



OPERATIONAL PERFORMANCE OF AUTOMOTIVE  
PARTS ASSEMBLY PROCESSES USING PRODUCTION  
CAPACITY LOSS EQUATION

AMIR HAMZAH BIN ABDUL RASIB

DOCTOR OF PHILOSOPHY

2016



**Faculty of Manufacturing Engineering**

**OPERATIONAL PERFORMANCE OF AUTOMOTIVE  
PARTS ASSEMBLY PROCESSES USING PRODUCTION  
CAPACITY LOSS EQUATION**

**Amir Hamzah Bin Abdul Rasib**

**Doctor of Philosophy**

**2016**

**OPERATIONAL PERFORMANCE OF AUTOMOTIVE PARTS ASSEMBLY  
PROCESSES USING PRODUCTION CAPACITY LOSS EQUATION**

**AMIR HAMZAH BIN ABDUL RASIB**

**A thesis submitted  
in fulfillment of the requirements for the degree of Doctor of Philosophy**

**Faculty of Manufacturing Engineering**

**UNIVERSITI TEKNIKAL MALAYSIA MELAKA**

**2016**

## DECLARATION

I declare that this thesis entitled “Operational Performance of Automotive Parts Assembly Processes Using Production Capacity Loss Equation” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....

Name : Amir Hamzah Bin Abdul Rasib

Date : .....

## APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Doctor of Philosophy.

Signature : .....

Main Supervisor Name : Dr. Zuhriah Binti Ebrahim .....

Date : .....

Signature : .....

Co-Supervisor Name : Prof. Datuk Dr. Mohd Razali bin Muhamad .....

Date : .....

## **DEDICATION**

I dedicated this dissertation to my beloved wife, Rupisah Binti Sedik, who has offered unwavering support and encouragement during the past four years of my doctoral journey. Thanks Sayang for your support and counsel! This work is also dedicated to my children (Muhammad Syafiq Aikal, Nurain Syafiqah, Nuramirah Haziqah, and Muhammad Arif Muzaffar). You have made me stronger, better and more fulfilled than I could have ever imagined.

## ABSTRACT

Hidden Time Loss (HTL) occurs along the production processes that have a significant effect on productivity in the automotive industry. Currently, Overall Equipment Efficiency (OEE) is the most popular performance measurement tool used in the production line. In this regard, availability, performance, and quality are the parameters used in OEE. However, OEE is not really fit for measuring operation performance of the manual assembly process and the semi-auto assembly process. There would be a certain amount of HTL occurring along the manual assembly process and semi-auto assembly process. HTL becomes critical when an assembly process involves a high product variety in the same production line. The aim of this research is to provide a measure for HTL through the determination of Time Loss Measures (TLM) components known as: (i) Non-valued Changeover Time (NVCOT), (ii) Inefficient Processing Time (IPT), (iii) Unnecessary Overtime (UOT), and (iv) Non-conformance Time (NCT). A Framework of TLM had been developed through a thorough literature study on manufacturing operations. Then, an equation for Production Capacity Loss (PCL) was derived based on the structure of TLM components. Finally, the structure of TLM components and the PCL equation were validated by using case study at five automotive manufacturing companies in Malaysia. The results of the case study show that HTL did occur through the four TLM components that caused an amount of PCL. In economic view, PCL can be converted into Gross Profit Loss (GPL). A significant finding from this research is the effect of TLM components on HTL in the context of different assembly features: (i) Right and Left, (ii) Product Variety, (iii) Model Variety, and (iv) Front and Rear. HTL does exist in the manual assembly process and semi-auto assembly process, especially in the automotive industry. The results show that UOT contributes as the highest HTL from the aspects of Right and Left, Model Variety, and Front and Rear; and NCT contributes the highest HTL from the aspect of Product Variety. In conclusion, PCL can be used as a measuring tool for the manufacturing companies to monitor continuously the operational performance of the manual assembly process and semi-auto assembly process.

