10	8	3	3	3	13	4	2	49.77	0.45
26	37	7	5	13	8	3	5	2	14	3	2	50.00	0.43
26	46	7	6	13	5	3	4	3	13	1	2	50.23	0.42
27	37	6	6	7	8	5	8	1	11	1	3	50.24	0.41
27	31	6	5	7	5	8	7	4	14	1	2	50.40	0.40
27	40	7	4	8	6	5	4	1	12	4	1	50.72	0.39
27	41	5	6	10	7	6	2	3	11	2	1	50.94	0.39
27	45	4	5	8	5	7	7	4	16	2	1	51.16	0.36
27	47	7	4	11	6	5	4	2	14	4	2	51.19	0.34
27	47	4	4	9	6	4	5	1	14	1	4	51.44	0.34
27	41	6	7	13	6	3	7	3	13	4	1	51.68	0.33
27	43	4	7	14	5	3	7	1	16	2	4	52.04	0.32
28	25	7	4	8	5	7	3	2	16	1	3	52.37	0.30
28	48	7	6	13	8	7	2	2	14	3	1	52.75	0.26
28	42	7	4	13	8	6	8	2	15	4	4	52.87	0.25
28	36	7	4	12	5	5	7	4	16	3	3	53.04	0.25
28	40	6	4	12	5	5	7	3	13	3	1	53.10	0.25
28	46	7	7	9	4	6	7	4	12	3	3	53.22	0.25
28	48	5	6	14	6	3	5	1	16	4	2	53.24	0.25
28	45	5	6	11	4	4	8	3	15	3	4	53.45	0.25
29	46	7	6	8	8	8	7	1	10	2	2	53.46	0.24
28	46	5	3	14	7	3	7	2	13	1	1	53.89	0.24
29	42	5	6	14	8	7	7	4	15	4	4	54.42	0.20
29	31	4	6	11	8	8	8	3	13	1	4	54.67	0.20
29	46	4	6	10	5	8	7	2	15	1	1	54.91	0.19
29	45	7	7	13	4	5	8	1	16	1	2	55.07	0.19
29	28	5	7	14	4	6	2	1	16	2	4	55.48	0.18
30	28	6	5	10	7	5	7	3	16	1	1	56.13	0.15
30	42	5	6	9	4	6	7	4	13	2	4	56.35	0.15
30	48	5	5	14	6	3	3	1	16	4	4	56.53	0.14
30	48	7	6	14	4	7	7	4	15	2	2	56.72	0.14
30	48	7	5	13	4	3	8	4	15	1	2	57.14	0.14
31	31	4	7	8	5	5	8	3	15	3	3	57.45	0.13
31	36	4	4	8	5	6	7	3	15	1	1	57.79	0.13
31	27	7	5	11	5	8	8	1	10	3	4	57.84	0.13
31	48	7	6	14	7	3	7	1	14	1	3	58.01	0.11
31	36	4	4	9	5	5	7	4	16	1	4	58.06	0.11
31	34	4	7	14	5	4	7	3	15	3	4	58.33	0.11
32	30	7	5	8	7	7	7	1	15	2	1	58.57	0.10
31	46	4	4	12	4	5	7	3	14	4	2	58.92	0.10
32	47	5	6	9	7	3	8	3	13	4	4	59.15	0.09
32	35	5	7	9	6	3	8	3	13	4	4	59.22	0.09
32	41	6	4	10	5	5	7	2	11	1	1	59.63	0.09
32	41	6	4	11	6	3	6	2	16	1	1	59.91	0.08
32	26	7	7	13	4	8	8	4	16	2	3	60.00	0.08
33	47	7	6	9	8	8	8	3	12	2	1	60.37	0.08
33	46	6	6	10	7	5	7	1	11	2	1	60.66	0.07
33	46	7	6	9	7	3	8	1	16	2	4	60.83	0.07
33	47	7	4	11	8	7	3	3	13	4	2	60.83	0.07
33	41	4	6	11	8	4	7	3	13	3	4	61.37	0.07
33	40	4	6	13	8	7	8	3	13	1	4	61.55	0.06
33	46	4	7	13	6	4	7	2	15	4	1	61.63	0.06
33	33	6	7	14	4	4	2	1	15	3	1	62.32	0.06
34	39	7	6	14	7	7	8	4	15	1	4	62.49	0.05

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	MP	Kf	Km	Kmf	Ke	WIP	BL
35	30	7	5	8	7	7	7	4	16	2	4	63.36	0.05
34	25	5	5	12	5	3	5	3	16	2	3	63.50	0.05
35	43	7	4	13	8	8	5	4	14	2	3	64.34	0.04
35	35	6	4	8	4	5	4	3	16	1	4	64.34	0.04
35	36	6	6	12	5	5	3	3	16	1	2	64.38	0.04
36	46	7	6	8	7	3	8	4	13	2	1	65.19	0.04
36	47	7	6	12	8	8	5	3	11	3	1	65.65	0.03
36	47	6	7	12	8	4	2	3	13	4	4	65.72	0.03
36	27	7	6	14	8	5	8	3	16	1	4	66.08	0.03
36	47	5	6	13	7	3	7	4	15	4	2	66.31	0.03
36	35	5	7	13	5	3	8	4	15	4	1	66.64	0.02
37	37	5	7	11	8	5	3	1	12	4	4	67.61	0.02
37	35	5	7	11	8	7	4	1	14	4	2	67.65	0.02
37	42	5	6	11	4	3	8	3	14	3	1	68.87	0.02
37	29	5	4	11	4	3	8	3	14	3	1	69.47	0.02
38	36	6	6	14	5	3	7	2	13	1	3	69.86	0.01
38	46	5	7	12	5	7	4	1	14	1	1	70.07	0.01
39	42	7	6	8	7	3	7	3	14	3	1	70.14	0.01
39	36	7	6	12	8	8	5	3	11	3	3	70.55	0.01
39	42	7	6	12	7	7	7	3	14	3	1	70.68	0.01
39	47	7	7	14	6	7	3	3	14	1	4	70.79	0.01
39	40	6	7	13	6	4	7	2	13	4	1	70.91	0.01
39	40	6	7	13	6	3	4	1	16	2	1	71.36	0.01
39	40	7	4	13	4	5	8	3	15	4	4	72.15	0.01
40	42	7	6	12	6	7	8	2	15	2	1	72.39	0.01
40	40	7	5	14	4	5	4	1	16	1	2	73.55	0.01
40	40	7	7	14	4	7	2	1	16	1	1	73.89	0.01
41	42	7	6	12	4	8	5	3	13	4	1	74.96	0.00
43	41	5	5	8	6	8	8	1	13	4	4	77.22	0.00
42	33	6	7	12	4	4	2	1	15	2	2	77.36	0.00
43	39	6	6	14	7	8	7	3	15	4	3	77.49	0.00
43	42	7	6	12	6	3	8	2	15	3	1	77.82	0.00
44	46	7	6	14	7	4	8	3	15	2	1	79.17	0.00
44	48	6	5	9	5	7	7	4	13	1	1	79.31	0.00
44	46	6	5	11	5	7	6	4	15	4	1	79.56	0.00
43	48	6	3	11	6	8	8	2	13	1	4	80.41	0.00
45	42	7	6	11	6	3	5	3	14	4	1	81.10	0.00
45	42	7	6	12	4	8	7	2	13	4	1	81.71	0.00
45	40	7	7	14	4	8	7	2	13	1	2	81.78	0.00
45	28	7	7	14	6	3	8	2	14	1	3	82.14	0.00
45	42	5	6	12	4	7	6	2	13	2	1	82.58	0.00
46	48	7	7	14	5	7	4	2	14	1	1	82.98	0.00
45	29	6	4	14	5	8	4	3	14	2	4	83.84	0.00
47	36	6	7	9	6	6	7	2	15	4	4	83.86	0.00
47	42	6	6	12	6	7	7	3	14	4	1	84.35	0.00
47	48	7	6	13	5	7	4	4	13	1	2	84.42	0.00
48	42	7	4	9	7	7	5	1	15	4	4	87.21	0.00
48	48	6	4	14	6	4	7	4	13	1	3	88.00	0.00
47	32	6	7	12	3	8	4	3	14	2	4	88.65	0.00
48	25	5	4	12	5	3	6	2	15	1	4	92.36	0.00
48	16	5	4	11	5	4	8	4	15	4	3	99.33	0.00
47	34	5	3	11	4	8	3	4	12	4	2	104.80	0.00
48	46	6	4	10	3	3	2	4	16	4	1	126.13	0.00

C3. HEKC-II - PAC OPTIMISED SETTINGS FOR UPPER PROCESSING TIME VARIABILITY

Table C-3. Production Authorisation Card Settings for HEKC-II Strategy 40HV

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	DE	Kf	Km	Kmf	Ke	WIP	BL
19	47	7	7	9	9	8	0	4	19	1	4	36.84	46.23
19	57	8	8	16	8	7	0	2	20	4	4	36.86	46.20
20	49	5	7	7	9	7	0	4	10	4	1	36.87	45.22
20	39	6	7	7	9	9	0	4	14	4	4	37.07	44.47
20	59	9	4	8	10	10	0	4	20	2	4	37.46	43.87
20	35	7	8	8	9	7	0	3	20	1	4	37.53	43.83
20	59	6	7	8	5	10	0	4	19	4	2	37.65	43.74
20	46	9	6	12	10	8	0	4	18	2	3	37.70	43.74
20	47	5	3	9	7	10	0	4	20	1	2	37.71	43.73
20	45	6	8	14	6	9	0	3	18	3	2	37.74	43.69
21	35	5	3	7	6	9	0	4	20	3	2	37.79	43.11
20	60	5	8	6	9	10	6	3	12	4	4	37.82	9.77
19	31	5	4	7	10	6	3	4	20	4	2	37.85	8.36
19	40	9	8	7	7	6	2	3	17	4	1	37.90	8.34
19	49	5	8	7	9	4	4	1	19	2	4	37.91	8.28
19	42	8	8	7	5	6	4	2	20	4	2	37.97	8.16
19	57	5	4	7	5	10	2	4	20	1	4	38.03	8.03
19	26	6	8	8	7	10	8	4	18	3	2	38.24	7.44
19	58	5	4	8	6	5	3	3	20	2	2	38.27	7.32
19	55	6	5	8	7	4	5	1	19	4	1	38.38	7.28
19	57	6	6	16	10	9	10	2	20	2	4	38.39	7.17
19	60	7	8	16	10	6	10	3	19	4	4	38.40	7.11
19	57	6	5	13	6	10	10	4	13	2	3	38.42	7.08
19	52	5	7	17	6	4	3	3	20	2	4	38.46	7.08
19	60	6	6	13	10	4	4	4	18	3	1	38.50	7.05
19	57	9	6	17	5	9	7	4	18	4	3	38.51	7.01
19	59	9	5	16	5	9	10	3	20	2	4	38.51	7.01
19	33	9	7	12	5	7	3	2	18	2	3	38.52	6.96
19	57	9	5	10	5	7	7	3	19	2	2	38.53	6.95
19	57	6	6	11	5	7	6	3	18	3	1	38.57	6.89
19	58	7	5	9	4	10	6	4	12	2	2	38.92	6.55
19	57	6	5	11	4	7	10	3	20	3	2	38.95	6.49
19	56	9	5	17	4	10	5	1	18	4	4	39.00	6.48
19	39	9	6	17	4	7	1	4	18	1	3	39.02	6.43
20	59	6	5	7	9	10	9	3	10	4	1	39.07	5.61
20	57	8	3	7	6	5	3	2	10	3	4	39.18	5.55
20	58	5	4	7	5	10	2	4	10	4	1	39.27	5.44
20	48	5	8	7	8	4	1	2	11	3	4	39.35	5.02
20	56	6	5	7	9	10	9	4	19	4	4	39.36	4.90
20	35	8	6	7	9	6	4	4	18	2	3	39.36	4.86
20	40	5	8	7	8	4	4	1	12	3	4	39.45	4.82
20	52	9	7	7	6	6	2	2	15	2	1	39.46	4.81
20	52	6	7	7	6	4	3	1	15	2	2	39.48	4.79
20	33	8	8	7	5	8	2	2	19	4	3	39.51	4.72
20	54	8	4	7	5	7	2	2	18	1	4	39.57	4.70
20	35	6	4	7	5	10	10	1	19	4	4	39.58	4.69
20	23	7	3	8	10	10	2	1	10	4	1	39.82	4.57
20	60	9	6	8	10	5	10	2	19	2	2	39.83	4.25
20	60	5	8	8	8	5	4	2	19	3	4	39.83	4.25
20	49	9	7	8	10	4	4	2	20	4	4	39.86	4.22
20	57	8	8	8	7	5	9	4	20	1	3	39.89	4.19
20	45	8	3	8	8	9	7	2	20	2	2	39.90	4.18
20	57	8	8	8	5	7	3	3	19	4	4	39.96	4.15
20	46	8	8	8	5	9	2	3	19	4	3	39.99	4.15

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	DE	Kf	Km	Kmf	Ke	WIP	BL
20	60	9	7	9	10	6	1	2	18	2	2	39.99	4.15
20	60	5	8	8	5	6	4	1	19	2	4	40.02	4.14
20	60	5	8	14	8	5	7	3	18	3	2	40.04	4.10
20	58	6	4	14	9	9	4	4	19	4	3	40.06	4.07
20	59	6	3	18	9	7	9	4	15	4	1	40.17	4.06
20	60	9	4	15	5	9	6	3	12	2	3	40.17	4.06
20	58	8	8	9	5	10	7	3	19	4	1	40.17	4.04
20	40	7	6	9	5	10	9	3	18	1	4	40.17	4.03
20	60	8	6	13	5	7	9	2	20	2	2	40.18	4.01
20	54	8	4	10	5	6	5	4	19	1	4	40.22	3.98
20	37	8	8	17	5	4	1	4	15	4	4	40.26	3.98
20	59	6	4	18	5	4	10	4	20	3	4	40.27	3.97
20	35	8	3	15	5	4	3	4	14	4	2	40.33	3.97
20	28	4	8	12	5	4	10	2	18	3	1	40.34	3.97
20	59	4	4	18	5	4	10	1	19	4	2	40.35	3.96
20	57	6	7	8	4	6	9	2	19	1	4	40.52	3.87
20	60	9	5	9	4	7	7	3	19	3	1	40.64	3.78
20	59	6	5	12	4	7	2	4	18	4	4	40.66	3.73
20	59	4	4	14	4	9	4	4	20	1	3	40.74	3.73
21	51	9	6	7	10	7	1	4	19	2	2	40.86	3.17
21	33	9	5	7	6	8	2	2	15	4	1	40.92	3.15
21	51	5	6	7	5	9	9	2	17	4	1	41.05	3.08
21	52	8	8	8	6	6	3	2	10	2	1	41.25	2.97
21	37	9	4	8	10	4	9	4	11	3	4	41.39	2.78
21	51	5	6	8	6	7	10	2	14	4	2	41.42	2.71
21	51	7	6	8	9	6	10	3	17	1	4	41.42	2.69
21	51	4	6	8	9	5	4	4	20	4	1	41.49	2.69
21	60	7	6	8	5	7	10	4	17	4	4	41.55	2.64
21	26	9	6	8	5	5	8	4	19	1	4	41.60	2.63
21	60	6	8	9	8	4	5	3	18	4	4	41.62	2.59
21	57	5	4	10	8	6	7	4	19	2	4	41.65	2.58
21	43	5	6	11	7	7	3	3	19	4	2	41.67	2.58
21	57	9	7	16	6	10	9	4	20	1	3	41.72	2.56
21	51	9	6	9	5	5	10	4	20	1	3	41.78	2.56
21	43	5	7	11	5	8	3	4	19	2	2	41.81	2.55
21	36	8	8	14	5	5	7	2	18	3	3	41.82	2.53
21	43	5	7	14	5	5	1	4	20	1	4	41.86	2.53
21	23	7	7	14	5	8	4	1	19	4	4	41.89	2.53
21	59	6	8	15	5	4	3	4	12	4	4	41.92	2.52
21	59	9	8	15	5	4	10	2	19	1	2	41.94	2.51
21	58	4	3	10	5	6	2	4	20	1	4	41.99	2.51
21	57	9	7	9	4	7	9	3	20	2	4	42.25	2.45
22	29	6	4	7	9	9	9	4	20	2	3	42.31	2.23
22	54	7	5	7	9	4	1	3	20	2	4	42.33	2.22
22	60	7	6	7	10	4	1	4	16	4	4	42.34	2.21
22	60	8	5	7	6	8	3	2	19	4	2	42.36	2.20
22	49	6	8	7	10	9	2	1	20	3	4	42.38	2.20
22	39	7	5	7	6	6	4	2	19	4	1	42.40	2.18
22	39	7	5	7	5	8	4	2	19	4	4	42.46	2.16
22	57	7	4	7	5	8	3	2	18	4	4	42.50	2.16
22	44	5	8	8	8	5	4	3	10	3	4	42.64	2.14
22	35	7	5	8	6	7	4	1	10	4	1	42.74	2.10
22	57	8	8	8	6	6	3	1	10	1	2	42.80	2.09
22	42	9	5	8	8	7	2	3	16	3	4	42.93	1.85
22	29	8	6	8	8	7	1	4	16	4	2	42.94	1.84
22	34	5	4	8	7	5	8	1	20	4	3	43.01	1.83
22	57	9	8	8	10	4	2	2	19	3	1	43.03	1.82
22	38	6	8	8	5	5	1	3	19	2	4	43.11	1.80
22	34	7	6	9	10	5	9	3	13	4	2	43.15	1.80
22	33	9	7	9	10	10	1	4	18	4	2	43.16	1.77
22	57	7	5	9	6	8	5	2	18	4	2	43.18	1.77
22	39	7	5	9	6	7	9	3	19	4	4	43.19	1.76
22	33	5	7	10	10	7	4	4	18	4	4	43.24	1.75
22	53	7	4	18	9	6	8	2	20	2	3	43.28	1.74
22	32	7	4	13	6	10	10	3	17	2	2	43.31	1.74
22	46	5	6	18	6	7	1	4	16	2	2	43.31	1.74
22	46	7	5	9	5	9	7	4	20	2	3	43.32	1.73
22	57	8	8	17	8	4	1	4	18	1	4	43.36	1.72
22	35	5	4	18	5	10	3	4	20	2	4	43.44	1.71
22	56	7	8	15	5	5	5	1	20	2	1	43.55	1.70
22	25	7	7	17	5	4	2	1	18	1	4	43.64	1.70
22	29	5	3	16	5	5	3	3	17	4	1	43.64	1.70

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	DE	Kf	Km	Kmf	Ke	WIP	BL
22	58	8	4	11	5	4	6	1	16	2	1	43.65	1.70
23	60	9	8	7	9	4	1	3	14	3	2	43.78	1.62
23	60	5	4	7	10	4	2	3	19	3	3	43.82	1.61
23	57	5	6	7	7	4	4	2	18	2	3	43.82	1.61
23	60	9	8	7	10	4	1	2	18	1	4	43.88	1.59
23	60	9	4	7	6	6	9	3	18	1	3	43.88	1.59
23	60	8	6	8	7	8	10	3	10	4	1	44.10	1.58
23	46	9	7	8	6	10	9	1	10	2	4	44.20	1.56
23	57	8	7	8	7	7	4	4	18	3	4	44.48	1.31
23	39	7	7	8	8	5	1	3	19	1	2	44.54	1.29
23	59	6	4	9	9	6	1	1	20	4	4	44.79	1.24
23	30	9	6	11	8	5	1	4	19	4	4	44.86	1.24
23	31	9	6	11	8	5	1	2	20	4	2	44.87	1.24
23	58	9	5	11	10	8	2	4	20	2	3	44.87	1.24
23	51	7	7	17	8	6	10	4	20	2	2	44.88	1.23
23	44	6	4	12	7	10	7	4	18	4	3	44.90	1.23
23	59	7	4	16	8	4	9	3	20	4	4	44.93	1.22
23	56	7	6	16	7	10	9	3	19	1	2	44.95	1.22
23	60	9	7	16	8	4	9	4	19	2	1	44.99	1.22
23	26	7	8	11	5	7	8	2	18	2	4	45.04	1.21
23	26	8	7	11	5	7	4	4	18	3	2	45.05	1.21
23	54	6	7	15	5	6	9	1	20	2	2	45.10	1.21
23	35	7	7	12	5	4	1	4	18	2	2	45.15	1.20
23	24	5	7	18	5	4	9	4	17	1	2	45.25	1.19
23	58	6	8	13	5	4	9	1	20	1	2	45.26	1.19
23	55	9	3	11	5	5	4	1	18	4	4	45.34	1.19
23	57	6	3	18	5	4	5	1	14	3	4	45.42	1.18
23	29	5	6	9	4	6	9	3	20	2	3	45.48	1.17
23	44	7	8	10	4	6	8	1	14	3	4	45.67	1.17
23	60	9	7	11	4	6	3	2	15	1	4	45.67	1.14
24	46	9	6	8	8	4	4	2	11	3	1	45.89	1.04
24	27	9	8	8	6	10	2	1	11	2	4	45.98	1.03
24	57	9	6	8	8	10	5	2	19	4	4	46.00	0.95
24	60	4	6	8	8	4	5	3	19	3	4	46.19	0.94
24	60	4	7	8	5	5	3	2	19	3	2	46.32	0.93
24	53	8	7	9	6	10	7	3	19	3	3	46.33	0.90
24	39	6	4	9	7	4	10	4	18	3	4	46.37	0.90
24	54	9	8	9	5	8	2	4	19	2	4	46.45	0.89
24	45	9	5	11	7	10	1	2	20	2	2	46.46	0.89
24	60	7	6	18	10	8	4	4	19	2	2	46.48	0.88
24	32	9	8	14	9	6	1	3	19	2	3	46.48	0.88
24	31	9	8	10	9	10	1	4	18	2	1	46.49	0.88
24	57	6	5	12	10	6	2	4	19	1	2	46.54	0.87
24	26	9	4	10	5	7	10	2	18	1	2	46.69	0.86
24	60	9	5	18	5	9	8	2	19	1	2	46.71	0.86
24	56	9	5	17	5	4	2	2	18	4	4	46.75	0.86
24	30	4	8	10	5	4	3	1	18	2	4	46.91	0.85
24	26	8	3	12	5	4	7	4	18	1	4	47.12	0.85
24	20	9	7	10	5	5	3	4	19	3	2	47.19	0.85
24	37	4	5	9	4	8	5	3	20	1	2	47.27	0.84
24	27	4	5	9	4	7	8	3	20	1	4	47.31	0.83
24	60	8	8	18	4	6	2	4	17	4	1	47.32	0.82
24	60	7	8	13	4	5	4	1	17	1	2	47.45	0.82
25	57	7	6	8	8	6	9	4	16	4	4	47.55	0.71
25	60	9	5	8	8	4	9	3	16	2	4	47.59	0.71
25	29	9	6	8	6	10	3	2	17	2	1	47.65	0.70
25	60	9	5	9	6	9	8	3	17	3	2	47.89	0.67
25	52	6	4	9	9	9	3	3	20	4	4	47.90	0.66
25	59	9	5	9	6	4	4	3	17	4	2	47.97	0.65
25	60	5	6	16	10	9	7	4	17	3	2	48.08	0.65
25	60	8	8	15	10	9	2	3	20	1	3	48.12	0.64
25	52	8	5	17	8	9	7	3	16	4	1	48.15	0.64
25	57	9	6	18	8	8	9	4	19	4	1	48.15	0.64
25	34	8	8	15	9	5	9	1	19	4	3	48.16	0.64
25	35	9	5	10	6	10	8	1	18	1	3	48.16	0.64
25	59	5	5	18	10	9	9	4	18	3	1	48.16	0.64
25	59	7	8	11	5	9	1	4	19	4	4	48.24	0.63
25	38	6	8	13	5	7	9	3	17	3	2	48.27	0.63
25	37	9	4	17	5	10	9	4	19	4	3	48.29	0.63
25	59	9	6	11	5	6	9	1	20	3	2	48.31	0.63
25	32	6	3	13	6	10	2	3	17	2	2	48.52	0.62
25	58	4	8	15	5	9	2	4	17	1	4	48.53	0.62

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	DE	Kf	Km	Kmf	Ke	WIP	BL
25	37	9	4	9	4	10	9	4	17	4	3	48.66	0.62
25	56	4	7	9	4	8	9	4	20	3	4	48.82	0.62
25	49	7	7	10	4	8	1	1	18	2	2	48.88	0.61
25	53	5	8	11	4	8	4	3	20	4	1	48.93	0.60
25	53	5	7	18	4	10	2	1	19	4	2	48.95	0.60
26	57	9	7	8	9	4	1	4	15	4	2	49.14	0.53
26	33	7	6	8	8	4	3	3	19	1	4	49.22	0.52
26	36	8	6	9	9	6	4	4	14	2	4	49.42	0.50
26	60	9	6	9	6	10	9	3	20	3	2	49.49	0.49
26	55	7	6	9	5	6	4	3	18	2	4	49.63	0.48
26	46	6	6	10	7	6	5	4	18	1	4	49.66	0.47
26	57	5	5	10	7	4	8	4	19	4	4	49.68	0.47
26	58	7	5	13	10	6	4	4	20	4	4	49.70	0.47
26	33	9	7	17	7	6	9	1	19	3	2	49.77	0.47
26	58	9	7	13	7	10	3	1	17	4	1	49.83	0.47
26	52	8	8	17	5	9	9	3	16	3	4	49.90	0.46
26	54	4	8	16	10	4	2	2	20	3	4	49.99	0.46
26	56	9	7	14	5	9	9	1	19	1	4	50.01	0.46
26	50	5	4	12	5	6	6	1	19	2	1	50.06	0.46
26	28	9	6	12	5	8	7	2	19	1	1	50.26	0.45
26	26	8	3	13	9	9	4	1	18	4	1	50.38	0.45
26	45	8	8	17	4	9	6	3	20	4	2	50.53	0.44
27	60	7	8	8	10	8	7	3	12	1	2	50.61	0.44
26	32	6	5	13	4	10	8	2	17	3	1	50.61	0.44
27	39	5	7	8	9	5	2	4	19	3	2	50.69	0.40
27	50	8	5	8	7	4	5	4	19	3	4	50.71	0.40
27	31	9	6	8	7	10	7	1	16	2	1	50.80	0.40
27	53	6	5	8	5	10	9	2	20	1	2	50.92	0.40
27	59	8	8	9	10	7	9	2	20	2	3	51.02	0.37
27	37	9	5	9	10	8	5	4	16	1	2	51.08	0.37
27	48	8	5	10	8	10	1	4	19	4	2	51.18	0.36
27	51	9	5	10	9	7	4	3	20	1	4	51.24	0.36
27	38	7	8	17	8	10	4	4	19	3	2	51.31	0.35
27	37	9	5	16	10	4	9	3	18	4	4	51.37	0.35
27	38	8	6	12	10	9	9	1	19	1	2	51.40	0.35
27	36	8	8	18	10	4	9	1	19	2	1	51.51	0.35
27	50	8	6	11	5	4	10	4	19	4	4	51.58	0.35
27	32	4	5	15	7	10	9	4	17	1	4	51.72	0.35
27	39	4	5	13	5	8	4	3	16	4	4	51.83	0.34
27	56	8	3	10	8	8	7	4	19	1	4	51.92	0.34
27	37	9	3	14	8	6	4	4	20	3	4	52.03	0.34
27	34	5	7	18	4	6	2	2	19	2	2	52.25	0.32
28	45	8	5	8	6	9	4	2	20	3	1	52.36	0.31
28	60	5	8	8	8	5	4	1	18	2	2	52.36	0.31
28	53	4	5	8	9	8	1	2	20	2	1	52.70	0.30
28	59	8	6	11	10	6	9	3	15	4	1	52.91	0.27
28	51	7	5	17	9	7	5	3	20	4	1	52.99	0.26
28	58	7	6	13	10	10	1	1	19	3	4	52.99	0.26
28	58	9	6	13	10	8	2	4	19	1	2	52.99	0.26
28	37	9	8	15	8	7	8	1	18	2	1	53.06	0.26
28	54	5	8	16	9	5	3	1	17	1	2	53.12	0.26
28	50	5	4	18	10	4	5	3	17	2	1	53.17	0.26
28	54	5	8	16	5	6	3	3	17	4	3	53.22	0.26
28	36	8	8	14	5	5	7	1	19	3	1	53.31	0.25
28	22	7	6	12	7	4	9	4	19	1	2	53.77	0.25
28	51	9	3	18	8	6	5	3	20	2	4	53.87	0.25
29	56	7	8	8	9	8	1	1	16	2	4	53.89	0.24
29	38	7	7	8	10	10	1	2	20	1	3	53.90	0.24
29	54	5	5	8	9	8	1	1	19	1	4	54.06	0.23
29	40	7	5	9	8	9	1	2	20	4	2	54.22	0.21
29	39	6	5	10	10	9	3	3	20	3	4	54.40	0.21
29	54	7	5	10	9	10	1	3	19	4	1	54.45	0.20
29	44	6	6	11	10	10	1	1	18	1	3	54.61	0.20
29	59	9	8	15	6	8	7	4	19	2	4	54.62	0.20
29	54	7	8	18	8	9	8	2	20	2	1	54.63	0.20
29	57	7	6	15	8	4	8	3	20	2	2	54.64	0.20
29	29	7	5	12	6	7	2	1	19	2	4	54.69	0.20
29	35	6	4	11	5	9	3	1	17	4	2	54.88	0.20
29	35	5	4	14	5	10	3	1	17	2	2	55.02	0.19
29	38	7	8	11	4	9	1	3	18	3	1	55.46	0.19
29	59	7	8	12	4	8	8	3	19	2	4	55.46	0.18
30	37	9	6	8	8	9	4	2	20	4	1	55.53	0.18

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	DE	Kf	Km	Kmf	Ke	WIP	BL
30	57	9	4	8	10	10	7	4	18	3	4	55.60	0.18
30	29	5	4	8	10	4	6	2	18	1	2	55.85	0.18
30	35	7	5	9	7	10	9	1	13	4	4	55.85	0.17
30	37	9	6	9	9	10	1	2	20	4	1	55.92	0.16
30	60	8	6	10	10	10	10	4	20	1	4	56.08	0.16
30	31	7	6	10	6	5	1	4	17	2	2	56.11	0.16
30	57	9	4	10	10	6	3	2	18	3	2	56.17	0.16
30	49	8	7	11	8	7	3	1	17	4	2	56.18	0.15
30	60	7	8	10	6	6	4	1	20	2	1	56.21	0.15
30	30	6	6	17	10	8	8	4	19	2	4	56.24	0.15
30	58	9	5	18	9	6	5	1	20	3	4	56.28	0.15
30	59	7	4	10	6	6	7	2	19	1	2	56.29	0.15
30	53	7	5	12	6	4	8	4	17	2	2	56.30	0.15
30	49	7	6	17	10	4	4	4	18	2	1	56.34	0.15
30	49	8	4	12	6	7	5	2	17	4	2	56.36	0.15
30	31	6	4	13	10	10	7	4	20	2	1	56.42	0.15
30	58	9	6	11	5	9	9	1	18	4	1	56.46	0.15
30	51	8	5	13	5	4	3	1	20	2	1	56.69	0.15
30	26	5	8	15	5	5	6	1	18	1	4	56.90	0.15
30	26	8	4	13	5	4	8	3	18	4	1	57.00	0.14
30	57	5	8	10	4	6	2	1	18	3	2	57.14	0.14
30	51	5	6	12	4	10	10	1	18	1	3	57.32	0.14
31	39	5	8	8	10	5	4	1	19	4	1	57.34	0.14
31	40	7	5	9	7	7	10	4	13	4	4	57.41	0.13
30	57	5	4	15	4	6	7	1	19	4	1	57.60	0.13
31	46	9	5	10	7	7	5	1	18	4	1	57.81	0.12
31	36	9	5	14	10	5	9	2	14	4	4	57.85	0.12
31	56	6	5	18	10	9	9	2	19	4	2	57.89	0.11
31	37	9	5	18	9	10	10	3	20	4	1	57.94	0.11
31	56	6	4	18	5	10	9	2	17	1	4	58.35	0.11
31	37	7	5	9	4	9	8	1	17	4	1	58.47	0.11
31	33	4	6	12	10	8	8	4	20	4	2	58.56	0.11
32	50	8	8	8	8	9	10	2	16	2	1	58.77	0.11
32	52	6	5	8	10	9	1	3	20	1	4	58.81	0.11
32	57	9	8	8	10	4	2	1	20	3	2	58.84	0.10
32	33	8	4	8	10	4	9	3	20	4	2	59.05	0.10
32	50	6	5	8	5	4	2	2	20	1	2	59.12	0.10
32	60	7	8	9	5	5	4	4	16	1	3	59.38	0.09
32	39	7	6	12	6	8	2	4	18	2	4	59.48	0.09
32	60	5	5	13	10	8	10	3	19	4	2	59.61	0.09
32	51	7	5	11	5	7	4	3	18	2	1	59.69	0.08
32	52	6	6	18	5	9	4	2	17	4	2	59.79	0.08
32	37	7	8	18	5	10	1	4	18	1	3	59.82	0.08
32	51	7	5	12	5	4	2	4	18	2	2	59.85	0.08
32	39	8	6	12	5	4	10	1	19	3	4	59.91	0.08
32	37	9	4	18	7	4	9	4	19	1	2	59.91	0.08
32	56	8	8	10	4	8	7	4	16	2	2	60.23	0.08
33	57	6	8	8	7	9	10	2	18	1	4	60.45	0.08
32	38	7	4	16	4	9	9	3	19	1	3	60.83	0.08
33	60	8	7	10	10	10	9	2	20	3	4	60.94	0.07
33	33	6	7	10	7	5	1	3	18	4	1	61.05	0.07
33	46	9	7	14	10	6	9	3	19	1	4	61.18	0.07
33	39	9	7	14	10	6	9	2	18	3	1	61.19	0.07
33	58	6	5	12	10	4	1	4	16	4	1	61.24	0.07
33	36	6	5	12	7	4	3	1	18	4	3	61.26	0.06
33	59	9	6	17	9	4	10	1	20	1	2	61.33	0.06
33	39	6	7	13	5	5	1	2	18	4	1	61.47	0.06
33	47	6	7	18	5	5	2	2	19	3	1	61.54	0.06
34	51	8	6	8	8	4	2	2	19	4	1	62.13	0.06
34	53	8	8	8	7	4	3	1	20	2	4	62.13	0.06
33	58	8	6	11	4	10	1	1	16	1	4	62.13	0.06
34	38	8	5	8	7	4	4	2	19	4	1	62.17	0.06
34	51	8	6	8	5	9	2	1	19	1	4	62.31	0.06
34	53	8	8	8	5	4	3	4	20	1	4	62.35	0.06
34	56	7	8	9	6	8	10	1	20	4	2	62.53	0.05
34	52	9	6	10	7	7	5	3	18	4	4	62.59	0.05
34	35	9	6	10	9	10	2	1	20	4	1	62.72	0.05
34	37	9	8	12	8	7	8	3	20	2	4	62.72	0.05
34	40	8	8	12	8	9	6	3	20	1	2	62.80	0.05
34	30	8	8	15	10	9	10	4	18	2	4	62.88	0.05
34	34	7	5	15	10	4	4	2	18	4	4	62.90	0.05
34	58	9	8	18	10	4	1	4	20	2	1	62.92	0.05

