"SMART" AGROLOGISTICS: INTELLIGENT SPATIAL DECISION SUPPORT SYSTEM FOR SUSTAINABLE POTATO AGRO-INDUSTRY LOGISTICS DEVELOPMENT

RINDRA YUSIANTO

STUDY PROGRAM OF AGRO-INDUSTRIAL ENGINEERING
POSTGRADUATE SCHOOL
IPB UNIVERSITY
BOGOR
2021

DECLARATION OF ORIGINALITY AND COPYRIGHT TRANSFER

We now declare that the dissertation entitled "SMART" AGROLOGISTICS: Intelligent Spatial Decision Support System for Sustainable Potato Agro-Industry Logistics Development is my work with the supervisor's direction, and we have never submitted it in any universities. All incorporated originated from other published and unpublished papers clearly stated in the text and quotations.

Now, we declare that the copyright of this paper, we transfer to IPB University.

Bogor, August 2021

Rindra Yusianto
F361180081

RINGKASAN

RINDRA YUSIANTO. "SMART" AGROLOGISTIK: Sistem Pengambilan Keputusan Spasial Cerdas untuk Pengembangan Agro-industri Logistik Kentang Berkelanjutan. Dibimbing oleh Prof Dr Ir MARIMIN, MSc, Prof Dr Ir SUPRIHATIN dan Dr Ir HARTRISARI HARDJOMIDJOJO, DEA.

Kentang *(Solanum tuberosum L.)* merupakan bahan pangan hortikultura esensial setelah gandum, beras, dan jagung. Indonesia merupakan produsen ke-10 dunia dan terbesar di Asia Tenggara, dengan tingkat pertumbuhan 8,4% per tahun dan rata-rata produksi 1,3 juta ton/tahun. Produksi terbesar provinsi Jawa Tengah yaitu 277.702 ton. Di Indonesia, kentang merupakan komoditas strategis yang memiliki potensi mendukung diversifikasi dan mendukung ketahanan pangan nasional yang berkelanjutan. Tren ketahanan pangan global, kompleksitas dan ketidakpastian pengambilan keputusan, serta tuntutan kelestarian lingkungan telah melahirkan teknologi adaptif. Logistik agroindustri (agrologistik) adalah logistik modern yang berkaitan dengan pengolahan bahan baku hortikultura pangan. Masalah utama agrologistik adalah karakteristik produk yang memiliki kerentanan, kompleksitas, dan ketidakpastian tinggi, disebabkan sifat komoditas yang mudah rusak, kepekaan terhadap perubahan iklim, dan fluktuasi harga yang tinggi. Kualitas menurun dengan cepat setelah panen, mengakibatkan potensi kerugian hingga 40%. Selain itu, kondisi spasial mempengaruhi kemampuan pasokan secara signifikan, sementara perhitungan matematis standar tidak dapat menyelesaikan masalah ini. Oleh karena itu, diperlukan Sistem Pendukung Keputusan (SPK) untuk meningkatkan ketahanan pangan berkelanjutan yang mempertimbangkan karakteristik produk hortikultura pangan dengan perspektif spasial.

Dalam penelitian ini dikembangkan "SMART" AGROLOGISTIK yaitu suatu prototipe aplikasi SPK spasial cerdas untuk pengembangan agrologistik kentang berkelanjutan. Prototipe ini mendukung kerangka kerja SMART yang merupakan simulasi model yang adaptif *reliable* dan terintegrasi. Prototipe ini telah mampu menentukan lokasi yang paling sesuai untuk pengembangan kentang berkelanjutan. Prototipe ini mampu mengintegrasikan Internet of Things (IoT) yaitu sensor SHT15 untuk kelembaban dan suhu dan sensor Rain Gauge untuk curah hujan. Analisis spasial terhadap dimensi lingkungan yang terdiri dari tiga faktor fisik yaitu ketinggian, tekstur tanah, dan persentase kemiringan, dan tiga faktor iklim yaitu suhu, kelembaban, dan curah hujan ini, merupakan upaya untuk memperbaiki rendahnya produktivitas saat ini, sebesar 16,99 ton/ha, dan target pemenuhan kebutuhan industri yang hanya tercapai 85,93%. Pada level implementasi prototipe di Wonosobo, Jawa Tengah, menunjukkan bahwa rata-rata sampel penelitian memiliki keberlanjutan yang sangat sesuai yaitu 11,05%, kondisi baik dengan beberapa faktor penghambat sebesar 62,01%, dan kondisi cukup berkelanjutan sebesar 22,9%. Sedangkan 4,04% tidak tercatat. Titik keberlanjutan diperoleh di Kejajar (P_1), Garung (P_2), Mojotengah (P_3), Kalikajar (P_5), dan Kepil (P_{13}), sehingga untuk memenuhi kebutuhan industri, lokasi ini diprioritaskan.

