



**Faculty of Manufacturing Engineering**

**DESIGN AND SIMULATION OF AUTOMATED MATERIAL  
HANDLING SYSTEM FOR AUTOMOTIVE ASSEMBLY  
PROCESS**

**Seha binti Mohd Saffar**

**Master of Science in Manufacturing Engineering**

**2019**

**DESIGN AND SIMULATION OF AUTOMATED MATERIAL HANDLING  
SYSTEM FOR AUTOMOTIVE ASSEMBLY PROCESS**

**SEHA BINTI MOHD SAFFAR**

**A thesis submitted  
in fulfillment of the requirements for the degree of Master of Science in  
Manufacturing Engineering**

**Faculty of Manufacturing Engineering**

**UNIVERSITI TEKNIKAL MALAYSIA MELAKA**

**2019**

## DECLARATION

I declare that this thesis entitled “Design and Simulation of Automated Material Handling System for Automotive Assembly Process” 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 : .....

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 Master of Science in Manufacturing Engineering.

Signature : .....

Supervisor Name : .....

Date : .....

## **DEDICATION**

To my beloved mother and father,

My beloved family,

To my beloved husband,

Who believed in me.

## ABSTRACT

Improvement of process parameters for effective and efficient material handling system in manufacturing industry has been studied extensively lately in view of observed increases in demand for high technology to increase production and profit. This thesis investigates an actual industrial problem relating to improvement in material supply system in production line and inventory system in a warehouse. A case study was selected as a method to collect data in actual industry situation. The study aims to assess the influence of automated material handling system in an automotive industry by proposing a new integrated system design by mean of numerical analysis on significant effect and influence on the system. The system performance of the proposed integrated design was measured and compared to the current system. The system design and analysis were performed using Quest software. The methodology consisted of six phases. Firstly, data were gathered from actual industry as a case study. These data served as guideline and offer input on design limitation of the proposed integrated system. Secondly, a design concept was proposed using standard principle of design consideration for manufacturing. A full factorial design with two levels of three factors was applied as the design of experiment to analyze the performance measure of the integrated system and the current system. This thesis concludes that the overall result shows that the bottleneck for transport system was reduced by about 87% and 85% reduced was observed for the storage system. The transport equipment was utilized 4 times greater than the current transport system. Due to increment in utilization, the production output increased four times from the current system. Overall result showed decrement in cycle time of 63% for model 4 compared to model 1. The constraint for this research work was the preparedness of manufacturing industry towards flexibilities and leans. For future improvement, the simulation clock can be set in order to establish appropriate environment and the transition distance of entities between movement and distance of each resource to the others are properly premeditated. Also, in-depth study on Quest software and additional study on Delmia v5 as alternative simulation tool can be considered for virtual 3D simulation with ergonomic human movement results and analysis.