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	DE	Kf	Km	Kmf	Ke	WIP	BL
34	33	5	7	10	5	5	8	4	20	4	4	63.04	0.05
34	49	6	8	14	5	9	10	4	18	4	2	63.07	0.05
34	51	9	5	18	9	4	7	3	20	1	1	63.30	0.05
34	30	5	8	15	5	5	4	2	20	1	2	63.50	0.05
34	30	5	8	17	5	8	4	1	20	1	2	63.55	0.04
34	51	8	5	11	4	6	1	4	20	2	1	63.79	0.04
34	53	7	6	18	4	10	5	1	20	3	4	63.91	0.04
34	54	8	8	13	4	4	9	1	20	2	1	64.31	0.04
35	59	9	7	12	9	10	1	3	18	4	2	64.37	0.04
35	59	9	7	11	6	9	3	3	19	4	4	64.39	0.04
35	50	7	7	11	9	7	4	4	20	4	1	64.40	0.04
35	57	9	8	18	9	5	5	2	20	2	2	64.46	0.04
35	46	5	7	13	9	10	1	2	20	1	4	64.77	0.03
35	59	9	7	12	4	9	5	1	19	2	2	65.44	0.03
36	32	8	6	9	7	8	4	2	19	1	4	65.85	0.03
36	58	7	8	14	10	4	1	1	19	1	2	66.27	0.03
36	50	9	6	18	5	10	9	1	18	3	3	66.49	0.03
36	32	8	6	14	9	6	3	3	18	1	1	66.55	0.03
37	57	9	8	8	10	4	2	1	20	3	3	67.07	0.02
37	60	9	8	10	9	5	9	3	19	2	1	67.61	0.02
37	51	8	7	10	6	9	4	2	17	2	1	67.64	0.02
37	60	7	7	14	10	4	7	4	19	3	4	67.80	0.02
37	60	7	8	14	10	7	3	1	20	3	4	67.81	0.02
38	36	7	7	8	10	9	1	1	19	1	2	68.78	0.02
38	39	8	7	9	10	4	1	1	20	4	2	69.14	0.01
38	49	8	7	11	8	7	3	4	20	4	1	69.34	0.01
38	31	7	5	14	10	7	1	3	16	2	4	69.72	0.01
39	57	8	8	8	6	8	3	2	20	2	2	70.31	0.01
39	57	8	7	8	6	4	1	2	20	4	2	70.37	0.01
39	35	9	6	9	9	10	2	4	19	3	4	70.73	0.01
39	57	9	6	10	5	7	1	4	20	4	4	71.09	0.01
39	32	8	6	18	5	6	7	2	18	1	4	71.65	0.01
39	59	5	6	15	9	7	4	1	20	3	4	71.72	0.01
39	46	5	7	16	5	9	4	4	20	4	1	72.01	0.01
39	58	6	7	11	4	8	4	2	17	4	2	72.03	0.01
40	59	9	7	12	9	8	1	1	18	1	4	72.78	0.01
40	34	9	5	12	9	7	9	2	19	2	1	73.02	0.01
40	46	6	5	15	9	10	1	2	19	3	1	73.09	0.01
40	46	9	6	12	4	8	7	4	18	1	4	73.77	0.01
41	39	6	8	9	7	5	2	1	20	1	2	74.31	0.01
41	59	9	5	9	9	10	10	3	17	3	1	74.31	0.01
41	34	9	8	13	8	6	3	3	17	4	2	74.46	0.00
41	39	8	7	16	7	6	5	2	20	1	4	74.48	0.00
41	60	9	5	12	7	5	1	4	18	3	4	74.58	0.00
41	43	5	6	18	8	7	3	2	19	2	4	75.21	0.00
41	36	7	5	12	4	9	9	1	18	1	4	75.84	0.00
42	59	9	6	12	10	4	4	1	19	3	4	76.16	0.00
42	58	7	6	15	5	10	1	4	20	1	4	76.46	0.00
43	60	8	7	8	9	5	7	1	16	3	2	76.95	0.00
43	50	7	8	9	10	4	1	3	19	2	4	77.41	0.00
43	39	7	7	10	9	4	10	4	20	4	4	77.62	0.00
43	60	7	8	14	8	5	9	4	19	1	2	77.80	0.00
44	50	7	7	8	10	9	1	4	19	4	1	78.68	0.00
44	39	7	6	8	10	6	3	1	16	1	3	78.81	0.00
44	57	8	8	8	5	9	1	1	18	1	4	78.90	0.00
43	59	9	8	14	4	5	1	4	19	2	2	78.93	0.00
44	58	9	7	15	10	9	1	4	13	4	4	79.36	0.00
45	36	9	6	8	5	7	6	1	18	1	2	80.81	0.00
45	49	7	6	10	7	9	5	1	20	3	4	81.02	0.00
45	54	6	8	12	5	10	7	4	19	2	3	81.53	0.00
45	36	9	6	14	5	6	9	1	15	2	1	81.73	0.00
46	57	8	7	9	5	9	1	4	18	4	4	82.49	0.00
46	57	6	6	11	5	9	4	3	18	4	1	83.33	0.00
46	57	9	6	17	4	6	8	2	18	3	3	84.01	0.00
47	57	9	8	17	9	6	4	2	18	2	4	84.36	0.00
48	59	8	8	9	5	9	1	3	19	3	1	85.89	0.00
48	59	8	8	9	5	10	2	3	20	4	1	85.91	0.00
48	50	9	8	15	9	10	10	2	19	4	4	86.03	0.00
48	39	8	7	11	6	7	4	4	17	3	4	86.07	0.00
48	34	7	8	15	8	4	6	2	19	3	3	86.94	0.00
48	57	9	6	17	4	4	5	2	19	4	3	87.76	0.00
48	59	6	5	18	4	8	9	3	17	4	1	88.98	0.00

HEKC-II - PAC OPTIMISED SETTINGS FOR UPPER PROCESSING TIME VARIABILITY

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	DE	Kf	Km	Kmf	Ke	WIP	BL
49	56	8	5	16	10	5	10	1	17	2	1	89.20	0.00
50	60	8	8	13	10	10	6	2	20	3	4	89.34	0.00
49	56	8	5	16	6	4	9	1	20	4	1	89.46	0.00
50	43	8	6	14	5	9	9	3	18	2	3	89.94	0.00
50	59	7	5	8	5	10	9	3	15	2	2	90.51	0.00
51	57	9	8	12	9	5	8	1	20	4	1	91.10	0.00
51	57	8	8	16	8	4	1	2	19	1	2	91.20	0.00
50	59	7	5	18	5	10	9	2	17	4	1	91.65	0.00
51	57	7	8	9	4	9	6	2	12	3	3	91.79	0.00
51	49	9	6	11	4	9	1	4	19	3	1	92.32	0.00
50	58	9	5	18	4	4	9	1	13	4	4	93.10	0.00
52	48	6	5	8	7	9	3	2	16	2	3	95.42	0.00
52	57	7	5	12	5	10	9	3	18	4	1	95.90	0.00
52	57	8	5	16	4	9	10	3	18	1	3	96.93	0.00

C4. HKC - PAC OPTIMISED SETTINGS FOR UPPER PROCESSING TIME VARIABILITY

Table C-4. Production Authorisation Card Settings for HKC Strategy 40HV

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	Kf	Km	Kmf	Ke	WIP	BL
20	31	8	8	6	7	10	3	14	4	4	37.38	11.70
20	59	4	3	6	9	9	4	20	2	1	37.52	11.70
20	56	3	3	6	6	7	4	15	4	1	37.80	11.67
19	22	7	8	7	8	8	4	18	1	1	37.99	9.05
19	54	7	6	9	8	7	2	18	4	3	38.13	7.62
19	54	6	7	9	8	7	2	18	4	3	38.13	7.62
19	54	7	6	16	7	10	4	18	3	4	38.17	7.54
19	54	4	7	9	8	7	3	12	4	3	38.17	7.55
19	32	7	4	18	10	5	2	12	2	2	38.18	7.53
19	31	7	4	17	6	5	3	14	2	2	38.19	7.49
19	38	7	4	18	10	7	2	12	2	1	38.27	7.48
19	29	8	3	11	5	10	4	18	2	2	38.30	7.38
19	54	6	7	13	5	10	2	20	1	4	38.32	7.35
19	21	5	6	10	5	10	4	19	4	1	38.37	7.32
19	21	7	7	10	5	10	4	19	4	1	38.38	7.30
19	21	8	8	8	4	7	3	15	2	3	38.61	7.02
19	38	8	7	10	4	7	3	18	3	4	38.71	6.89
19	38	7	6	18	4	7	3	12	4	1	38.86	6.83
20	36	5	8	7	7	10	3	11	4	2	39.07	5.49
20	36	4	8	7	9	10	3	11	2	2	39.09	5.44
20	53	9	8	7	10	4	4	20	4	3	39.14	5.31
20	50	9	8	7	9	10	1	15	4	1	39.25	5.26
20	34	4	3	7	5	10	3	17	2	1	39.37	5.14
20	35	5	3	7	5	4	3	15	2	1	39.43	5.08
20	25	8	5	8	10	7	4	16	1	3	39.62	4.45
20	25	4	5	8	9	7	1	18	2	1	39.75	4.43
20	36	8	5	16	8	9	3	20	2	4	39.76	4.27
20	53	7	8	10	9	5	4	20	4	4	39.76	4.32
20	25	7	5	18	9	5	3	20	2	4	39.79	4.27
20	25	7	7	13	7	9	2	20	4	4	39.79	4.27
20	34	6	8	14	10	5	4	20	1	2	39.84	4.24
20	31	7	8	15	10	9	1	19	4	4	39.86	4.24
20	31	7	8	10	5	9	2	15	3	4	39.90	4.21
20	58	7	4	17	5	10	4	15	3	4	39.91	4.20
20	49	6	3	10	5	7	4	15	4	3	39.94	4.20
20	31	7	5	11	4	7	2	18	2	4	40.35	3.97
20	34	8	8	11	4	10	2	13	2	2	40.37	3.96
20	50	9	8	13	4	10	3	15	1	4	40.40	3.94
20	25	8	4	12	4	7	2	15	3	3	40.40	3.95
20	25	6	7	17	4	9	2	14	1	2	40.43	3.94
21	26	8	8	7	8	10	2	13	3	4	40.48	3.54
21	43	5	8	7	8	9	4	15	1	3	40.55	3.50
21	43	5	8	7	6	9	4	15	1	4	40.58	3.49
21	30	7	8	7	9	5	1	15	2	4	40.60	3.47
21	38	7	4	8	8	7	4	13	4	4	41.09	2.88
21	55	7	5	8	9	10	1	20	2	2	41.19	2.86
21	55	7	3	8	8	10	4	18	1	3	41.23	2.84
21	35	7	8	10	10	9	4	16	4	2	41.34	2.71
21	30	6	5	14	10	10	4	20	4	4	41.37	2.71
21	42	7	4	10	10	7	4	13	1	2	41.40	2.69
21	42	7	4	17	6	7	3	13	4	4	41.40	2.70
21	38	5	8	17	8	9	3	15	1	3	41.42	2.68
21	54	8	6	9	5	6	4	19	4	2	41.42	2.67
21	39	6	5	14	6	9	2	15	3	1	41.48	2.67
21	42	7	4	17	5	7	4	15	3	4	41.51	2.65
21	31	6	3	18	6	4	3	19	3	3	41.57	2.65
21	38	6	8	18	5	7	4	19	4	1	41.58	2.64
21	55	6	3	18	5	7	1	20	1	4	41.75	2.62
22	42	6	4	7	10	5	3	13	3	1	41.96	2.55
21	31	9	7	10	4	9	2	15	4	4	41.97	2.51

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	Kf	Km	Kmf	Ke	WIP	BL
21	42	5	8	18	4	5	1	17	4	1	42.28	2.50
21	29	5	8	10	4	4	3	15	1	2	42.35	2.48
22	34	4	8	7	4	7	2	13	4	1	42.71	2.35
22	39	7	8	10	10	10	4	10	4	2	42.87	2.15
22	22	8	5	9	8	5	4	17	3	3	42.94	1.86
22	24	7	7	10	8	5	2	19	3	4	42.96	1.82
22	43	8	7	14	10	5	3	20	3	2	42.97	1.81
22	29	6	8	13	10	5	3	15	1	3	43.02	1.81
22	24	7	8	10	10	5	3	14	4	1	43.04	1.81
22	22	8	8	13	10	5	2	17	2	3	43.06	1.81
22	35	5	8	12	6	7	2	20	3	1	43.08	1.80
22	30	6	5	14	5	9	2	20	3	4	43.10	1.78
22	31	7	8	13	4	9	3	15	1	4	43.70	1.69
22	26	7	8	10	4	4	1	20	4	3	44.02	1.68
23	30	7	5	8	10	5	1	11	3	4	44.08	1.56
23	53	9	8	8	10	5	3	12	1	4	44.11	1.46
23	54	7	8	9	5	7	2	18	4	4	44.52	1.29
23	35	7	7	10	10	7	4	16	1	3	44.53	1.28
23	30	6	8	11	8	10	3	15	4	3	44.54	1.28
23	32	6	6	16	8	10	1	20	3	4	44.65	1.26
23	32	6	6	16	8	6	1	20	3	3	44.66	1.26
23	31	6	7	14	5	10	2	15	1	4	44.75	1.25
23	30	6	5	17	5	5	1	15	3	3	44.84	1.24
23	30	7	8	11	4	10	3	15	4	3	45.24	1.21
23	30	6	8	11	4	10	3	15	2	3	45.25	1.20
23	30	6	8	11	4	10	3	15	3	3	45.25	1.21
23	28	8	7	17	4	10	2	20	1	3	45.30	1.19
23	22	7	5	16	4	9	4	20	4	1	45.52	1.18
24	34	8	5	8	10	6	2	20	3	1	45.70	1.04
24	41	7	6	9	9	9	4	19	4	4	45.94	0.95
24	54	6	5	10	10	7	3	13	1	2	46.11	0.94
24	34	8	5	18	10	8	3	20	2	2	46.15	0.91
24	57	9	8	16	9	7	2	20	3	1	46.23	0.91
24	57	6	7	16	9	7	2	20	2	1	46.24	0.91
24	40	6	4	18	6	4	4	19	2	1	46.38	0.90
24	20	7	8	17	6	7	1	19	4	4	46.82	0.89
24	35	7	4	17	4	7	4	19	2	4	46.89	0.86
25	54	6	6	8	7	8	4	19	4	4	47.14	0.78
25	56	7	6	8	10	9	1	19	4	2	47.22	0.78
25	56	7	6	8	8	10	1	19	1	2	47.30	0.78
25	56	9	4	8	5	6	1	19	2	2	47.41	0.76
25	29	7	5	10	10	9	3	14	1	3	47.67	0.69
25	54	6	5	10	7	8	3	14	1	4	47.68	0.68
25	30	7	8	10	10	9	1	16	4	3	47.71	0.67
25	26	7	7	14	8	7	4	14	3	2	47.77	0.67
25	43	6	6	14	9	9	3	15	1	4	47.78	0.66
25	25	8	7	14	8	7	4	16	3	4	47.79	0.66
25	32	8	7	18	8	10	2	19	2	1	47.84	0.66
25	30	7	8	10	4	10	1	17	1	4	48.53	0.65
25	30	7	8	10	4	9	1	16	1	2	48.56	0.64
26	43	5	7	8	10	9	1	19	4	2	48.78	0.59
26	42	5	7	8	8	5	1	19	4	4	48.78	0.60
26	56	5	3	8	8	10	4	18	4	3	49.16	0.58
26	28	8	5	10	10	9	2	19	3	2	49.23	0.50
26	29	7	7	10	5	9	4	20	4	4	49.38	0.49
26	25	9	5	17	9	6	3	19	3	2	49.43	0.48
26	48	5	8	16	9	5	1	19	3	4	49.47	0.48
26	35	7	7	13	5	8	1	20	4	4	49.63	0.48
26	24	7	3	11	10	7	4	19	1	4	49.96	0.46
26	58	9	8	16	4	7	3	19	2	2	50.20	0.45
26	35	7	7	13	4	5	4	20	3	4	50.27	0.45
27	30	7	8	10	10	10	4	19	3	4	50.80	0.37
27	59	7	5	18	9	9	4	20	1	2	51.05	0.36
27	59	7	6	18	5	9	4	20	4	2	51.16	0.35
27	32	6	4	14	10	4	2	19	3	1	51.18	0.35
27	59	8	3	18	8	9	4	20	3	2	51.63	0.35
28	27	9	7	14	8	10	2	15	3	3	52.63	0.28
28	54	8	4	16	7	10	3	15	3	1	52.76	0.27
28	31	5	7	18	5	10	4	20	4	2	52.84	0.26
28	28	7	7	13	5	4	4	20	2	3	52.96	0.26
28	28	9	3	13	10	10	2	15	4	1	53.61	0.26
28	28	9	3	17	8	8	1	17	1	4	53.70	0.26

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	Kf	Km	Kmf	Ke	WIP	BL
28	28	9	4	13	4	10	1	15	2	2	53.75	0.26
29	34	6	5	13	9	9	4	14	2	4	54.17	0.22
29	37	7	5	18	7	5	4	20	2	4	54.24	0.21
29	42	5	7	18	9	5	3	17	4	4	54.27	0.20
29	34	7	5	18	4	7	4	20	1	4	55.19	0.19
30	43	7	6	17	9	9	3	15	1	3	55.89	0.16
30	57	9	4	18	10	10	3	20	1	2	56.06	0.15
30	30	7	4	11	4	8	3	15	4	4	56.85	0.15
30	26	7	6	16	4	9	1	20	3	4	57.16	0.14
31	27	8	8	10	10	5	2	17	2	4	57.39	0.13
31	26	7	8	10	10	4	1	20	2	2	57.66	0.12
31	26	7	8	10	10	4	1	20	2	4	57.66	0.12
31	25	7	8	18	9	6	1	17	3	1	58.07	0.12
32	42	7	8	10	9	4	4	16	2	4	58.94	0.10
32	43	6	7	14	10	9	3	15	1	2	59.16	0.09
32	43	5	7	14	8	9	3	15	4	2	59.22	0.09
32	42	7	7	14	6	4	2	15	4	1	59.39	0.09
32	43	7	8	15	10	5	1	17	1	1	59.64	0.08
32	43	6	6	14	4	9	3	15	1	2	60.23	0.08
33	36	7	7	17	8	6	3	20	1	4	60.83	0.07
33	29	6	8	17	8	4	1	19	1	2	61.17	0.07
33	28	5	8	17	8	9	1	15	1	4	61.31	0.07
33	29	7	8	17	4	10	1	19	2	2	62.04	0.06
33	40	6	8	17	4	5	4	15	1	4	62.12	0.06
34	33	8	8	10	9	10	2	13	1	3	62.14	0.06
34	32	7	7	10	9	9	2	16	1	2	62.25	0.05
34	35	7	7	10	4	9	4	16	4	2	63.03	0.05
34	33	8	7	10	4	10	4	20	1	3	63.12	0.05
35	54	8	7	10	10	9	3	14	1	4	63.80	0.04
35	54	7	5	10	9	9	3	14	1	4	63.85	0.04
35	54	6	6	10	9	9	3	14	1	4	63.85	0.04
35	30	7	8	10	4	9	2	16	4	2	64.86	0.04
35	30	7	4	10	4	9	4	15	4	2	65.38	0.04
36	36	6	8	10	9	9	1	15	4	4	65.55	0.03
36	40	7	7	17	8	9	4	15	3	3	65.74	0.03
36	40	6	8	17	8	6	4	15	1	4	65.81	0.03
36	36	7	8	17	8	6	1	17	4	2	65.84	0.03
37	34	7	5	18	9	10	4	20	1	4	67.58	0.02
37	28	7	4	10	8	9	2	20	3	1	68.52	0.02
37	28	8	7	10	4	9	2	20	4	1	68.77	0.02
38	43	9	7	10	5	7	1	19	1	2	69.13	0.01
38	40	6	8	17	7	10	4	15	1	4	69.20	0.01
38	28	8	7	10	9	9	1	20	4	4	69.58	0.01
38	29	5	5	18	7	9	3	15	4	2	70.07	0.01
39	48	7	7	14	9	8	2	16	4	2	70.65	0.01
40	34	9	8	13	10	9	3	15	3	4	72.36	0.01
40	35	7	7	13	6	6	2	15	4	4	72.43	0.01
40	34	9	8	10	4	9	1	19	1	4	73.23	0.01
41	60	7	8	14	8	8	4	13	4	3	73.96	0.01
42	44	7	8	10	10	10	1	13	3	2	75.38	0.00
42	35	6	8	10	7	10	2	20	3	4	75.65	0.00
42	35	7	7	10	5	9	2	20	1	4	75.79	0.00
42	40	6	7	17	7	10	1	15	1	4	76.04	0.00
42	35	7	7	10	4	10	2	20	1	4	76.54	0.00
42	35	7	7	10	4	6	2	20	1	3	76.55	0.00
43	30	7	8	10	6	9	2	15	3	4	78.19	0.00
44	55	8	7	10	10	7	2	17	1	2	78.79	0.00
44	55	8	7	10	5	7	4	16	1	2	79.01	0.00
44	55	8	8	10	4	7	2	17	4	2	79.69	0.00
44	54	8	7	10	4	5	2	17	4	4	79.76	0.00
45	40	7	8	17	8	7	1	19	4	4	80.83	0.00
45	36	7	8	15	6	9	1	20	3	4	81.01	0.00
45	36	7	7	15	4	4	1	20	3	4	82.48	0.00
46	54	7	7	18	5	9	4	16	4	2	82.71	0.00
46	54	7	6	18	4	9	4	16	4	2	83.62	0.00
47	55	9	5	9	5	7	4	18	3	2	84.53	0.00
48	38	7	8	18	10	4	3	20	1	4	86.02	0.00
48	35	7	8	10	5	7	1	20	2	4	86.27	0.00
48	35	7	6	13	5	8	4	17	4	4	86.62	0.00
48	35	7	8	13	4	8	3	20	4	4	87.31	0.00
49	38	7	7	10	5	8	2	20	4	3	87.58	0.00
50	35	7	7	10	9	4	1	17	3	4	89.77	0.00

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	Kf	Km	Kmf	Ke	WIP	BL
51	40	7	8	17	8	7	3	20	1	4	91.04	0.00
51	40	7	7	17	8	7	2	20	1	4	91.06	0.00
52	43	7	7	10	10	7	4	14	3	4	92.24	0.00
54	39	7	8	17	7	4	1	20	1	3	96.62	0.00
55	35	7	7	10	10	4	1	14	1	2	99.95	0.00

C5. DNC HEKC-II - PAC OPTIMISED SETTINGS FOR LOWER PROCESSING TIME VARIABILITY

Table C-5. Production Authorisation Card Settings for DNC HEKC-II Strategy 40LV

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	MP	Kf	Km	Kmf	Ke	DE	WIP	BL
11	22	7	7	4	8	7	6	3	12	1	4	7	33.68	11.64
11	34	5	7	4	6	7	6	1	16	4	4	5	33.68	11.64
11	47	5	3	4	4	7	6	1	13	3	1	9	33.69	11.62
11	42	4	4	4	5	3	6	1	8	2	4	4	33.69	11.61
12	43	5	7	4	7	3	5	1	13	2	4	5	33.74	11.36
12	46	6	7	4	7	5	5	2	13	4	2	7	33.74	11.36
12	46	7	2	4	8	5	5	2	16	1	4	8	33.79	11.33
12	46	4	2	4	4	5	5	4	11	1	1	5	33.79	11.32
12	21	7	6	4	3	7	5	1	13	3	4	9	33.81	11.25
12	30	7	7	4	3	3	5	2	16	1	2	3	33.85	11.20
12	16	7	4	4	3	3	5	1	13	1	1	5	33.87	11.17
13	46	3	5	5	6	6	4	1	10	2	4	4	33.87	10.91
13	47	6	2	5	5	7	4	1	11	2	4	6	33.92	10.88
12	46	3	7	7	7	3	5	1	8	4	2	8	34.05	10.87
12	48	4	2	5	3	6	5	1	16	1	1	9	34.05	10.85
12	16	7	3	5	3	3	5	1	11	1	3	5	34.06	10.79
13	48	7	7	7	7	8	4	2	11	1	3	10	34.08	10.59
13	48	3	3	7	6	7	4	1	11	4	4	6	34.09	10.59
13	48	3	5	7	4	8	4	2	15	4	2	10	34.10	10.58
13	28	7	7	6	3	6	4	4	15	1	4	2	34.11	10.49
15	37	5	6	6	8	6	2	1	13	3	1	5	34.18	10.15
15	36	7	7	7	5	4	2	1	10	4	1	1	34.32	9.95
15	47	5	5	7	5	5	2	1	12	4	2	8	34.32	9.93
15	33	5	7	9	8	3	2	4	14	2	1	4	34.39	9.90
15	45	7	5	13	5	5	2	4	10	3	3	6	34.39	9.89
15	47	3	5	11	8	7	2	4	16	4	1	8	34.41	9.88
12	48	6	4	4	6	7	6	3	11	1	1	1	34.44	6.61
12	40	6	4	4	6	6	6	3	11	1	1	5	34.44	6.60
12	45	7	4	4	5	3	6	1	9	1	1	4	34.44	6.59
12	35	3	7	4	8	8	6	4	11	3	2	10	34.45	6.59
12	45	7	3	4	5	3	6	1	8	1	2	4	34.47	6.55
12	39	3	6	4	5	4	6	4	8	4	3	3	34.47	6.55
12	47	7	7	4	5	8	6	1	7	4	4	3	34.50	6.50
13	26	7	7	4	7	3	5	1	11	1	4	6	34.54	6.34
13	27	5	7	4	8	7	5	2	13	2	1	4	34.54	6.34
13	25	4	6	4	8	7	5	2	13	2	3	5	34.54	6.34
13	47	4	6	4	6	8	5	1	13	1	4	2	34.54	6.34
13	23	5	4	4	6	7	5	1	16	4	3	2	34.54	6.34
13	26	3	4	4	6	3	5	1	10	2	3	6	34.55	6.33
13	47	3	6	4	7	8	5	1	13	4	4	4	34.55	6.33
13	43	3	4	4	7	4	5	3	12	2	1	9	34.55	6.33
13	25	3	6	4	6	5	5	4	13	3	4	2	34.56	6.33
13	47	6	7	4	5	8	5	1	7	4	1	10	34.59	6.28
13	23	5	3	4	3	6	5	1	15	1	2	3	34.66	6.25
13	23	5	3	4	3	6	5	1	12	1	4	3	34.66	6.25
13	43	6	5	4	3	8	5	1	9	3	4	8	34.67	6.25
13	27	6	2	4	3	7	5	2	13	4	4	2	34.75	6.24
13	47	6	2	4	3	8	5	1	15	2	2	2	34.75	6.24
12	48	5	3	5	7	3	6	3	12	4	4	8	34.77	6.07
14	42	6	6	5	3	8	4	2	16	1	3	1	34.89	5.82
14	21	6	6	5	3	4	4	3	13	2	4	2	34.89	5.81
13	40	5	4	4	6	7	6	2	11	2	2	4	34.91	5.27
13	45	7	4	4	5	3	6	1	13	4	4	1	34.91	5.26
13	45	7	3	4	5	3	6	1	9	4	1	1	34.92	5.25
13	38	4	6	4	5	4	6	2	7	3	1	8	34.99	5.17
14	44	6	6	4	6	7	5	2	13	3	2	5	35.05	5.02
14	27	7	4	4	5	3	5	3	13	4	4	4	35.05	5.02
14	28	7	3	4	3	7	5	4	12	4	3	1	35.19	4.99
14	27	7	3	4	3	7	5	2	12	1	4	1	35.19	4.99
14	24	3	6	4	3	7	5	4	16	1	3	4	35.21	4.97

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	MP	Kf	Km	Kmf	Ke	DE	WIP	BL
14	46	5	4	4	6	8	6	3	13	2	4	4	35.27	4.73
14	24	3	4	4	5	7	6	1	10	2	1	4	35.30	4.73
11	24	7	5	4	7	8	8	2	15	1	1	9	35.35	4.60
11	26	6	4	4	4	3	8	3	16	4	3	5	35.37	4.59
11	47	3	4	4	8	7	8	2	9	2	4	2	35.38	4.59
11	43	4	6	4	7	8	8	2	8	2	1	4	35.38	4.58
11	45	7	3	4	5	8	8	2	7	4	3	4	35.44	4.54
12	46	4	4	4	5	8	7	4	14	1	2	3	35.44	4.41
12	46	4	7	4	6	3	7	4	12	1	4	7	35.44	4.41
12	45	5	4	4	5	7	7	4	8	1	4	3	35.47	4.39
12	48	3	6	4	8	4	7	3	8	4	2	8	35.49	4.38
12	47	3	3	4	5	8	7	4	7	1	1	9	35.55	4.34
13	43	5	5	5	5	8	6	3	11	3	1	4	35.62	4.06
14	44	4	5	5	6	6	5	4	13	2	1	5	35.79	3.83
14	24	7	5	5	8	3	5	4	10	4	4	4	35.79	3.83
14	46	4	3	5	5	7	5	3	11	2	1	2	35.79	3.83
14	19	7	7	5	8	3	5	1	9	1	4	3	35.81	3.82
14	40	4	2	5	4	3	5	3	11	2	2	5	35.96	3.79
12	47	5	6	4	6	8	8	1	16	3	4	10	35.98	3.60
12	47	5	4	4	5	5	8	3	16	1	4	2	35.98	3.60
12	34	5	3	4	5	8	8	1	9	4	4	4	35.99	3.60
12	47	6	4	4	4	8	8	1	8	3	3	10	36.04	3.57
15	47	5	3	6	8	3	4	3	11	3	1	6	36.08	3.46
13	25	5	4	4	6	7	7	2	10	2	1	4	36.09	3.42
13	27	7	5	4	6	8	7	1	10	1	1	2	36.09	3.41
13	28	3	3	4	8	8	7	4	16	1	4	1	36.12	3.41
13	48	3	7	4	6	3	7	4	15	3	4	2	36.12	3.41
13	28	5	7	4	5	3	7	4	7	2	1	2	36.24	3.34
14	37	6	6	5	7	7	6	1	14	3	4	8	36.35	3.03
13	47	6	4	4	8	5	8	4	13	1	4	5	36.48	3.02
13	43	6	7	4	5	4	8	4	13	4	1	4	36.48	3.02
13	48	6	5	4	8	3	8	4	16	2	4	3	36.48	3.02
14	25	4	4	5	5	5	6	4	7	4	2	10	36.48	3.00
13	34	4	6	4	6	7	8	1	8	1	1	2	36.54	2.98
13	47	5	4	4	8	7	8	1	8	2	4	5	36.54	2.98
15	22	7	7	5	6	3	5	3	13	1	4	1	36.56	2.78
15	48	7	3	5	5	3	5	1	13	1	3	5	36.57	2.78
15	37	6	3	5	4	3	5	3	12	4	4	3	36.59	2.78
14	46	5	7	4	6	8	8	1	13	2	4	1	36.84	2.69
14	48	5	6	4	5	4	8	3	13	3	4	2	36.84	2.69
14	48	5	4	4	5	3	8	2	16	4	3	6	36.84	2.69
14	47	4	4	4	5	7	8	1	8	2	4	5	36.92	2.64
15	46	6	7	5	8	4	6	2	13	4	1	1	36.95	2.42
15	43	4	4	5	6	3	6	4	13	3	4	7	36.95	2.42
15	25	7	4	5	5	3	6	3	13	4	3	5	36.96	2.42
15	21	7	2	5	6	3	6	1	13	1	2	7	37.19	2.41
16	48	7	4	5	5	3	5	1	13	1	4	5	37.23	2.21
16	46	7	6	5	5	3	5	1	16	4	2	10	37.23	2.20
16	18	3	3	5	8	4	5	1	9	1	2	9	37.34	2.19
17	37	5	7	4	6	7	7	2	13	3	1	7	37.69	2.05
17	25	5	4	4	8	4	8	2	11	2	4	10	37.72	2.05
17	47	5	7	4	4	4	8	3	15	1	2	3	37.72	2.04
17	25	6	3	4	6	8	8	1	11	1	4	4	37.72	2.04
17	33	4	5	6	8	5	4	3	16	4	1	5	37.77	1.88
17	40	5	6	5	4	7	5	1	11	1	2	3	37.83	1.86
18	47	7	5	6	6	3	3	3	7	3	1	4	38.20	1.80
18	26	7	6	6	6	6	3	3	10	4	3	5	38.31	1.63
18	47	7	6	5	6	4	5	2	12	4	1	8	38.41	1.60
18	28	7	3	5	5	8	5	1	11	2	2	5	38.42	1.60
18	46	4	4	5	5	8	6	3	14	1	1	4	38.47	1.58
18	37	4	6	5	6	3	6	4	16	4	1	1	38.47	1.58
18	37	6	5	5	6	3	6	4	13	3	4	2	38.47	1.58
18	36	7	4	5	5	3	6	4	16	4	4	3	38.47	1.58
18	48	4	3	6	8	4	4	2	8	4	4	9	38.59	1.53
17	37	6	5	6	6	3	5	1	13	3	1	9	38.61	1.53
18	47	3	3	6	6	3	4	3	10	1	1	4	38.66	1.50
17	26	7	6	5	8	7	7	4	14	2	1	3	38.89	1.47
17	47	6	7	5	7	8	8	1	14	2	4	5	39.00	1.44
19	28	7	3	5	5	8	6	1	16	2	4	7	39.08	1.37
18	46	5	6	7	5	3	4	3	11	1	3	8	39.19	1.29
19	28	7	4	6	6	8	4	4	9	2	2	3	39.34	1.25
19	47	7	7	6	6	8	4	4	13	3	3	2	39.35	1.24

