

Outline

I.	Introduction.....	1
II.	Incorporating human factors in order picking planning models: Framework and research opportunities	25
III.	Using qualitative interviewing to examine human factors in warehouse order picking	55
IV.	A simulated annealing approach for the joint order batching and order picker routing problem with weight restrictions.....	71
V.	Production economics and the learning curve: A meta-analysis	92
VI.	An experimental investigation of learning effects in order picking systems.....	115
VII.	The effect of worker learning and forgetting on storage reassignment decisions in order picking systems	140
VIII.	The effect of worker learning on manual order picking processes.....	161
IX.	Conclusions and implications	183

Table of Contents

Preface..... iii

Acknowledgments.....v

Outline..... vii

Table of Contents viii

List of Abbreviations xiv

List of Figuresxv

List of Tables xvii

I. Introduction 1

1. Motivation..... 1

2. Research design 3

3. Area under investigation 5

4. Systematic literature review..... 8

4.1. Literature search and selection strategy 9

4.2. Descriptive results..... 10

4.3. Content analysis: Recent trends in picker-to-part order picking research 12

4.4. Summary..... 23

II. Incorporating human factors in order picking planning models: Framework and research opportunities25

1. Introduction..... 27

2. The significance of HF in OP 30

3. A systematic literature review 33

3.1. Keywords definition and literature search 33

3.2. Paper selection 34

3.3. Results..... 34

4. Conceptual framework..... 35

4.1. Performance impact 36

4.2.	Quality impact	37
4.3.	Occupational health issues	37
4.4.	Results of the systematic literature review in light of the developed framework	38
5.	Discussion	38
5.1.	Perceptual aspects	38
5.2.	Mental aspects	40
5.3.	Physical aspects	42
5.4.	Psychosocial aspects	45
6.	Research opportunities	46
6.1.	Planning models	46
6.2.	Methodological considerations	51
6.3.	Organizational considerations	52
7.	Conclusion	53
III.	Using qualitative interviewing to examine human factors in warehouse order picking.....	55
1.	Introduction	57
1.1.	Qualitative research in logistics	57
1.2.	HF in OP processes	57
1.3.	There is a need for qualitative research in OP	58
2.	Literature review	59
3.	Order picking task analysis	60
4.	Conceptual method development	62
4.1.	Semi-structured interviews	62
4.2.	Conceptual method for semi-structured interviews in OP	63
4.3.	Interview guide	65
5.	Data analysis	68
6.	Discussion	69

7.	Conclusion	70
IV.	A simulated annealing approach for the joint order batching and order picker routing problem with weight restrictions.....	71
1.	Introduction.....	73
2.	Literature review	74
2.1.	Planning problems in order picking.....	74
2.2.	Simulated annealing approaches applied to warehouse management	78
3.	Problem description	78
4.	Model development	80
4.1.	Definitions	80
4.2.	The division policies	82
4.3.	The refinement strategy	83
4.4.	Defining item attributes	84
4.5.	Storage assignment strategy.....	85
4.6.	Routing policies	85
4.7.	Summary.....	85
5.	Numerical study	86
6.	Conclusion	90
V.	Production economics and the learning curve: A meta-analysis.....	92
1.	Introduction.....	94
2.	Learning curve models.....	95
2.1.	Log-linear models	95
2.2.	Exponential models.....	97
2.3.	Hyperbolic models	98
2.4.	Summary of learning curve models	98
3.	The literature review approach	99
3.1.	Problem formulation	100
3.2.	Taxonomy	100

3.3.	Methodology	101
3.4.	Data extraction process and data meta-tags	102
3.5.	Descriptive analysis.....	103
4.	Curve fitting	105
4.1.	Methodology	105
4.2.	Results	106
4.3.	Discussion	111
5.	Conclusion.....	113
VI.	An experimental investigation of learning effects in order picking systems	115
1.	Introduction	117
2.	Literature review	118
3.	Data collection.....	121
4.	Descriptive results	125
5.	Analysis of learning curve models	127
5.1.	The Wright learning curve	127
5.2.	The de Jong learning curve	129
5.3.	The Stanford B learning curve	129
5.4.	The time constant learning curve	130
5.5.	The 3-parameter hyperbolic model	131
5.6.	The dual phase learning curve.....	132
5.7.	Discussion and results	135
6.	Summary	137
VII.	The effect of worker learning and forgetting on storage reassignment decisions in order picking systems	140
1.	Introduction	142
2.	Literature review	143
2.1.	Order picking.....	143
2.2.	Learning and forgetting	145

3.	Problem description	146
3.1.	The manual order picking process	146
3.2.	Storage assignment strategies under study	147
3.3.	Human learning in manual order picking systems.....	148
3.4.	The problem of changing an existing storage assignment	148
4.	Model development	149
4.1.	Definitions	149
4.2.	Order picking time	151
4.3.	Worker heterogeneity and structure of workforce	152
4.4.	Change in storage assignment.....	152
5.	Numerical study.....	155
5.1.	Estimation of parameters	155
5.2.	Results.....	155
5.3.	Discussion.....	157
6.	Conclusion	159
VIII.	The effect of worker learning on manual order picking processes.....	161
1.	Introduction.....	163
2.	Literature review.....	164
2.1.	Order picking literature.....	164
2.2.	Learning literature.....	166
2.3.	Synthesis of both research streams	167
3.	Learning in order picking: empirical observations	167
3.1.	Experimental investigations.....	167
3.2.	Expert interviews	168
4.	Problem description	170
5.	Model development	172
5.1.	Definitions	172
5.2.	Order picking time	173

5.3.	Zoning	174
5.4.	Order picker characteristics	175
6.	Numerical experimentation	175
6.1.	Determination of parameters	175
6.2.	Results	176
7.	Conclusion.....	181
IX.	Conclusions and implications	183
1.	Summary and conclusions.....	183
2.	Research implications.....	185
3.	Managerial insights	187
	References	189