## **ABSTRAK**

*Sejak kebelakangan ini, penyelidikan dalam peningkatan sistem pengendalian bahan yang berkesan, cekap dan permintaan teknologi terbaru telah meningkat untuk mendapatkan satu peningkatan pengeluaran keuntungan dalam industri pembuatan. Isu-isu semasa telah diperkenalkan oleh ramai penyelidik. Tetapi, masih terdapat kekurangan dalam mengenal pasti punca masalah sebenar. Penyelidikan ini cuba untuk mengkaji salah satu daripada masalah sebenar di dalam sistem integrasi antara sistem bekalan bahan dalam barisan pengeluaran dan sistem inventori dalam gudang. Kajian kes dipilih sebagai satu kaedah untuk mengumpul data dalam keadaan industri yang sebenar. Matlamat kajian adalah untuk menilai pengaruh pengendalian bahan secara automatik dalam proses pemasangan industri automotif dengan mencadangkan satu rekabentuk baru sistem integrasi menggunakan simulasi dan analisis kesan utama yang mempengaruhi prestasi sistem. Termasuk juga, menganalisis prestasi sistem integrasi baru dengan sistem semasa dalam kajian kes. Kaedah pendekatan menggunakan perisian CAD (Delmia & Quest). Terdapat 6 fasa dirancang untuk mencapai matlamat. Pengumpulan awal data dilaksanakan di fasa 1 untuk mengumpul semua data yang berkaitan dari situasi industri yang sebenar di kilang terpilih untuk kajian kes. Ia memberikan garis panduan dan batasan dalam merekabentuk sistem integrasi baru nanti. Yang ke-2, idea atau konsep reka bentuk yang akan dilakukan menggunakan piawai prinsip pertimbangan reka bentuk untuk pembuatan. Rekabentuk dengan faktor penuh, 2 aras 3 faktor akan digunakan sebagai reka bentuk eksperimen untuk menganalisis pengukuran prestasi sistem integrasi dengan sistem semasa dalam kajian kes. Kesimpulannya, hasil keseluruhan tesis ini menunjukkan hasil yang lebih baik di mana kesesakan sistem pengangkutan dikurangkan kira-kira 87% dan 85% dikurangkan dalam sistem storan. Sistem pengangkutan juga digunakan 4 kali ganda dari model 1. Disebabkan kenaikan penggunaan, pengeluaran juga meningkat 4 kali ganda dari model 1. Hasil keseluruhan menunjukkan penurunan masa kitaran model 4 adalah 63% dari model 1. Halangan untuk penyelidikan ini adalah kesediaan sistem pembuatan ke arah fleksibiliti dan 'lean'. Beberapa penambahbaikan boleh dilakukan seperti penetapan jam waktu simulasi dan jarak untuk setiap entiti dan sumber yang lebih teliti. Untuk analisis simulasi, kajian mendalam untuk perisian Quest dan penambahan penyelidikan pada Delmia V5 sebagai alat simulasi juga diperlukan untuk menghasilkan simulasi 3D maya dengan gerakan manusia ergonomik.*

## ACKNOWLEDGEMENTS

First and foremost, I would like to take this opportunity to express my sincere acknowledgement to my supervisor Associate Professor Dr. Zamberi Bin Jamaludin and my co-supervisor Dr. Fairul Azni Bin Jafar from the Faculty of Manufacturing Engineering Universiti Teknikal Malaysia Melaka (UTeM) for their essential supervision, support and encouragement towards the completion of this thesis.

I would also like to express my greatest gratitude to En.Mohd Hidayat Bin AB Rahman from Faculty of Technology Engineering, for his advice and teaching in Delmia Quest Simulation software. Also, my deepest gratitude to Mawea's engineers in providing great service and guideline in conducting simulation using Delmia Quest Simulation software. Special thanks to Zamalah scholarship for funding financial support in 3 semesters of my study. Not forgetting, research grant FRGS/1/2015/TK03/FKP/02/F00277 for funding for the financial support throughout the semester left of this master study.

Special thanks to my husband, my beloved parents and siblings, and my colleagues for their moral support in completing this degree. Lastly, thank you to everyone who had been to the crucial parts of realization of this project.



## TABLE OF CONTENTS

	<b>PAGE</b>
<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>vii</b>
<b>LIST OF FIGURES</b>	<b>x</b>
<b>LIST OF APPENDICES</b>	<b>xvii</b>
<b>LIST OF ABBREVIATIONS</b>	<b>xviii</b>
<b>LIST OF PUBLICATIONS</b>	<b>xx</b>
<b>CHAPTER</b>	
<b>1. INTRODUCTION</b>	<b>1</b>
1.1 Background	1
1.2 Research motivation	4
1.3 Problem statement	5
1.4 Research question	6
1.5 Research hypothesis	7
1.6 Research objectives	7
1.7 Research scope	8
1.8 Research outline	9
<b>2. LITERATURE REVIEW</b>	<b>11</b>
2.1 Overview of material handling	11
2.1.1 Supply chain	12
2.1.2 Material supply	13
2.1.3 Material feeding applications	15
2.1.4 Benefits of material handling system	15
2.2 Technologies in material handling system	16
2.2.1 Transport equipment	16
2.2.2 Storage equipment	18
2.3 System design and development	21
2.4 Simulation method for investigating MHS	28
2.5 Experimentation and analysis of performance measure	30
2.6 Summary	37
<b>3. METHODOLOGY</b>	<b>38</b>
3.1 Overall project progress flowchart	38
3.2 Research approach	40
3.2.1 Interview	41
3.2.2 Survey & questionnaire	44
3.2.3 Observations	46