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	MP	Kf	Km	Kmf	Ke	DE	WIP	BL
19	47	5	3	6	4	8	4	4	11	1	4	1	39.37	1.24
18	47	4	3	6	4	3	5	1	12	4	4	8	39.43	1.22
18	29	7	4	7	6	8	5	4	10	3	2	2	39.73	1.16
19	40	7	5	7	6	8	3	1	13	4	2	2	39.85	1.09
19	40	5	3	7	4	8	4	3	12	3	3	2	40.14	1.00
19	46	4	4	6	6	7	5	1	12	2	3	4	40.14	0.99
19	46	5	6	6	4	7	5	1	15	1	3	4	40.16	0.99
19	40	7	7	9	7	8	4	4	10	3	2	2	40.48	0.96
19	41	7	5	9	6	3	4	2	13	3	4	7	40.50	0.96
19	45	7	7	13	4	8	4	1	13	1	2	1	40.52	0.96
19	26	4	7	10	6	3	4	4	16	4	4	8	40.53	0.96
19	48	4	3	14	4	3	4	2	16	4	4	5	40.60	0.95
19	25	6	6	7	8	3	6	3	15	4	1	3	40.76	0.88
20	43	6	7	9	6	4	2	1	16	4	4	8	40.93	0.87
20	47	6	7	10	8	7	2	2	10	2	4	3	40.96	0.87
19	22	4	4	8	6	3	6	3	14	2	1	7	40.96	0.87
19	38	5	7	14	5	6	6	1	14	2	4	4	40.99	0.86
19	34	6	4	7	8	7	8	4	15	3	3	9	41.07	0.84
19	32	4	3	7	7	7	8	3	12	2	1	1	41.09	0.84
19	35	6	7	14	5	8	7	2	15	3	4	1	41.13	0.84
19	40	6	5	12	6	6	7	3	13	3	1	2	41.13	0.84
19	42	4	7	10	6	4	7	4	16	3	3	3	41.14	0.84
20	46	3	4	6	4	4	5	1	12	1	2	6	41.19	0.79
20	25	6	5	14	6	7	3	1	12	2	3	4	41.29	0.78
20	44	6	4	8	5	5	4	1	9	2	2	5	41.43	0.75
20	47	6	7	6	6	6	7	2	9	2	2	10	41.47	0.74
20	47	4	5	6	6	5	8	1	14	1	4	1	41.50	0.73
20	37	6	5	7	6	3	6	1	13	1	1	4	41.60	0.71
20	46	7	4	12	8	4	5	4	12	1	2	6	41.73	0.70
20	42	6	5	8	8	3	6	4	13	1	4	4	41.81	0.69
20	47	4	4	8	5	3	6	2	11	4	4	2	41.82	0.69
20	45	5	5	7	6	7	8	2	11	4	4	9	41.83	0.68
20	47	5	6	7	4	3	8	3	15	2	2	3	41.92	0.68
20	47	4	4	8	8	5	8	2	14	4	4	1	41.97	0.66
21	48	7	5	6	6	4	6	1	15	4	3	3	41.98	0.63
21	47	5	7	9	8	6	2	1	10	2	4	2	42.22	0.62
21	46	3	3	6	4	4	5	1	13	1	1	5	42.23	0.62
21	47	7	7	10	6	4	2	3	10	1	3	3	42.27	0.62
21	47	4	6	10	6	4	2	3	14	1	1	2	42.28	0.62
21	22	6	7	6	6	7	7	2	16	1	3	4	42.37	0.59
21	24	7	3	6	8	3	8	4	16	1	4	1	42.42	0.59
21	37	7	5	10	6	8	3	2	13	3	4	3	42.50	0.58
21	32	6	4	13	6	5	3	2	13	3	3	5	42.50	0.58
21	23	7	5	14	5	6	3	1	12	1	2	4	42.52	0.58
21	48	7	6	8	4	6	3	3	15	1	2	9	42.53	0.58
21	19	7	4	8	5	3	3	3	12	2	3	8	42.58	0.57
21	37	7	5	8	6	3	5	1	13	2	4	3	42.74	0.54
21	37	6	6	11	6	8	5	1	13	2	1	3	42.78	0.54
21	46	7	3	9	5	3	5	3	11	1	4	10	42.84	0.53
21	21	6	4	8	5	3	6	1	13	2	1	5	42.85	0.53
21	45	5	4	14	8	8	6	4	12	3	2	5	42.85	0.53
21	28	5	6	8	8	5	8	2	15	4	4	2	42.88	0.52
21	34	6	3	8	8	6	8	4	15	1	3	2	42.91	0.52
21	47	7	4	11	6	6	8	2	14	2	4	2	42.93	0.52
21	48	6	3	10	7	7	8	1	15	4	3	3	42.96	0.52
21	48	6	3	12	4	3	8	3	13	4	4	1	43.07	0.52
22	43	5	6	6	6	3	6	4	11	4	3	2	43.07	0.49
22	48	7	5	6	6	4	8	1	15	3	4	2	43.37	0.46
22	39	6	4	6	8	3	8	2	12	1	4	5	43.38	0.46
22	46	4	3	7	6	7	4	1	11	1	3	6	43.42	0.45
22	45	6	7	10	8	4	2	4	10	3	3	5	43.64	0.44
22	43	7	7	11	5	7	2	4	13	1	2	1	43.65	0.44
22	35	7	5	14	5	7	2	3	11	1	2	4	43.66	0.44
22	42	4	4	8	6	3	3	1	11	4	2	10	43.72	0.42
22	36	7	6	7	6	4	8	3	15	1	4	1	43.79	0.41
22	41	5	4	14	4	4	4	1	12	2	1	10	43.93	0.41
22	45	7	3	9	8	3	4	3	12	4	1	2	43.94	0.41
22	39	6	5	12	6	8	5	4	11	3	2	3	43.95	0.40
22	48	5	7	14	8	8	5	4	14	2	1	3	43.95	0.40
22	45	4	4	9	5	8	6	1	16	1	1	3	43.98	0.40
22	47	4	4	10	6	4	6	1	16	1	2	2	44.00	0.40
22	43	7	7	11	7	6	7	4	10	4	2	5	44.01	0.40

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	MP	Kf	Km	Kmf	Ke	DE	WIP	BL
22	46	7	7	14	6	8	7	4	15	1	3	3	44.01	0.40
22	41	5	7	14	8	8	7	4	13	3	2	5	44.01	0.40
22	41	6	7	11	8	4	7	4	13	3	1	5	44.01	0.40
22	45	4	3	8	8	5	8	2	12	4	4	3	44.02	0.40
22	34	6	4	12	8	4	8	2	12	4	4	9	44.02	0.40
22	37	5	3	14	6	6	7	1	15	1	4	2	44.06	0.39
22	28	5	5	12	5	3	7	2	10	4	4	8	44.06	0.39
22	43	5	3	11	6	8	8	4	13	3	4	4	44.07	0.39
22	48	6	4	14	8	3	8	1	14	1	2	3	44.07	0.39
22	40	6	5	11	5	3	8	2	12	2	1	2	44.08	0.39
23	36	7	6	6	7	3	5	1	11	3	4	9	44.28	0.38
23	37	6	3	6	6	3	6	1	10	1	3	9	44.32	0.38
23	47	4	3	6	6	8	6	2	16	3	4	1	44.35	0.38
23	32	7	7	6	6	7	7	4	16	4	4	4	44.51	0.36
23	47	6	3	6	5	6	8	1	16	1	1	4	44.59	0.36
23	36	7	4	6	4	3	7	1	16	4	1	10	44.60	0.36
23	24	6	6	6	4	3	7	4	16	3	1	2	44.62	0.36
23	24	6	3	7	5	7	3	1	12	3	1	4	44.77	0.33
23	25	5	3	7	8	3	3	3	16	1	4	3	44.79	0.33
23	24	7	7	8	6	6	2	2	11	3	3	4	44.84	0.33
23	46	5	6	8	7	3	2	2	13	2	4	3	44.89	0.33
23	48	6	6	8	8	6	3	4	15	1	2	2	45.02	0.31
23	48	7	7	8	7	6	3	4	11	1	3	4	45.02	0.31
23	23	7	4	7	8	3	8	1	11	3	3	2	45.07	0.31
23	29	7	3	7	7	3	8	3	15	1	2	7	45.11	0.31
23	48	7	4	8	7	6	6	4	12	2	3	1	45.16	0.30
23	27	7	4	8	6	6	6	2	11	3	2	4	45.16	0.30
23	46	6	6	8	7	3	5	3	11	1	4	3	45.21	0.30
23	31	6	6	8	8	6	8	1	15	1	1	2	45.21	0.30
23	25	7	5	12	7	8	6	3	10	2	1	3	45.27	0.30
23	25	7	4	13	7	8	6	3	10	3	1	8	45.27	0.30
23	45	7	4	14	8	6	7	3	11	1	1	2	45.27	0.29
23	45	6	5	10	6	7	8	1	11	1	4	10	45.28	0.29
23	47	5	7	9	4	7	8	3	15	2	2	5	45.31	0.29
23	48	7	3	9	5	3	6	2	16	4	2	6	45.39	0.29
23	47	5	4	14	4	3	8	1	11	3	2	8	45.42	0.29
23	43	6	3	11	4	3	8	2	14	1	3	9	45.49	0.29
23	43	3	6	10	8	5	7	4	13	4	1	7	45.67	0.29
23	43	3	6	10	8	4	8	4	13	3	1	2	45.68	0.29
23	18	7	6	13	4	5	7	4	12	3	2	7	45.72	0.28
24	41	4	7	6	6	4	8	2	12	2	1	1	45.79	0.28
24	46	4	3	6	6	4	8	1	14	1	4	1	45.89	0.27
24	37	4	3	6	6	4	8	4	15	1	3	10	45.89	0.27
24	24	7	3	6	7	3	8	1	16	2	2	6	45.91	0.27
24	48	7	4	7	6	7	3	1	15	1	4	4	46.12	0.25
24	32	5	3	7	6	7	6	2	12	4	2	2	46.39	0.23
24	30	5	7	7	5	3	8	2	11	1	1	3	46.39	0.23
24	46	4	4	7	5	3	7	4	14	1	1	3	46.42	0.23
24	48	7	3	7	8	3	7	4	16	1	2	8	46.50	0.23
24	41	7	7	11	7	6	2	4	10	4	2	3	46.58	0.22
24	33	5	6	13	8	6	2	4	13	2	2	2	46.58	0.22
24	30	5	7	12	7	8	2	3	13	2	1	1	46.59	0.22
24	33	6	4	14	6	8	4	1	14	3	1	5	46.65	0.21
24	42	6	6	9	8	6	8	3	10	1	2	1	46.66	0.21
24	32	7	7	12	6	7	7	4	15	2	4	5	46.67	0.21
24	35	5	7	13	8	8	8	3	14	2	2	2	46.67	0.21
24	44	5	4	12	5	7	8	3	12	2	3	2	46.68	0.21
24	40	7	4	9	8	3	6	1	16	4	4	5	46.73	0.21
24	48	6	4	14	4	4	8	2	14	3	3	4	46.74	0.21
24	30	5	4	10	4	4	8	1	11	1	4	8	46.74	0.21
24	44	5	4	14	6	3	7	3	15	2	2	4	46.76	0.21
24	48	4	5	13	4	4	6	1	16	1	3	2	46.76	0.21
24	44	5	3	13	7	8	7	2	10	3	3	3	46.78	0.21
24	44	5	3	10	8	5	8	2	11	3	2	5	46.78	0.21
24	45	6	3	14	6	6	8	4	13	3	1	5	46.79	0.21
24	48	7	3	12	5	6	8	4	13	2	2	1	46.79	0.21
24	39	4	3	13	8	8	8	3	11	1	1	1	46.81	0.21
24	37	4	3	14	4	5	8	2	12	1	3	1	46.86	0.21
24	47	5	3	14	4	3	6	4	13	1	1	1	46.95	0.21
24	26	3	7	14	8	5	6	4	16	1	3	10	47.19	0.21
24	44	3	3	13	7	7	5	1	10	3	4	3	47.27	0.20
24	47	3	3	13	6	8	7	4	11	4	1	2	47.29	0.20

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	MP	Kf	Km	Kmf	Ke	DE	WIP	BL
24	44	3	4	14	4	3	5	2	13	2	2	5	47.35	0.20
25	43	6	7	7	8	6	3	3	15	3	4	9	47.63	0.18
25	40	5	6	7	5	4	6	4	14	4	4	1	47.75	0.17
25	44	4	7	8	8	7	3	4	15	2	1	4	48.06	0.16
25	48	5	5	9	6	4	2	1	16	3	3	1	48.08	0.16
25	48	6	4	9	7	4	2	1	11	3	2	1	48.08	0.16
25	45	4	7	8	5	7	8	2	13	1	3	6	48.12	0.15
25	28	7	7	9	7	4	6	1	11	1	3	6	48.16	0.15
25	28	5	4	9	6	4	6	1	16	1	2	6	48.16	0.15
25	48	5	7	10	6	6	5	2	14	3	4	3	48.17	0.15
25	47	7	7	12	8	7	6	4	16	1	2	9	48.17	0.15
25	25	6	4	14	5	4	8	1	11	1	4	9	48.21	0.15
25	47	4	4	13	8	6	8	2	12	3	1	3	48.22	0.15
25	42	7	7	12	4	8	5	1	14	4	3	2	48.24	0.15
25	47	6	4	10	4	8	5	1	13	4	1	1	48.24	0.15
25	32	4	7	9	4	8	8	1	15	2	4	9	48.27	0.15
25	30	5	7	13	7	3	8	3	13	4	1	8	48.28	0.15
25	46	4	4	10	4	7	8	1	14	2	1	4	48.29	0.15
25	40	4	5	12	4	4	5	4	10	1	1	2	48.31	0.15
25	48	4	7	14	6	3	8	1	11	4	4	8	48.32	0.15
25	44	4	3	9	8	5	8	3	12	1	4	1	48.36	0.15
25	44	4	3	13	7	6	7	2	10	1	1	8	48.37	0.15
25	46	4	3	10	5	4	7	4	14	3	2	1	48.38	0.15
25	43	5	3	10	4	6	5	1	15	2	4	1	48.40	0.15
25	44	5	3	13	7	3	7	2	12	3	4	4	48.44	0.15
25	47	4	3	13	4	4	8	2	14	1	1	3	48.45	0.15
25	43	3	6	10	8	6	7	4	13	2	1	10	48.82	0.14
25	47	3	6	13	5	5	7	1	15	4	4	3	48.83	0.14
25	40	3	4	14	5	8	8	4	15	3	1	9	48.83	0.14
25	48	3	3	11	8	6	5	4	12	4	4	2	48.97	0.14
25	47	3	3	14	5	8	8	3	12	1	2	5	48.98	0.14
25	47	3	3	13	4	4	5	1	10	1	2	3	49.08	0.14
26	47	7	4	7	7	8	8	4	10	1	2	8	49.27	0.12
26	44	5	5	9	8	5	8	3	14	1	4	1	49.72	0.11
26	37	5	5	10	6	7	8	2	13	3	1	6	49.74	0.11
26	47	6	5	13	6	4	6	2	13	1	3	5	49.75	0.11
26	47	4	6	13	6	8	8	1	13	1	4	4	49.80	0.11
26	46	4	4	12	5	5	5	1	12	2	1	3	49.81	0.11
26	48	7	3	9	5	6	6	3	11	2	4	1	49.94	0.10
26	42	7	3	9	5	3	5	3	11	1	4	8	50.06	0.10
26	48	4	4	10	4	3	3	4	10	4	4	7	50.12	0.10
26	43	3	6	13	8	6	7	4	13	3	1	6	50.55	0.10
26	33	3	3	12	7	7	8	2	15	1	1	5	50.77	0.10
27	35	6	4	7	7	7	6	3	10	4	1	1	50.79	0.09
27	29	6	4	8	6	8	6	4	10	1	4	2	51.19	0.08
27	44	5	6	10	8	5	5	3	14	3	4	5	51.35	0.07
27	32	6	5	12	5	5	8	4	15	2	4	2	51.36	0.07
27	44	4	5	10	5	4	6	3	16	3	3	5	51.44	0.07
27	48	7	5	13	4	8	6	1	15	2	2	9	51.44	0.07
27	42	6	5	12	4	8	5	4	14	2	1	2	51.45	0.07
27	35	7	5	12	6	3	2	1	11	1	4	1	51.49	0.07
27	45	4	4	9	6	3	5	3	13	1	1	3	51.55	0.07
27	43	5	3	14	6	8	6	4	13	3	4	4	51.65	0.07
28	35	7	7	7	6	6	3	1	13	3	3	3	52.37	0.06
28	28	5	5	7	6	6	5	1	10	1	1	3	52.37	0.06
28	35	6	3	7	7	6	3	1	14	4	1	3	52.76	0.06
28	45	7	5	8	5	4	3	2	10	1	4	5	52.79	0.05
28	48	7	5	9	8	5	2	1	13	3	1	4	52.93	0.05
28	48	6	6	9	8	6	5	3	11	4	4	3	52.95	0.05
28	47	7	7	10	8	8	6	2	11	1	1	9	52.98	0.05
28	47	5	6	10	6	6	5	1	13	4	4	3	52.98	0.05
28	42	6	5	12	6	7	5	3	14	4	2	4	52.99	0.05
28	27	6	6	12	6	7	7	4	15	1	3	2	53.01	0.05
28	48	4	7	14	5	6	8	1	11	1	4	3	53.10	0.05
28	37	5	4	10	5	3	6	4	10	2	4	1	53.16	0.05
28	26	4	3	13	6	6	4	1	12	1	4	1	53.57	0.05
29	47	7	7	7	6	6	6	4	14	1	2	9	54.02	0.04
28	48	3	7	10	6	6	8	4	15	1	4	3	54.20	0.04
28	28	3	5	12	6	7	7	4	15	3	1	3	54.22	0.04
29	45	7	7	8	5	5	6	2	10	1	4	6	54.43	0.04
29	45	7	6	10	6	7	3	1	15	1	4	5	54.62	0.03
29	46	7	7	11	6	6	6	4	14	2	4	4	54.63	0.03

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	MP	Kf	Km	Kmf	Ke	DE	WIP	BL
29	46	5	7	13	7	6	3	4	13	2	2	4	54.64	0.03
29	46	6	4	13	7	7	8	2	10	3	4	6	54.66	0.03
29	48	5	4	11	6	6	8	1	16	2	1	6	54.67	0.03
29	47	7	4	13	5	4	6	4	16	1	4	3	54.67	0.03
29	39	4	7	14	5	7	8	1	13	2	4	3	54.79	0.03
29	44	7	3	12	6	6	8	4	10	3	4	4	55.12	0.03
29	41	5	3	13	8	8	7	2	12	3	1	2	55.13	0.03
29	47	5	3	14	4	4	6	1	11	3	4	1	55.25	0.03
29	47	3	4	9	8	4	6	3	10	1	1	4	56.06	0.03
29	46	3	4	12	6	6	5	4	16	1	2	4	56.13	0.03
30	48	7	7	13	6	7	3	4	11	1	4	5	56.29	0.02
30	41	6	6	12	8	6	2	1	15	4	2	9	56.29	0.02
30	47	7	4	11	6	5	4	1	16	3	3	1	56.33	0.02
30	46	6	7	12	4	5	6	3	13	1	4	2	56.40	0.02
30	41	6	7	12	4	6	2	3	15	1	3	2	56.43	0.02
30	46	4	6	12	6	6	8	1	12	1	1	1	56.49	0.02
30	40	4	6	14	6	3	6	4	14	4	4	5	56.67	0.02
30	46	4	6	13	6	3	8	1	13	1	1	1	56.67	0.02
30	48	4	7	10	6	3	3	2	15	4	3	2	56.77	0.02
30	47	6	3	13	7	3	8	1	16	3	4	9	57.08	0.02
30	29	4	3	12	4	8	5	1	14	3	4	1	57.23	0.02
30	44	6	5	12	3	5	6	1	14	2	1	1	57.88	0.02
30	46	5	7	12	3	5	6	3	13	4	4	2	57.89	0.02
31	36	6	6	12	6	6	7	1	15	4	4	3	57.95	0.02
31	30	6	4	10	6	4	6	2	13	2	2	7	58.03	0.02
31	25	5	6	14	8	3	3	3	15	1	3	3	58.33	0.02
31	45	7	4	13	4	3	2	1	14	3	4	7	58.35	0.02
31	48	5	3	9	4	8	3	1	13	4	4	9	58.86	0.01
31	26	7	3	9	7	3	8	1	15	2	3	6	58.94	0.01
31	43	6	3	10	4	3	6	3	13	4	4	3	58.98	0.01
31	43	4	3	10	4	4	7	4	15	3	3	3	59.08	0.01
32	48	6	5	9	7	4	3	2	15	3	4	4	59.57	0.01
32	46	7	4	10	7	3	8	4	13	2	2	5	59.88	0.01
32	34	7	6	9	4	3	4	2	10	1	1	1	59.88	0.01
32	36	6	3	10	6	6	7	1	12	4	1	9	60.51	0.01
32	48	5	3	14	6	4	5	1	16	4	4	4	60.55	0.01
32	47	6	3	13	7	3	8	2	16	1	1	10	60.70	0.01
33	48	6	6	10	6	6	5	4	12	1	3	1	61.26	0.01
33	40	6	6	12	5	4	8	3	14	1	4	2	61.29	0.01
33	28	7	5	14	5	6	6	3	13	1	2	4	61.36	0.01
33	33	7	4	12	6	4	7	1	13	4	4	4	61.41	0.01
33	46	5	4	14	5	5	3	4	14	1	3	4	61.45	0.01
33	47	7	5	10	6	3	2	1	15	4	4	8	61.46	0.01
33	39	7	7	14	4	3	8	3	13	1	4	3	61.57	0.01
33	46	4	6	13	5	8	8	2	11	1	2	1	61.71	0.01
33	37	4	6	14	8	7	2	4	13	1	2	2	61.96	0.01
34	34	6	6	8	7	7	6	1	11	1	1	4	62.73	0.01
34	40	7	5	13	7	8	5	2	10	3	1	8	62.94	0.01
34	47	5	6	11	8	6	5	1	13	1	3	3	62.98	0.01
34	43	4	6	9	5	6	5	1	12	3	2	3	63.43	0.00
34	43	4	4	9	5	6	8	2	15	4	1	5	63.59	0.00
34	48	4	7	14	8	8	4	4	13	4	4	9	63.81	0.00
35	47	6	7	10	5	5	8	1	13	4	1	8	64.59	0.00
35	47	7	7	13	5	7	3	4	13	1	2	1	64.60	0.00
35	46	5	5	11	8	6	4	3	16	1	4	5	64.70	0.00
35	45	7	6	14	4	8	8	1	13	3	3	1	64.72	0.00
35	42	4	6	10	6	3	2	3	14	3	1	2	65.93	0.00
36	40	6	7	14	7	8	3	4	10	3	2	2	66.26	0.00
36	34	7	7	12	7	5	7	1	14	1	4	3	66.27	0.00
36	40	5	7	14	5	8	3	4	13	3	4	2	66.40	0.00
36	28	7	6	13	5	3	6	3	13	4	4	4	66.64	0.00
36	46	5	4	14	8	3	5	4	12	1	4	4	66.82	0.00
36	43	4	5	8	5	7	5	1	12	2	2	2	66.88	0.00
36	46	4	7	13	5	8	7	2	13	1	3	3	67.07	0.00
36	46	7	5	14	3	3	5	4	16	1	1	4	67.85	0.00
37	46	6	6	9	8	4	2	1	16	4	4	3	67.90	0.00
37	46	6	6	13	4	4	6	4	16	3	3	1	68.07	0.00
37	46	5	4	9	4	4	2	1	15	3	1	4	68.75	0.00
38	43	6	7	8	8	8	3	1	13	4	3	2	69.41	0.00
38	37	7	7	14	6	8	2	1	13	3	1	8	69.60	0.00
38	48	7	7	12	4	8	8	4	16	3	1	8	69.73	0.00
38	48	5	7	12	6	8	5	1	14	3	3	4	69.75	0.00

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	MP	Kf	Km	Kmf	Ke	DE	WIP	BL
38	43	5	6	10	6	4	2	3	16	3	3	10	69.82	0.00
38	48	6	4	12	6	6	8	2	14	4	1	2	70.02	0.00
38	45	5	5	10	4	3	4	3	16	3	4	1	70.16	0.00
38	28	5	4	12	6	7	2	4	10	4	1	1	70.84	0.00
38	48	5	6	14	3	4	8	3	13	4	3	3	71.20	0.00
39	47	7	5	8	8	3	3	1	10	3	1	4	71.24	0.00
39	48	7	7	14	6	8	5	3	16	3	3	1	71.26	0.00
39	34	6	6	10	4	4	4	2	10	1	4	1	71.53	0.00
39	48	5	4	12	5	3	6	4	14	1	4	7	72.17	0.00
39	26	7	4	10	4	3	5	2	14	2	4	7	72.75	0.00
40	43	7	7	10	7	7	8	1	13	1	4	8	72.92	0.00
40	36	7	7	14	5	3	6	2	10	1	4	8	73.15	0.00
40	46	5	7	10	8	3	8	4	15	3	4	2	73.37	0.00
40	48	7	4	12	6	7	8	4	15	3	4	5	73.54	0.00
40	47	7	4	12	6	3	7	4	13	4	4	4	73.74	0.00
40	41	7	4	14	5	3	2	2	12	4	4	3	74.32	0.00
40	48	6	4	10	4	3	2	2	10	4	4	7	74.54	0.00
41	48	7	5	14	5	8	2	4	16	3	3	2	74.75	0.00
41	41	5	6	12	6	8	4	1	10	3	4	8	75.06	0.00
41	48	5	6	12	4	5	2	1	10	4	4	3	75.34	0.00
41	28	5	4	8	4	3	7	4	15	1	2	4	76.20	0.00
42	43	7	5	8	4	8	5	2	12	2	1	2	76.33	0.00
42	46	7	5	10	7	6	7	1	14	4	1	2	76.39	0.00
42	34	6	5	11	7	4	8	2	10	4	1	3	76.50	0.00
42	39	6	5	8	4	3	8	2	12	2	1	5	76.54	0.00
41	46	6	3	11	5	8	7	3	15	3	3	10	77.33	0.00
41	46	7	3	9	4	3	5	2	13	4	1	8	77.69	0.00
43	47	7	5	8	8	8	8	4	14	1	4	4	77.89	0.00
43	48	6	6	14	6	3	5	4	11	1	2	1	78.19	0.00
43	44	7	4	9	4	3	7	1	13	2	4	9	79.19	0.00
44	37	7	6	8	6	4	5	3	13	3	1	1	79.45	0.00
44	42	6	7	12	4	5	8	1	11	4	3	3	79.81	0.00
44	48	5	6	14	7	3	8	4	13	2	4	4	80.38	0.00
44	48	7	4	14	8	3	5	4	16	1	2	6	80.94	0.00
45	38	7	5	13	5	8	8	1	10	1	1	2	81.55	0.00
44	37	5	6	11	3	8	5	1	13	3	2	2	82.19	0.00
45	46	5	5	12	5	3	4	3	10	1	4	9	82.84	0.00

C6. DNC HKC - PAC OPTIMISED SETTINGS FOR LOWER PROCESSING TIME VARIABILITY

Table C-6. Production Authorisation Card Settings for DNC HKC Strategy 40LV

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	MP	Kf	Km	Kmf	Ke	WIP	BL
11	20	4	6	4	8	5	6	3	11	4	4	33.68	11.65
11	35	6	5	4	8	8	6	3	11	4	2	33.68	11.65
11	26	3	7	4	4	4	6	4	13	4	2	33.69	11.63
11	31	3	2	4	4	4	6	4	15	2	2	33.73	11.62
12	39	7	5	4	4	3	5	2	9	1	4	33.74	11.36
12	28	5	5	4	3	8	5	2	15	1	4	33.81	11.26
13	48	5	7	5	7	3	4	4	10	3	4	33.86	10.92
13	30	3	4	5	7	5	4	4	9	2	4	33.87	10.91
13	30	3	3	5	6	8	4	2	16	4	4	33.87	10.91
13	19	3	6	5	3	3	4	2	15	4	4	33.99	10.70
13	42	7	6	6	4	6	4	4	15	1	4	34.01	10.65
14	34	7	2	5	8	4	3	4	12	1	2	34.05	10.55
13	26	6	2	6	3	8	4	1	11	4	1	34.16	10.48
15	25	7	3	6	6	7	2	4	16	1	2	34.17	10.15
15	30	7	3	6	6	7	2	2	13	1	4	34.17	10.15
13	35	7	5	13	3	8	4	4	11	1	4	34.17	10.47
15	30	7	7	6	7	3	2	3	15	4	1	34.18	10.14
15	46	7	4	12	8	3	2	4	15	1	4	34.37	9.92
15	46	4	4	9	5	4	2	1	13	1	4	34.37	9.93
15	47	3	6	13	5	6	2	3	11	3	2	34.38	9.91
15	26	7	3	11	4	5	2	1	16	4	3	34.39	9.83
15	25	7	7	14	4	7	2	1	16	1	3	34.39	9.83
12	30	4	3	4	7	7	6	3	15	3	3	34.43	6.60
12	29	4	5	4	5	5	6	1	15	1	4	34.43	6.60
12	37	4	5	4	4	8	6	1	15	4	4	34.43	6.59
13	33	7	6	4	8	8	5	2	15	3	3	34.53	6.36
13	37	3	3	4	5	8	5	2	16	4	1	34.54	6.35
13	19	7	2	4	8	6	5	4	7	3	2	34.67	6.27
12	42	4	5	5	4	8	6	1	12	4	2	34.77	6.09
12	27	3	7	5	8	4	6	2	9	4	4	34.78	6.08
13	35	4	7	4	6	4	6	1	12	1	3	34.88	5.33
13	26	6	6	4	3	5	6	1	10	4	3	35.01	5.27
14	42	3	2	4	7	8	5	2	14	4	1	35.15	5.04
11	48	7	3	4	8	8	8	3	16	1	2	35.31	4.64
11	34	3	5	4	5	4	8	1	14	4	1	35.33	4.64
11	17	7	7	4	6	5	8	1	12	2	1	35.37	4.63
15	37	7	7	4	4	7	5	4	9	1	3	35.37	4.60
12	43	7	7	4	8	4	7	1	14	4	4	35.39	4.44
12	33	3	3	4	8	4	7	1	15	3	1	35.42	4.43
12	47	7	7	4	7	3	7	3	8	3	3	35.43	4.41
12	44	7	6	4	3	8	7	2	16	1	3	35.59	4.39
12	44	7	5	4	3	8	7	2	16	1	2	35.59	4.39
12	41	3	5	4	3	8	7	3	16	4	4	35.61	4.39
11	46	7	6	7	8	3	8	1	11	4	4	35.63	4.36
11	45	5	4	7	4	6	8	4	16	1	1	35.63	4.38
11	39	6	7	12	8	5	8	3	16	4	3	35.63	4.37
11	46	4	6	14	6	4	8	4	14	2	1	35.63	4.37
11	42	6	6	12	5	7	8	4	16	3	3	35.63	4.37
11	48	7	4	14	8	8	8	3	9	2	4	35.63	4.37
11	42	7	5	13	6	3	8	2	10	3	4	35.64	4.35
11	41	7	6	12	6	3	8	3	15	3	4	35.64	4.35
11	46	7	6	12	8	7	8	2	8	4	2	35.66	4.34
11	44	4	6	13	7	8	8	4	8	4	4	35.66	4.34
12	20	6	5	5	6	6	7	3	8	4	1	35.67	4.22
12	28	5	5	6	6	7	7	3	16	4	3	35.70	4.17
13	46	4	2	5	8	7	6	2	10	3	4	35.72	4.06
13	46	7	6	6	7	8	6	3	15	3	2	35.79	3.96
13	35	6	3	14	6	8	6	3	12	2	4	35.87	3.92
13	42	6	3	13	5	3	6	2	14	2	2	35.89	3.92
12	28	5	5	4	5	7	8	4	15	4	1	35.90	3.62