## ABSTRAK

*'Hidden Time Loss' (HTL) berlaku semasa proses pengeluaran yang memberi kesan penting kepada produktiviti dalam industry automotif. Terkini, 'Overall Equipment Effectiveness' (OEE) adalah merupakan alat pengukur prestasi yang paling popular digunakan dalam barisan pengeluaran. Dalam hal ini, kebolehsediaan, prestasi, dan kualiti adalah merupakan pengukur-pengukur di dalam OEE. Namun begitu, OEE tidaklah sepenuhnya lengkap untuk mengukur prestasi operasi terutama bagi proses pemasangan secara manual dan proses pemasangan secara separa auto. Berkemungkinan berlakunya HTL semasa proses pemasangan secara manual dan proses pemasangan secara separa auto. HTL menjadi kritikal apabila proses pemasangan melibatkan pelbagai produk dikeluarkan dari barisan pengeluaran yang sama. Tujuan penyelidikan ini adalah untuk menyediakan pengukuran HTL menggunakan komponen-komponen 'Time Loss Measures' (TLM) seperti: (i) 'Non-valued Changeover Time' (NVCOT), 'Inefficient Processing Time' (IPT), 'Unnecessary Overtime' (UOT), and 'Non-conformance Time' (NCT). Model TLM dibangunkan berdasarkan kepada kajian 'literature' yang terperinci terhadap operasi pembuatan. Seterusnya, formula untuk 'Production Capacity Loss' (PCL) dibangunkan berdasarkan kepada struktur komponen-komponen TLM. Struktur komponen-komponen TLM dan formula PCL disahkan melalui kajian kes terhadap lima syarikat pembuatan automotif di Malaysia. Keputusan kajian kes telah membuktikan bahawa HTL wujud menerusi empat komponen TLM berkenaan yang menyebabkan berlakunya PCL. Dari sudut ekonomi, PCL boleh diolah kepada 'Gross Profit Loss' (GPL). Penemuan penting daripada penyelidikan ini adalah kesan komponen-komponen TLM terhadap HTL dalam konteks 'assembly features' yang berbeza: (i) Komponen Kanan dan Kiri, (ii) Jenis Produk, (iii) Jenis Model, dan (iv) Komponen Depan dan Belakang. Terbukti, HTL sememangnya wujud dalam proses pemasangan secara manual dan proses pemasangan secara separa auto terutama dalam industri automotif. Di sini UOT adalah penyumbang tertinggi kepada HTL dari aspek komponen Kanan dan Kiri, Jenis Model, dan komponen Depan dan Belakang. Sementara NCT adalah penyumbang tertinggi HTL daripada aspek Jenis Produk. Kesimpulannya, PCL boleh digunakan sebagai alat pengukuran prestasi operasi bagi proses pemasangan secara manual dan proses pemasangan secara separa auto dimana pemantauan prestasi boleh dilakukan dari semasa ke semasa.*



## ACKNOWLEDGMENTS

I thank ALLAH (my Lord) the all high, the all great and merciful who made it possible for me to conduct the Ph.D. study and complete this thesis.

I would like to take this opportunity to express my sincere acknowledgment to my supervisor Dr. Zuhriah Binti Ebrahim from the Faculty of Manufacturing Engineering, Universiti Teknikal Malaysia Melaka (UTeM) for her essential supervision, support, and encouragement towards the completion of this thesis. Her thoughtful advice and constant support extended to me will always be remembered. May ALLAH bless him and her family.

I would also like to express my greatest gratitude to Professor Datuk Dr. Mohd Razali Bin Muhamad, Deputy Vice Chancellor of Universiti Teknikal Malaysia Melaka (UTeM) - Academic and International as co-supervisor of this research for his advice and suggestions in the evaluation of this research.

Special thanks to Manufacturing Engineering Faculty of UTeM for the use of the facilities to pursue the research and complete this thesis.