Penelitian ini memodifikasi metode multi-thresholding dengan teknik *overlay* dan *geoprocessing* untuk memprediksi jumlah panen. Modifikasi metode ini adalah upaya menyeimbangkan pasokan dan permintaan. Permintaan bahan baku industri kentang di Jawa Tengah saat ini sebesar 117.000 ton/tahun. Pengembangan prototipe mempertimbangkan dimensi ekonomi yaitu hasil prediksi dan harga bahan baku, juga mengintegrasikan IoT, yaitu penginderaan jauh menggunakan drone DJI quadcopters. Implementasi prototipe menunjukkan tingkat akurasi

89,35% dengan rata-rata total panen 13,79 ton/ha. Menggunakan prototipe ini, prediksi total panen kentang untuk industri adalah 72.765 ton/tahun. Sehingga masih terjadi kekurangan sebesar 44.235 ton/tahun. Pengambil keputusan dapat menggunakan metode ini untuk memenuhi kebutuhan bahan baku kentang industri, dimana model ini telah mampu merekomendasikan peningkatan produksi 21.829 ton/tahun (30%) dan memenuhi dari daerah lain sebesar 22.406 ton/tahun (31%).

Selanjutnya prototipe ini mampu menentukan koordinat Pusat Logistik (LC) komoditas hortikultura pangan yang lebih rasional dalam pengembangan agrologistik kentang berkelanjutan. Modifikasi metode Center of Gravity (COG) dengan mempertimbangkan perspektif spasial dari dimensi sosial yaitu kepadatan penduduk, kemacetan spasial-temporal, dan indeks zona rawan bahaya ini, mampu memperbaiki metode COG klasik yang memiliki kelemahan yaitu sering menemukan titik optimal di daerah padat penduduk. Hasil simulasi prototipe ini menunjukkan lokasi LC yang paling optimal yaitu pada koordinat 7°21'38.8"S, 110°08'10.2 "E, koordinat ini lebih rasional untuk komoditas hortikultura pangan.

Rute optimal untuk komoditas hortikultura pangan tidak hanya ditentukan berdasarkan jarak terpendek tetapi perlu juga mempertimbangkan kriteria dengan perspektif lingkungan dan berbagai alternatif yang kompleks dan tidak pasti. Penelitian ini menawarkan prototipe aplikasi dengan algoritma baru, yaitu algoritma spasial Dijkstra yang mensinergikan dimensi lingkungan, ekonomi, dan sosial dengan analisis spasial. Metode baru ini melengkapi algoritma Dijkstra klasik dengan menambahkan perhitungan bobot dan kriteria menggunakan pendekatan non-numeric Multi-Expert Multi-Criteria Decision Making (ME-MCDM). Metode baru ini menggunakan analisis spasial yang mempertimbangkan perspektif lingkungan, yaitu jarak, biaya, resiko, dan uitilitas. Hasil simulasi prototipe menunjukkan rute paling optimal melalui P (V_1, V_2, V_3, V_5) dengan nilai alternatif total (TAV) sebesar 1.547. Hasil penelitian menunjukkan bahwa metode baru ini telah mampu memberikan solusi yang lebih masuk akal dan bermakna dibandingkan hasil algoritma Dijkstra klasik. Berdasarkan validasi model, metode baru ini dapat memverifikasi bahwa rute optimal untuk komoditas hortikultura pangan tidak selalu merupakan rute terpendek. Sehingga metode baru ini dapat digunakan untuk pemilihan rute distribusi yang lebih sesuai untuk komoditas ini.

Simulasi model dalam prototipe ini mampu menunjukkan bahwa transparansi logistik yaitu manajemen material dan distribusi fisik dapat memprediksi ketersediaan, keterjangkauan dan pemanfaatan pangan dibandingkan dengan kondisi sebenarnya sebesar 95,86%. Hal ini menunjukkan bahwa faktor-faktor dalam dimensi keberlanjutan terlibat, saling berinteraksi dan mempengaruhi pengembangan prototipe aplikasi "SMART" AGROLOGISTIK. Prototipe dan pendekatan baru ini telah mampu menunjukkan keseimbangan pasokan and permintaan dalam simulasi model yang adaptif, sehingga dapat meningkatkan ketahanan pangan. Selain itu, pendekatan ini juga telah mampu mengusulkan struktur kelembagaan yang lebih cocok untuk agro-industri kentang di Jawa Tengah yang memberikan peran lebih besar kepada Gabungan Kelompok Tani (Gapoktan) dan industri kecil menengah (IKM). Akhirnya, pendekatan ini juga menunjukkan bahwa kolaborasi IoT dalam kerangka kerja SPK spasial cerdas dapat menjadi solusi alternatif untuk meminimalkan ketidakseimbangan pasokan dan permintaan dalam pengembangan agrologistik kentang berkelanjutan.