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	MP	Kf	Km	Kmf	Ke	WIP	BL
13	46	4	6	4	7	6	7	3	11	4	1	36.01	3.45
13	28	6	4	4	6	8	7	2	16	4	3	36.01	3.45
13	23	6	4	4	6	8	7	2	9	3	2	36.01	3.44
13	35	3	2	4	6	4	7	1	15	3	1	36.20	3.42
15	44	6	5	7	5	6	4	1	13	4	4	36.22	3.42
12	45	5	5	5	8	6	8	2	9	4	4	36.25	3.37
12	27	6	7	5	5	8	8	3	16	2	2	36.25	3.37
13	48	4	5	4	8	8	8	2	10	1	2	36.35	3.05
13	21	7	4	4	7	3	8	2	16	1	1	36.37	3.05
13	46	7	4	4	7	5	8	2	8	3	4	36.41	3.01
14	42	7	3	4	7	3	7	1	13	1	3	36.52	2.86
15	42	3	6	5	7	8	5	1	16	4	4	36.54	2.81
15	37	3	6	5	7	4	5	1	16	3	1	36.54	2.80
15	30	3	3	5	8	4	5	1	8	3	1	36.57	2.80
13	48	6	4	5	7	8	8	2	15	4	2	36.86	2.71
15	30	3	7	6	5	8	5	1	16	1	3	36.89	2.63
15	18	7	7	4	6	6	7	2	14	3	1	36.92	2.53
15	46	4	4	4	7	6	8	3	16	1	3	36.97	2.49
15	32	3	3	4	8	8	8	4	16	1	3	37.02	2.48
15	46	6	7	4	5	4	8	1	7	1	2	37.18	2.41
16	22	7	3	7	7	5	4	1	12	4	4	37.19	2.37
16	22	3	3	4	6	3	7	3	9	1	1	37.27	2.30
16	22	7	3	4	7	5	7	3	8	4	1	37.27	2.27
16	24	6	3	5	7	7	6	2	16	4	1	37.34	2.10
17	42	6	3	4	8	4	8	1	16	2	4	37.53	2.09
15	18	7	7	5	6	5	7	1	15	3	1	37.65	2.06
17	23	6	3	5	5	8	5	2	16	1	4	37.70	1.89
17	35	5	3	5	8	3	6	1	14	1	4	37.82	1.84
17	42	7	3	7	8	7	4	3	13	1	4	38.08	1.74
17	48	3	5	7	6	4	4	1	16	4	4	38.17	1.74
16	25	4	6	7	7	3	6	1	15	4	4	38.22	1.71
16	25	4	5	7	7	3	6	1	14	3	4	38.22	1.71
17	35	4	7	14	6	7	4	4	10	3	1	38.22	1.72
17	18	7	4	14	6	3	4	1	15	4	1	38.33	1.70
17	35	4	7	6	5	6	5	3	12	3	4	38.37	1.57
17	40	5	5	7	5	4	5	4	13	1	2	38.57	1.51
17	44	7	7	5	6	5	7	1	10	1	1	38.58	1.51
17	27	4	5	6	8	3	6	2	12	3	2	38.63	1.45
17	35	5	7	6	8	3	6	2	13	1	1	38.63	1.45
17	42	4	3	6	4	3	6	1	16	4	1	38.68	1.45
19	45	4	6	5	5	7	5	3	15	1	4	38.90	1.42
18	46	5	3	7	8	8	4	4	13	2	3	38.97	1.32
18	48	7	5	5	5	3	7	3	10	4	1	39.11	1.30
18	46	5	6	9	6	5	4	4	12	2	1	39.16	1.29
18	48	6	5	12	7	7	4	1	13	1	1	39.18	1.29
19	45	4	5	6	6	5	4	3	15	4	2	39.23	1.27
19	46	4	5	6	8	4	4	2	12	4	1	39.24	1.27
18	45	4	3	6	5	7	6	2	9	1	1	39.27	1.21
18	34	7	7	6	7	3	6	2	9	1	3	39.28	1.21
18	45	4	7	10	7	7	5	4	10	2	1	39.47	1.17
18	44	5	4	12	8	6	5	4	10	3	1	39.47	1.17
18	21	5	6	12	6	6	5	1	10	3	4	39.49	1.17
18	28	4	3	13	8	8	5	1	16	2	4	39.49	1.17
18	28	3	7	11	6	7	5	2	10	4	4	39.57	1.17
18	44	4	3	7	8	8	6	1	16	2	2	39.59	1.12
19	45	4	7	7	8	5	3	2	14	1	1	39.67	1.11
18	39	4	6	8	7	4	6	3	10	1	3	39.69	1.11
18	26	4	7	8	4	4	6	1	14	3	3	39.71	1.11
18	41	4	7	9	4	8	6	3	14	2	1	39.72	1.10
19	41	7	6	8	7	6	3	4	11	4	4	39.80	1.09
19	46	4	6	14	8	4	3	2	12	3	2	39.84	1.09
19	45	7	5	8	7	3	3	1	13	1	2	39.86	1.09
19	25	7	5	8	8	3	3	3	10	1	1	39.87	1.08
19	37	7	4	7	6	8	4	4	12	1	2	39.88	1.02
19	37	4	5	7	8	3	4	1	14	4	4	39.93	1.02
19	43	5	7	12	6	6	4	1	10	3	1	40.15	0.98
19	44	7	3	11	6	4	4	2	13	2	1	40.16	0.98
19	25	6	3	10	6	3	4	2	14	4	3	40.19	0.98
19	44	7	3	10	4	3	4	1	13	1	1	40.24	0.98
19	19	4	7	12	7	3	4	4	13	3	1	40.26	0.97
19	46	4	7	6	8	4	7	1	14	3	1	40.31	0.93
19	45	4	5	12	5	5	5	2	14	4	1	40.36	0.92

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	MP	Kf	Km	Kmf	Ke	WIP	BL
19	29	7	5	12	5	4	5	1	16	1	4	40.37	0.92
19	19	7	7	6	7	6	8	3	11	2	2	40.41	0.91
19	45	7	6	7	6	4	7	1	16	2	2	40.54	0.88
19	29	7	4	7	7	8	8	4	14	1	1	40.60	0.87
19	42	7	3	7	7	8	8	1	11	1	1	40.61	0.87
19	45	4	4	10	8	7	7	2	11	4	1	40.63	0.87
19	25	4	5	13	6	8	7	3	15	1	3	40.63	0.87
19	37	4	5	10	8	4	7	1	14	4	1	40.64	0.87
19	19	4	7	7	5	6	8	2	14	1	2	40.66	0.86
19	29	4	7	12	5	3	7	4	13	4	1	40.69	0.86
19	29	4	5	9	5	4	8	2	15	1	4	40.69	0.86
19	48	6	4	12	6	5	8	2	15	1	3	40.69	0.86
19	42	6	4	12	6	5	8	1	16	1	1	40.70	0.86
19	29	4	4	9	6	4	8	1	15	4	2	40.70	0.86
19	46	4	3	11	7	6	8	1	11	3	4	40.71	0.85
19	44	4	3	10	7	7	8	4	15	1	3	40.71	0.85
19	19	4	7	8	5	5	8	2	14	1	4	40.74	0.85
19	29	4	5	10	5	3	8	3	16	1	1	40.76	0.85
20	39	4	7	6	4	8	5	2	10	1	1	40.78	0.81
20	40	6	7	14	8	5	3	1	16	1	1	40.99	0.80
20	19	5	5	10	7	7	3	3	12	4	1	41.07	0.80
20	28	7	4	6	6	4	8	1	16	2	3	41.10	0.75
20	23	7	4	6	6	7	8	1	16	2	4	41.11	0.75
20	47	4	7	6	8	3	8	3	11	1	4	41.13	0.75
20	47	7	4	12	4	3	4	4	11	4	1	41.28	0.75
20	47	7	3	11	5	7	5	2	15	4	3	41.33	0.73
20	27	7	5	7	7	8	8	2	9	4	3	41.41	0.71
20	40	7	5	14	7	3	6	3	15	2	2	41.47	0.70
20	38	6	6	14	6	5	8	3	15	1	3	41.51	0.69
20	47	4	4	13	7	8	8	3	15	1	2	41.51	0.69
20	25	4	3	12	8	8	8	1	16	1	1	41.54	0.69
20	41	3	6	11	6	7	8	2	10	1	1	41.68	0.68
21	27	5	7	6	8	5	5	3	16	1	1	41.75	0.65
21	42	5	4	7	5	8	4	2	12	3	2	41.96	0.61
21	47	5	3	8	6	6	3	3	16	1	2	42.14	0.60
21	19	6	5	6	7	4	8	3	15	4	3	42.15	0.60
21	43	5	5	11	5	8	3	4	16	1	4	42.18	0.60
21	42	7	3	12	5	8	3	2	14	4	3	42.21	0.59
21	25	7	4	9	5	3	3	3	10	4	1	42.26	0.59
21	24	5	7	7	7	3	5	1	14	2	4	42.27	0.57
21	44	6	3	7	4	8	6	2	13	1	4	42.28	0.56
21	25	5	4	8	6	8	5	1	11	3	3	42.36	0.56
21	25	4	6	9	6	8	5	4	14	1	2	42.39	0.55
21	24	4	7	14	6	5	5	4	14	2	4	42.39	0.55
21	29	5	6	14	8	3	5	1	16	4	4	42.46	0.55
21	46	6	3	13	8	6	6	4	10	4	2	42.47	0.54
21	41	7	7	9	5	6	8	4	16	1	4	42.48	0.54
21	46	4	6	14	7	7	8	4	15	2	2	42.49	0.54
21	41	4	5	14	7	7	8	3	15	1	4	42.49	0.54
21	43	6	7	12	5	7	8	3	13	4	2	42.49	0.54
21	47	6	5	14	6	4	8	3	14	4	3	42.49	0.54
21	41	6	4	14	7	3	8	4	15	2	3	42.55	0.54
21	43	7	6	12	7	3	8	3	15	1	2	42.55	0.54
21	37	6	5	11	5	3	8	2	16	4	1	42.56	0.54
21	27	4	3	14	8	3	8	1	14	2	4	42.59	0.53
21	27	3	4	9	6	5	8	3	12	2	4	42.71	0.53
22	32	7	4	6	6	6	5	2	14	4	4	42.87	0.51
22	37	5	6	6	4	8	8	1	9	1	2	43.02	0.49
22	35	7	4	7	8	4	4	1	9	2	4	43.14	0.47
22	19	7	6	6	4	7	7	2	12	3	1	43.27	0.47
22	37	7	4	13	8	6	2	3	14	4	4	43.37	0.45
22	42	7	4	7	4	8	5	1	11	4	4	43.41	0.43
22	32	7	4	14	7	7	4	3	15	4	3	43.55	0.42
22	46	6	6	14	5	4	4	1	15	1	1	43.57	0.42
22	37	4	5	11	5	8	4	1	14	2	1	43.58	0.42
22	37	7	7	8	7	5	7	2	13	1	4	43.60	0.41
22	37	7	7	12	8	5	8	1	13	2	1	43.64	0.41
22	46	7	7	14	6	7	8	3	13	3	4	43.64	0.41
22	26	6	3	13	6	5	7	4	13	1	3	43.68	0.41
22	37	7	3	13	8	4	8	2	13	2	4	43.69	0.41
22	46	6	3	10	8	8	8	4	16	3	2	43.69	0.41
22	26	7	3	8	7	3	8	1	14	1	1	43.75	0.41

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	MP	Kf	Km	Kmf	Ke	WIP	BL
22	19	7	6	12	4	5	7	3	13	3	1	43.84	0.40
22	20	5	3	9	8	3	8	1	16	1	4	43.87	0.40
22	31	3	3	10	6	5	7	3	14	4	4	43.98	0.40
22	18	5	5	14	8	3	7	1	14	4	1	44.00	0.40
22	18	5	5	13	7	3	8	1	14	4	1	44.00	0.40
22	18	7	6	14	4	3	8	4	16	3	3	44.03	0.40
22	17	3	5	10	5	5	5	2	15	3	4	44.33	0.40
22	17	3	5	11	5	5	8	4	16	3	3	44.38	0.39
23	42	3	4	6	8	7	5	4	13	4	2	44.47	0.39
23	42	3	4	6	8	3	5	3	13	3	1	44.51	0.38
22	37	7	2	14	8	4	7	2	13	4	4	44.63	0.38
22	16	3	7	14	5	3	8	2	16	4	3	44.69	0.38
23	44	7	7	7	4	8	7	4	9	1	4	44.75	0.33
23	32	4	3	7	7	7	7	3	15	4	3	44.84	0.32
23	46	6	7	12	8	6	4	4	10	3	2	44.90	0.31
23	25	7	5	9	5	5	7	1	15	1	3	44.95	0.30
23	26	7	7	10	8	4	7	1	15	1	4	44.95	0.30
23	42	4	6	14	5	4	8	1	13	2	4	44.97	0.30
23	42	7	6	11	4	6	8	4	11	1	1	44.98	0.30
23	47	6	3	14	4	8	6	3	10	3	2	45.05	0.30
23	46	4	4	11	5	3	8	3	13	4	2	45.07	0.30
23	41	5	3	9	5	3	8	4	10	1	2	45.12	0.30
23	34	3	7	14	5	4	6	2	12	4	1	45.34	0.30
23	47	3	7	14	4	4	6	1	10	2	1	45.37	0.30
23	48	3	7	14	5	3	6	4	15	2	1	45.44	0.29
23	19	3	7	12	8	7	8	2	12	4	3	45.56	0.29
23	18	3	6	14	7	6	5	2	11	4	4	45.68	0.29
23	18	3	6	14	4	8	8	4	11	3	4	45.73	0.29
24	39	7	3	7	6	4	4	4	13	4	1	46.11	0.25
24	41	4	6	7	8	4	5	4	16	3	3	46.13	0.24
24	39	4	5	7	4	8	5	1	11	4	2	46.17	0.23
24	44	4	3	7	8	5	5	4	16	3	3	46.23	0.23
24	39	5	3	7	4	7	7	3	11	4	1	46.30	0.23
24	42	7	6	12	7	7	7	3	14	3	1	46.38	0.22
24	25	7	5	14	6	5	8	1	11	1	3	46.39	0.22
24	45	4	7	13	6	7	7	3	10	1	2	46.40	0.22
24	18	5	7	12	7	7	7	1	10	3	4	46.88	0.21
24	19	4	4	12	4	3	6	3	13	4	4	46.90	0.21
24	48	6	6	10	3	3	7	2	16	1	2	47.36	0.20
24	18	3	5	10	5	7	6	1	11	4	4	47.37	0.20
24	48	3	7	12	3	8	8	4	13	4	3	47.76	0.20
25	47	6	5	8	6	8	8	3	14	3	3	47.84	0.16
25	39	7	7	8	4	7	5	3	12	4	1	47.88	0.16
25	46	7	6	13	5	7	5	3	12	1	3	47.90	0.16
25	42	7	6	12	6	6	5	3	15	1	3	47.90	0.16
25	29	4	7	11	8	6	8	3	15	2	1	47.94	0.15
25	44	4	5	13	8	7	8	3	14	3	1	47.94	0.15
25	45	4	7	11	6	6	5	1	16	3	2	47.94	0.15
25	39	5	6	12	4	8	8	4	15	1	4	47.95	0.15
25	22	5	6	9	5	8	6	4	10	2	1	48.00	0.15
25	31	4	3	12	5	7	8	3	13	2	4	48.10	0.15
25	42	4	5	14	5	3	7	4	11	4	1	48.12	0.15
25	22	4	3	13	5	8	6	1	14	1	2	48.20	0.15
25	48	3	6	10	8	8	8	1	14	3	1	48.55	0.15
25	18	4	5	13	6	7	5	1	16	3	4	48.59	0.15
25	18	5	4	14	4	5	8	1	12	4	4	48.61	0.15
25	31	3	3	12	4	6	5	3	13	4	2	48.74	0.15
25	22	3	7	14	5	3	6	2	12	1	2	48.82	0.14
25	46	7	3	14	3	6	6	2	16	1	3	49.21	0.14
26	40	7	7	8	7	7	8	3	11	2	2	49.41	0.11
26	42	6	5	13	6	7	2	1	16	2	4	49.47	0.11
26	48	6	4	9	5	7	4	2	15	2	1	49.48	0.11
26	42	6	7	12	6	7	4	2	15	4	3	49.48	0.11
26	42	7	6	14	5	7	7	2	16	4	1	49.49	0.11
26	42	7	6	12	5	4	6	2	14	3	1	49.50	0.11
26	32	4	4	9	4	6	6	1	10	4	1	49.60	0.11
26	37	6	5	11	5	3	8	1	15	1	4	49.67	0.11
26	47	6	3	13	4	5	6	4	16	2	2	49.75	0.11
26	34	4	3	12	4	3	8	2	15	4	2	50.00	0.10
26	47	3	5	11	4	7	6	3	16	3	3	50.34	0.10
26	37	3	3	11	5	7	7	1	16	4	4	50.50	0.10
26	27	4	7	13	3	3	8	2	12	4	1	50.66	0.10

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	MP	Kf	Km	Kmf	Ke	WIP	BL
27	42	7	7	7	4	8	7	1	11	3	1	50.79	0.09
27	31	7	7	8	6	6	4	4	12	2	3	50.99	0.08
27	44	5	4	9	5	8	8	1	15	1	4	51.09	0.08
27	47	5	4	12	5	8	8	4	10	1	3	51.11	0.08
27	40	5	5	9	4	8	8	2	12	1	3	51.14	0.07
27	47	7	4	12	7	3	4	1	11	1	1	51.34	0.07
27	45	4	6	11	7	3	8	4	16	1	1	51.39	0.07
27	45	4	6	10	4	3	4	1	11	1	3	51.48	0.07
27	31	3	5	8	7	6	5	4	14	4	1	52.00	0.07
27	34	3	7	8	6	5	7	1	15	4	1	52.01	0.07
27	41	3	4	14	5	8	6	2	16	4	4	52.10	0.07
27	47	3	4	14	5	8	6	1	15	4	1	52.11	0.07
28	28	5	5	7	6	6	5	1	10	1	1	52.29	0.06
28	46	7	4	8	7	6	4	2	13	3	4	52.64	0.05
28	39	7	6	10	8	6	7	2	13	4	2	52.73	0.05
28	37	5	5	11	5	5	7	2	13	4	4	52.73	0.05
28	46	4	4	10	4	5	5	2	15	1	4	52.92	0.05
28	37	7	5	14	6	3	6	1	14	2	2	52.96	0.05
28	46	4	4	11	5	3	8	1	13	1	1	53.10	0.05
28	44	4	7	10	4	3	8	2	14	1	2	53.12	0.05
28	32	3	6	10	7	4	7	1	10	4	1	53.93	0.05
28	48	3	6	14	7	7	5	4	12	3	2	53.93	0.05
29	47	7	5	7	4	7	5	1	11	3	4	53.98	0.05
29	45	4	6	7	6	4	6	3	11	1	4	54.08	0.04
28	43	3	6	10	8	3	7	4	10	4	4	54.15	0.04
29	38	5	4	14	7	8	7	2	10	2	1	54.41	0.04
29	48	7	5	11	4	5	7	1	12	4	4	54.44	0.04
29	23	6	7	12	5	8	4	2	15	4	4	54.61	0.04
29	46	4	4	14	5	3	7	3	10	4	3	54.80	0.03
29	45	4	3	8	8	3	7	3	16	4	4	55.15	0.03
29	23	4	3	14	6	8	4	4	11	4	3	55.31	0.03
29	23	7	3	12	6	3	7	4	11	2	2	55.33	0.03
29	29	7	5	11	3	4	5	3	12	1	3	55.70	0.03
30	31	7	4	8	7	6	7	4	13	4	1	55.97	0.03
31	43	7	5	7	7	7	8	3	14	1	3	57.18	0.02
31	28	7	5	7	5	6	8	1	15	4	1	57.23	0.02
31	42	7	7	7	4	8	7	4	12	3	4	57.25	0.02
31	29	7	7	8	8	6	8	3	15	3	4	57.60	0.02
31	37	5	5	8	4	8	4	2	13	4	2	57.66	0.02
31	41	7	7	13	7	6	8	3	14	1	2	57.69	0.02
31	47	5	4	12	5	8	8	3	16	2	4	57.77	0.02
31	29	7	7	14	4	5	5	3	13	1	3	57.78	0.02
31	44	6	7	12	6	3	8	4	10	1	1	57.95	0.02
31	29	7	7	14	6	3	6	1	13	2	2	57.98	0.02
31	29	4	7	13	6	3	8	1	16	3	1	58.25	0.01
31	29	5	6	12	3	7	5	4	15	4	4	59.32	0.01
32	25	5	4	8	6	8	5	3	10	3	1	59.53	0.01
32	28	4	5	13	5	6	5	1	16	2	1	59.76	0.01
33	43	7	7	13	5	7	2	2	15	3	1	61.02	0.01
33	43	5	7	9	4	5	4	4	13	1	1	61.11	0.01
33	43	5	7	12	4	3	4	4	15	1	4	61.38	0.01
33	46	4	6	14	6	6	8	4	13	4	3	61.44	0.01
33	46	4	7	13	6	7	2	1	10	4	1	61.68	0.01
33	24	4	4	12	6	3	8	1	10	1	3	62.19	0.01
34	34	6	6	8	7	7	6	1	11	1	1	62.57	0.01
34	46	6	7	10	7	8	3	3	15	2	1	62.68	0.01
34	43	6	7	12	4	8	2	2	16	3	1	62.76	0.01
34	34	7	5	13	4	8	7	2	10	4	4	62.79	0.01
34	37	7	4	13	4	8	8	4	15	3	2	62.90	0.01
34	48	4	5	14	8	6	8	2	16	3	1	63.22	0.00
34	44	4	4	13	6	8	8	2	16	3	3	63.36	0.00
34	46	7	3	10	7	7	6	3	16	2	2	63.94	0.00
34	30	6	3	12	4	8	7	3	16	3	1	64.06	0.00
35	47	7	6	8	7	8	2	2	15	3	4	64.20	0.00
35	35	7	5	8	8	8	8	2	15	4	1	64.23	0.00
35	47	6	5	9	5	8	8	1	15	2	1	64.33	0.00
35	47	5	5	12	4	6	7	4	13	3	1	64.49	0.00
35	42	7	4	9	5	8	3	1	14	3	4	64.53	0.00
35	42	5	4	12	4	6	6	2	16	1	1	64.69	0.00
35	42	6	5	14	4	3	2	2	13	4	1	64.71	0.00
35	42	7	4	12	5	3	4	1	11	4	1	64.85	0.00
35	42	4	6	9	8	8	7	1	14	4	4	64.96	0.00

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	MP	Kf	Km	Kmf	Ke	WIP	BL
35	44	4	6	9	6	6	7	2	14	3	1	64.97	0.00
35	39	4	4	9	8	4	2	1	16	2	4	65.74	0.00
36	36	7	5	14	8	6	4	2	10	1	4	66.02	0.00
36	26	7	5	12	7	6	8	2	10	1	1	66.38	0.00
36	36	5	5	10	5	3	3	4	16	2	4	66.43	0.00
36	26	5	4	12	7	3	7	1	10	1	3	66.98	0.00
36	47	4	7	14	4	8	3	4	15	1	2	67.54	0.00
37	48	7	6	13	6	6	3	1	16	2	3	67.67	0.00
37	27	7	6	11	6	5	4	4	16	4	1	68.01	0.00
37	41	6	4	12	4	8	8	3	16	4	1	68.09	0.00
37	27	5	6	12	5	8	6	1	11	1	3	68.10	0.00
37	24	5	7	14	5	4	6	1	11	4	3	68.68	0.00
37	24	5	7	14	5	3	6	2	11	3	2	68.91	0.00
38	41	6	6	8	6	4	5	2	11	4	4	69.23	0.00
38	41	7	6	8	4	7	4	2	13	3	4	69.27	0.00
38	44	7	6	12	8	4	4	2	10	1	4	69.34	0.00
38	44	7	7	11	4	5	8	3	13	2	2	69.40	0.00
38	47	5	7	14	5	5	2	2	16	1	1	69.57	0.00
38	46	6	4	12	4	6	4	4	16	1	4	69.86	0.00
38	44	5	4	12	6	4	8	2	11	1	2	69.92	0.00
38	41	4	6	12	6	7	8	4	16	4	1	70.46	0.00
38	44	4	7	11	4	6	8	1	13	1	3	70.53	0.00
39	41	7	6	8	4	7	3	2	12	3	4	70.95	0.00
39	46	7	6	14	6	7	7	3	15	3	2	71.00	0.00
39	46	7	6	14	6	4	7	2	10	3	2	71.01	0.00
39	46	7	6	13	7	4	2	1	16	2	4	71.02	0.00
39	46	5	6	14	4	8	8	4	11	2	2	71.28	0.00
39	46	7	6	14	4	3	6	2	14	2	1	71.34	0.00
39	46	5	4	14	8	6	7	4	12	1	1	71.70	0.00
39	47	5	4	14	4	6	6	3	16	1	3	71.77	0.00
39	46	4	6	14	6	7	7	3	15	3	2	72.31	0.00
40	42	7	6	12	6	6	7	2	12	4	1	72.67	0.00
40	35	7	7	9	8	3	6	2	11	3	1	72.96	0.00
40	37	7	5	12	6	3	6	3	13	2	4	73.03	0.00
41	46	7	6	13	6	7	7	1	15	3	4	74.34	0.00
41	41	7	6	12	5	7	3	3	11	3	1	74.35	0.00
41	42	7	5	12	5	7	4	4	13	4	2	74.43	0.00
41	39	5	6	14	7	8	7	3	11	3	2	74.65	0.00
41	46	7	6	13	4	3	6	4	13	2	2	74.68	0.00
41	46	7	4	12	8	3	8	2	14	1	1	75.35	0.00
42	34	7	5	11	5	5	6	1	10	1	4	76.20	0.00
42	44	7	5	14	4	6	5	1	15	1	2	76.21	0.00
42	34	7	4	9	8	3	6	2	13	2	1	77.18	0.00
43	42	7	5	12	8	4	8	2	16	4	4	77.84	0.00
43	43	7	5	12	4	3	2	4	13	4	2	78.26	0.00
43	47	7	5	14	3	6	8	3	11	4	1	79.34	0.00
44	45	5	6	14	4	3	8	2	13	3	1	80.25	0.00
44	44	5	6	14	8	3	3	1	16	2	4	80.55	0.00
44	44	6	7	13	3	5	5	2	15	3	4	80.96	0.00

C7. HEKC-II - PAC OPTIMISED SETTINGS FOR LOWER PROCESSING TIME VARIABILITY

Table C-7. Production Authorisation Card Settings DNC HEKC-II Strategy 40LV

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	De	Kf	Km	Kmf	Ke	WIP	BL
18	45	8	3	6	10	10	0	3	9	1	2	34.47	44.30
18	52	4	7	6	9	6	0	1	9	3	2	34.51	44.28
18	28	3	5	6	7	9	0	3	10	2	1	34.58	42.98
18	54	8	4	6	10	9	0	3	17	1	4	34.58	42.96
18	53	4	8	6	9	5	0	4	15	4	2	34.65	42.92
17	51	9	3	6	10	4	1	2	9	1	3	34.65	11.32
17	27	9	8	6	8	10	4	2	9	4	1	34.65	11.29
17	51	4	3	6	7	10	10	2	9	4	4	34.66	11.29
17	60	3	5	6	6	10	10	1	9	2	1	34.68	11.27
17	23	4	5	6	4	10	9	1	9	2	2	34.72	11.03
17	22	3	4	6	4	10	7	1	9	1	4	34.74	11.01
17	52	4	4	6	10	9	1	1	10	3	2	34.76	9.19
17	31	4	6	6	10	4	1	4	10	3	2	34.76	9.19
17	22	7	7	6	9	10	1	1	10	4	2	34.76	9.19
17	59	7	4	6	8	9	5	4	10	2	1	34.77	9.17
17	35	6	6	6	7	6	9	1	10	1	4	34.77	9.16
17	49	9	3	6	10	4	9	1	10	4	3	34.77	9.16
17	38	4	3	6	5	7	8	1	10	4	2	34.77	9.16
17	43	6	5	6	8	10	3	4	20	1	3	34.77	9.15
17	27	6	6	6	9	4	3	1	16	1	4	34.77	9.15
17	58	9	5	6	10	7	10	1	11	1	1	34.77	9.15
17	50	5	8	6	8	9	8	1	18	4	3	34.77	9.15
17	59	8	6	6	8	6	10	4	13	1	2	34.77	9.15
17	53	6	5	6	10	7	10	2	18	4	2	34.77	9.15
17	51	7	6	6	9	8	9	3	18	4	1	34.77	9.15
17	56	4	4	6	5	5	4	2	16	1	2	34.77	9.15
17	58	5	6	6	5	7	7	3	11	4	2	34.77	9.14
17	60	4	8	6	5	6	6	1	19	1	4	34.77	9.14
17	51	9	3	6	9	4	9	4	20	1	4	34.77	9.14
17	43	4	3	6	7	6	10	3	20	1	4	34.77	9.14
17	46	6	3	6	9	10	9	2	19	3	1	34.77	9.14
17	21	4	3	6	7	6	8	2	16	1	1	34.78	9.13
17	60	5	3	6	4	5	10	2	10	2	1	34.80	9.06
17	42	7	8	6	4	7	3	4	13	4	3	34.80	9.06
17	45	7	6	6	4	6	7	1	18	3	4	34.80	9.05
17	57	6	5	6	4	6	8	2	16	1	2	34.80	9.05
17	60	7	6	6	4	6	10	4	13	4	2	34.80	9.05
17	53	7	3	6	4	9	10	2	20	4	1	34.80	9.05
17	48	3	8	6	4	7	5	4	11	1	4	34.83	9.04
17	31	3	3	6	4	4	4	3	20	4	4	34.83	9.03
17	17	7	8	6	4	10	1	1	10	1	4	34.89	9.01
17	17	7	8	6	4	4	1	2	10	1	4	34.90	9.00
17	17	9	3	6	4	10	5	1	10	1	1	34.90	8.98
17	17	7	3	6	4	7	7	2	10	1	4	34.90	8.98
17	17	4	8	6	4	7	3	1	19	3	4	34.90	8.98
17	17	9	4	6	4	7	8	4	18	1	4	34.90	8.97
17	50	7	5	7	6	10	7	1	10	1	2	34.90	8.96
17	27	8	8	7	9	10	7	1	10	4	2	34.90	8.96
17	53	9	5	7	10	5	10	2	11	4	2	34.91	8.96
17	59	5	4	7	9	8	6	3	18	1	4	34.91	8.96
17	58	9	8	7	9	7	7	4	15	1	4	34.91	8.96
17	54	7	6	7	6	5	10	1	19	3	4	34.91	8.96
17	58	5	5	7	9	4	10	3	15	2	2	34.91	8.96
17	55	5	8	7	9	10	9	2	20	4	1	34.91	8.96
17	60	4	8	7	9	4	10	1	12	1	1	34.91	8.96
17	58	8	4	7	6	4	9	3	14	4	1	34.91	8.96
17	60	7	3	7	9	8	7	3	11	3	1	34.91	8.96
17	50	8	3	7	8	7	10	4	12	4	4	34.91	8.95
17	51	7	3	7	10	10	10	1	19	2	2	34.91	8.95
17	60	8	3	7	8	9	9	4	20	1	1	34.91	8.95

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	De	Kf	Km	Kmf	Ke	WIP	BL
17	52	7	3	7	9	4	10	3	19	3	1	34.91	8.95
17	22	4	4	7	10	4	8	2	16	3	2	34.91	8.95
17	21	4	7	7	10	4	10	4	10	1	4	34.91	8.95
17	19	4	4	7	7	10	7	3	10	1	2	34.93	8.94
17	52	7	8	7	4	5	7	2	12	4	2	34.93	8.86
17	60	5	8	7	4	5	8	2	19	4	4	34.93	8.86
17	50	4	4	7	4	4	7	2	19	1	3	34.93	8.86
17	58	5	3	7	4	9	8	1	13	1	4	34.93	8.86
17	59	3	8	7	4	7	10	1	19	4	1	34.96	8.84
17	59	9	6	8	4	10	7	4	20	4	2	34.97	8.84
17	36	8	5	9	4	5	9	2	13	3	4	34.97	8.84
17	57	8	5	12	4	5	8	2	19	4	4	34.98	8.84
17	51	7	8	15	4	6	8	3	15	1	2	34.98	8.84
17	58	4	6	18	4	8	10	2	11	3	4	34.98	8.84
17	24	9	5	14	4	5	9	3	19	1	3	34.98	8.84
17	60	8	8	18	4	4	10	2	18	4	3	34.98	8.84
17	52	6	7	11	4	6	9	1	10	2	2	34.98	8.83
17	58	4	6	17	4	7	9	1	10	3	2	34.98	8.83
17	58	4	3	18	4	8	7	3	10	1	4	34.98	8.83
17	21	6	8	17	4	10	9	1	10	1	4	34.98	8.82
17	24	3	8	9	4	6	5	3	16	1	3	35.01	8.82
17	60	3	8	16	4	6	9	1	19	1	2	35.01	8.82
17	36	3	3	9	4	7	8	1	13	4	2	35.01	8.81
17	43	3	3	15	4	5	9	1	12	1	4	35.01	8.81
17	60	3	3	17	4	10	9	1	10	4	4	35.01	8.81
17	18	9	3	12	4	6	9	2	20	2	3	35.03	8.79
17	17	7	3	7	4	9	5	1	10	1	2	35.05	8.78
17	18	3	8	17	4	10	3	1	12	1	4	35.06	8.78
17	17	9	7	10	4	5	7	4	20	3	4	35.09	8.75
17	17	4	7	10	4	4	8	4	12	3	1	35.09	8.75
17	17	7	5	18	4	8	5	2	10	1	4	35.09	8.75
17	17	7	3	16	4	6	5	3	10	2	2	35.09	8.75
17	17	3	3	18	4	7	6	4	18	1	3	35.12	8.73
17	16	3	6	7	4	10	9	2	11	2	1	35.17	8.70
17	16	9	4	10	4	7	2	2	13	1	3	35.19	8.69
17	16	6	8	16	4	6	4	1	20	4	1	35.19	8.69
17	15	3	7	7	10	8	6	1	18	4	1	35.31	8.68
17	15	3	6	7	5	4	10	4	19	1	4	35.31	8.67
17	15	8	7	7	4	5	1	1	12	4	2	35.32	8.63
17	15	4	6	7	4	4	9	4	19	1	1	35.32	8.60
17	15	7	8	8	4	6	1	3	16	1	4	35.36	8.60
17	15	9	7	17	4	5	5	2	19	1	3	35.37	8.58
17	15	3	4	8	4	10	7	1	18	4	3	35.39	8.56
17	14	9	8	6	4	5	8	4	18	1	4	35.51	8.56
17	14	9	4	6	4	8	10	4	20	1	4	35.51	8.56
17	14	3	8	6	4	6	9	1	16	4	1	35.53	8.54
17	15	8	2	9	4	6	10	3	15	1	1	35.55	8.50
17	14	4	3	7	9	9	9	4	10	1	2	35.67	8.43
17	14	7	3	7	8	9	10	4	10	4	2	35.67	8.43
17	14	7	4	7	9	7	10	3	15	1	1	35.67	8.42
17	14	4	3	7	9	10	7	2	19	1	2	35.67	8.42
18	39	4	8	6	6	6	1	2	9	1	2	36.00	5.84
18	27	9	6	6	6	8	3	1	9	1	3	36.00	5.83
18	51	7	3	6	6	10	2	4	9	4	1	36.00	5.82
18	60	5	3	6	7	8	10	1	9	1	1	36.00	5.82
18	53	3	8	6	10	6	10	2	9	1	1	36.05	5.81
18	48	8	8	6	4	8	1	4	9	1	4	36.06	5.75
18	29	6	5	6	4	10	2	4	9	4	1	36.06	5.74
18	47	5	7	6	4	8	5	1	9	1	1	36.06	5.74
18	28	7	7	6	5	6	1	2	10	1	1	36.28	4.34
18	52	6	7	6	9	6	1	1	20	3	4	36.31	4.31
18	30	4	6	6	9	10	1	4	12	4	3	36.31	4.31
18	58	8	8	6	7	4	2	4	15	3	4	36.31	4.31
18	28	9	6	6	10	6	3	2	12	1	4	36.31	4.31
18	55	9	4	6	10	8	3	2	20	2	4	36.31	4.31
18	30	6	8	6	6	7	6	1	20	2	4	36.31	4.31
18	43	5	4	6	9	7	9	1	15	3	4	36.31	4.31
18	59	8	6	6	7	6	10	1	20	1	4	36.31	4.31
18	26	5	8	6	6	6	9	1	15	1	4	36.31	4.31
18	25	9	8	6	7	4	3	2	20	3	4	36.31	4.31
18	53	5	6	6	5	5	6	2	19	4	4	36.31	4.31
18	60	5	6	6	5	10	9	4	12	3	4	36.31	4.31