I am very grateful and acknowledge the substantial financial support from MyBrain15 (MyPhD) scholarship, Ministry of Higher Education Malaysia for the Ph.D. study.

I would like to express my heartfelt thanks to all the Managing Director, General Manager, and Management Staff of the manufacturing companies that participated: Mr. Kokichi Suzuki, Mr. Kiyoshi Sawada, Mr. Fairez Mansor, Mr. Azni Mohd. Daud, Mr. Mohd. Saharin Zakaria, Mr. Adli Khairul Mohd Kassim, Mr. Mohd. Sani Ariffin, Ms. Cecilia Yap Choi Har, Ms. Nurul Shakina Surani, Ms. Noor Safarah Yatim, Mr. Shahrudin Mohamed, Mr. Mohd. Hadzrul Harith Ibrahim, Mr. Mohamad Azreen Zainudin, Mr. Azmi Ahmat, Mr. Ramli Abdul Khalid, Ms. Nurul Wahida Sazali, Mr. Muhammad Hanafiah Abd. Rahman, Mr. Khairul Ihsan, all of whom provided unconditional cooperation during my industrial visits and data collection.

I also want to offer thanks to my Mama, Nafsiah Binti Samsudin, who instilled in me the love of learning from an early age and advice. Thanks also to my mother-in-law (Zaliha Binti Saimin), father-in-law (Sidek Bin Untong), and siblings for their moral support in completing this study. Finally, to the loving memory of my Ayah, Hj. Abdul Rasib Bin Hj. Katib. You have successfully made me the person I am becoming. You will always be remembered. Last but not least, million thanks to everyone who had been to the crucial parts of realization of this research.

---

## TABLE OF CONTENTS

	PAGE
<b>DECLARATION</b>	
<b>APPROVAL</b>	
<b>DEDICATION</b>	
<b>ABSTRACT</b>	<b>i</b>
<b>ABSTRAK</b>	<b>ii</b>
<b>ACKNOWLEDGEMENTS</b>	<b>iii</b>
<b>TABLE OF CONTENTS</b>	<b>iv</b>
<b>LIST OF TABLES</b>	<b>viii</b>
<b>LIST OF FIGURES</b>	<b>x</b>
<b>LIST OF APPENDICES</b>	<b>xiii</b>
<b>LIST OF ABBREVIATIONS</b>	<b>xix</b>
<b>LIST OF GLOSSARIES/TERMINOLOGIES</b>	<b>xx</b>
<b>LIST OF SYMBOLS</b>	<b>xxiii</b>
<b>LIST OF PUBLICATIONS</b>	<b>xxv</b>
<b>CHAPTER</b>	
<b>1. INTRODUCTION</b>	<b>1</b>
1.1 Research Background	1
1.2 Research Motivation	3
1.3 Research Question	5
1.4 Research Aim and Objectives	5
1.5 Research Scope	6
1.6 The Significant of the Research	6
1.7 Thesis Outline	6
<b>2. LITERATURE REVIEW</b>	<b>8</b>
2.1 Preliminaries	8
2.2 Customer Demand	9
2.3 Categories of Performance Measures for Manufacturing	11
2.3.1 Financial Performance Measures	13
2.3.2 Non-financial Performance Measures	16
2.3.2.1 Overall Equipment Effectiveness (OEE)	17
2.3.2.2 Total Effective Equipment Performance (TEEP)	20
2.3.2.3 Overall Factory Effectiveness (OFE)	21
2.3.2.4 Overall Throughput Effectiveness (OTE)	21
2.3.2.5 Overall Line Effectiveness (OLE)	22
2.3.2.6 Overall Equipment Effectiveness of a Manufacturing Line (OEEML)	23
2.4 Existing Operational Performance Measures	25
2.4.1 The Component of Operational Performance Measures	29
2.4.1.1 Quality Performance	30
2.4.1.2 Delivery Performance	31
2.4.1.3 Flexibility Performance	33
2.4.1.3.1 Volume Flexibility	34
2.4.1.3.2 Product Mix Flexibility	34
2.5 Production Capacity	37
2.6 The Significant of Production Capacity Loss (PCL) Measures	38
2.7 Summary	41