3.2.4	Compilation of method on data gathering	47
3.3	Phase 1: Understanding research problem and data gathering of case study company	48
3.3.1	Overview of case study company	50
3.3.2	Case study: Factory layout and distance travel	51
3.3.3	Case study: Parts supply	52
3.3.4	Case study: Transport & storage equipment of material handling system	54
3.4	Phase 2: Design and propose new material handling system	55
3.4.1	Planning: Design consideration and prerequisite step	59
3.4.1.1	Layout system flow	59
3.4.1.2	Space utilization & unit load	66
3.4.1.3	Automated material handling system integration	69
3.4.2	Design on delmia/quest simulation software	79
3.4.2.1	Result presentation	79
3.4.2.2	Modelling element of quest	81
3.4.2.3	Decision point logic for material handling elements: AGV, Train and labour element	93
3.4.2.4	Depart requirement and part destination for AGV, train and labour element	100
3.4.3	Part entry	107
3.4.4	Running the simulation	107
3.5	Phase 3: Design of experiment	108
3.6	Phase 4 & 5: Data compilation/ expected result & analysis	109
3.7	Summary	111
<b>4.</b>	<b>RESULT AND DISCUSSION</b>	<b>114</b>
4.1	Results	115
4.1.1	Simulation result for model 1	115
4.1.1.1	Element class satistic	115
4.1.1.2	Warehouse source statistic	118
4.1.1.3	Buffer statistic: Pick up points	120
4.1.1.4	Buffer statistic : Drop off points	121
4.1.1.5	Transportation statistic	124
4.1.2	Simulation result for model 2	129
4.1.2.1	Element class satistic	129
4.1.2.2	Warehouse source statistic	132
4.1.2.3	Buffer statistic: Pick up points	134
4.1.2.4	Buffer statistic : Drop off points	135
4.1.2.5	Transportation statistic	137
4.1.3	Simulation result for model 3	142
4.1.3.1	Element class satistic	142
4.1.3.2	Warehouse source statistic	145
4.1.3.3	Buffer statistic: Pick up points	147
4.1.3.4	Buffer statistic : Drop off points	147
4.1.3.5	Transportation statistic	150
4.1.4	Simulation result for model 4	154
4.1.4.1	Element class satistic	154

4.1.4.2	Warehouse source statistic	156
4.1.4.3	Buffer statistic: Pick up points	158
4.1.4.4	Buffer statistic : Drop off points	159
4.1.4.5	Transportation statistic	162
4.2	Discussion of overall result for all models	165
4.2.1	Discussion on influences of AMH transport equipment to the current system	169
4.2.2	Discussion on influences of AMH storage equipment to the current system	178
4.2.3	Discussion on influences of integration AMH and new layout to the current system	185
4.3	Summary of overall result in discussion	195
<b>5.</b>	<b>CONCLUSION AND RECOMMENDATIONS FOR FUTURE RESEARCH</b>	<b>203</b>
5.1	Overview	203
5.2	Conclusion	203
5.3	Recommendations & future work	206
	<b>REFERENCES</b>	<b>208</b>
	<b>APPENDICES</b>	<b>229</b>

## LIST OF TABLES

<b>TABLE</b>	<b>TITLE</b>	<b>PAGE</b>
2.1	Performance measure using 95% confidence interval (Christopher, 2005)	31
2.2	Level of Factors (Carlo, 2008)	34
2.3	Comparison in correlation metrics used by other authors as their performance measure	35
3.1	Compilation of data gathering method in a review of design and simulation of AMHS in the assembly process	48
3.2	Distance from warehouse to each process in chassis line	52
3.3	Type of part in assembly process	53
3.4	Definition and type of material handling equipment suitable for every different type of layout design (Tompkins et al., 2010)	62
3.5	Distance from warehouse to each process in a new chassis line	66
3.6	Parts arrangement for bins in warehouse which contain the name of bin along with their allocated name of parts	67
3.7	Parts allocation for old layout consisted of name of every drop off stations according to their name of parts	68
3.8	Parts allocation for new layout	69
3.9	Summary of transportation configuration for old layout	76
3.10	Summary of transportation configuration for new layout	77