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	De	Kf	Km	Kmf	Ke	WIP	BL
18	25	9	4	6	5	7	6	3	15	3	2	36.31	4.31
18	52	4	5	6	5	6	6	1	16	1	4	36.31	4.31
18	54	4	8	6	5	10	10	1	15	3	2	36.31	4.31
18	45	9	3	6	10	5	2	4	16	1	4	36.31	4.31
18	52	9	3	6	7	5	3	1	15	1	4	36.31	4.31
18	52	4	3	6	10	10	10	3	20	1	4	36.31	4.31
18	52	4	3	6	7	6	10	4	14	2	3	36.31	4.31
18	59	9	5	6	4	8	4	2	10	1	4	36.32	4.29
18	44	4	7	6	4	10	8	1	10	4	2	36.32	4.29
18	31	9	3	6	4	10	7	4	10	4	2	36.33	4.29
18	41	4	3	6	4	9	7	2	10	1	3	36.33	4.29
18	41	8	8	6	4	7	3	4	11	1	4	36.34	4.27
18	52	6	8	6	4	7	5	3	11	3	2	36.34	4.27
18	58	5	4	6	4	9	7	3	17	4	4	36.34	4.27
18	58	5	6	6	4	9	9	2	16	1	3	36.34	4.27
18	25	9	5	6	4	6	4	2	15	2	2	36.34	4.27
18	52	4	7	6	4	5	4	1	16	1	4	36.34	4.27
18	52	4	8	6	4	7	4	4	15	1	2	36.34	4.27
18	24	4	4	6	4	5	9	1	16	4	4	36.34	4.27
18	43	7	3	6	4	7	5	2	12	4	4	36.34	4.27
18	35	7	3	6	4	5	9	1	17	4	2	36.34	4.27
18	52	4	3	6	4	6	10	4	18	3	3	36.35	4.27
18	22	6	7	6	4	9	7	4	19	2	1	36.35	4.27
18	20	5	6	6	4	8	3	1	15	2	4	36.37	4.26
18	56	3	6	6	4	9	1	2	20	1	1	36.41	4.26
18	27	3	6	6	4	7	7	1	18	2	4	36.41	4.26
18	39	3	8	6	4	8	10	1	12	1	1	36.41	4.26
18	20	3	6	6	4	7	4	2	20	1	2	36.43	4.25
18	18	5	5	6	4	6	4	2	14	4	4	36.45	4.24
18	18	9	6	6	4	5	7	1	18	4	1	36.45	4.24
18	17	7	8	6	4	10	5	1	10	1	1	36.52	4.22
18	40	9	6	7	7	6	1	4	10	2	1	36.59	4.03
18	25	6	6	7	10	5	9	3	10	1	1	36.60	4.02
18	52	9	4	7	5	5	2	4	10	1	1	36.60	4.02
18	49	9	5	7	8	8	1	4	12	2	4	36.60	4.02
18	49	9	6	7	7	8	1	3	12	3	4	36.60	4.02
18	58	4	5	7	6	6	1	3	14	1	2	36.60	4.02
18	28	9	6	7	9	5	3	3	12	2	3	36.60	4.02
18	47	6	7	7	8	8	6	4	18	2	4	36.60	4.02
18	55	5	6	7	10	9	10	3	19	3	4	36.60	4.02
18	52	6	8	7	6	5	3	2	12	3	1	36.60	4.02
18	52	4	6	7	10	7	8	2	15	4	2	36.60	4.02
18	41	4	6	7	6	8	8	4	15	1	4	36.60	4.02
18	54	4	5	7	10	7	10	3	16	4	1	36.60	4.02
18	47	5	8	7	5	8	4	1	18	1	2	36.60	4.02
18	60	4	7	7	5	10	10	1	12	2	2	36.60	4.02
18	60	9	3	7	10	9	4	4	19	3	4	36.60	4.02
18	20	9	6	7	6	5	1	4	10	1	1	36.62	4.02
18	20	8	4	7	10	4	7	1	11	1	4	36.63	4.01
18	20	4	5	7	7	8	8	2	19	1	2	36.63	4.01
18	60	5	6	7	4	8	9	1	20	1	3	36.64	3.98
18	52	8	8	7	4	4	7	1	16	1	2	36.64	3.98
18	52	8	8	7	4	6	4	1	10	2	4	36.64	3.98
18	51	8	6	7	4	8	9	3	10	3	4	36.64	3.98
18	51	7	4	7	4	4	3	3	10	1	3	36.64	3.98
18	35	7	3	7	4	4	9	2	14	4	2	36.64	3.98
18	43	7	3	7	4	4	9	4	10	4	4	36.65	3.97
18	20	6	6	7	4	8	7	1	15	4	1	36.67	3.97
18	20	8	3	7	4	4	10	3	15	3	4	36.67	3.97
18	19	4	5	7	4	8	3	1	10	1	2	36.70	3.96
18	45	7	6	8	4	8	7	4	11	4	1	36.71	3.95
18	48	8	3	8	4	8	7	1	16	3	1	36.72	3.95
18	46	5	7	8	4	6	7	4	10	4	4	36.72	3.94
18	51	9	7	8	4	10	10	3	10	1	1	36.72	3.94
18	46	9	8	8	4	4	4	4	10	4	4	36.72	3.94
18	51	4	8	8	4	4	3	1	10	3	2	36.72	3.94
18	50	8	5	10	4	9	4	4	10	2	2	36.74	3.94
18	46	9	7	17	4	7	7	3	10	4	4	36.74	3.94
18	53	9	8	17	4	9	10	2	10	3	2	36.74	3.94
18	44	4	7	10	4	9	10	1	10	4	4	36.74	3.94
18	23	5	5	9	4	10	9	1	10	4	4	36.74	3.94
18	23	6	7	18	4	5	9	3	10	1	3	36.74	3.94

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	De	Kf	Km	Kmf	Ke	WIP	BL
18	60	7	3	11	4	9	3	1	10	2	1	36.74	3.94
18	21	4	4	13	4	4	9	1	10	1	4	36.75	3.93
18	45	3	8	17	4	4	10	1	15	1	2	36.81	3.93
18	52	3	7	11	4	6	4	3	10	3	1	36.81	3.93
18	29	3	5	17	4	9	9	1	10	2	4	36.81	3.93
18	31	3	5	17	4	9	9	1	10	2	4	36.81	3.93
18	50	3	7	16	4	4	1	2	10	2	1	36.81	3.93
18	55	3	3	18	4	4	9	1	10	3	1	36.82	3.92
18	20	3	6	13	4	5	5	1	20	1	2	36.83	3.92
18	18	7	8	8	4	8	3	4	11	1	2	36.83	3.91
18	18	8	3	8	4	10	4	4	10	1	3	36.84	3.90
18	18	3	8	8	4	4	7	3	15	4	4	36.90	3.90
18	17	6	7	8	4	9	9	3	16	1	1	36.94	3.87
18	17	7	8	17	4	6	3	1	10	2	1	36.97	3.87
18	16	6	6	7	4	8	3	1	10	1	1	37.05	3.86
18	16	8	7	8	4	4	2	4	10	2	2	37.14	3.82
18	16	7	7	17	4	4	3	1	10	4	2	37.16	3.82
19	47	7	8	6	8	7	4	3	10	1	4	37.50	3.02
19	31	9	4	6	7	7	5	1	10	3	2	37.50	3.02
19	42	7	7	6	6	6	9	4	10	2	1	37.50	3.02
19	38	4	4	6	6	7	8	2	10	1	4	37.51	3.02
19	37	9	7	6	4	6	3	2	10	1	4	37.54	2.99
19	29	9	5	6	4	6	8	4	10	4	1	37.54	2.99
19	21	6	4	6	4	6	2	1	10	3	4	37.56	2.98
19	36	8	8	6	6	5	3	4	11	1	1	37.57	2.93
19	58	7	7	6	10	8	6	3	11	1	4	37.57	2.93
19	54	9	5	6	10	10	1	4	19	4	4	37.57	2.93
19	57	7	5	6	10	4	3	2	20	4	2	37.57	2.93
19	60	5	8	6	10	10	6	4	20	1	4	37.57	2.93
19	44	9	7	6	10	5	10	2	18	1	2	37.57	2.93
19	32	9	8	6	7	4	9	4	19	1	4	37.57	2.93
19	59	9	8	6	9	4	9	2	15	1	1	37.57	2.93
19	48	4	7	6	5	8	2	4	15	2	1	37.58	2.93
19	23	9	4	6	8	7	5	1	18	1	2	37.58	2.93
19	24	5	3	6	10	10	4	2	20	4	4	37.59	2.93
19	27	5	6	6	4	10	1	1	14	4	1	37.61	2.91
19	38	4	6	6	4	5	2	4	16	4	2	37.61	2.91
19	60	5	6	6	4	7	10	1	20	1	1	37.61	2.91
19	56	4	5	6	4	10	10	4	18	1	4	37.61	2.91
19	59	4	8	6	4	7	9	2	19	1	1	37.61	2.91
19	23	5	4	6	4	10	2	1	18	4	1	37.61	2.90
19	19	8	5	6	4	10	1	1	18	1	1	37.70	2.88
19	19	6	8	6	4	7	5	1	18	1	4	37.70	2.88
19	18	6	8	6	4	7	7	1	14	1	1	37.79	2.86
19	17	8	3	6	7	7	8	2	11	2	1	37.90	2.86
19	18	3	3	6	4	7	4	3	14	1	1	37.90	2.85
19	17	8	3	6	4	6	7	2	15	1	4	37.94	2.83
19	16	9	4	6	6	8	6	1	15	1	2	38.15	2.81
19	16	8	4	6	6	5	10	4	14	1	2	38.15	2.81
19	16	4	7	6	4	8	9	3	19	4	4	38.19	2.78
19	28	7	5	7	7	6	2	3	10	2	4	38.20	2.21
19	32	8	8	7	6	5	9	4	10	2	4	38.20	2.21
19	55	9	5	7	10	7	10	2	10	2	1	38.20	2.21
19	29	4	8	7	9	10	10	4	10	3	4	38.20	2.21
19	30	8	5	7	9	4	9	1	10	4	3	38.20	2.21
19	48	9	3	7	8	7	9	1	10	4	1	38.21	2.21
19	54	6	6	7	9	8	1	4	12	2	4	38.22	2.20
19	59	7	4	7	10	10	3	2	14	1	1	38.22	2.20
19	59	4	8	7	8	7	8	4	19	1	2	38.22	2.20
19	30	4	6	7	5	8	9	3	18	2	2	38.22	2.20
19	29	7	3	7	9	9	3	1	12	4	3	38.23	2.20
19	54	9	3	7	8	7	4	4	19	4	4	38.23	2.20
19	21	9	4	7	9	4	9	2	20	1	1	38.25	2.20
19	38	6	5	7	4	10	5	3	11	3	4	38.28	2.17
19	57	4	6	7	4	8	6	1	10	2	1	38.28	2.17
19	21	6	4	7	4	4	7	2	14	4	2	38.31	2.17
19	58	9	8	8	9	10	1	2	10	1	1	38.35	2.17
19	32	7	8	8	6	6	3	1	10	1	1	38.35	2.16
19	59	4	8	8	10	10	8	4	10	4	2	38.35	2.16
19	59	8	6	8	8	6	1	1	11	1	4	38.36	2.16
19	38	6	4	8	6	6	4	1	20	3	2	38.36	2.16
19	59	7	8	8	10	4	9	3	16	1	1	38.36	2.16

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	De	Kf	Km	Kmf	Ke	WIP	BL
19	59	7	6	9	8	8	10	2	20	2	4	38.39	2.16
19	19	5	8	7	4	9	4	4	13	1	4	38.39	2.15
19	19	4	8	7	4	9	5	1	19	1	3	38.39	2.15
19	58	4	3	9	5	4	7	3	18	3	3	38.41	2.15
19	24	8	3	10	8	4	7	4	11	1	1	38.41	2.15
19	54	9	3	18	5	4	3	3	20	1	4	38.41	2.15
19	40	5	5	8	4	9	1	4	18	3	4	38.42	2.13
19	35	8	8	8	4	7	8	1	20	2	3	38.42	2.13
19	60	9	4	9	4	6	1	1	20	3	4	38.45	2.13
19	21	5	6	8	4	9	7	2	11	1	2	38.45	2.12
19	38	5	4	11	4	4	2	1	11	2	1	38.46	2.12
19	22	7	8	16	4	4	1	4	16	3	1	38.47	2.12
19	58	8	6	14	4	8	1	1	10	2	4	38.47	2.12
19	58	5	5	17	4	9	9	4	10	1	3	38.47	2.11
19	29	9	8	16	4	5	9	2	10	1	1	38.47	2.11
19	52	6	3	18	4	4	10	2	10	4	1	38.49	2.11
19	19	4	6	8	4	9	7	1	11	1	2	38.54	2.11
19	53	3	8	8	4	4	10	2	10	1	2	38.56	2.11
19	19	6	3	9	4	8	6	1	19	4	3	38.58	2.11
19	19	5	5	17	4	5	5	2	10	4	4	38.59	2.10
19	18	6	8	10	4	4	8	1	15	1	1	38.67	2.09
19	18	4	8	17	4	4	7	1	11	1	3	38.67	2.09
19	18	3	7	17	4	10	5	2	15	4	4	38.78	2.08
19	16	8	3	7	4	4	5	1	18	1	2	38.96	2.07
19	16	4	4	8	8	10	4	4	15	2	1	39.02	2.06
19	16	5	5	8	5	10	1	4	18	4	1	39.03	2.06
19	16	9	4	9	8	7	9	2	15	4	3	39.06	2.06
19	16	8	7	16	7	8	8	1	11	1	2	39.06	2.06
19	16	5	7	18	6	8	5	1	19	3	4	39.06	2.06
19	16	8	4	10	10	4	2	2	14	2	4	39.06	2.06
19	16	9	3	17	5	7	10	2	20	2	4	39.07	2.06
19	24	8	2	9	4	4	1	3	10	3	4	39.16	2.05
19	16	3	8	16	9	5	7	1	20	3	4	39.17	2.05
19	51	3	2	18	4	10	9	1	10	3	1	39.27	2.05
20	60	5	7	7	8	4	1	4	9	2	4	39.35	2.00
20	46	4	8	7	6	7	10	4	9	1	4	39.36	2.00
20	52	8	3	7	10	9	8	3	9	3	1	39.37	2.00
20	48	9	7	7	9	10	6	4	10	4	4	39.72	1.36
20	57	8	8	7	7	5	4	3	11	3	2	39.75	1.35
20	38	7	5	7	7	10	9	3	11	4	1	39.75	1.35
20	38	7	5	7	7	7	9	2	11	4	1	39.75	1.35
20	52	9	8	7	10	10	1	4	20	1	4	39.75	1.35
20	55	8	6	7	10	8	8	2	16	1	3	39.75	1.35
20	30	7	5	7	7	9	10	3	16	2	2	39.75	1.35
20	46	9	7	7	5	9	6	3	14	1	4	39.75	1.35
20	59	4	5	7	5	8	8	3	15	2	2	39.76	1.35
20	26	9	3	7	10	4	7	4	11	3	4	39.77	1.34
20	22	7	8	7	5	10	1	1	18	4	3	39.77	1.34
20	26	6	8	7	4	4	7	1	16	2	2	39.84	1.32
20	58	4	5	7	4	4	8	2	15	2	4	39.84	1.32
20	22	7	4	7	4	7	1	4	12	4	1	39.86	1.32
20	26	5	4	8	8	9	10	1	20	1	3	39.99	1.29
20	49	4	7	8	9	5	3	2	17	4	4	39.99	1.29
20	26	4	7	8	5	5	4	2	18	4	2	39.99	1.29
20	41	8	3	8	5	10	5	1	16	1	4	40.02	1.29
20	59	7	5	9	7	8	7	1	10	4	2	40.04	1.28
20	60	7	6	9	6	7	9	4	11	3	1	40.04	1.28
20	60	5	6	9	6	5	9	2	11	2	4	40.04	1.28
20	52	5	4	9	6	9	9	1	17	1	1	40.04	1.28
20	38	7	5	17	6	10	9	2	12	4	4	40.05	1.28
20	60	7	5	18	8	6	10	2	20	2	2	40.05	1.28
20	52	7	4	12	6	8	9	4	18	4	2	40.05	1.28
20	34	6	8	12	10	10	2	4	12	4	1	40.05	1.28
20	38	7	8	14	6	9	3	4	12	3	1	40.05	1.28
20	24	6	8	9	5	10	6	1	20	3	1	40.05	1.28
20	60	7	7	18	5	4	10	4	10	2	4	40.06	1.28
20	58	8	3	14	5	10	10	2	10	1	1	40.08	1.28
20	22	8	7	10	5	4	4	1	18	3	4	40.08	1.28
20	26	7	8	8	4	8	1	3	20	4	3	40.08	1.26
20	26	5	4	8	4	8	10	3	20	1	2	40.08	1.26
20	48	5	7	8	4	4	10	1	20	3	2	40.09	1.26
20	54	4	5	8	4	5	2	4	11	1	1	40.09	1.26

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	De	Kf	Km	Kmf	Ke	WIP	BL
20	27	5	3	8	4	8	7	2	19	1	1	40.11	1.26
20	27	6	7	8	4	5	7	1	10	1	1	40.11	1.26
20	55	5	5	17	4	10	10	4	10	1	1	40.18	1.25
20	54	4	8	17	4	7	2	4	10	4	1	40.18	1.25
20	60	4	4	14	4	4	1	4	10	1	1	40.19	1.25
20	60	3	8	8	4	8	4	2	10	1	4	40.31	1.25
20	19	9	5	17	4	7	2	4	20	1	1	40.32	1.24
20	28	3	7	18	4	9	1	4	10	4	4	40.37	1.24
20	18	4	4	8	4	4	9	1	16	4	1	40.41	1.23
20	17	7	3	15	5	8	2	1	10	1	2	40.62	1.23
20	17	3	5	16	6	4	5	2	20	4	2	40.78	1.22
20	17	3	3	11	5	7	2	2	12	4	4	40.80	1.22
20	16	8	5	8	8	4	5	1	11	1	2	41.03	1.21
20	16	5	5	12	10	7	7	4	10	4	2	41.08	1.21
20	16	5	8	13	10	5	9	1	18	2	1	41.09	1.21
20	16	4	3	17	6	4	1	3	19	1	1	41.11	1.20
21	26	9	7	7	6	5	9	4	10	3	1	41.19	0.90
21	56	8	8	7	8	7	7	3	11	1	1	41.24	0.89
21	26	9	7	7	6	10	3	4	11	1	1	41.24	0.89
21	60	9	5	7	8	4	2	4	11	1	4	41.24	0.89
21	26	9	7	7	5	9	4	3	11	2	1	41.24	0.89
21	50	5	5	7	10	6	1	4	16	4	2	41.24	0.88
21	60	9	7	7	9	9	1	1	16	2	4	41.24	0.88
21	45	9	8	7	7	7	4	3	12	2	1	41.24	0.88
21	60	6	8	7	9	5	9	4	18	4	1	41.24	0.88
21	53	9	6	7	7	4	4	4	13	1	4	41.25	0.88
21	36	6	8	7	5	7	9	4	14	1	3	41.25	0.88
21	53	6	6	7	5	6	2	2	18	4	1	41.25	0.88
21	56	8	5	7	5	9	10	2	15	1	1	41.25	0.88
21	52	9	3	7	6	5	4	1	17	4	4	41.28	0.88
21	50	9	3	7	6	10	1	2	18	3	1	41.28	0.88
21	41	4	3	7	10	6	10	1	12	1	3	41.29	0.88
21	60	4	3	7	6	4	8	1	12	2	2	41.29	0.88
21	53	4	8	7	4	7	1	2	10	1	1	41.30	0.88
21	50	5	6	7	4	9	8	1	16	4	4	41.34	0.87
21	37	4	8	7	4	6	1	4	16	1	4	41.34	0.87
21	40	4	6	7	4	8	8	1	12	2	2	41.34	0.87
21	58	8	3	7	4	4	3	1	15	4	2	41.38	0.87
21	45	9	6	8	5	7	7	4	10	1	1	41.55	0.81
21	55	8	8	8	5	4	1	1	10	1	2	41.56	0.81
21	40	9	7	8	10	7	1	4	12	3	2	41.56	0.81
21	35	6	8	8	9	8	9	1	20	4	3	41.56	0.81
21	26	5	4	8	9	8	2	2	20	3	1	41.57	0.81
21	44	5	4	8	10	4	6	1	18	4	2	41.57	0.81
21	30	9	3	8	7	7	1	2	11	3	1	41.60	0.81
21	52	9	3	8	10	10	2	2	14	4	2	41.61	0.81
21	55	4	3	8	5	5	5	1	18	1	2	41.62	0.81
21	56	8	6	9	9	10	10	2	10	4	4	41.64	0.81
21	54	4	8	9	9	9	6	2	10	3	3	41.65	0.81
21	35	6	8	9	5	5	6	1	16	4	2	41.65	0.80
21	60	5	4	9	9	4	10	3	13	4	1	41.66	0.80
21	42	5	6	11	5	7	9	1	16	1	4	41.67	0.80
21	56	9	8	15	9	4	5	2	17	4	4	41.67	0.80
21	42	9	8	11	8	4	5	1	14	4	4	41.67	0.80
21	53	4	4	12	5	8	10	4	16	1	3	41.67	0.80
21	31	9	4	18	5	4	2	1	11	1	2	41.67	0.80
21	38	4	7	11	5	4	1	3	20	2	2	41.68	0.80
21	54	6	4	8	4	6	9	3	18	3	2	41.68	0.80
21	56	5	6	8	4	8	10	2	12	4	1	41.68	0.80
21	43	4	4	8	4	10	7	2	18	1	1	41.69	0.80
21	59	4	8	8	4	7	2	1	11	4	1	41.69	0.80
21	27	5	7	8	4	7	5	2	10	1	2	41.72	0.79
21	39	6	5	16	4	7	3	3	12	1	4	41.77	0.79
21	55	8	7	17	4	8	8	4	12	1	2	41.77	0.79
21	58	7	5	18	4	6	7	4	15	4	4	41.77	0.79
21	54	8	6	11	4	8	9	1	18	4	4	41.77	0.79
21	43	6	8	17	4	5	9	4	19	4	3	41.77	0.79
21	55	9	7	17	4	9	10	1	20	1	1	41.77	0.79
21	43	4	8	12	4	6	10	2	19	4	4	41.78	0.79
21	53	9	8	12	4	4	5	4	16	2	3	41.78	0.79
21	51	8	7	17	4	8	1	4	11	1	4	41.78	0.79
21	57	6	7	18	4	7	10	4	11	4	2	41.78	0.79

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	De	Kf	Km	Kmf	Ke	WIP	BL
21	43	6	8	18	4	10	10	4	11	1	2	41.78	0.79
21	31	6	4	17	4	10	7	2	11	1	2	41.78	0.79
21	26	5	8	10	4	7	3	1	11	4	1	41.78	0.79
21	26	5	8	17	4	5	4	3	11	4	1	41.78	0.79
21	37	9	6	10	4	4	2	4	11	2	4	41.79	0.79
21	59	5	7	12	4	4	5	3	11	1	3	41.79	0.79
21	22	6	8	10	4	7	9	2	14	4	3	41.81	0.79
21	43	7	3	9	4	4	5	1	11	2	1	41.82	0.79
21	26	5	7	9	4	9	8	1	10	1	4	41.82	0.78
21	26	4	7	9	4	8	4	4	10	1	4	41.83	0.78
21	45	6	8	9	4	4	10	1	10	1	2	41.83	0.78
21	50	6	3	16	4	8	3	4	10	1	1	41.88	0.78
21	20	8	3	15	4	6	8	3	18	4	2	41.96	0.78
21	23	3	3	8	4	7	9	4	10	1	4	42.07	0.78
21	48	3	8	16	4	6	9	1	10	2	2	42.13	0.77
21	18	6	4	8	4	4	9	1	19	4	1	42.17	0.77
21	18	9	5	17	4	10	2	2	20	1	4	42.26	0.76
21	17	4	7	10	9	4	3	4	18	1	2	42.50	0.76
21	18	3	5	16	4	7	2	1	20	4	2	42.54	0.76
21	18	3	8	10	4	4	8	1	10	4	1	42.62	0.74
22	53	9	6	7	10	7	4	2	10	1	2	42.66	0.64
22	48	9	6	7	6	8	9	3	12	3	2	42.73	0.62
22	50	9	3	7	8	7	9	1	17	2	4	42.80	0.62
22	26	8	3	7	7	7	10	2	17	4	1	42.80	0.62
22	26	8	3	7	7	9	10	2	20	1	1	42.80	0.62
22	51	5	6	7	4	10	1	2	20	4	1	42.82	0.61
22	60	9	7	8	9	9	5	2	10	1	3	43.10	0.53
22	50	9	7	8	10	4	9	3	12	1	1	43.14	0.53
22	22	6	6	8	8	10	3	1	15	4	4	43.19	0.53
22	60	8	8	9	9	7	4	1	10	4	1	43.23	0.53
22	58	5	7	9	6	9	5	2	18	3	1	43.24	0.52
22	54	5	4	9	5	8	2	3	14	4	4	43.24	0.52
22	58	8	7	8	4	10	3	1	18	1	3	43.26	0.52
22	51	5	8	8	4	10	4	4	17	4	1	43.26	0.52
22	47	9	6	8	4	9	4	1	11	1	3	43.26	0.52
22	30	4	3	8	4	9	3	4	18	4	2	43.34	0.52
22	51	8	8	9	4	8	2	4	20	3	1	43.36	0.52
22	60	5	8	16	4	9	8	1	19	2	3	43.38	0.51
22	27	8	4	16	4	5	10	4	19	1	1	43.38	0.51
22	26	7	5	17	4	10	1	4	20	1	3	43.38	0.51
22	26	8	8	17	4	8	3	1	18	1	3	43.38	0.51
22	26	8	8	16	4	4	4	3	18	2	3	43.39	0.51
22	49	4	7	13	4	4	8	4	13	4	1	43.40	0.51
22	30	7	3	10	4	6	9	2	18	2	1	43.45	0.51
22	26	5	3	14	4	6	9	2	17	1	4	43.45	0.51
22	59	7	8	13	4	5	3	4	10	4	2	43.46	0.51
22	26	5	8	12	4	9	3	2	10	4	1	43.47	0.51
22	51	6	3	18	4	10	10	4	10	3	1	43.53	0.51
22	51	3	5	8	4	10	2	3	10	4	3	43.71	0.51
22	19	8	7	9	4	9	2	4	20	2	2	43.76	0.50
22	19	5	3	18	4	10	3	4	14	4	4	43.84	0.50
23	54	9	4	7	6	5	9	1	20	4	1	44.25	0.44
23	59	5	4	7	10	8	7	1	18	3	1	44.25	0.44
23	60	4	7	7	9	9	3	2	20	1	4	44.27	0.44
23	54	5	8	7	4	4	1	3	11	3	1	44.33	0.44
23	60	4	4	7	4	9	3	1	20	4	4	44.36	0.44
23	60	6	3	7	4	4	3	2	12	2	2	44.45	0.43
23	50	5	4	8	7	4	9	2	10	4	2	44.67	0.36
23	60	8	4	8	10	8	4	1	20	1	4	44.70	0.36
23	38	6	3	8	8	4	3	2	14	4	4	44.81	0.35
23	55	5	7	9	6	4	6	2	10	3	4	44.82	0.35
23	46	4	8	9	5	9	7	3	12	1	4	44.85	0.35
23	25	9	7	18	5	6	4	1	20	4	4	44.88	0.35
23	25	4	5	14	10	10	10	1	14	4	4	44.89	0.35
23	30	7	3	9	8	7	2	2	17	4	2	44.93	0.35
23	58	5	3	10	10	8	3	2	12	4	4	44.96	0.35
23	54	8	3	16	8	9	3	1	19	2	4	44.96	0.35
23	60	7	3	17	10	10	9	4	18	1	4	44.96	0.35
23	59	8	3	17	8	4	1	1	20	4	2	44.97	0.35
23	60	8	3	17	8	4	7	2	20	2	4	44.98	0.35
23	54	4	7	9	4	8	1	4	20	3	1	44.98	0.34
23	54	9	6	17	4	6	10	4	11	2	1	45.00	0.34

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	De	Kf	Km	Kmf	Ke	WIP	BL
23	28	4	6	14	4	8	3	1	20	4	2	45.01	0.34
23	28	4	6	16	4	4	10	1	19	1	4	45.01	0.34
23	38	7	5	13	4	8	10	2	10	2	1	45.07	0.34
23	28	7	7	15	4	7	7	2	10	4	1	45.08	0.34
23	28	7	6	13	4	5	3	2	10	4	2	45.08	0.34
23	53	4	8	18	4	8	9	3	10	1	4	45.09	0.34
23	20	8	3	14	8	7	6	1	18	4	4	45.26	0.34
23	20	8	8	13	4	8	6	2	18	3	2	45.32	0.33
23	20	7	8	12	4	6	10	1	16	2	4	45.32	0.33
23	19	5	8	15	4	7	9	1	13	4	4	45.56	0.33
23	19	5	8	15	4	7	10	1	14	4	2	45.56	0.33
23	19	9	4	18	4	4	3	3	16	4	4	45.56	0.33
23	19	7	8	13	4	6	10	2	10	2	1	45.68	0.33
24	54	9	8	7	10	7	6	3	19	2	1	45.80	0.32
24	60	8	5	7	9	4	4	4	13	4	4	45.80	0.32
24	60	7	8	7	4	4	10	3	11	1	1	45.89	0.32
24	38	8	8	7	4	6	4	1	13	1	1	45.89	0.32
24	38	8	8	7	4	5	4	3	13	1	1	45.89	0.32
24	50	7	8	7	4	4	10	1	12	1	3	45.89	0.32
24	49	9	5	8	10	5	10	2	13	4	4	46.28	0.24
24	49	9	4	8	7	6	10	3	13	1	4	46.28	0.24
24	49	8	8	8	7	4	1	1	14	1	2	46.29	0.24
24	31	7	7	8	5	4	4	3	12	4	1	46.30	0.24
24	23	8	5	8	6	10	5	4	20	4	4	46.36	0.24
24	23	5	5	8	6	10	5	1	18	1	1	46.37	0.24
24	27	6	8	9	6	9	7	4	20	4	4	46.43	0.24
24	34	8	8	9	10	4	8	4	20	3	4	46.43	0.24
24	46	4	6	9	10	10	7	2	20	2	4	46.46	0.24
24	46	8	7	13	5	10	3	2	10	4	2	46.47	0.24
24	46	6	7	18	5	9	7	1	10	1	4	46.47	0.24
24	39	4	5	14	9	8	7	2	14	4	4	46.50	0.24
24	60	4	5	16	5	10	9	4	20	4	3	46.50	0.24
24	57	4	8	18	10	4	1	1	20	3	4	46.51	0.24
24	23	8	4	18	9	6	6	4	10	3	2	46.54	0.23
24	23	9	5	17	7	4	1	4	19	1	1	46.56	0.23
24	23	4	5	10	6	6	6	1	11	1	2	46.57	0.23
24	23	4	5	10	6	5	6	3	11	1	2	46.57	0.23
24	46	6	7	16	4	10	3	1	19	4	2	46.59	0.23
24	51	5	5	16	4	7	9	1	13	1	2	46.59	0.23
24	60	4	5	18	4	8	4	4	18	1	2	46.63	0.23
24	36	4	6	18	4	4	8	4	15	1	3	46.63	0.23
24	31	9	7	9	4	4	4	2	10	2	2	46.64	0.23
24	49	6	7	18	4	9	7	1	10	4	1	46.69	0.23
24	36	4	6	18	4	7	7	2	10	1	3	46.72	0.23
24	21	6	4	16	4	9	10	1	10	1	4	46.98	0.22
24	20	8	4	15	4	7	4	2	11	4	1	47.08	0.22
24	55	3	6	12	4	8	10	3	19	4	2	47.43	0.22
24	54	3	8	17	4	6	3	4	20	1	1	47.43	0.22
24	23	3	8	10	4	4	4	1	12	3	1	47.51	0.22
24	60	3	5	18	4	7	4	1	10	2	4	47.52	0.22
24	18	9	7	11	10	8	8	1	20	4	2	47.85	0.22
24	20	3	6	15	4	7	9	2	20	4	1	47.86	0.21
25	51	5	4	8	8	9	10	1	11	3	1	47.88	0.17
25	30	7	8	8	6	7	3	1	17	3	3	47.88	0.17
25	54	9	8	8	10	4	2	3	17	1	1	47.89	0.17
25	25	6	8	8	7	4	3	1	17	1	4	47.93	0.17
25	60	4	4	8	10	8	10	1	14	1	2	47.94	0.17
25	43	4	8	8	6	4	2	2	12	4	1	47.95	0.17
25	23	6	4	8	7	4	10	2	11	1	4	48.02	0.17
25	54	7	8	9	10	4	10	4	10	2	3	48.02	0.16
25	48	9	6	9	8	9	8	3	20	2	1	48.03	0.16
25	52	7	4	9	9	4	10	2	17	1	4	48.05	0.16
25	47	5	7	10	7	4	1	1	16	3	4	48.08	0.16
25	57	8	8	10	6	4	10	3	19	3	1	48.08	0.16
25	30	6	4	10	8	4	10	2	12	4	1	48.09	0.16
25	59	4	8	16	10	6	3	2	10	1	4	48.12	0.16
25	56	4	7	11	9	10	5	4	11	1	1	48.13	0.16
25	58	4	8	18	5	10	2	4	10	2	1	48.14	0.16
25	23	9	4	18	8	9	2	1	10	1	4	48.20	0.16
25	44	5	6	10	4	7	10	2	12	2	1	48.20	0.16
25	48	5	6	10	4	8	8	1	17	1	1	48.20	0.16
25	44	9	7	17	4	9	1	4	12	1	2	48.21	0.16