<b>3.</b>	<b>RESEARCH METHODOLOGY</b>	<b>44</b>
3.1	Preliminaries	44
3.2	Research Design	45
3.2.1	Identification of TLM Components	48
3.2.1.1	Literature Study	49
3.2.1.2	Selection of Significant Factor	50
3.2.1.3	Determine Measurable Items	50
3.2.1.4	Categorisation of HTL Items	51
3.2.1.5	A Study of HTL Items Relationship	51
3.2.1.6	Classification of HTL Components	51
3.2.1.7	Introduction to TLM Components	51
3.2.2	Development of TLM Framework	52
3.2.2.1	Verification of Initial TLM Framework	53
3.2.2.2	Finalisation of TLM Framework	53
3.2.3	Development of PCL Equation	54
3.2.4	Validation of TLM Components Equation and PCL Equation	55
3.2.4.1	Data Collection	56
3.2.4.2	Data Analysis	56
3.2.4.3	Results and Discussion	56
3.3	Summary	57
<b>4.</b>	<b>DEVELOPMENT OF TIME LOSS MEASURES (TLM) FRAMEWORK</b>	<b>58</b>
4.1	Preliminaries	58
4.2	Identification of TLM Components	59
4.2.1	Identifying of the Significant Factor of TLM	59
4.2.1.1	Justification of Method as the Significant Factor of TLM	60
4.2.1.2	Significant Issues of Method Factor	62
4.2.2	Classification of Non-measurable and Measurable Items	63
4.2.3	Classification of HTL Items	65
4.2.4	Clarification of HTL Components	68
4.2.5	The HTL Components Relationship	70
4.2.5.1	Non-valued Changeover Time (NVCOT)	71
4.2.5.2	Inefficient Processing Time (IPT)	75
4.2.5.3	Unnecessary Overtime (UOT)	77
4.2.5.4	Non-conformance Time (NCT)	77
4.3	Development of TLM Framework	79
4.3.1	Compatibility with Agility Measure	79
4.3.2	Compatibility with Leanness Measure	81
4.3.3	Compatibility with Sustainability Measure	84
4.3.4	Compatibility with Fitness Measure	86
4.3.5	Compatibility with Flexibility Measure	88
4.3.6	Compatibility with Responsiveness Measure	90
4.3.7	Development of Initial TLM Framework	92
4.4	Verification of the Initial TLM Framework	93
4.4.1	Consideration of Companies and Practitioners	94
4.4.2	Personal Profile	94
4.4.3	Verification Checklist	96