3.11	Summary of number of vehicles required for old layout	78
3.12	Summary of number of vehicles required for new layout	79
3.13	Result presentation (Sharfiza, 2005)	80
3.14	List of AGV and train decision point for model 1 and 2	94
3.15	List of AGV decision point for model 3	96
3.16	List of AGV decision point for model 4	97
3.17	List of labour decision point at warehouse of model 1 and 2	99
3.18	List of factors and levels used as variables (Carlo, 2008)	108
3.19	Models used in the design of experiments (Carlo, 2008)	109
3.20	Template for result of experiment	110
4.1	Total created parts and parts in system for every assemble parts during simulation/working hour of model 1	116
4.2	Production output of real industry situation (before simulation) and model 1 (after simulation)	118
4.3	Warehouse output and creation rate for every source in warehouse of model 1	119
4.4	Statistic result of pick up buffer of model 1	121
4.5	Statistic result of drop off buffer of model 1	121
4.6	Performance table for transportation of model 1	124
4.7	Performance table for decision point of model 1	126
4.8	Total created parts and parts in system for every assemble parts during simulation time of model 2	130
4.9	Warehouse output and creation rate for every source in warehouse of model 2	133
4.10	Statistic result of pick up buffer of model 2	135

4.11	Statistic result of drop off buffer for model 2	135
4.12	Performance table for transportation of model 2	138
4.13	Performance table for decision point of model 2	140
4.14	Total created parts and parts in system for every assemble parts during simulation for model 3	143
4.15	Warehouse output and creation rate for every source in warehouse of model 3	145
4.16	Statistic result of pick up buffer of model 3	147
4.17	Statistic result of drop off buffer for model 3	148
4.18	Performance table for transformation of model 3	150
4.19	Performance table for decision point of model 3	152
4.20	Total part created and parts in system for every assemble parts during simulation for model 4	154
4.21	Warehouse output and part creation rate for every source in warehouse	156
4.22	Statistic Result of pick up buffer for model 4	159
4.23	Statistic result of drop off buffer for model 4	160
4.24	Performance table for transportation of model 4	163
4.25	Performance table for decision point of model 4	163
4.26	The correlation of significant impact of MHS and Layout between literature and the research case study.	166
4.27	Correlation of performance measure between literature review and research case study.	167

## LIST OF FIGURES

<b>FIGURE</b>	<b>TITLE</b>	<b>PAGE</b>
2.1	The part supply implementation in assembly line(Suhartini et al., 2013)	19
2.2	The sample of picking list from actual automation assembly parts (Sharifah, 2015)	20
2.3	Mother trolley carry carts in plant layout of actual automation factory (Sharifah, 2015)	20
2.4	The analysis model for assembly system design (Bellgran, 2004)	23
2.5	Work methodology to design and analysis material handling system (Santosh, 2016)	26
2.6	Methodology of simulation of assembly line balancing (Jamil and Razali, 2016; Banks, 2004)	27
3.1	Overall research flowchart	39
3.2	The study used Likert 5-point scale (Ho and Nguyen, 2006; Itaya and Niwa, 2007)	45
3.3	Preliminary data gathering process flowchart	50
3.4	Example of Egemin's AGV	55
3.5	Design consideration process flow	56
3.6	Design process flow for design of material handling system (Ulrich and Eppinger, 2016)	57
3.7	Five steps of basic approach in facilities planning (Reyneke, 2010)	61