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	De	Kf	Km	Kmf	Ke	WIP	BL
25	35	9	8	18	4	7	2	4	12	3	4	48.21	0.16
25	58	5	8	11	4	10	9	3	18	2	4	48.21	0.16
25	43	9	6	18	4	9	4	4	20	4	2	48.21	0.16
25	39	5	8	16	4	9	8	1	11	3	3	48.23	0.16
25	26	9	7	16	4	9	1	3	18	1	3	48.23	0.16
25	52	5	8	9	4	8	1	4	10	3	1	48.24	0.16
25	54	5	7	14	4	10	3	4	10	3	4	48.31	0.16
25	58	5	8	14	4	6	4	4	10	1	4	48.31	0.16
25	58	5	8	13	4	4	4	3	10	2	2	48.32	0.16
25	58	4	5	13	4	4	4	1	10	1	3	48.38	0.16
25	22	9	8	16	4	5	9	2	15	4	1	48.44	0.15
25	26	8	3	18	4	7	2	4	11	1	1	48.48	0.15
25	35	9	3	12	4	10	2	3	10	1	2	48.55	0.15
25	59	7	3	18	4	9	9	2	10	4	1	48.55	0.15
25	54	3	8	9	6	8	1	4	12	2	1	49.16	0.15
25	55	3	6	9	5	8	10	4	12	1	4	49.16	0.15
25	31	3	8	9	10	4	1	1	19	1	4	49.17	0.15
25	44	3	6	16	5	8	2	1	10	4	4	49.19	0.15
25	28	3	8	11	9	5	2	4	11	3	1	49.20	0.15
25	34	3	4	18	5	10	2	4	11	1	1	49.20	0.15
25	46	3	7	17	6	4	4	1	11	3	1	49.21	0.15
25	20	9	3	18	4	9	2	2	10	2	4	49.22	0.15
25	51	3	8	9	4	8	10	1	20	2	2	49.30	0.15
25	44	3	5	10	4	5	4	4	14	4	1	49.34	0.15
25	46	3	4	13	4	6	9	1	14	4	3	49.35	0.15
25	53	3	4	18	4	5	6	3	17	1	4	49.35	0.15
25	58	3	7	9	4	8	10	4	10	1	4	49.36	0.15
25	44	3	5	9	4	8	2	2	10	1	1	49.36	0.15
25	43	3	6	11	4	10	3	3	10	1	1	49.43	0.15
25	50	3	6	18	4	9	2	2	10	1	1	49.43	0.15
26	57	6	7	8	9	5	3	1	10	1	1	49.45	0.12
26	28	5	4	8	6	6	2	1	11	1	1	49.51	0.12
26	46	4	4	8	10	9	7	3	17	2	2	49.59	0.11
26	46	5	7	8	4	6	7	2	11	4	1	49.64	0.11
26	41	9	8	9	8	9	3	1	20	2	4	49.65	0.11
26	48	9	7	9	5	9	5	1	20	4	1	49.66	0.11
26	58	6	4	9	7	5	6	2	18	1	2	49.66	0.11
26	47	9	7	10	8	5	9	2	19	2	1	49.69	0.11
26	47	5	7	12	7	7	9	1	16	1	2	49.70	0.11
26	43	9	7	10	8	4	6	3	12	2	4	49.70	0.11
26	47	9	8	15	10	4	10	1	20	2	1	49.72	0.11
26	44	5	4	11	10	4	1	3	12	4	1	49.72	0.11
26	52	8	4	15	6	4	3	2	20	2	1	49.73	0.11
26	44	4	8	16	6	6	3	1	20	3	1	49.78	0.11
26	39	4	6	16	5	6	10	3	19	4	4	49.79	0.11
26	57	4	4	10	6	4	2	3	12	1	1	49.79	0.11
26	24	8	7	15	5	4	10	4	13	4	3	49.82	0.11
26	48	9	6	17	4	8	1	2	12	1	1	49.84	0.11
26	58	5	6	16	4	8	4	3	11	1	4	49.85	0.11
26	60	4	5	18	4	8	1	1	12	1	4	49.91	0.11
26	32	4	4	13	4	7	4	1	15	3	4	49.92	0.11
26	44	5	8	13	4	7	7	2	10	1	2	49.94	0.11
26	59	7	4	18	4	10	2	3	10	4	4	49.94	0.11
26	44	4	4	18	4	6	3	1	10	1	1	50.03	0.11
26	60	4	3	13	4	4	2	3	12	4	1	50.26	0.10
26	21	8	3	12	6	4	2	1	20	1	4	50.52	0.10
26	20	4	5	15	4	4	2	2	18	4	1	50.85	0.10
27	54	6	6	8	8	5	3	4	15	4	4	51.13	0.08
27	28	8	6	8	9	5	3	3	19	3	2	51.14	0.08
27	60	9	8	9	10	4	4	2	10	4	4	51.27	0.07
27	52	6	5	9	5	10	9	2	12	1	1	51.29	0.07
27	50	5	8	18	5	6	3	3	10	3	1	51.34	0.07
27	58	9	4	14	10	5	3	3	19	1	4	51.35	0.07
27	47	9	4	13	7	4	3	2	10	4	4	51.36	0.07
27	47	5	4	11	5	5	3	2	16	2	1	51.36	0.07
27	52	6	5	9	4	9	9	2	20	1	1	51.42	0.07
27	33	9	8	10	4	6	7	3	20	4	1	51.46	0.07
27	58	5	5	17	4	9	9	1	13	1	4	51.47	0.07
27	60	9	6	14	4	8	2	3	10	1	4	51.57	0.07
27	51	4	8	18	4	10	9	4	10	4	1	51.68	0.07
27	40	4	8	18	4	7	9	1	10	1	4	51.68	0.07
27	23	9	3	12	6	7	10	2	12	4	3	52.03	0.07

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	De	Kf	Km	Kmf	Ke	WIP	BL
27	56	4	3	14	4	8	9	4	10	1	2	52.15	0.07
27	23	6	3	11	4	8	2	1	10	1	1	52.30	0.07
27	23	9	3	17	4	4	3	2	10	4	3	52.31	0.07
28	54	6	4	8	4	6	9	1	19	3	4	52.94	0.05
28	48	9	5	17	7	8	9	1	10	3	3	52.97	0.05
28	53	6	8	12	5	5	2	3	10	4	1	52.99	0.05
28	53	5	5	12	5	8	9	1	20	2	1	52.99	0.05
28	43	9	4	10	6	10	8	1	19	2	2	53.00	0.05
28	60	9	4	17	5	9	9	3	19	1	2	53.02	0.05
28	55	4	7	16	8	9	4	1	10	4	2	53.13	0.05
28	53	4	4	10	5	8	10	1	17	1	1	53.17	0.05
28	24	4	4	9	5	4	10	3	19	1	1	53.34	0.05
28	34	9	3	10	8	4	3	4	10	4	3	53.59	0.05
28	39	5	3	18	5	4	2	1	10	1	2	53.62	0.05
28	49	4	3	10	5	8	1	1	12	4	2	53.75	0.05
29	39	5	7	8	9	6	6	2	20	1	2	54.43	0.04
29	40	7	4	8	8	8	2	4	14	2	4	54.47	0.04
29	39	9	7	9	10	9	2	4	10	1	1	54.55	0.04
29	54	5	7	9	8	9	3	2	18	4	2	54.59	0.03
29	39	5	6	9	7	4	2	4	20	2	4	54.60	0.03
29	41	7	4	10	6	6	8	4	10	2	2	54.65	0.03
29	28	8	4	9	5	10	1	4	20	1	2	54.66	0.03
29	48	5	4	10	5	10	8	4	12	3	2	54.68	0.03
29	59	4	5	9	10	8	10	3	15	2	4	54.81	0.03
29	42	4	7	12	8	4	6	1	10	2	4	54.86	0.03
29	40	8	3	16	10	4	7	2	20	3	1	55.50	0.03
29	36	6	3	10	4	4	8	2	14	4	2	55.62	0.03
29	52	4	3	17	9	8	7	2	15	2	1	55.70	0.03
29	47	4	3	15	4	8	8	2	19	3	2	55.85	0.03
30	34	8	5	8	5	10	9	1	19	2	4	56.09	0.03
30	41	8	7	9	9	4	8	3	10	1	3	56.22	0.02
30	44	9	8	9	8	9	4	3	15	3	1	56.24	0.02
30	51	6	8	10	9	10	1	4	18	3	1	56.28	0.02
30	44	9	8	15	8	10	4	3	11	3	3	56.29	0.02
30	58	9	5	17	6	9	2	1	15	1	4	56.29	0.02
30	48	5	8	18	8	9	10	2	17	1	4	56.30	0.02
30	53	9	4	18	6	8	6	3	11	4	1	56.35	0.02
30	50	9	4	18	6	8	6	4	14	4	3	56.35	0.02
30	45	8	4	11	5	5	8	3	12	2	3	56.36	0.02
30	52	6	5	9	4	7	9	3	19	2	3	56.38	0.02
30	58	6	5	17	4	6	10	3	18	2	2	56.43	0.02
30	60	4	5	13	8	9	4	3	10	4	1	56.58	0.02
30	43	4	8	15	8	6	4	3	11	4	3	56.59	0.02
30	44	4	6	18	9	10	1	4	19	3	1	56.59	0.02
30	50	4	6	15	5	6	8	2	11	4	3	56.60	0.02
30	48	4	5	14	5	6	9	2	12	1	2	56.60	0.02
30	44	4	4	10	8	4	7	1	20	2	1	56.66	0.02
30	40	4	4	16	6	4	1	3	12	2	1	56.67	0.02
30	32	4	4	17	4	8	1	2	15	1	3	56.80	0.02
30	25	4	4	16	4	8	7	4	15	4	4	57.05	0.02
30	48	6	3	9	6	4	5	1	20	1	4	57.41	0.02
30	58	6	3	10	9	7	10	3	18	2	3	57.44	0.02
30	48	8	3	11	6	8	2	4	12	1	2	57.45	0.02
30	56	7	3	14	8	6	10	3	20	2	2	57.45	0.02
30	48	9	3	13	4	9	9	3	18	1	4	57.60	0.02
30	25	8	3	16	4	7	10	1	19	4	1	57.85	0.02
31	54	9	8	9	8	7	7	1	19	4	1	57.90	0.02
31	33	9	8	16	10	10	10	2	20	1	2	57.95	0.02
31	53	9	8	17	4	9	10	1	11	3	1	58.10	0.02
31	51	4	8	9	5	5	3	1	19	1	1	58.32	0.02
31	38	4	8	16	6	4	3	4	20	1	1	58.37	0.02
31	25	4	5	17	4	10	3	4	14	1	1	58.84	0.01
32	58	7	6	14	8	9	4	4	20	4	1	59.61	0.01
32	60	5	8	18	4	10	8	1	10	3	1	59.89	0.01
32	26	4	7	8	4	8	6	2	10	1	4	60.39	0.01
33	43	5	8	13	7	9	1	1	18	1	1	61.32	0.01
34	58	6	5	8	9	4	2	2	12	2	4	62.75	0.01
34	52	9	8	17	8	7	4	3	20	4	4	62.93	0.01
34	45	8	4	16	10	4	8	2	12	1	4	63.19	0.01
34	38	4	7	18	9	7	2	4	12	4	4	63.81	0.00
34	50	4	6	18	4	4	10	3	20	1	1	63.98	0.00
35	49	9	6	8	10	5	9	1	12	1	2	64.39	0.00

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	De	Kf	Km	Kmf	Ke	WIP	BL
35	54	5	7	8	8	9	3	1	19	4	4	64.48	0.00
35	49	9	6	18	8	5	9	2	11	1	4	64.60	0.00
35	43	8	8	9	4	4	1	1	11	4	1	64.71	0.00
35	49	4	5	14	4	9	1	4	11	4	4	65.92	0.00
36	59	8	6	8	8	6	1	4	12	1	2	66.06	0.00
36	55	5	5	8	10	10	1	4	12	1	2	66.21	0.00
36	51	9	7	16	10	7	4	4	11	2	1	66.26	0.00
36	53	9	4	17	6	8	6	4	12	4	4	66.69	0.00
36	52	4	8	13	8	8	2	1	10	2	4	67.69	0.00
36	54	4	7	18	5	9	2	3	10	3	3	67.72	0.00
37	59	6	8	8	7	4	7	2	11	3	4	67.74	0.00
37	55	8	8	9	5	7	4	1	19	1	1	67.89	0.00
37	60	7	8	17	5	9	6	2	10	1	1	67.94	0.00
37	55	7	5	9	4	10	10	2	19	3	4	68.07	0.00
37	50	6	4	9	8	4	7	2	19	4	1	68.45	0.00
37	48	9	4	18	7	9	10	1	11	1	4	68.47	0.00
37	26	5	8	18	6	6	5	2	20	4	1	69.28	0.00
38	58	9	6	14	6	7	6	4	17	3	4	69.60	0.00
38	59	5	6	18	10	4	9	3	14	3	2	69.84	0.00
38	60	4	8	18	9	8	4	4	14	3	1	72.03	0.00
38	44	4	5	14	10	9	4	2	13	3	3	72.08	0.00
39	48	9	4	9	10	4	1	1	10	4	4	72.11	0.00
41	60	9	7	8	9	9	5	4	12	1	1	74.40	0.00
41	55	8	8	9	5	7	4	4	20	1	2	74.55	0.00
41	53	7	8	15	4	10	5	4	19	4	2	74.75	0.00
41	34	5	8	17	4	6	8	1	10	1	1	75.44	0.00
42	60	7	6	13	8	10	4	1	19	3	3	76.28	0.00
42	58	5	5	17	5	5	9	4	16	1	2	77.04	0.00
43	53	6	8	17	6	8	9	2	11	1	2	78.00	0.00
43	47	9	4	16	4	7	3	2	17	3	3	80.83	0.00
46	51	7	8	8	8	4	8	4	18	2	4	82.75	0.00

C8. HKC - PAC OPTIMISED SETTINGS FOR LOWER PROCESSING TIME VARIABILITY

Table C-8. Production Authorisation Card Settings for HKC Strategy 40LV

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	Kf	Km	Kmf	Ke	WIP	BL
17	22	8	8	6	4	4	1	9	4	1	34.72	11.03
17	43	4	5	6	4	5	3	9	2	1	34.72	11.03
17	36	4	6	6	8	5	4	10	1	1	34.76	9.17
17	45	4	3	6	8	9	4	16	1	1	34.77	9.15
17	47	6	7	6	5	6	2	20	1	4	34.77	9.15
17	26	9	6	6	10	4	3	19	3	4	34.77	9.15
17	46	5	5	6	9	10	4	16	4	2	34.77	9.16
17	55	4	5	6	9	7	3	11	1	4	34.77	9.15
17	26	8	4	6	8	4	4	17	2	2	34.77	9.15
17	24	8	8	6	4	9	1	10	2	4	34.79	9.06
17	53	9	4	6	4	8	4	10	3	1	34.79	9.06
17	30	9	6	6	4	9	1	10	1	4	34.79	9.06
17	24	8	6	6	4	10	2	20	1	1	34.80	9.05
17	45	5	3	6	4	9	4	16	2	1	34.80	9.05
17	24	8	6	6	4	6	3	12	4	1	34.80	9.05
17	20	5	4	6	4	4	1	12	2	2	34.81	9.03
17	41	7	7	7	8	4	4	13	4	4	34.90	8.96
17	47	4	6	7	8	6	1	14	4	3	34.90	8.97
17	28	9	3	7	10	4	2	18	3	2	34.90	8.96
17	25	7	3	7	8	7	1	10	1	2	34.90	8.97
17	45	7	6	7	4	9	1	10	3	4	34.93	8.87
17	30	7	7	7	4	10	3	18	1	1	34.93	8.87
17	30	7	7	7	4	10	3	18	4	1	34.93	8.87
17	30	7	6	7	4	10	3	18	1	1	34.93	8.87
17	21	8	4	7	4	10	1	19	1	3	34.93	8.87
17	36	6	7	8	4	10	4	19	3	4	34.95	8.86
17	31	7	7	11	4	9	2	20	1	2	34.96	8.86
17	41	3	6	7	4	4	1	18	4	1	34.96	8.85
17	29	6	8	8	4	8	1	12	4	1	34.96	8.86
17	51	9	4	16	4	8	4	18	1	2	34.96	8.86
17	51	8	4	16	4	9	4	18	1	2	34.96	8.86
17	25	3	6	7	4	7	1	10	3	4	34.96	8.85
17	36	3	7	8	4	6	1	20	3	3	34.98	8.84
17	48	3	5	18	4	6	1	18	2	1	34.99	8.84
17	48	3	6	10	4	9	1	14	1	2	34.99	8.84
17	44	7	2	7	4	7	1	16	2	1	35.13	8.78
17	54	6	2	16	4	8	3	11	2	1	35.16	8.75
17	42	6	2	17	4	4	2	16	1	4	35.16	8.76
17	54	8	2	18	4	4	4	10	2	1	35.16	8.75
17	40	3	2	11	4	4	1	18	2	4	35.19	8.74
18	21	4	3	6	5	5	1	9	1	1	36.02	5.82
18	48	9	8	6	10	8	1	10	2	4	36.29	4.34
18	46	9	8	6	6	9	1	10	2	2	36.29	4.34
18	44	9	6	6	5	5	2	20	4	1	36.30	4.32
18	36	9	8	6	10	7	1	12	2	3	36.30	4.32
18	34	4	3	6	8	4	3	17	4	4	36.30	4.32
18	53	9	5	6	10	7	4	15	4	4	36.30	4.32
18	21	9	8	6	8	5	4	11	4	1	36.31	4.31
18	52	7	7	6	4	5	4	10	3	4	36.32	4.29
18	51	4	7	6	4	5	2	10	4	4	36.32	4.29
18	52	8	6	6	4	5	4	17	3	2	36.33	4.28
18	22	7	6	6	4	6	4	12	3	1	36.34	4.27
18	44	4	6	7	5	10	2	10	1	1	36.59	4.04
18	32	7	6	7	10	7	4	14	2	1	36.59	4.04
18	34	6	7	7	5	6	4	13	1	1	36.59	4.04
18	38	8	3	7	5	6	1	11	2	1	36.60	4.03
18	21	4	6	7	4	5	4	12	3	1	36.64	3.99
18	40	5	6	11	4	10	4	10	2	1	36.69	3.97
18	34	6	7	17	4	7	4	10	2	2	36.69	3.97
18	36	9	4	8	4	7	2	10	2	1	36.69	3.97

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	Kf	Km	Kmf	Ke	WIP	BL
18	36	9	3	9	4	7	1	10	2	1	36.70	3.97
18	25	3	3	8	4	4	3	10	4	4	36.76	3.96
18	36	3	8	18	4	7	3	19	4	4	36.76	3.96
18	44	3	6	8	4	8	1	15	2	1	36.76	3.96
18	26	3	5	18	4	6	3	19	3	3	36.76	3.96
18	25	6	2	8	5	9	1	13	4	4	37.04	3.94
18	53	4	2	16	4	10	4	17	3	3	37.08	3.90
19	21	9	7	6	10	5	2	10	4	3	37.52	3.01
19	21	8	6	6	10	5	2	10	2	3	37.52	3.01
19	43	4	5	6	9	9	3	18	1	2	37.54	2.96
19	36	6	7	6	6	8	4	18	4	3	37.54	2.96
19	58	7	7	6	4	5	1	10	2	4	37.54	2.99
19	36	4	7	6	8	5	4	11	4	1	37.55	2.96
19	31	4	6	6	10	7	1	11	3	3	37.55	2.96
19	41	7	4	6	4	10	3	11	2	2	37.58	2.94
19	43	8	6	6	4	4	2	17	1	3	37.58	2.94
19	33	5	2	6	10	9	1	16	4	3	38.13	2.89
19	40	5	4	7	8	5	1	10	1	1	38.18	2.23
19	55	7	5	7	9	7	3	11	3	4	38.19	2.22
19	26	7	6	7	6	4	1	13	4	4	38.20	2.22
19	42	4	6	7	4	7	4	10	1	1	38.24	2.19
19	32	7	6	8	8	4	4	15	3	2	38.30	2.19
19	32	8	8	10	8	4	2	16	1	4	38.32	2.19
19	31	6	7	9	9	4	3	12	4	4	38.32	2.19
19	26	7	5	11	9	4	2	20	3	4	38.32	2.19
19	53	9	3	14	5	4	1	10	2	1	38.34	2.18
19	26	8	7	8	4	5	1	16	4	1	38.35	2.17
19	31	8	6	10	4	10	4	12	2	4	38.36	2.17
19	32	9	3	8	4	4	3	10	3	4	38.37	2.16
19	24	7	7	9	4	6	3	10	4	2	38.37	2.16
19	23	7	6	9	4	10	1	12	3	1	38.37	2.16
19	38	4	7	17	4	4	2	10	1	4	38.38	2.16
19	24	7	7	9	4	7	1	10	4	3	38.38	2.16
19	26	3	5	9	4	9	1	20	1	4	38.48	2.16
19	53	3	4	12	4	10	1	17	3	3	38.48	2.16
19	36	6	2	10	9	7	4	13	1	1	38.98	2.13
19	52	4	2	16	10	5	4	16	1	1	38.98	2.13
19	31	6	2	11	10	4	3	11	1	3	38.99	2.13
19	34	7	2	11	5	4	4	18	3	4	38.99	2.13
19	53	8	2	14	4	6	1	16	1	4	39.03	2.11
19	53	7	2	18	4	6	4	17	3	3	39.03	2.11
19	58	7	2	14	4	4	4	10	2	1	39.05	2.10
19	42	3	2	17	4	9	2	20	1	3	39.15	2.10
20	39	3	4	7	7	10	3	9	1	4	39.50	1.99
20	42	4	5	7	9	4	1	10	4	1	39.70	1.37
20	22	6	6	7	10	5	4	14	3	1	39.73	1.36
20	42	4	6	7	4	10	4	12	1	2	39.76	1.35
20	31	4	7	8	6	8	4	14	1	3	39.88	1.31
20	58	6	7	8	9	8	1	10	2	1	39.88	1.32
20	45	5	4	8	8	9	4	15	4	1	39.89	1.31
20	60	4	6	15	8	9	4	11	4	3	39.91	1.31
20	29	7	7	14	10	7	2	11	2	3	39.91	1.31
20	47	6	6	15	9	8	3	10	1	4	39.91	1.31
20	30	7	4	12	9	10	3	16	1	2	39.91	1.31
20	30	7	5	12	10	10	3	16	2	2	39.91	1.31
20	25	9	4	15	6	4	3	17	4	2	39.92	1.31
20	31	4	4	11	8	4	4	17	4	2	39.92	1.31
20	26	8	4	15	10	4	4	19	2	4	39.92	1.31
20	28	4	7	17	10	4	1	16	1	4	39.93	1.31
20	31	4	5	11	9	4	1	14	1	1	39.94	1.31
20	49	5	4	8	4	8	3	13	1	4	39.94	1.30
20	29	6	5	8	4	8	1	12	1	1	39.95	1.30
20	53	7	5	16	4	9	4	20	1	3	39.97	1.30
20	24	6	5	11	4	8	4	17	3	4	39.97	1.29
20	53	7	5	16	4	10	4	20	4	3	39.97	1.30
20	56	8	7	11	4	9	4	20	2	2	39.97	1.30
20	56	4	7	14	4	7	2	11	4	4	39.98	1.29
20	44	8	4	18	4	4	2	16	4	1	39.98	1.29
20	30	4	7	12	4	4	1	20	2	1	39.99	1.29
20	22	7	7	18	4	4	2	15	2	3	40.00	1.29
20	34	7	3	9	4	9	1	10	4	3	40.02	1.29
20	21	9	3	11	4	4	4	10	2	3	40.07	1.28

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	Kf	Km	Kmf	Ke	WIP	BL
20	26	3	5	9	4	8	3	10	3	4	40.18	1.28
20	48	3	6	10	4	4	1	10	2	4	40.19	1.28
20	18	4	3	9	4	7	1	14	3	4	40.29	1.27
20	17	9	5	9	4	8	2	18	3	1	40.52	1.25
20	16	8	4	15	8	6	4	20	2	1	40.90	1.24
21	38	8	7	7	10	9	4	10	2	2	41.15	0.91
21	32	6	7	7	5	10	2	18	2	2	41.18	0.90
21	30	9	7	7	5	10	2	20	1	1	41.19	0.90
21	30	8	7	7	5	10	2	20	2	1	41.19	0.90
21	47	7	6	7	4	9	4	10	3	2	41.23	0.90
21	25	9	5	7	4	9	4	20	1	2	41.24	0.89
21	25	7	5	7	4	10	1	10	4	4	41.24	0.90
21	25	7	5	7	4	10	1	10	1	3	41.24	0.90
21	40	8	6	8	10	9	3	15	2	2	41.43	0.83
21	42	4	4	8	10	10	3	12	1	3	41.43	0.83
21	51	8	7	8	6	9	4	12	4	2	41.43	0.83
21	28	7	3	8	9	6	1	18	1	4	41.47	0.83
21	48	6	6	10	7	9	4	11	4	3	41.48	0.83
21	60	6	4	10	9	9	4	10	2	4	41.48	0.83
21	54	8	7	18	7	10	1	11	4	4	41.49	0.83
21	38	7	4	8	4	5	1	13	1	3	41.49	0.82
21	26	6	5	8	4	10	1	14	1	3	41.50	0.82
21	53	9	4	8	4	7	3	10	4	4	41.51	0.82
21	40	7	5	8	4	4	1	10	4	2	41.52	0.82
21	51	8	7	17	4	10	2	12	1	4	41.54	0.82
21	35	6	7	17	4	7	4	15	1	3	41.54	0.82
21	55	8	5	9	4	9	1	16	3	3	41.54	0.82
21	53	6	6	16	4	9	4	12	4	3	41.54	0.82
21	51	4	7	17	4	9	2	11	1	3	41.55	0.82
21	35	3	5	10	5	5	4	14	2	3	41.77	0.81
21	52	3	5	10	5	9	4	16	4	4	41.77	0.81
21	22	3	7	16	8	5	3	10	1	2	41.80	0.81
21	22	3	8	17	10	9	1	19	1	4	41.81	0.81
21	58	3	3	18	10	4	4	11	4	1	41.84	0.81
22	51	9	8	7	9	10	2	10	1	3	42.62	0.64
22	44	4	4	7	8	7	4	10	2	1	42.63	0.64
22	40	9	6	7	9	10	1	11	1	4	42.66	0.63
22	52	8	7	7	4	4	4	15	1	2	42.72	0.62
22	60	9	7	7	4	9	1	16	1	4	42.72	0.62
22	51	5	8	8	7	7	3	11	4	4	42.98	0.54
22	47	5	7	8	10	4	2	12	1	3	42.99	0.54
22	26	9	7	9	9	7	1	10	1	1	43.04	0.54
22	56	9	6	8	4	5	2	14	4	2	43.04	0.54
22	51	9	7	18	5	8	4	12	1	4	43.05	0.54
22	56	5	7	17	10	8	2	12	4	4	43.05	0.54
22	47	9	5	9	8	4	4	10	1	1	43.05	0.54
22	51	8	7	18	5	8	4	12	4	4	43.05	0.54
22	52	9	7	9	10	8	4	12	1	1	43.05	0.54
22	48	8	8	18	10	10	2	11	1	1	43.06	0.54
22	47	9	6	18	9	4	1	10	2	2	43.07	0.54
22	47	9	6	18	9	4	1	16	2	4	43.07	0.54
22	37	9	6	10	9	4	1	10	1	2	43.07	0.54
22	59	5	6	17	9	4	1	11	3	1	43.08	0.54
22	45	9	3	11	6	10	4	10	2	2	43.12	0.54
22	58	7	5	15	4	9	1	20	2	2	43.12	0.53
22	56	5	6	17	4	8	2	12	1	2	43.12	0.53
22	40	7	8	18	4	9	1	15	1	1	43.13	0.53
22	39	8	7	10	4	4	4	15	2	1	43.13	0.53
22	42	6	6	10	4	8	3	10	3	1	43.15	0.53
22	40	9	8	17	4	10	2	10	2	4	43.15	0.53
22	24	6	5	9	4	9	4	10	4	1	43.15	0.53
22	24	6	4	9	4	4	4	10	1	1	43.16	0.53
22	28	6	3	10	4	4	2	10	2	3	43.23	0.53
22	53	3	4	16	8	9	3	11	4	1	43.49	0.53
23	58	9	5	7	5	10	4	16	1	1	44.17	0.46
23	20	5	7	7	4	5	2	12	1	2	44.53	0.44
23	35	6	8	8	10	5	2	18	1	1	44.54	0.37
23	32	6	6	8	5	4	1	11	4	1	44.57	0.37
23	41	7	6	8	4	8	4	13	2	1	44.61	0.36
23	27	8	7	10	9	5	2	15	4	4	44.63	0.36
23	38	7	6	10	9	8	4	13	1	2	44.63	0.36
23	43	5	7	11	9	9	4	11	1	2	44.63	0.36

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	Kf	Km	Kmf	Ke	WIP	BL
23	53	6	5	16	10	4	4	15	4	2	44.65	0.36
23	35	4	6	18	5	5	2	12	3	3	44.65	0.36
23	44	6	6	14	9	4	3	11	2	2	44.65	0.36
23	60	4	6	17	9	4	1	11	4	1	44.68	0.36
23	30	8	8	18	4	6	3	15	1	2	44.70	0.36
23	35	4	6	10	4	10	1	14	1	3	44.72	0.36
23	48	9	4	18	4	7	4	10	2	2	44.74	0.35
23	40	6	3	15	4	4	4	18	4	4	44.81	0.35
23	19	6	6	8	5	8	4	11	2	1	45.06	0.35
23	19	4	7	8	9	8	4	11	2	4	45.07	0.35
23	19	5	5	8	4	8	4	11	1	1	45.15	0.35
23	28	3	7	10	4	4	3	10	1	3	45.34	0.34
24	34	6	7	7	5	4	2	10	2	4	45.68	0.34
24	25	7	6	7	10	4	2	10	2	2	45.70	0.34
24	40	5	7	7	10	4	4	15	3	2	45.72	0.33
24	35	8	7	7	10	9	1	15	3	1	45.72	0.33
24	60	8	7	7	4	9	1	16	1	4	45.78	0.33
24	29	6	6	8	4	5	3	11	4	3	46.19	0.25
24	26	7	5	9	10	8	4	19	1	4	46.21	0.24
24	31	8	7	9	10	4	2	17	1	4	46.22	0.24
24	35	7	7	13	9	4	2	20	4	2	46.24	0.24
24	24	7	7	9	10	4	4	19	1	2	46.26	0.24
24	52	4	7	18	5	9	4	14	3	2	46.26	0.24
24	52	5	7	9	4	4	2	11	1	2	46.29	0.24
24	43	6	6	11	4	10	3	11	4	2	46.30	0.24
24	35	7	7	9	4	8	1	10	3	1	46.31	0.24
24	31	6	8	11	4	8	1	11	4	4	46.31	0.24
24	47	5	6	11	4	9	4	10	2	2	46.34	0.24
24	42	7	6	11	4	9	4	10	3	2	46.34	0.24
24	42	6	6	17	4	4	4	10	2	4	46.35	0.24
24	21	8	7	16	5	10	3	20	3	3	46.47	0.24
24	21	6	4	11	6	9	4	10	4	2	46.47	0.24
24	21	7	8	18	5	4	4	14	4	3	46.49	0.24
24	21	8	7	18	4	4	4	20	2	3	46.56	0.23
24	21	4	6	11	4	9	4	10	2	3	46.62	0.23
24	19	7	8	16	9	10	4	15	1	2	46.95	0.23
24	36	3	4	11	4	9	4	11	3	2	47.13	0.23
24	58	3	3	16	4	5	1	16	4	1	47.29	0.23
25	31	7	8	8	9	8	1	10	4	4	47.69	0.17
25	43	5	7	8	4	9	4	12	1	1	47.79	0.17
25	31	7	8	8	4	4	3	15	4	1	47.80	0.17
25	36	6	6	11	5	7	4	10	2	1	47.83	0.16
25	55	8	6	15	9	9	1	18	4	4	47.83	0.16
25	53	9	6	18	5	10	4	11	3	3	47.83	0.16
25	45	8	6	18	10	4	2	12	1	3	47.85	0.16
25	34	7	7	11	4	10	3	18	1	3	47.90	0.16
25	51	9	7	16	4	4	2	14	3	3	47.91	0.16
25	35	7	6	18	4	5	1	11	4	3	47.91	0.16
25	42	8	6	11	4	9	3	10	1	2	47.94	0.16
25	43	4	7	10	4	10	4	12	1	3	47.95	0.16
25	45	7	3	11	4	8	4	16	1	1	48.15	0.16
25	21	9	4	13	4	8	2	11	1	1	48.28	0.16
25	51	3	7	16	5	5	3	10	3	1	48.92	0.15
25	55	3	3	18	6	4	4	10	1	2	49.15	0.15
26	42	7	6	8	6	6	1	16	1	4	49.33	0.12
26	57	5	5	8	8	9	4	20	2	1	49.33	0.12
26	57	5	4	8	8	9	4	20	2	1	49.34	0.12
26	28	5	4	8	6	6	1	11	1	1	49.36	0.12
26	43	4	7	8	9	7	4	12	1	1	49.41	0.12
26	43	4	7	8	10	7	4	12	1	1	49.41	0.12
26	42	6	7	18	9	10	3	10	2	1	49.45	0.11
26	45	8	8	17	10	8	2	12	1	2	49.45	0.11
26	44	6	6	17	10	8	2	11	4	1	49.46	0.11
26	32	6	4	9	7	4	2	18	4	1	49.46	0.11
26	44	6	7	12	10	4	4	12	1	4	49.47	0.11
26	60	8	4	13	9	4	2	12	2	2	49.48	0.11
26	26	7	5	10	9	4	4	11	2	3	49.50	0.11
26	26	6	4	10	10	4	3	11	1	3	49.51	0.11
26	49	5	4	9	4	6	3	20	4	1	49.51	0.11
26	53	8	5	18	4	9	4	19	4	3	49.52	0.11
26	29	8	5	13	4	4	1	12	1	3	49.54	0.11
26	40	5	6	17	4	5	2	10	4	1	49.57	0.11