4.4.4	Verification Results	96
4.4.5	The Propose TLM Framework	97
4.4.5.1	Operation	98
4.4.5.2	Process	99
4.4.5.3	Hidden Time Loss Components	99
4.4.5.4	Hidden Time Loss Items	99
4.4.5.5	TLM Components	100
4.4.5.6	Existing Performance Measures	100
4.5	Summary	100
<b>5.</b>	<b>DETERMINATION OF PRODUCTION CAPACITY LOSS USING THE TLM FRAMEWORK</b>	<b>102</b>
5.1	Preliminaries	102
5.2	Development of NVCOT Equation	103
5.3	Development of IPT Equation	106
5.4	Development of UOT Equation	110
5.5	Development of NCT Equation	113
5.6	Development of Production Capacity Loss (PCL) Equation	116
5.7	Derivation of Gross Profit Loss (GPL) Equation	117
5.8	Case Studies and Data Collection	119
5.8.1	Case Studies	120
5.8.2	Data Collection	123
5.8.2.1	Non-valued Changeover Time (NVCOT)	123
5.8.2.2	Inefficient Processing Time (IPT)	125
5.8.2.3	Unnecessary Overtime (UOT)	126
5.8.2.4	Non-conformance Time (NCT)	127
5.8.3	Data Limitation	127
5.8.4	Assumptions	128
5.8.4.1	Non-valued Changeover Time (NVCOT)	128
5.8.4.2	Actual Process Cycle Time	129
5.8.4.3	On-hold/KIV	129
5.9	Summary	132
<b>6.</b>	<b>RESULTS AND DISCUSSION</b>	<b>135</b>
6.1	Preliminaries	135
6.2	Data Analysis	137
6.2.1	Non-valued Changeover Time (NVCOT)	137
6.2.2	Inefficient Processing Time (IPT)	147
6.2.3	Unnecessary Overtime (UOT)	154
6.2.4	Non-conformance Time (NCT)	163
6.3	Validation of TLM Components Results, the PCL, and the GPL	171
6.3.1	Results of Non-valued Changeover Time (NVCOT)	171
6.3.2	Results of Inefficient Processing Time (IPT)	185
6.3.3	Results of Unnecessary Overtime (UOT)	198
6.3.4	Results of Non-conformance Time (NCT)	214
6.3.5	Results of Production Capacity Loss (PCL) and Gross Profit Loss (GPL)	229
6.4	The Effects of TLM Components Based on Assembly Features	232
6.5	Actual Validtion of Case Studies	238
6.6	Summary	238

<b>7. CONCLUSION AND RECOMMENDATION</b>	<b>240</b>
7.1 Conclusion	240
7.2 Contribution	243
7.3 Suggestion of Future Research	244
<b>REFERENCES</b>	<b>245</b>
<b>APPENDICES</b>	<b>274</b>

## LIST OF TABLES

TABLE	TITLE	PAGE
2.1	Major Loss Classifications and Definitions (Nakajima, 1988)	19
4.1	Examine Factor of HTL	61
4.2	Input-Output Model Explanation	66
4.3	Categorisation of Operation Item	66
4.4	Sorting of Process Phases	69
4.5	Components of Initial TLM Framework	92
4.6	Companies Involved in Verification Proses	95
4.7	Sample Personal Profile of the Interviewees	95
4.8	Verification Analysis Results of Opinions	97
5.1	Conditions for NVCOT of CM	104
5.2	Conditions for NVCOT of NM	105
5.3	Conditions for NVCOT of RU	106
5.4	Conditions for IPT	108
5.5	Conditions for $t_{apct}$ of Process $t_{Process}$	109
5.6	Conditions for $t_{apct}$ of $t_{Transfer}$	109
5.7	Conditions for UOT	113
5.8	Summary of Operation Characteristics	122
5.9	Sources and Samples of Data Collection	124
5.10	Summary of Parameters Used for NVCOT	132
5.11	Summary of Parameters Used for IPT	132
5.12	Summary of Parameters Used for UOT	133
5.13	Summary of Parameters Used for NCT	133
5.14	Summary of Parameters Used for GP	134
5.15	Summary of Parameters Used for PCLpcs	134
6.1	List of Product Variety and Model Variety for Company C	141
6.2	Main Process for Company A (Based on Workstation)	174

6.3	List of Product Variety and Model Variety for Company B	175
6.4	Summary of Influencing Factors for Each Product on NVCOT	182
6.5	Summary of Situations for Each Company and Product on UOT	211
6.6	Summary of Situation for Each Company and Product on NCT	226
6.7	Summary of Assembly Features and Related Companies	232
6.8	UOT as the Main Contributor to HTL	236
6.9	NCT as the 2nd Contributor to HTL	236
6.10	NVCOT as the 3rd Contributor to HTL	237
6.11	IPT as the 4th Contributor to HTL but Appears as Merit Time	238
6.12	Advantage Components of TLM over OEE	239
7.1	The Rank of TLM Components towards HTL	240
7.2	Summary of HTL Main Contributor	241