3.8	Steps applied in facilities planning process (Tompkins et al, 2010)	61
3.9	Assembly approaches used at Volvo’s Kalmar plant. Straight-line Assembly (Tompkins et al., 2010)	65
3.10	Assembly approaches used at Volvo’s Kalmar plant. Dock Assembly (Tompkins et al., 2010)	65
3.11	Source characteristic box in Quest software	84
3.12	The list of sources in all models	85
3.13	Bins and cart used for parts storage during transferred	86
3.14	Sink characteristic dialog box	87
3.15	The buffer connection between source and operator	88
3.16	The process flow of buffer between sources to cart	88
3.17	List of buffers for old and new layout	90
3.18	The location of buffers at warehouse and assembly line for model 1 and 2	91
3.19	The location of buffers at warehouse and assembly line for model 3	92
3.20	The location of buffers at warehouse and assembly line for model 4	92
3.21	The location of AGV and train decision point (red-cross mark) for model 1 and 2	95
3.22	The location of AGV decision point (red-cross mark) for model 3	98
3.23	The location of AGV decision point (red-cross mark) for model 4	98
3.24	The location of labour decision point (red-cross mark) for model 1 and 2	100
3.25	The process flow of AGV and train depart requirement and	102



	part destination for model 1 and 2	
3.26	The process flow of train departs requirement and part destination for model 3	103
3.27	The process flow of AGV depart requirement and part destination for model 4	104
3.28	The process flow of labor departs requirement and part destination for model 1 and 2	106
4.1	Warehouse output during simulation run time of model 1	119
4.2	Part creation rate during simulation run time of model 1	120
4.3	The line graph of bottleneck in assembly line buffer of model 1	123
4.4	The line graph of number of part entries in assembly line buffer of model 1	123
4.5	Line graph of average part residence for transport system of model 1	125
4.6	Line graph of part capacity of transportation during simulation of model 1	126
4.7	The line graph of transportation process performance for model 1	128
4.8	The line graph of transport utilization for model 1	129
4.9	Warehouse output during simulation run time for model 2	132
4.10	Part creation rate during simulation run time of model 2	134
4.11	The line graph of bottleneck in assembly line supply buffer for model 2	136
4.12	The line graph of number of part entries in assembly line buffer for model 2	137
4.13	Line graph of average part residence for transport system for	139

	model 2	
4.14	Line graph of part capacity of transportation during simulation for model 2	139
4.15	The line graph of transportation process performance for model 2	141
4.16	The line graph of transport utilization for model 2	142
4.17	Warehouse output during simulation run time for model 3	146
4.18	Part creation rate during simulation run time for model 3	146
4.19	The line graph of bottleneck in assembly line supply buffer for model 3	149
4.20	The line graph of number of part entries in assembly line buffer for model 3	149
4.21	Bar graph of average part residence for transport system of model 3	151
4.22	Bar graph of part capacity of transportation during simulation for model 3	151
4.23	The line graph of transportation process performance for model 3	153
4.24	The line graph of transport utilization for model 3	153
4.25	Warehouse output during simulation run time for model 4	157
4.26	Part creation rate during simulation run time of model 4	158
4.27	The line graph of bottleneck in assembly line supply buffer for model 4	161
4.28	Line graph of number of part entries in assembly line buffer for model 4	162

4.29	Line graph of transportation process performance for model 4	164
4.30	Line graph of transport utilization for model 4	165
4.31	Bar graph of comparison number of parts and part in system	170
4.32	Comparison of warehouse output during simulation run time	171
4.33	Comparison of part creation rate in warehouse	172
4.34	Comparison of times performance in pickup point buffer	173
4.35	Comparison of parts performance in pickup point buffer	173
4.36	Line graph of comparison in assembly line buffer model 1 and 2	174
4.37	Line graph of comparison number of parts entries in assembly line buffer model 1 and 2	175
4.38	Line graph of comparison of average part residence time for transport system	176
4.39	The chart area of comparison transport process performance	177
4.40	The line graph of comparison of transport utilization	177
4.41	The bar graph of comparison number of parts and part in system	179
4.42	Line graph of warehouse output during simulation run time	180
4.43	Line graph of part creation at warehouse	180
4.44	Comparison of Time Performance in pickup point buffer	181
4.45	The pie chart of comparison number of parts entries at warehouse pick up point	182
4.46	Comparison number of parts entries in assembly line buffer	183
4.47	Comparison of bottleneck in assembly line buffer	183
4.48	The bar graph of comparison part capacity to supply during simulation	184
4.49	The chart of comparison of transport utilization	185