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	Kf	Km	Kmf	Ke	WIP	BL
26	42	4	7	11	4	7	3	12	1	3	49.60	0.11
26	60	4	8	12	4	5	1	10	2	4	49.65	0.11
26	31	8	3	11	9	9	2	10	3	1	49.78	0.11
26	45	8	3	18	10	4	4	12	2	3	49.80	0.11
26	42	7	3	15	9	4	1	14	1	3	49.80	0.11
26	29	7	3	9	4	7	4	15	1	3	49.83	0.11
26	54	4	3	17	4	8	1	20	1	1	49.95	0.11
26	55	3	8	15	10	6	1	10	1	4	50.95	0.10
26	57	3	5	14	7	7	1	15	3	4	50.97	0.10
26	57	3	5	16	10	7	2	19	2	4	50.97	0.10
26	40	3	5	11	6	4	1	11	2	4	51.00	0.10
26	37	3	6	11	5	4	1	11	2	4	51.01	0.10
26	33	3	7	18	4	4	4	20	2	4	51.07	0.10
27	40	5	8	11	6	10	3	10	2	3	51.08	0.08
27	40	5	4	18	7	9	1	17	2	1	51.12	0.08
27	43	4	5	11	9	8	3	10	1	1	51.19	0.08
27	38	4	4	17	5	10	3	12	2	4	51.21	0.08
27	36	7	3	17	5	9	4	11	2	3	51.54	0.07
27	54	4	3	18	4	8	1	19	1	2	51.73	0.07
27	24	8	3	17	4	8	4	14	1	1	51.76	0.07
28	52	8	7	8	4	4	1	13	1	2	52.68	0.06
28	40	8	8	9	10	9	3	15	3	2	52.69	0.05
28	46	7	6	11	6	8	3	11	1	3	52.73	0.05
28	47	8	8	9	4	9	3	10	3	2	52.80	0.05
28	53	7	5	16	4	10	4	11	4	3	52.81	0.05
28	57	7	4	14	4	4	4	11	2	1	52.86	0.05
28	37	4	7	18	6	10	4	18	1	3	52.88	0.05
28	59	4	4	17	8	6	3	18	3	2	52.91	0.05
28	54	8	3	18	4	4	4	19	2	3	53.43	0.05
28	22	7	3	18	8	5	2	15	1	1	53.88	0.05
29	55	7	8	11	8	9	2	10	1	2	54.37	0.04
29	46	7	5	11	6	8	1	10	4	3	54.38	0.04
29	56	7	8	11	10	4	1	10	1	2	54.39	0.04
29	47	8	7	18	8	4	1	16	4	4	54.40	0.04
29	40	7	8	18	4	8	1	12	1	2	54.46	0.04
29	43	6	6	11	4	9	3	10	1	4	54.49	0.04
29	43	4	5	11	6	9	3	10	1	2	54.59	0.03
29	47	4	4	16	5	7	3	13	3	4	54.64	0.03
29	22	9	8	9	10	4	3	15	3	4	55.13	0.03
29	55	8	3	9	8	10	4	19	2	1	55.20	0.03
30	28	8	4	8	5	10	4	20	2	1	56.02	0.03
30	36	7	6	10	10	8	2	11	4	3	56.03	0.02
30	53	8	8	18	9	4	2	11	1	2	56.05	0.02
30	38	8	5	9	4	9	1	16	1	2	56.08	0.02
30	54	8	8	13	4	5	4	18	2	2	56.11	0.02
30	38	8	6	10	4	10	2	10	1	3	56.14	0.02
30	42	5	4	14	4	4	4	10	1	2	56.24	0.02
30	26	8	4	13	4	8	1	12	1	2	56.32	0.02
30	52	4	8	16	10	10	3	10	3	4	56.32	0.02
30	55	4	5	17	8	4	4	11	4	2	56.35	0.02
30	53	4	4	18	4	10	3	10	1	3	56.51	0.02
30	60	6	3	18	9	10	2	10	2	2	57.17	0.02
30	53	7	3	14	5	9	1	13	3	2	57.18	0.02
30	26	8	3	13	10	8	1	12	3	2	57.30	0.02
30	28	7	3	9	4	9	4	10	1	4	57.31	0.02
31	38	8	5	9	10	9	4	11	1	1	57.68	0.02
31	46	8	6	11	6	8	4	10	4	3	57.69	0.02
31	33	8	7	9	5	4	4	15	4	1	57.69	0.02
31	59	8	8	15	10	10	4	16	1	2	57.69	0.02
31	54	8	7	17	5	10	2	16	2	2	57.69	0.02
31	43	7	6	11	10	4	4	11	2	4	57.71	0.02
31	32	7	6	10	8	4	4	16	3	4	57.71	0.02
31	43	5	5	11	4	9	3	12	1	3	57.79	0.02
31	35	5	6	11	4	9	4	11	3	3	57.80	0.02
31	44	4	5	9	4	9	1	17	4	3	58.14	0.02
31	55	4	7	17	4	10	4	16	2	4	58.17	0.02
31	55	9	3	11	6	7	2	10	2	2	59.27	0.02
31	55	6	3	17	5	10	4	15	2	1	59.28	0.01
32	33	7	8	17	10	10	4	17	4	3	59.35	0.01
32	53	7	7	18	4	10	4	20	3	3	59.43	0.01
32	40	4	5	18	4	5	1	20	1	1	59.98	0.01
33	46	7	6	8	9	9	3	10	3	1	60.85	0.01

CWn	CWr	CWe	CWf	Ks	Ksr	Kr	Kf	Km	Kmf	Ke	WIP	BL
33	46	9	8	9	9	9	1	19	1	3	60.98	0.01
33	38	7	7	17	7	10	2	16	4	4	61.01	0.01
33	42	8	5	11	4	8	1	11	2	1	61.12	0.01
34	31	7	6	8	7	8	4	19	3	3	62.58	0.01
34	51	6	6	16	10	4	4	10	1	1	62.69	0.01
34	53	7	6	18	9	4	3	11	2	2	62.69	0.01
34	48	7	6	18	10	4	3	11	2	4	62.69	0.01
34	55	7	5	18	9	4	1	15	1	2	62.71	0.01
34	35	8	5	11	4	10	2	12	2	3	62.77	0.01
34	35	8	5	11	4	9	1	11	1	3	62.78	0.01
34	49	6	6	15	4	4	3	10	1	2	62.81	0.01
34	40	4	6	8	7	4	4	13	3	4	63.42	0.00
34	42	4	6	11	9	4	3	12	4	4	63.56	0.00
35	43	7	7	8	6	6	2	12	1	4	64.20	0.00
35	60	8	8	17	9	10	2	10	1	4	64.33	0.00
35	43	7	7	18	5	9	3	12	3	2	64.34	0.00
35	42	6	5	16	8	10	1	20	2	2	64.36	0.00
35	42	7	7	11	4	6	2	12	1	2	64.41	0.00
35	40	7	6	15	4	8	1	15	1	1	64.43	0.00
35	44	7	8	10	4	10	4	10	4	1	64.45	0.00
35	42	6	4	16	5	9	1	11	1	1	64.68	0.00
35	40	7	4	15	4	8	1	15	2	1	64.75	0.00
36	54	7	5	17	6	8	1	11	1	2	66.04	0.00
36	54	7	6	17	4	8	1	11	1	2	66.09	0.00
36	45	5	6	11	4	9	4	10	1	1	66.25	0.00
36	43	4	6	8	10	7	1	11	2	1	67.33	0.00
36	55	4	8	17	8	6	1	10	1	4	67.42	0.00
37	49	7	6	18	10	9	3	11	4	3	67.67	0.00
37	44	5	6	11	8	4	4	10	2	1	67.85	0.00
37	44	6	4	10	8	7	1	19	4	1	68.22	0.00
38	49	8	6	18	9	8	3	15	4	2	69.33	0.00
38	43	8	7	17	9	4	4	15	3	4	69.35	0.00
38	46	9	6	13	4	7	1	20	3	2	69.42	0.00
38	42	5	6	17	5	10	2	15	1	3	69.56	0.00
38	60	7	4	17	9	10	4	13	3	4	70.03	0.00
39	43	7	7	17	8	6	4	12	4	4	71.00	0.00
39	31	8	6	10	4	10	2	11	4	3	71.30	0.00
39	42	5	8	17	4	10	1	15	1	4	71.38	0.00
39	53	7	4	15	5	7	2	13	1	2	71.90	0.00
39	55	8	4	9	4	9	1	14	4	2	71.96	0.00
40	60	9	6	9	10	5	3	10	1	2	72.63	0.00
40	50	8	7	18	9	4	3	10	1	4	72.68	0.00
40	34	7	7	17	6	10	1	10	2	4	72.74	0.00
40	41	8	6	17	4	9	4	16	3	1	72.76	0.00
40	44	5	7	11	8	4	4	10	1	4	73.04	0.00
40	28	7	6	10	9	10	4	11	1	4	73.70	0.00
41	58	9	6	8	10	7	3	14	1	3	74.20	0.00
41	48	8	7	9	7	10	1	10	1	3	74.29	0.00
41	38	5	6	11	5	4	4	10	1	4	74.82	0.00
42	58	8	8	18	9	4	4	12	1	2	76.01	0.00
42	40	7	5	17	7	9	4	11	4	4	76.20	0.00
43	36	9	7	13	5	7	4	19	4	3	77.73	0.00
43	53	7	8	11	4	4	4	19	2	3	77.76	0.00
44	36	7	7	14	4	5	2	10	3	1	79.56	0.00
43	40	8	4	12	9	4	1	10	3	1	80.35	0.00
44	36	7	4	15	10	4	1	20	4	1	83.04	0.00

APPENDIX D. SERVICE LEVEL AND BACKLOG COMPARISON

D1. DNC HKC 90 HV - RELATIONSHIP BETWEEN SL VS BL FOR EACH WIP VALUE

Table D-1. SL to BL Relation - DNC HEKC-II Strategy 90HV – Higher WIP Value Range

WIP	BACKLOG	SERVICE LEVEL
51.256	10.004	56.63%
51.418	9.996	56.77%
51.449	9.923	57.11%
51.451	9.869	57.12%
51.510	9.819	57.31%
51.693	9.756	57.28%
51.854	9.627	57.73%
52.692	9.259	58.00%
53.402	9.201	58.21%
53.596	9.050	58.52%
53.847	8.905	59.04%
55.504	4.707	72.15%
55.592	4.624	72.37%
55.822	4.468	72.69%
55.937	4.434	73.09%
56.130	4.326	73.52%
56.216	4.272	73.71%
56.495	4.265	73.73%
56.496	4.227	73.82%
56.515	4.162	73.98%
56.732	4.086	74.36%
56.923	4.043	74.65%
57.094	3.979	74.88%
57.331	3.901	75.15%
57.436	3.845	75.40%
57.676	3.840	75.50%
57.782	3.828	75.65%
57.825	3.811	75.57%
58.209	3.729	76.29%
58.443	3.699	76.45%
58.948	3.551	77.00%
58.997	3.505	77.13%
59.258	3.390	77.53%
59.677	3.291	77.80%
60.251	3.238	78.32%
60.545	3.212	78.58%
60.741	3.174	78.71%
61.004	2.984	79.41%
61.234	2.891	79.54%

WIP	BACKLOG	SERVICE LEVEL
61.272	2.860	79.72%
61.287	2.846	79.94%
61.399	2.809	79.94%
61.401	2.805	80.07%
61.571	2.773	80.26%
61.733	2.770	80.28%
62.098	2.742	80.51%
62.127	2.733	80.56%
62.567	2.721	80.66%
62.865	2.700	80.67%
62.886	2.659	81.01%
63.333	2.655	81.07%
63.626	2.574	81.14%
63.667	2.568	81.20%
64.206	1.831	85.59%
65.257	1.588	87.12%
65.670	1.557	87.21%
65.794	1.539	87.37%
65.936	1.481	87.57%
66.104	1.456	87.70%
66.418	1.454	87.85%
66.854	1.392	88.13%
67.302	1.350	88.43%
68.811	1.327	88.75%
68.825	1.237	89.30%
69.133	1.187	89.51%
69.475	1.172	89.68%
70.206	1.158	89.77%
70.760	1.129	89.89%
71.067	1.114	90.09%
71.106	1.076	90.41%
71.296	1.021	90.67%
71.412	0.976	90.90%
71.675	0.971	91.02%
73.016	0.782	92.70%
73.722	0.759	92.81%
74.092	0.743	93.05%
74.337	0.724	93.19%
74.749	0.596	94.05%

DNC HKC 90 HV - RELATIONSHIP BETWEEN SL vs BL FOR EACH WIP VALUE

WIP	BACKLOG	SERVICE LEVEL
74.958	0.594	94.19%
75.371	0.569	94.40%
75.742	0.553	94.42%
76.797	0.519	94.57%
76.840	0.517	94.67%
77.535	0.505	94.92%
77.605	0.489	94.99%
78.084	0.478	95.08%
78.097	0.443	95.38%
78.976	0.441	95.49%
79.643	0.422	95.61%
79.927	0.417	95.64%
80.087	0.390	95.94%
80.140	0.378	95.98%
81.076	0.359	96.06%
82.562	0.338	96.30%
82.739	0.336	96.30%
83.737	0.321	96.48%
83.815	0.317	96.52%
84.041	0.307	96.61%
84.627	0.240	97.48%
84.946	0.233	97.49%
85.306	0.228	97.55%
85.989	0.220	97.61%
86.008	0.219	97.63%
86.252	0.209	97.75%
87.101	0.206	97.76%
87.572	0.205	97.79%
88.063	0.183	97.99%
89.629	0.164	98.17%
90.913	0.160	98.21%
91.348	0.157	98.22%
91.492	0.153	98.28%
92.003	0.148	98.37%
92.638	0.139	98.48%
93.122	0.139	98.48%
93.464	0.135	98.50%

WIP	BACKLOG	SERVICE LEVEL
93.568	0.129	98.53%
94.072	0.127	98.52%
94.298	0.123	98.50%
95.160	0.122	98.58%
95.742	0.099	98.97%
95.886	0.098	98.99%
96.120	0.096	98.95%
96.494	0.094	99.01%
96.557	0.089	99.04%
97.453	0.086	99.08%
98.935	0.079	99.11%
99.750	0.070	99.24%
100.696	0.067	99.25%
103.245	0.052	99.39%
105.911	0.044	99.54%
106.294	0.038	99.57%
108.901	0.034	99.58%
108.993	0.031	99.57%
109.284	0.030	99.59%
109.859	0.030	99.61%
111.506	0.025	99.68%
111.509	0.023	99.71%
112.409	0.020	99.71%
113.197	0.020	99.73%
113.779	0.018	99.76%
115.620	0.015	99.78%
117.047	0.014	99.78%
119.050	0.012	99.82%
120.649	0.009	99.83%
124.638	0.009	99.84%
128.218	0.009	99.84%
128.366	0.008	99.85%
130.060	0.006	99.88%
132.538	0.006	99.88%
135.106	0.005	99.85%
139.913	0.005	99.88%
148.948	0.004	99.89%

D2. HKC 40 HV - RELANTIONSHIP BETWEEN SL VS BL FOR EACH WIP VALUE

Table D-2. SL to BL Relation - HKC Strategy 40HV – Lower WIP Value Range

WIP	BACKLOG	SERVICE LEVEL
37.382	11.917	39.39%
37.385	11.697	39.52%
37.489	11.681	39.52%
37.800	11.672	39.74%
37.989	9.050	42.80%
38.132	7.617	46.13%
38.132	7.617	46.13%
38.167	7.553	46.23%
38.169	7.536	46.39%
38.178	7.526	46.27%
38.192	7.494	46.40%
38.209	7.412	46.44%
38.299	7.379	46.88%
38.324	7.352	46.96%
38.372	7.320	46.77%
38.383	7.297	46.93%
38.613	7.024	47.96%
38.707	6.893	48.61%
38.856	6.825	48.59%
39.069	5.490	55.06%
39.090	5.443	55.15%
39.138	5.311	55.78%
39.250	5.257	55.79%
39.372	5.140	56.29%
39.431	5.077	56.51%
39.615	4.449	58.83%
39.736	4.431	59.06%
39.755	4.431	58.88%
39.759	4.318	59.55%
39.763	4.272	59.51%
39.775	4.268	59.66%
39.795	4.266	59.69%
39.836	4.245	59.62%
39.858	4.242	59.66%
39.898	4.208	60.13%
39.907	4.203	60.06%
39.942	4.199	60.05%
40.172	4.148	60.31%
40.353	3.970	61.29%
40.372	3.960	61.39%
40.398	3.950	61.43%
40.404	3.941	61.38%
40.411	3.932	61.45%
40.480	3.539	65.11%
40.553	3.496	65.34%
40.576	3.487	65.38%
40.604	3.471	65.32%
41.086	2.879	68.51%
41.191	2.863	68.70%
41.232	2.836	68.80%
41.316	2.830	68.85%
41.338	2.706	69.50%
41.368	2.706	69.51%
41.399	2.697	69.54%
41.401	2.688	69.65%
41.418	2.685	69.73%
41.423	2.670	69.76%
41.484	2.668	69.78%
41.510	2.649	69.98%
41.568	2.648	69.92%

WIP	BACKLOG	SERVICE LEVEL
41.581	2.637	69.97%
41.714	2.628	70.15%
41.749	2.622	70.15%
41.956	2.555	72.31%
42.232	2.459	72.86%
42.706	2.348	73.88%
42.867	2.150	74.78%
42.928	1.822	77.05%
42.961	1.821	76.96%
42.972	1.815	77.03%
43.022	1.812	77.15%
43.043	1.810	77.06%
43.057	1.807	77.11%
43.085	1.799	77.17%
43.099	1.777	77.35%
43.657	1.719	77.92%
43.697	1.689	78.20%
44.017	1.679	78.33%
44.083	1.557	80.46%
44.110	1.461	81.10%
44.521	1.397	81.61%
44.524	1.295	82.45%
44.531	1.285	82.48%
44.542	1.276	82.58%
44.605	1.270	82.64%
44.650	1.263	82.64%
44.657	1.258	82.69%
44.754	1.255	82.78%
44.837	1.240	82.88%
45.244	1.211	83.26%
45.247	1.207	83.31%
45.252	1.201	83.33%
45.304	1.194	83.52%
45.519	1.183	83.47%
45.696	1.039	85.59%
45.939	0.952	86.45%
46.108	0.943	86.62%
46.154	0.912	86.84%
46.227	0.910	86.85%
46.239	0.908	86.85%
46.334	0.892	87.04%
46.824	0.891	87.08%
46.894	0.860	87.49%
47.140	0.782	88.90%
47.220	0.779	88.94%
47.298	0.775	88.94%
47.379	0.760	89.11%
47.666	0.687	89.81%
47.678	0.684	89.84%
47.714	0.672	89.91%
47.740	0.660	90.01%
47.825	0.658	90.08%
48.328	0.649	90.19%
48.527	0.646	90.30%
48.562	0.641	90.37%
48.752	0.590	91.39%
48.780	0.587	91.42%
49.158	0.581	91.53%
49.226	0.498	92.34%
49.339	0.485	92.49%

HKC 40 HV - RELANTIONSHIP BETWEEN SL vs BL FOR EACH WIP VALUE

WIP	BACKLOG	SERVICE LEVEL
49.405	0.485	92.49%
49.432	0.482	92.55%
49.475	0.482	92.52%
49.626	0.479	92.60%
49.929	0.471	92.66%
49.962	0.464	92.74%
50.199	0.454	92.88%
50.266	0.448	92.97%
50.796	0.375	94.22%
51.048	0.357	94.38%
51.165	0.355	94.44%
51.178	0.353	94.44%
51.629	0.348	94.52%
51.796	0.344	94.55%
52.632	0.275	95.73%
52.636	0.273	95.72%
52.762	0.271	95.74%
52.836	0.263	95.87%
52.961	0.263	95.88%
53.477	0.259	95.98%
53.611	0.259	95.92%
53.672	0.253	96.02%
53.748	0.251	96.00%
54.171	0.217	96.70%
54.243	0.207	96.80%
54.271	0.203	96.82%
54.891	0.198	96.91%
55.192	0.188	97.03%
55.669	0.174	97.30%
55.895	0.160	97.50%
56.057	0.154	97.55%
56.394	0.150	97.61%
56.852	0.149	97.64%
57.162	0.144	97.74%
57.393	0.126	98.03%
57.624	0.120	98.10%
58.073	0.117	98.15%
58.937	0.096	98.48%
58.958	0.095	98.48%
59.110	0.088	98.55%
59.637	0.085	98.59%
60.231	0.084	98.66%
60.825	0.067	98.88%
61.165	0.067	98.90%
61.306	0.067	98.89%
62.039	0.064	98.96%
62.118	0.063	98.96%
62.143	0.063	98.99%
62.249	0.054	99.07%
63.032	0.050	99.15%
63.118	0.049	99.16%
63.792	0.044	99.21%
63.804	0.044	99.25%
63.847	0.043	99.25%
63.850	0.043	99.26%
64.859	0.038	99.33%
65.376	0.037	99.34%

WIP	BACKLOG	SERVICE LEVEL
65.488	0.033	99.38%
65.546	0.032	99.42%
65.632	0.030	99.43%
65.737	0.028	99.46%
65.810	0.028	99.46%
65.844	0.027	99.48%
66.670	0.026	99.51%
67.579	0.020	99.60%
68.518	0.019	99.61%
68.739	0.015	99.68%
68.947	0.015	99.69%
69.128	0.015	99.68%
69.196	0.015	99.70%
69.579	0.014	99.70%
70.074	0.012	99.73%
70.650	0.010	99.78%
72.170	0.008	99.82%
72.360	0.008	99.83%
72.432	0.007	99.83%
72.818	0.006	99.85%
73.962	0.006	99.86%
75.377	0.005	99.89%
75.647	0.003	99.92%
75.795	0.003	99.92%
76.037	0.003	99.92%
76.541	0.003	99.93%
76.547	0.003	99.93%
78.186	0.002	99.95%
78.712	0.002	99.96%
79.009	0.002	99.96%
79.131	0.002	99.96%
79.302	0.001	99.96%
79.688	0.001	99.96%
79.688	0.001	99.96%
79.688	0.001	99.96%
79.762	0.001	99.97%
80.167	0.001	99.97%
80.167	0.001	99.97%
80.830	0.001	99.97%
81.008	0.001	99.97%
82.483	0.001	99.97%
82.713	0.001	99.97%
83.622	0.001	99.98%
84.530	0.001	99.98%
86.025	0.000	99.98%
86.265	0.000	99.99%
86.616	0.000	99.99%
87.307	0.000	99.99%
87.576	0.000	99.99%
89.774	0.000	99.99%
91.041	0.000	99.99%
91.064	0.000	99.99%
92.241	0.000	99.99%
95.247	0.000	99.99%
96.624	0.000	99.99%
99.301	0.000	99.99%

APPENDIX E. ANOVA TABLES AND REPORTS

E1. DNC HEKC-II 90 HV - METAMODEL WIP REPORT

Table E-1. ANOVA Results for HV 90 DNC HEKC-II WIP Responses

Response 1 WIP

ANOVA for selected factorial model

Analysis of variance table [Partial sum of squares - Type III]

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	784368.7168	8	98046.0896	3.050764265	0.002315053	significant
A-CWn	153617.4118	1	153617.4118	4.779900067	0.029253911	
C-CWe	91564.29565	1	91564.29565	2.849079267	0.092046162	
F-Ksr	100933.3799	1	100933.3799	3.140604074	0.076970794	
H-MP	118006.8184	1	118006.8184	3.671854595	0.055905025	
L-Kmf	122565.5406	1	122565.5406	3.813702035	0.05138915	
M-Ke	88275.60625	1	88275.60625	2.746749678	0.098075879	
N-DE	0.358420329	1	0.358420329	1.11525E-05	0.997336769	
HL	109405.3058	1	109405.3058	3.404213249	0.065617759	
Residual	16165517.49	503	32138.20574			
Cor Total	16949886.2	511				

The Model F-value of 3.05 implies the model is significant. There is only
a 0.23% chance that an F-value this large could occur due to noise.

Values of "Prob > F" less than 0.0500 indicate model terms are significant.
In this case A is a significant model term.

Table E-2. ANOVA WIP Report for the DNC HEKC-II Strategy 90HV

Std. Dev.	179.2713188	R-Squared	0.046275751
Mean	100.2074529	Adj R-Squared	0.031107175
C.V. %	178.9001852	Pred R-Squared	0.011841122
PRESS	16749180.53	Adeq Precision	7.450763344
-2 Log Likelihood	6757.347032	BIC	6813.491954
		AICc	6775.705598

The "Pred R-Squared" of 0.0118 is in reasonable agreement with the "Adj R-Squared" of 0.0311
i.e. the difference is less than 0.2.

"Adeq Precision" measures the signal to noise ratio. A ratio greater than 4 is desirable.
Ratio of 7.451 indicates an adequate signal. This model can be used to navigate the design space.

Factor	Coefficient Estimate	df	Standard Error	95% CI Low	95% CI High	VIF

Intercept	100.2074529	1	7.922747824	84.64169832	115.7732074	
A-CWn	17.32148976	1	7.922747824	1.755735199	32.88724431	1
C-CWe	-13.372977	1	7.922747824	-28.9387316	2.192777516	1
F-Ksr	-14.0404953	1	7.922747824	-29.6062498	1.525259281	1
H-MP	-15.1816359	1	7.922747824	-30.7473904	0.384118703	1
L-Kmf	-15.4720982	1	7.922747824	-31.0378527	0.093656395	1
M-Ke	-13.1306243	1	7.922747824	-28.6963788	2.435130297	1
N-DE	0.026458264	1	7.922747824	-15.5392963	15.59221282	1
HL	14.61787392	1	7.922747824	-0.94788064	30.18362847	1

Final Equation in Terms of Coded Factors:

WIP	=
100.2074529	
17.32148976	* A
-13.372977	* C
-14.0404953	* F
-15.1816359	* H
-15.4720982	* L
-13.1306243	* M
0.026458264	* N
14.61787392	* HL

The equation in terms of coded factors can be used to make predictions about the response for given levels of each factor. By default, the high levels of the factors are coded as +1 and the low levels of the factors are coded as -1. The coded equation is useful for identifying the relative impact of the factors by comparing the factor coefficients.

Final Equation in Terms of Actual Factors:

WIP	=
179.7820918	
34.64297951	* CWn
-4.45765901	* CWe
-5.61619811	* Ksr
-15.8179036	* MP
-47.3466794	* Kmf
-8.75374951	* Ke
0.006614566	* DE
3.898099711	* MP * Kmf

The equation in terms of actual factors can be used to make predictions about the response for given levels of each factor. Here, the levels should be specified in the original units for each factor. This equation should not be used to determine the relative impact of each factor because the coefficients are scaled to accommodate the units of each factor and the intercept is not at the center of the design space.

E2. DNC HEKC-II 90 HV - METAMODEL BL REPORT

Table E-3. ANOVA Results for HV 90 DNC HEKC-II BL Responses

Response 2 BL
Transform: Inverse
ANOVA for selected factorial model
Analysis of variance table [Partial sum of squares - Type III]

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	2980.260751	8	372.5325939	805.5591836	3.6404E-281	significant
A-CWn	2185.513133	1	2185.513133	4725.922519	6.8626E-258	
C-CWe	6.585001085	1	6.585001085	14.23931271	0.00018015	
F-Ksr	612.4514526	1	612.4514526	1324.356312	5.2039E-143	
H-MP	16.1290898	1	16.1290898	34.87731442	6.46997E-09	
L-Kmf	34.21058144	1	34.21058144	73.97647483	1.01017E-16	
N-DE	0.004133097	1	0.004133097	0.008937349	0.924719799	
AF	116.7825546	1	116.7825546	252.5289353	2.246E-46	
AL	8.584806191	1	8.584806191	18.56366283	1.97707E-05	
Residual	232.6134424	503	0.462452172			
Cor Total	3212.874194	511				

The Model F-value of 805.56 implies the model is significant. There is only a 0.01% chance that an F-value this large could occur due to noise.

Values of "Prob > F" less than 0.0500 indicate model terms are significant.
In this case A, C, F, H, L, AF, AL are significant model terms.

Table E-4. ANOVA BL Report for the DNC HEKC-II Strategy 90HV

Std. Dev.	0.680038361	R-Squared	0.92759958
Mean	4.733627395	Adj R-Squared	0.926448082
C.V. %	14.36611511	Pred R-Squared	0.924985531
PRESS	241.0120519	Adeq Precision	82.3411671
-2 Log Likelihood	1049.052402	BIC	1105.197323
		AICc	1067.410967

The "Pred R-Squared" of 0.9250 is in reasonable agreement with the "Adj R-Squared" of 0.9264
i.e. the difference is less than 0.2.

"Adeq Precision" measures the signal to noise ratio. A ratio greater than 4 is desirable.
Ratio of 82.341 indicates an adequate signal. This model can be used to navigate the design space.

Factor	Coefficient Estimate	df	Standard Error	95% CI Low	95% CI High	VIF
Intercept	4.733627395	1	0.030053734	4.674581084	4.792673707	
A-CWn	2.066054292	1	0.030053734	2.00700798	2.125100604	1
C-CWe	-0.11340781	1	0.030053734	-0.17245412	-0.05436149	1
F-Ksr	-1.09370665	1	0.030053734	-1.15275297	-1.03466034	1
H-MP	-0.17748839	1	0.030053734	-0.2365347	-0.11844208	1
L-Kmf	-0.25849089	1	0.030053734	-0.31753721	-0.19944458	1
N-DE	0.002841206	1	0.030053734	-0.05620511	0.061887518	1
AF	-0.47758866	1	0.030053734	-0.53663497	-0.41854235	1
AL	-0.12948822	1	0.030053734	-0.18853453	-0.07044191	1

Final Equation in Terms of Coded Factors:

1/(BL)	=
4.733627395	
2.066054292	* A
-0.11340781	* C
-1.09370665	* F
-0.17748839	* H

-0.25849089	* L
0.002841206	* N
-0.47758866	* AF
-0.12948822	* AL

The equation in terms of coded factors can be used to make predictions about the response for given levels of each factor. By default, the high levels of the factors are coded as +1 and the low levels of the factors are coded as -1. The coded equation is useful for identifying the relative impact of the factors by comparing the factor coefficients.

Final Equation in Terms of Actual Factors:

1/(BL)	=
-42.8120972	
8.193409796	* CWn
-0.0378026	* CWe
2.045978364	* Ksr
-0.07099536	* MP
0.949903994	* Kmf
0.000710302	* DE
-0.38207093	* CWn * Ksr
-0.17265096	* CWn * Kmf

The equation in terms of actual factors can be used to make predictions about the response for given levels of each factor. Here, the levels should be specified in the original units for each factor. This equation should not be used to determine the relative impact of each factor because the coefficients are scaled to accommodate the units of each factor and the intercept is not at the center of the design space.