## LIST OF FIGURES

FIGURE	TITLE	PAGE
2.1	The Six Big Losses for Computing OEE by Nakajima (1988)	19
2.2	Types of Performance Measures and their Relationships	36
3.1	Research Design	46
3.2	Detailed Process Flow of Research Methodology	46
3.3	Process Flow of Objective 1	48
3.4	Process Flow of Objective 2	52
3.5	Process Flow of Objective 3	54
3.6	Process Flow of Objective 4	55
4.1	Method Factor Significant Issues	62
4.2	Manufacturing Operation System	69
4.3	HTL Components Relationship	71
4.4	Initial Non-valued Changeover Time Structure	73
4.5	Initial Inefficient Processing Time Structure	76
4.6	Initial Unnecessary Overtime Structure	77
4.7	Initial Non-conformance Time Structure	78
4.8	Initial TLM Framework	93
4.9	Proposed TLM Framework	98
5.1	Proposed Non-valued Changeover Time Structure	103
5.2	Proposed Inefficient Processing Time Structure	107
5.3	Proposed Unnecessary Overtime Structure	110
5.4	Basic Understanding Concept for UOT	111
5.5	Proposed Non-conformance Time Structure	114
5.6	Common Procedure for NCT	115
6.1	Lot Movement in Production	141



6.2	Monthly Non-valued Changeover Time (NVCOT) for Company A (2009 ~ 2013)	172
6.3	Daily Non-valued Changeover Time (NVCOT) for Company B	176
6.4	Daily Non-valued Changeover Time (NVCOT) for Company C	178
6.5	Daily Non-valued Changeover Time (NVCOT) for Company D – FC	180
6.6	Daily Non-valued Changeover Time (NVCOT) for Company D – FT	181
6.7	Daily Non-valued Changeover Time (NVCOT) for Company E – RH	183
6.8	Daily Non-valued Changeover Time (NVCOT) for Company E – LH	184
6.9	Monthly Inefficient Processing Time (IPT) for Company A (2009 ~ 2013)	186
6.10	Daily Inefficient Processing Time (IPT) for Company B	188
6.11	Daily Inefficient Processing Time (IPT) for Company C	190
6.12	Daily Inefficient Processing Time (IPT) for Company D - FC	192
6.13	Daily Inefficient Processing Time (IPT) for Company D - FT	193
6.14	Daily Inefficient Processing Time (IPT) for Company D - RH	196
6.15	Daily Inefficient Processing Time (IPT) for Company D - LH	197
6.16	Monthly Unnecessary Overtime (UOT) for Company A (2009 ~ 2013)	201
6.17	Daily Unnecessary Overtime (UOT) for Company B	203
6.18	Daily Unnecessary Overtime (UOT) for Company C	205
6.19	Daily Unnecessary Overtime (UOT) for Company D - FC	208
6.20	Daily Unnecessary Overtime (UOT) for Company D - FT	209
6.21	Daily Unnecessary Overtime (UOT) for Company E - RH	212
6.22	Daily Unnecessary Overtime (UOT) for Company E - LH	213
6.23	Monthly Non-conformance Time (NCT) for Company A (2009 ~ 2013)	216
6.24	Daily Non-conformance Time (NCT) for Company B	218
6.25	Daily Non-conformance Time (NCT) for Company C	220
6.26	Daily Non-conformance Time (NCT) for Company D - FC	223
6.27	Daily Non-conformance Time (NCT) for Company D - FT	224
6.28	Daily Non-conformance Time (NCT) for Company E - RH	227
6.29	Daily Non-conformance Time (NCT) for Company E - LH	228
6.30	PCL and PCL/Net Operating Time Results Across Companies (Average for Three Months)	230
6.31	GPL Results Across Companies (Three Months)	232
6.32	HTL for Right and Left Feature by The TLM Components	234
6.33	HTL for Model Variety Feature by The TLM Components	234

6.34	HTL for Product Variety Feature by The TLM Components	235
6.35	HTL for Front and Rear Feature by The TLM Components	235