4.50	Comparison number of parts and part in system between model 3 and 4	186
4.51	Line graph of warehouse output during simulation run time between model 3 and 4	187
4.52	Line graph of part creation rate at warehouse between model 3 and 4	188
4.53	Comparison of time performance in pickup point buffer between model 3 and 4	189
4.54	Pie chart of comparison number of part entries at warehouse pickup point between model 3 and 4	190
4.55	Line graph of comparison of bottleneck in assembly line buffer model 3 and 4	191
4.56	Line graph of comparison of bottleneck in assembly line buffer model 3 and 4	192
4.57	Comparison of average part residence time for transport system	193
4.58	Comparison of Part capacity to supply during working hour	193
4.59	Comparison of transport process performance between model 3 and 4	194
4.60	Comparison of transport utilization between model 3 and 4	195
4.61	Comparison number of part created and part in system between all models	196
4.62	Comparison of warehouse output during simulation between all models	197
4.63	Comparison of part creation rate at warehouse source between all models	197

4.64	The comparison of time performance in pickup point buffer between all models	199
4.65	The pie chart of comparison part entries in transport pickup point for all models	199
4.66	The comparison of average part residence time for transport system between all models	200
4.67	The comparison of parts capacity to supply during simulation in all models	201
4.68	The Comparison transport utilization between all models	204

## LIST OF APPENDICES

APPENDIX	TITLE	PAGE
A	Draft picture of measurement of plant layout of case study	229
B	Part positioning for the car model	230
C	Schematic diagram of current layout in case study company	231
D	Drawing of new layout in case study company	232
E	Schematic diagram of new layout in case study company	233
F1	Flow diagram of parts allocation and transport flows from old layout	234
F2	Flow diagram of parts allocation and transport flows from new layout	235
G1	From – to chart showing flowrate in old layout	236
G2	From – to chart showing flowrate in new layout	237
H	Simulation control language for model 1 and model 2	238
I	Simulation control language for model 3 and model 4	244

## LIST OF ABBREVIATIONS

MHS	-	Material Handling System
AGV	-	Automated Guided Vehicle
EMS	-	Electrical Monorail System
AS/RS	-	High Rise Storage Retrieval System
MH	-	Material Handling
MHIA	-	Material Handling Industry of America
RFID	-	Radio Frequency Identification
VMI	-	Vendor Managed Inventory
SADT	-	Structure and Analysis Design Technique
AMR	-	Autonomous Mobile Robots
FUMAHES	-	Fuzzy-Attributes Material Handling Equipment
JIT	-	Just In Time
LIM	-	Linear Induction Motor
LCD	-	Liquid Crystal Display
WIP	-	Work in Process
PATH	-	Posture, Activities, Tools and Handling
MMH	-	Manual Material Handling
ANOVA	-	Analysis of Variance
HTA	-	Hierarchical Task Analysis
DoE	-	Design of Experiment

AMHS	-	Automated Material Handling System
DR	-	Dispatching Rule
DF	-	Degree of Freedom
SS	-	Sum of Square
MS	-	Mean of Square
F	-	Factors of the total deviation
P	-	Null Hypothesis
RSM	-	Response Surface Method
PC	-	Polycarbonate
FMS	-	Flexible Manufacturing System
MESA	-	Manufacturing Enterprise Solutions Association
DPE	-	Digital Process Engineering
DPM	-	Digital Process Manufacturing
APMP	-	Assembly Process Micro-Planning
PSL	-	Process Specification Language
CAAP	-	Computer Aided Assembly Process
CAD	-	Computer Aided Drawing
TT	-	Tugger Train
OL	-	Old Layout
NL	-	New Layout
PL	-	Picking List
PTL	-	Pick-To-Light
m	-	meter
hr.	-	hour
SCL	-	Simulation Control Language