E3. DNC HEKC-II 40 HV - METAMODEL WIP REPORT

Table E-5. ANOVA Results for 40 HV DNC HEKC-II WIP Responses

Response	1	WIP				
Transform:	Power	Lambda:	1	Constant:	0	
ANOVA for selected factorial model						
Analysis of variance table [Partial sum of squares - Type III]						
	Sum of		Mean	F	p-value	
Source	Squares	df	Square	Value	Prob > F	
Model	1734.943219	22	78.86105541	7585.167506	0	significant
A-CWn	1235.677607	1	1235.677607	118852.3484	0	
B-CWr	27.39622505	1	27.39622505	2635.077035	4.6818E-199	
C-CWe	4.498546617	1	4.498546617	432.6879656	2.60329E-69	
D-CWf	22.34749216	1	22.34749216	2149.469982	4.138E-181	
E-Ks	346.5631619	1	346.5631619	33333.8125	0	
F-Ksr	8.135060782	1	8.135060782	782.4622482	1.5695E-103	
G-Kr	4.013074465	1	4.013074465	385.9933382	8.90263E-64	
J-Km	4.45090539	1	4.45090539	428.1056443	8.83028E-69	
K-Kmf	2.924803608	1	2.924803608	281.3191527	3.30602E-50	
L-Ke	1.618927827	1	1.618927827	155.714867	3.22452E-31	
M-MP	27.01054624	1	27.01054624	2597.980925	8.6959E-198	
AB	1.605999605	1	1.605999605	154.4713795	5.1852E-31	
AD	1.578791866	1	1.578791866	151.8544318	1.41342E-30	
AE	2.364685598	1	2.364685598	227.4447922	1.77082E-42	
AM	6.532680587	1	6.532680587	628.3389977	8.63311E-90	
DM	1.393928591	1	1.393928591	134.0735526	1.44094E-27	
EJ	7.27965685	1	7.27965685	700.1861225	2.03656E-96	
EM	26.55514262	1	26.55514262	2554.178408	2.8668E-196	
FM	1.000355795	1	1.000355795	96.21816791	7.43914E-21	
JM	0.224264281	1	0.224264281	21.57062352	4.38915E-06	
KL	0.940977466	1	0.940977466	90.50692589	8.39031E-20	
EJM	0.83038496	1	0.83038496	79.86970228	8.19422E-18	
Residual	5.084008502	489	0.010396745			
Cor Total	1740.027227	511				

The Model F-value of 7585.17 implies the model is significant. There is only a 0.01% chance that an F-value this large could occur due to noise.

Values of "Prob > F" less than 0.0500 indicate model terms are significant.
In this case A, B, C, D, E, F, G, J, K, L, M, AB, AD, AE, AM, DM, EJ, EM, FM, JM, KL, EJM are significant model terms.
Values greater than 0.1000 indicate the model terms are not significant.
If there are many insignificant model terms (not counting those required to support hierarchy), model reduction may improve your model.

Table E-6. ANOVA WIP Report for the DNC HEKC-II Strategy 40HV

Std. Dev.	0.1019644	R-Squared	0.9970782
Mean	50.254696	Adj R-Squared	0.9969468
C.V. %	0.2028953	Pred R-Squared	0.9967969

PRESS	5.573506	Adeq Precision	343.7234
-2 Log Likelihood	-908.46594	BIC	-764.98447
		AICc	-860.20364

The "Pred R-Squared" of 0.9968 is in reasonable agreement with the "Adj R-Squared" of 0.9969
i.e. the difference is less than
0.2.

"Adeq Precision" measures the signal to noise ratio. A ratio greater than 4 is desirable. Your ratio of 343.723 indicates an adequate signal. This model can be used to navigate the design space.

Factor	Coefficient Estimate	df	Standard Error	95% CI Low	95% CI High	VIF
Intercept	50.254696	1	0.0045062	50.245842	50.26355	
A-CWn	1.5535227	1	0.0045062	1.5446687	1.5623767	1
B-CWr	-0.2313185	1	0.0045062	-0.2401725	-0.2224645	1
C-CWe	-0.0937349	1	0.0045062	-0.1025888	-0.0848809	1
D-CWf	-0.2089197	1	0.0045062	-0.2177737	-0.2000657	1
E-Ks	0.8227279	1	0.0045062	0.8138739	0.8315819	1
F-Ksr	-0.1260507	1	0.0045062	-0.1349047	-0.1171968	1
G-Kr	-0.0885327	1	0.0045062	-0.0973867	-0.0796787	1
J-Km	0.0932372	1	0.0045062	0.0843832	0.1020912	1
K-Kmf	-0.0755811	1	0.0045062	-0.0844351	-0.0667272	1
L-Ke	-0.0562314	1	0.0045062	-0.0650854	-0.0473774	1
M-MP	0.2296845	1	0.0045062	0.2208305	0.2385385	1
AB	-0.0560064	1	0.0045062	-0.0648604	-0.0471524	1
AD	-0.05553	1	0.0045062	-0.0643839	-0.046676	1
AE	0.0679597	1	0.0045062	0.0591058	0.0768137	1
AM	-0.1129564	1	0.0045062	-0.1218103	-0.1041024	1
DM	0.0521777	1	0.0045062	0.0433238	0.0610317	1
EJ	-0.1192396	1	0.0045062	-0.1280936	-0.1103856	1
EM	-0.22774	1	0.0045062	-0.236594	-0.218886	1
FM	0.044202	1	0.0045062	0.0353481	0.053056	1
JM	-0.0209288	1	0.0045062	-0.0297828	-0.0120749	1
KL	0.0428701	1	0.0045062	0.0340161	0.0517241	1
EJM	0.0402721	1	0.0045062	0.0314182	0.0491261	1

Final Equation in Terms of Coded Factors:

(WIP)^1	=
50.254696	
1.5535227	* A
-0.2313185	* B
-0.0937349	* C
-0.2089197	* D
0.8227279	* E
-0.1260507	* F
-0.0885327	* G
0.0932372	* J
-0.0755811	* K
-0.0562314	* L
0.2296845	* M
-0.0560064	* AB
-0.05553	* AD
0.0679597	* AE
-0.1129564	* AM
0.0521777	* DM
-0.1192396	* EJ
-0.22774	* EM
0.044202	* FM
-0.0209288	* JM
0.0428701	* KL
0.0402721	* EJM

The equation in terms of coded factors can be used to make predictions about the response for given levels of each factor. By default, the high levels of the factors are coded as +1 and the low levels of the factors are coded as -1. The coded equation is useful for identifying the relative impact of the factors by comparing the factor coefficients.

Final Equation in Terms of Actual Factors:

(WIP)^1	=
-0.8000385	
1.8127446	* CWn
0.0874892	* CWr
-0.0624899	* CWe
0.5739483	* CWf
0.0694002	* Ks
-0.1331472	* Ksr
-0.0354131	* Kr
0.229066	* Km
-0.0980209	* Kmf
-0.085121	* Ke
1.3806711	* MP
-0.0040005	* CWn * CWr
-0.027765	* CWn * CWf
0.0194171	* CWn * Ks
-0.0376521	* CWn * MP
0.0086963	* CWf * MP
-0.0177486	* Ks * Km
-0.0383098	* Ks * MP
0.0098227	* Ksr * MP
-0.0157495	* Km * MP
0.0190534	* Kmf * Ke
0.0012785	* Ks * Km * MP

The equation in terms of actual factors can be used to make predictions about the response for given levels of each factor. Here, the levels should be specified in the original units for each factor. This equation should not be used to determine the relative impact of each factor because the coefficients are scaled to accommodate the units of each factor and the intercept is not at the center of the design space.

E4. DNC HEKC-II 40 HV - METAMODEL BL REPORT

Table E-7. ANOVA Results for 40 HV DNC HEKC-II BL Responses

Response 2 BL
Transform: Natural Log Constant: 0
ANOVA for selected factorial model
Analysis of variance table [Partial sum of squares - Type III]

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	60.54970857	18	3.363872699	29287.9194	0	significant
A-CWn	30.14920409	1	30.14920409	262497.2877	0	
B-CWr	0.08845802	1	0.08845802	770.1692613	8.683E-103	
D-CWf	0.077875522	1	0.077875522	678.0316108	1.14267E-94	
E-Ks	15.68089984	1	15.68089984	136527.4407	0	
F-Ksr	0.061694463	1	0.061694463	537.1494773	6.34969E-81	
G-Kr	0.022212548	1	0.022212548	193.3959377	2.50757E-37	
J-Km	0.628464104	1	0.628464104	5471.790306	4.7479E-269	
M-MP	8.832922385	1	8.832922385	76904.78862	0	
AD	0.006389433	1	0.006389433	55.63028173	3.97307E-13	
AE	0.231344518	1	0.231344518	2014.225925	3.0775E-176	
AJ	0.045027826	1	0.045027826	392.0396136	1.23445E-64	
AM	0.017310262	1	0.017310262	150.71366	2.04999E-30	
EJ	0.179499268	1	0.179499268	1562.829681	5.6234E-155	
EM	4.329164593	1	4.329164593	37692.33709	0	
JM	0.156168166	1	0.156168166	1359.694936	7.8571E-144	
AEJ	0.011454138	1	0.011454138	99.72668114	1.64521E-21	
AEM	0.018052904	1	0.018052904	157.1795477	1.71776E-31	
EJM	0.013566492	1	0.013566492	118.1181214	8.23239E-25	
Residual	0.056623662	493	0.000114855			
Cor Total	60.60633223	511				

The Model F-value of 29287.92 implies the model is significant. There is only a 0.01% chance that an F-value this large could occur due to noise.

Values of "Prob > F" less than 0.0500 indicate model terms are significant.
In this case A, B, D, E, F, G, J, M, AD, AE, AJ, AM, EJ, EM, JM, AEJ, AEM, EJM are significant model terms.
Values greater than 0.1000 indicate the model terms are not significant.
If there are many insignificant model terms (not counting those required to support hierarchy), model reduction may improve your model.

Table E-8. ANOVA BL Report for the DNC HEKC-II Strategy 40HV

Std. Dev.	0.0107171	R-Squared	0.9990657
Mean	-0.7101331	Adj R-Squared	0.9990316
C.V. %	1.5091617	Pred R-Squared	0.9989923
PRESS	0.0610723	Adeq Precision	595.76604
-2 Log Likelihood	-3211.1493	BIC	-3092.6211
		AICc	-3171.6045

The "Pred R-Squared" of 0.9990 is in reasonable agreement with the "Adj R-Squared" of 0.9990 i.e. the difference is less than 0.2.

"Adeq Precision" measures the signal to noise ratio. A ratio greater than 4 is desirable. Your ratio of 595.766 indicates an adequate signal. This model can be used to navigate the design space.

Factor	Coefficient Estimate	df	Standard Error	95% CI Low	95% CI High	VIF
Intercept	-0.7101331	1	0.0004736	-0.7110637	-0.7092025	
A-CWn	-0.2426627	1	0.0004736	-0.2435932	-0.2417321	1
B-CWr	0.0131442	1	0.0004736	0.0122136	0.0140748	1
D-CWf	0.0123329	1	0.0004736	0.0114023	0.0132635	1
E-Ks	-0.175005	1	0.0004736	-0.1759356	-0.1740744	1
F-Ksr	0.0109771	1	0.0004736	0.0100465	0.0119077	1
G-Kr	0.0065866	1	0.0004736	0.0056561	0.0075172	1
J-Km	-0.0350353	1	0.0004736	-0.0359658	-0.0341047	1
M-MP	-0.1313461	1	0.0004736	-0.1322767	-0.1304155	1
AD	0.0035326	1	0.0004736	0.002602	0.0044632	1
AE	-0.0212566	1	0.0004736	-0.0221872	-0.0203261	1
AJ	-0.0093779	1	0.0004736	-0.0103085	-0.0084473	1
AM	0.0058146	1	0.0004736	0.004884	0.0067451	1
EJ	0.0187239	1	0.0004736	0.0177933	0.0196545	1
EM	0.0919532	1	0.0004736	0.0910227	0.0928838	1
JM	0.0174647	1	0.0004736	0.0165341	0.0183953	1
AEJ	0.0047298	1	0.0004736	0.0037993	0.0056604	1
AEM	0.005938	1	0.0004736	0.0050074	0.0068686	1
EJM	-0.0051475	1	0.0004736	-0.0060781	-0.0042169	1

Final Equation in Terms of Coded Factors:

Ln(BL)	=
-0.7101331	
-0.2426627	* A
0.0131442	* B
0.0123329	* D
-0.175005	* E
0.0109771	* F
0.0065866	* G
-0.0350353	* J
-0.1313461	* M
0.0035326	* AD
-0.0212566	* AE
-0.0093779	* AJ
0.0058146	* AM
0.0187239	* EJ
0.0919532	* EM
0.0174647	* JM
0.0047298	* AEJ
0.005938	* AEM
-0.0051475	* EJM

The equation in terms of coded factors can be used to make predictions about the response for given levels of each factor. By default, the high levels of the factors are coded as +1 and the low levels of the factors are coded as -1. The coded equation is useful for identifying the relative impact of the factors by comparing the factor coefficients.

Final Equation in Terms of Actual Factors:

Ln(BL)	=
2.7072369	
-0.0655999	* CWn
0.0009389	* CWr
-0.0397575	* CWf
0.2560875	* Ks
0.0073181	* Ksr
0.0026347	* Kr
0.1555667	* Km
-0.0792735	* MP
0.0017663	* CWn * CWf
-0.0147569	* CWn * Ks
-0.0078558	* CWn * Km
-0.0039998	* CWn * MP
-0.0091117	* Ks * Km
-0.0038217	* Ks * MP
0.0036564	* Km * MP
0.0004505	* CWn * Ks * Km
0.0005655	* CWn * Ks * MP
-0.0001634	* Ks * Km * MP

The equation in terms of actual factors can be used to make predictions about the response for given levels of each factor. Here, the levels should be specified in the original units for each factor. This equation should not be used to determine the relative impact of each factor because the coefficients are scaled to accommodate the units of each factor and the intercept is not at the center of the design space.

E5. HKC 90 HV - METAMODEL WIP REPORT

Table E-9. ANOVA Results for 90 HV HKC WIP Responses

Response 1 WIP
Transform: Natural Log Constant: 0
ANOVA for selected factorial model
Analysis of variance table [Partial sum of squares - Type III]

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	3.304560754	11	0.300414614	76523.23993	0	significant
A-CWn	2.492401065	1	2.492401065	634877.918	0	
B-CWr	0.000540075	1	0.000540075	137.5707168	3.10857E-28	
C-CWe	0.133452599	1	0.133452599	33993.76994	0	
E-Ks	0.002610885	1	0.002610885	665.0588251	6.74328E-94	
F-Ksr	0.595180222	1	0.595180222	151607.5345	0	
G-Kr	0.042508826	1	0.042508826	10828.07869	0	
J-Km	0.000402913	1	0.000402913	102.6322581	4.59105E-22	
AC	0.020038763	1	0.020038763	5104.382314	1.5241E-264	
CF	0.001803928	1	0.001803928	459.5063532	8.74414E-73	
FG	0.015160715	1	0.015160715	3861.819666	2.5359E-237	
FJ	0.000460763	1	0.000460763	117.3680178	1.03656E-24	
Residual	0.001962898	500	3.9258E-06			
Cor Total	3.306523652	511				

The Model F-value of 76523.24 implies the model is significant. There is only a 0.01% chance that an F-value this large could occur due to noise.

Values of "Prob > F" less than 0.0500 indicate model terms are significant.
In this case A, B, C, E, F, G, J, AC, CF, FG, FJ are significant model terms.
Values greater than 0.1000 indicate the model terms are not significant.
If there are many insignificant model terms (not counting those required to support hierarchy), model reduction may improve your model.

Table E-10. ANOVA WIP Report for the HKC Strategy 90HV

Std. Dev.	0.001981362	R-Squared	0.999406356
Mean	4.41078831	Adj R-Squared	0.999393296
C.V. %	0.044920816	Pred R-Squared	0.999377519
PRESS	0.002058248	Adeq Precision	879.2720591
-2 Log Likelihood	-4932.49584	BIC	-4857.63594
		AICc	-4907.87059

The "Pred R-Squared" of 0.9994 is in reasonable agreement with the "Adj R-Squared" of 0.9994 i.e. the difference is less than 0.2.

"Adeq Precision" measures the signal to noise ratio. A ratio greater than 4 is desirable. Your ratio of 879.272 indicates an adequate signal. This model can be used to navigate the design space.

Factor	Coefficient Estimate	df	Standard Error	95% CI Low	95% CI High	VIF
Intercept	4.41078831	1	8.75647E-05	4.41061627	4.41096035	
A-CWn	0.069770845	1	8.75647E-05	0.069598805	0.069942885	1
B-CWr	-0.00102705	1	8.75647E-05	-0.00119909	-0.00085501	1
C-CWe	-0.01614465	1	8.75647E-05	-0.01631669	-0.01597261	1
E-Ks	0.002258182	1	8.75647E-05	0.002086142	0.002430222	1
F-Ksr	-0.03409489	1	8.75647E-05	-0.03426693	-0.03392285	1
G-Kr	-0.00911181	1	8.75647E-05	-0.00928385	-0.00893977	1
J-Km	-0.0008871	1	8.75647E-05	-0.00105914	-0.00071506	1
AC	-0.00625605	1	8.75647E-05	-0.00642809	-0.00608401	1

CF	0.001877045	1	8.75647E-05	0.001705005	0.002049085	1
FG	-0.00544158	1	8.75647E-05	-0.00561362	-0.00526954	1
FJ	0.000948645	1	8.75647E-05	0.000776605	0.001120685	1

Final Equation in Terms of Coded Factors:

Ln(WIP)	=
4.41078831	
0.069770845	* A
-0.00102705	* B
-0.01614465	* C
0.002258182	* E
-0.03409489	* F
-0.00911181	* G
-0.0008871	* J
-0.00625605	* AC
0.001877045	* CF
-0.00544158	* FG
0.000948645	* FJ

The equation in terms of coded factors can be used to make predictions about the response for given levels of each factor. By default, the high levels of the factors are coded as +1 and the low levels of the factors are coded as -1. The coded equation is useful for identifying the relative impact of the factors by comparing the factor coefficients.

Final Equation in Terms of Actual Factors:

Ln(WIP)	=
3.394965557	
0.187802676	* CWn
-0.00015801	* CWr
0.016861891	* CWe
0.001505455	* Ks
-0.00956256	* Ksr
0.001252523	* Kr
-0.00100102	* Km
-0.00357489	* CWn * CWe
0.000153228	* CWe * Ksr
-0.00022211	* Ksr * Kr
6.77604E-05	* Ksr * Km

The equation in terms of actual factors can be used to make predictions about the response for given levels of each factor. Here, the levels should be specified in the original units for each factor. This equation should not be used to determine the relative impact of each factor because the coefficients are scaled to accommodate the units of each factor and the intercept is not at the center of the design space.

E6. HKC 90 HV - METAMODEL BL REPORT

Table E-11. ANOVA Results for 90 HV HKC BL Responses

Response 2 BL
Transform: Natural Log Constant: 0
ANOVA for selected factorial model
Analysis of variance table [Partial sum of squares - Type III]

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	189.3186409	9	21.03540454	31197.62108	0	significant
A-CWn	155.9947758	1	155.9947758	231355.9455	0	
C-CWe	0.854047941	1	0.854047941	1266.639013	2.2015E-139	
E-Ks	1.423868207	1	1.423868207	2111.73979	5.5114E-182	
F-Ksr	28.436027	1	28.436027	42173.48869	0	
G-Kr	1.706466673	1	1.706466673	2530.861746	3.3275E-198	
AC	0.192331104	1	0.192331104	285.2463756	5.2865E-51	
AE	0.067645986	1	0.067645986	100.3258026	1.18934E-21	
AF	0.070194682	1	0.070194682	104.105775	2.43684E-22	
FG	0.57328348	1	0.57328348	850.2370721	4.3052E-110	
Residual	0.338480074	502	0.000674263			
Cor Total	189.6571209	511				

The Model F-value of 31197.62 implies the model is significant. There is only
a 0.01% chance that an F-value this large could occur due to noise.

Values of "Prob > F" less than 0.0500 indicate model terms are significant.
In this case A, C, E, F, G, AC, AE, AF, FG are significant model terms.
Values greater than 0.1000 indicate the model terms are not significant.
If there are many insignificant model terms (not counting those required to support hierarchy),
model reduction may improve your model.

Table E-12. ANOVA BL Report for the HKC Strategy 90HV

Std. Dev.	0.025966576	R-Squared	0.998215305
Mean	-0.85578956	Adj R-Squared	0.998183309
C.V. %	3.034224516	Pred R-Squared	0.998143494
PRESS	0.352099651	Adeq Precision	517.480054
-2 Log Likelihood	-2295.67366	BIC	-2233.29041
		AICc	-2275.23454

The "Pred R-Squared" of 0.9981 is in reasonable agreement with the "Adj R-Squared" of 0.9982
i.e. the difference is less than 0.2.

"Adeq Precision" measures the signal to noise ratio. A ratio greater than 4 is desirable. Your
ratio of 517.480 indicates an adequate signal. This model can be used to navigate the design space.

Factor	Coefficient Estimate	df	Standard Error	95% CI Low	95% CI High	VIF
Intercept	-0.85578956	1	0.001147571	-0.85804419	-0.85353492	
A-CWn	-0.55197581	1	0.001147571	-0.55423045	-0.54972118	1
C-CWe	0.040841919	1	0.001147571	0.038587285	0.043096554	1
E-Ks	-0.05273512	1	0.001147571	-0.05498975	-0.05048048	1
F-Ksr	0.235667383	1	0.001147571	0.233412748	0.237922017	1
G-Kr	0.057731644	1	0.001147571	0.05547701	0.059986279	1
AC	0.019381607	1	0.001147571	0.017126972	0.021636241	1
AE	-0.01149439	1	0.001147571	-0.01374903	-0.00923976	1
AF	0.011708928	1	0.001147571	0.009454293	0.013963562	1
FG	0.033461833	1	0.001147571	0.031207199	0.035716468	1

Final Equation in Terms of Coded Factors:

Ln(BL)	=
-0.85578956	
-0.55197581	* A
0.040841919	* C
-0.05273512	* E
0.235667383	* F
0.057731644	* G
0.019381607	* AC
-0.01149439	* AE
0.011708928	* AF
0.033461833	* FG

The equation in terms of coded factors can be used to make predictions about the response for given levels of each factor. By default, the high levels of the factors are coded as +1 and the low levels of the factors are coded as -1. The coded equation is useful for identifying the relative impact of the factors by comparing the factor coefficients.

Final Equation in Terms of Actual Factors:

Ln(BL)	=
6.681826811	
-1.2614449	* CWn
-0.06031971	* CWe
0.064461326	* Ks
0.003356398	* Ksr
-0.0074592	* Kr
0.011075204	* CWn * CWe
-0.01532586	* CWn * Ks
0.006690816	* CWn * Ksr
0.001365789	* Ksr * Kr

The equation in terms of actual factors can be used to make predictions about the response for given levels of each factor. Here, the levels should be specified in the original units for each factor. This equation should not be used to determine the relative impact of each factor because the coefficients are scaled to accommodate the units of each factor and the intercept is not at the center of the design space.

E7. HKC 40 HV - METAMODEL WIP REPORT

Table E-13. ANOVA Results for 40 HV HKC WIP Responses

Response 1 WIP
Transform: Inverse
ANOVA for selected factorial model
Analysis of variance table [Partial sum of squares - Type III]

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	0.000249953	12	2.08294E-05	58860.44736	0	significant
A-CWn	0.000217224	1	0.000217224	613839.8952	0	
B-CWr	8.35671E-07	1	8.35671E-07	2361.466233	2.4503E-191	
D-CWf	8.8125E-06	1	8.8125E-06	24902.64691	0	
E-Ks	7.68413E-07	1	7.68413E-07	2171.407037	6.9567E-184	
F-Ksr	1.87479E-05	1	1.87479E-05	52978.44483	0	
G-Kr	8.3403E-07	1	8.3403E-07	2356.829904	3.6733E-191	
H-Kf	2.10356E-07	1	2.10356E-07	594.4314712	4.80709E-87	
K-Kmf	6.07515E-07	1	6.07515E-07	1716.736428	1.1944E-163	
L-Ke	8.45075E-07	1	8.45075E-07	2388.039676	2.4368E-192	
AD	4.29771E-07	1	4.29771E-07	1214.461004	8.9439E-136	
FG	3.39379E-07	1	3.39379E-07	959.0272514	2.8824E-118	
KL	2.97959E-07	1	2.97959E-07	841.9823864	3.4455E-109	
Residual	1.76585E-07	499	3.53878E-10			
Cor Total	0.00025013	511				

The Model F-value of 58860.45 implies the model is significant. There is only a 0.01% chance that an F-value this large could occur due to noise.

Values of "Prob > F" less than 0.0500 indicate model terms are significant.
In this case A, B, D, E, F, G, H, K, L, AD, FG, KL are significant model terms.
Values greater than 0.1000 indicate the model terms are not significant.
If there are many insignificant model terms (not counting those required to support hierarchy), model reduction may improve your model.

Std. Dev.	1.88116E-05	R-Squared	0.999294025
Mean	0.019225636	Adj R-Squared	0.999277048
C.V. %	0.097846665	Pred R-Squared	0.999256762
PRESS	1.85906E-07	Adeq Precision	793.1536482
-2 Log Likelihood	-9702.354187	BIC	-9621.255967
		AICc	-9675.623263

The "Pred R-Squared" of 0.9993 is in reasonable agreement with the "Adj R-Squared" of 0.9993 i.e. the difference is less than 0.2.

"Adeq Precision" measures the signal to noise ratio. A ratio greater than 4 is desirable. Your ratio of 793.154 indicates an adequate signal. This model can be used to navigate the design space.

Table E-14. ANOVA WIP Report for the HKC Strategy 40HV

Std. Dev.	1.8812E-05	R-Squared	0.99929403
Mean	0.01922564	Adj R-Squared	0.99927705
C.V. %	0.09784667	Pred R-Squared	0.99925676
PRESS	1.8591E-07	Adeq Precision	793.153648
-2 Log Likelihood	-9702.35419	BIC	-9621.25597

AICc	-9675.62326

The "Pred R-Squared" of 0.9993 is in reasonable agreement with the "Adj R-Squared" of 0.9993
i.e. the difference is less than
0.2.

"Adeq Precision" measures the signal to noise ratio. A ratio greater than 4 is desirable. Your
ratio of 793.154 indicates an adequate signal. This model can be used to navigate the design space.

Factor	Coefficient Estimate	df	Standard Error	95% CI Low	95% CI High	VIF
Intercept	0.01922564	1	8.3137E-07	0.019224	0.01922727	
A-CWn	-0.00065136	1	8.3137E-07	-0.00065299	-0.00064972	1
B-CWr	4.04E-05	1	8.3137E-07	3.8767E-05	4.2034E-05	1
D-CWf	0.00013119	1	8.3137E-07	0.00012956	0.00013283	1
E-Ks	-3.874E-05	1	8.3137E-07	-4.0374E-05	-3.7107E-05	1
F-Ksr	0.00019136	1	8.3137E-07	0.00018972	0.00019299	1
G-Kr	4.036E-05	1	8.3137E-07	3.8727E-05	4.1994E-05	1
H-Kf	2.0269E-05	1	8.3137E-07	1.8636E-05	2.1903E-05	1
K-Kmf	3.4446E-05	1	8.3137E-07	3.2813E-05	3.608E-05	1
L-Ke	4.0627E-05	1	8.3137E-07	3.8993E-05	4.226E-05	1
AD	2.8972E-05	1	8.3137E-07	2.7339E-05	3.0606E-05	1
FG	-2.5746E-05	1	8.3137E-07	-2.7379E-05	-2.4112E-05	1
KL	-2.4124E-05	1	8.3137E-07	-2.5757E-05	-2.249E-05	1

Final Equation in Terms of Coded Factors:

1/(WIP)	=
0.01922564	
-0.00065136	* A
4.04E-05	* B
0.00013119	* D
-3.874E-05	* E
0.00019136	* F
4.036E-05	* G
2.0269E-05	* H
3.4446E-05	* K
4.0627E-05	* L
2.8972E-05	* AD
-2.5746E-05	* FG
-2.4124E-05	* KL

The equation in terms of coded factors can be used to make predictions about the response for
given levels of each factor. By default, the high levels of the factors are coded as +1 and the
low levels of the factors are coded as -1. The coded equation is useful for identifying
the
relative impact of the factors by comparing the factor coefficients.

Final Equation in Terms of Actual Factors:

1/(WIP)	=
0.03737918	
-0.0007151	* CWn
2.2445E-06	* CWr
-0.00026042	* CWf
-9.6851E-06	* Ks
8.381E-05	* Ksr
3.3478E-05	* Kr
1.3513E-05	* Kf
4.9768E-05	* Kmf
5.3889E-05	* Ke
1.1589E-05	* CWn * CWf
-2.8607E-06	* Ksr * Kr
-1.0722E-05	* Kmf * Ke

The equation in terms of actual factors can be used to make predictions about the response for
given levels of each factor. Here, the levels should be specified in the original units for
each factor. This equation should not be used to determine the relative impact of each factor
because the coefficients are scaled to accommodate the units of each factor and the intercept
is not at the center of the design space.

E8. HKC 40 HV - METAMODEL BL REPORT

Table E-15. ANOVA Results for 40 HV HKC BL Responses

Response 2 BL
Transform: Natural Log Constant: 0
ANOVA for selected factorial model
Analysis of variance table [Partial sum of squares - Type III]

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	46.224577	10	4.6224577	57920.88136	0	significant
A-CWn	45.02723663	1	45.02723663	564205.7537	0	
B-CWr	0.013544888	1	0.013544888	169.721799	1.28283E-33	
D-CWf	0.207740302	1	0.207740302	2603.052781	1.4824E-200	
E-Ks	0.142230429	1	0.142230429	1782.193005	3.979E-167	
F-Ksr	0.773645153	1	0.773645153	9694.022537	0	
G-Kr	0.020881408	1	0.020881408	261.6507548	1.17282E-47	
J-Km	0.008645266	1	0.008645266	108.3279609	4.23742E-23	
AD	0.01954481	1	0.01954481	244.9027541	3.12145E-45	
AE	0.004742812	1	0.004742812	59.4289619	6.87093E-14	
FG	0.006365306	1	0.006365306	79.75933188	8.05287E-18	
Residual	0.039983012	501	7.98064E-05			
Cor Total	46.26456001	511				

The Model F-value of 57920.88 implies the model is significant. There is only a 0.01% chance that an F-value this large could occur due to noise.

Values of "Prob > F" less than 0.0500 indicate model terms are significant.
In this case A, B, D, E, F, G, J, AD, AE, FG are significant model terms.
Values greater than 0.1000 indicate the model terms are not significant.
If there are many insignificant model terms (not counting those required to support hierarchy), model reduction may improve your model.

Std. Dev.	0.008933443	R-Squared	0.999135775
Mean	-1.063832051	Adj R-Squared	0.999118524
C.V. %	0.839741896	Pred R-Squared	0.999097408
PRESS	0.041758028	Adeq Precision	592.4348837
-2 Log Likelihood	-3389.311062	BIC	-3320.689491
		AICc	-3366.783062

The "Pred R-Squared" of 0.9991 is in reasonable agreement with the "Adj R-Squared" of 0.9991 i.e. the difference is less than 0.2.

"Adeq Precision" measures the signal to noise ratio. A ratio greater than 4 is desirable. Your ratio of 592.435 indicates an adequate signal. This model can be used to navigate the design space.

Table E-16. ANOVA BL Report for the HKC Strategy 90HV

Std. Dev.	0.00893344	R-Squared	0.99913577
Mean	-1.06383205	Adj R-Squared	0.99911852
C.V. %	0.8397419	Pred R-Squared	0.99909741
PRESS	0.04175803	Adeq Precision	592.434884
-2 Log Likelihood	-3389.31106	BIC	-3320.68949
		AICc	-3366.78306

The "Pred R-Squared" of 0.9991 is in reasonable agreement with the "Adj R-Squared" of 0.9991

i.e. the difference is less than
0.2.

"Adeq Precision" measures the signal to noise ratio. A ratio greater than 4 is desirable. Your ratio of 592.435 indicates an adequate signal. This model can be used to navigate the design space.

Factor	Coefficient Estimate	df	Standard Error	95% CI Low	95% CI High	VIF
Intercept	-1.06383205	1	0.00039481	-1.06460773	-1.06305637	
A-CWn	-0.29655324	1	0.00039481	-0.29732892	-0.29577756	1
B-CWr	0.00514343	1	0.00039481	0.00436775	0.00591911	1
D-CWf	0.02014306	1	0.00039481	0.01936738	0.02091874	1
E-Ks	-0.01666715	1	0.00039481	-0.01744283	-0.01589147	1
F-Ksr	0.03887191	1	0.00039481	0.03809623	0.03964759	1
G-Kr	0.00638624	1	0.00039481	0.00561056	0.00716191	1
J-Km	-0.00410917	1	0.00039481	-0.00488485	-0.00333349	1
AD	0.00617847	1	0.00039481	0.00540279	0.00695415	1
AE	-0.00304357	1	0.00039481	-0.00381925	-0.00226789	1
FG	-0.00352594	1	0.00039481	-0.00430162	-0.00275026	1

Final Equation in Terms of Coded Factors:

Ln(BL)	=
-1.06383205	
-0.29655324	* A
0.00514343	* B
0.02014306	* D
-0.01666715	* E
0.03887191	* F
0.00638624	* G
-0.00410917	* J
0.00617847	* AD
-0.00304357	* AE
-0.00352594	* FG

The equation in terms of coded factors can be used to make predictions about the response for given levels of each factor. By default, the high levels of the factors are coded as +1 and the low levels of the factors are coded as -1. The coded equation is useful for identifying the
relative impact of the factors by comparing the factor coefficients.

Final Equation in Terms of Actual Factors:

Ln(BL)	=
6.93669147	
-0.29949338	* CWn
0.00028575	* CWr
-0.05867022	* CWf
0.0163773	* Ks
0.0156997	* Ksr
0.00487114	* Kr
-0.00205459	* Km
0.00247139	* CWn * CWf
-0.00076089	* CWn * Ks
-0.00039177	* Ksr * Kr

The equation in terms of actual factors can be used to make predictions about the response for given levels of each factor. Here, the levels should be specified in the original units for each factor. This equation should not be used to determine the relative impact of each factor because the coefficients are scaled to accommodate the units of each factor and the intercept is not at the center of the design space.

Proceed to Diagnostic Plots (the next icon in progression). Be sure to look at the:
1) Normal probability plot of the studentized residuals to check for normality of residuals.
2) Studentized residuals versus predicted values to check for constant error.
3) Externally Studentized Residuals to look for outliers, i.e., influential values.
4) Box-Cox plot for power transformations.

If all the model statistics and diagnostic plots are OK, finish up with the Model Graphs icon.