## LIST OF APPENDICES

APPENDIX	TITLE	PAGE
A	K-Chart for Research Scope	274
B1	Potential Spots of Literature Study	275
B2	List of Measurable and Non-measurable Items	276
B3	Verification Check List	277
B4	Verification Analysis Result	278
C	PCL and GPL Measures Format	279
<b>D1</b>	<b>Company A</b>	<b>280</b>
D1b(i)	Changeover Time Record for Head Lamp (HL)	280
D1b(ii)	Changeover Time Record for Rear Combination Lamp (RL)	281
D1c(i)	Actual Process Cycle Time Record for HL	282
D1c(ii)	Actual Process Cycle Time Record for RL	283
D1d(i)	Standard Process Cycle Time Record for HL	284
D1d(ii)	Standard Process Cycle Time Record for RL	285
D1e	Overtime Record for HL and RL	286
D1f(i)	Monthly Quality Record for HL	287
D1f(ii)	Monthly Quality Record for RL	288
D1g	Monthly NVCOT for HL and RL	289

D1h	Monthly Production Input (Pieces) versus Monthly NVCOT in Day Shift and Night Shift for HL and RL	290
D1i <sup>(i)</sup>	Monthly IPT and Merit Time for HL	291
D1i <sup>(ii)</sup>	Monthly IPT and Merit Time for RL	292
D1j	Monthly Production Input (Pieces) versus Monthly Merit Time for HL and RL	293
D1k <sup>(i)</sup>	Monthly UOT for HL	294
D1k <sup>(ii)</sup>	Monthly UOT for RL	295
D1l	Monthly Production Input (Pieces) versus Monthly UOT for HL and RL	296
D1m <sup>(i)</sup>	Monthly NCT for HL	297
D1m <sup>(ii)</sup>	Monthly NCT for RL	298
D1n	Monthly Rework, Scrap, and On-hold/KIV versus Monthly NCT for HL and RL	299
D1o	Validation of Case Study from Company A	300
<b>D2</b>	<b>Company B</b>	<b>301</b>
D2a	Production Schedule for Intake Manifold (IM)	301
D2b	Changeover Time Record for IM	302
D2c	Actual Process Cycle Time Record for IM	304
D2d	Standard Process Cycle Time Record for IM	305
D2e	Overtime Record for IM	306
D2f	Monthly Quality Record for IM	307
D2g	Daily NVCOT for IM	308
D2h	Daily Production Input (Lots) versus Daily NVCOT for IM	309
D2i	Daily IPT and Merit Time for IM	310
D2j	Daily Production Input (Pieces) versus Daily Merit Time for IM	311

D2k	Daily UOT for IM	312
D2l	Daily Production Input (Pieces) versus Daily UOT for IM	313
D2m	Daily NCT for IM	314
D2n	Daily Rework, Scrap, and On-hold/KIV versus Daily NCT for IM	315
D2o	Validation of Case Study from Company B	316
<b>D3</b>	<b>Company C</b>	<b>317</b>
D3a	Production Schedule for Door Latch (DL)	317
D3b	Changeover Time Record for DL	318
D3c	Actual Process Cycle Time Record for DL	319
D3d	Standard Process Cycle Time Record for DL	320
D3e	Overtime Record for DL	321
D3f	Monthly Quality Record for DL	322
D3g	Daily NVCOT for DL	323
D3h	Daily Production Input (Lots) versus Daily NVCOT for DL	324
D3i	Daily IPT and Merit Time for DL	325
D3j	Daily Production Input (Pieces) versus Daily Merit Time for DL	326
D3k	Daily UOT for DL	327
D3l	Daily Production Input (Pieces) versus Daily UOT for DL	328
D3m	Daily NCT for Door Latch (DL)	329
D3n	Daily Rework, Scrap, and On-hold/KIV versus Daily NCT for DL	330
D3o	Validation of Case Study from Company C	331

<b>D4</b>	<b>Company D</b>	<b>332</b>
D4a	Production Schedule for Front Corner (FC) and Fuel Tank (FT)	332
D4b	Changeover Time Record for FC and FT	333
D4c <sub>(i)</sub>	Actual Process Cycle Time Record for FC	334
D4c <sub>(ii)</sub>	Actual Process Cycle Time Record for FT	335
D4d	Standard Process Cycle Time Record for FC and FT	336
D4e <sub>(i)</sub>	Overtime Record for FC	337
D4e <sub>(ii)</sub>	Overtime Record for FT	338
D4f <sub>(i)</sub>	Monthly Quality Record for FC	339
D4f <sub>(ii)</sub>	Monthly Quality Record for FT	340
D4g <sub>(i)</sub>	Daily NVCOT for FC	341
D4g <sub>(ii)</sub>	Daily NVCOT for FT	342
D4h <sub>(i)</sub>	Daily Production Input (Pieces) Versus Daily NVCOT for FC	343
D4h <sub>(ii)</sub>	Daily Production Input (Pieces) Versus Daily NVCOT for FT	344
D4i <sub>(i)</sub>	Daily IPT and Merit Time for FC	345
D4i <sub>(ii)</sub>	Daily IPT and Merit Time for FT	346
D4j <sub>(i)</sub>	Daily Production Input (Pieces) versus Daily Merit Time for FC	347
D4j <sub>(ii)</sub>	Daily Production Input (Pieces) versus Daily Merit Time for FT	348
D4k <sub>(i)</sub>	Daily UOT for FC	349
D4k <sub>(ii)</sub>	Daily UOT for FT	350
D4l <sub>(i)</sub>	Daily Production Input (Pieces) versus Daily UOT for FC	351
D4l <sub>(ii)</sub>	Daily Production Input (Pieces) versus Daily UOT for FT	352

D4m(i)	Daily NCT for FC	353
D4m(ii)	Daily NCT for FT 354	
D4n(i)	Daily Rework, Scrap, and On-hold/KIV versus Daily NCT for Front Corner (FC)FC	355
D4n(ii)	Daily Rework, Scrap, and On-hold/KIV versus Daily NCT for FT	356
D4o	Validation of Case Study from Company D	357
<b>D5</b>	<b>Company E</b>	<b>358</b>
D5a(i)	Production Schedule for Right-Hand Handle Door Inside (RH)	358
D5a(ii)	Production Schedule for Left-Hand Handle Door Inside (LH)	359
D5b	Changeover Time Record for RH and LH	360
D5c	Actual Process Cycle Time Record for RH and LH	361
D5d	Standard Process Cycle Time Record for RH and LH	362
D5e	Overtime Record for RH and LH	363
D5f	Monthly Quality Record for RH and LH	364
D5g(i)	Daily NVCOT for RH	365
D5g(ii)	Daily NVCOT for LH	366
D5h(i)	Daily Production Input (Pieces) versus Daily NVCOT for RH	367
D5h(ii)	Daily Production Input (Pieces) versus Daily NVCOT for LH	368
D5i(i)	Daily IPT and Merit Time for RH	369
D5i(ii)	Daily IPT and Merit Time for LH	370
D5j(i)	Daily Production Input (Pieces) versus Daily Merit Time for RH	371
D5j(ii)	Daily Production Input (Pieces) versus	372

	Daily Merit Time for LH	
D5k(i)	Daily UOT for RH	373
D5k(ii)	Daily UOT for LH	374
D5l(i)	Daily Production Input (Pieces) versus Daily UOT for RH	375
D5l(ii)	Daily Production Input (Pieces) versus Daily UOT for LH	376
D5m(i)	Daily NCT for RH	377
D5m(ii)	Daily NCT for LH	378
D5n(i)	Daily Rework, Scrap, and On-hold/KIV versus Daily NCT for RH	379
D5n(ii)	Daily Rework, Scrap, and On-hold/KIV versus Daily NCT for LH	380
D5o	Validation of Case Study from Company E	381