Kata kunci: agroindustri kentang berkelanjutan, IoT, ketahanan pangan, spasial Dijkstra, SPK spasial cerdas, transparansi logistik

SUMMARY

RINDRA YUSIANTO. "SMART" AGROLOGISTICS: Intelligent Spatial Decision Support System for Sustainable Potato Agro-Industry Logistics Development. Supervised by MARIMIN, SUPRIHATIN, and HARTRISARI HARDJOMIDJOJO.

Potato *(Solanum tuberosum L.)* is an essential horticultural food after wheat, rice, and corn. Indonesia is the world's 10th producer and the largest in Southeast Asia, with a growth rate of 8.4% per year and an average production of 1.3 million tons/year. The most significant production in Indonesia is Central Java, which is 277,702 tons. In Indonesia, potato is a strategic horticultural commodity that prioritizes diversified food consumption and supports national sustainable food security. Trends in global food security, the complexity, uncertainty of decision-making, and demands for environmental sustainability have given birth to adaptive technology, including modern logistics. Agro-industry logistics (agro logistics) is a modern logistics related to processing food horticultural raw materials. The main problem is the product characteristics with high vulnerability, complexity, and uncertainty. The perishable nature of commodities, sensitivity to climate change, and high price fluctuations cause this. Quality declines rapidly after harvest, resulting in potential losses of up to 40%. In addition, the spatial conditions affect the supply capability, while standard mathematical calculations cannot solve this problem. Therefore, a Decision Support System (DSS) is needed to improve sustainable food security that considers the characteristics of food horticultural products with a spatial perspective.

This study developed "SMART" AGROLOGISTICS, a prototype application of an intelligent spatial decision-making system for sustainable potato agro logistics development. This prototype supports the SMART framework, a reliable and integrated simulation model that is adaptive and integrated. This prototype has determined the most suitable location for the development of potatoes as sustainable food horticulture. This prototype can integrate the IoT, namely SHT15 sensors for humidity and temperature and rain gauge sensors for rainfall. Spatial analysis of three physical factors: altitude, soil texture, slope percentage, and three factors: climate, temperature, humidity, and rainfall. The development of this prototype is an effort to increase productivity which is currently low, which is 16.99 tons/ha, and the target of meeting industrial needs, has only reached 85.93%. The prototype implementation level in Wonosobo, Central Java, shows that the average research sample with very suitable sustainability is 11.05%. Good condition with several inhibiting factors is 62.01%, and moderately sustainable condition is 22.9%. Meanwhile, we did not record 4.04%. Sustainability areas are in Kejajar (P_1), Garung (P_2), Mojotengah (P_3), Kalikajar (P_5), and Kepil (P_{13}), so we recommend prioritizing these locations to meet industry needs.

This study modifies the multi-thresholding method with overlay and geoprocessing techniques to predict the amount of harvest. The development of a prototype with a modification of this method attempts to balance supply and demand. The current demand for raw materials for the potato industry in Central Java is 117,000 tons/year. This prototype integrates IoT, namely remote sensing using DJI quadcopters drones to balance supply and demand. The prototype

implementation shows that the average total harvest is 13.79 tons/ha, with the accuracy rate of 89.35%. The predicted total industrial potato production is 72,765 tons/year. So there is still a shortage of production of 44,235 tons/year. Decision-makers can use this method to meet the needs of potato raw materials for industry. The modification of this model can recommend an increase in production of 21,829 tons/year (30%) and meet other regions by 22,406 tons/year (31%).

Furthermore, this prototype can determine the coordinates of the Logistics Center (LC) for food horticulture commodities that are more rational in developing sustainable potato agro logistics. The modification of the Center of Gravity (COG) method considers the spatial perspective of the social dimension, namely population density, spatial-temporal congestion, and the multi-hazard zone index. Can improve the classical COG method, which has the weakness that it often finds optimal points in densely populated areas. The simulation results of this prototype show that the most optimal LC location is at coordinates 7°21'38.8"S, 110°08'10.2"E; these coordinates are more rational for horticultural food commodities.

The optimal route for horticultural food commodities is determined based on the shortest distance. It needs to consider criteria with an environmental perspective and various complex and uncertain alternatives. This research offers a new algorithm, Dijkstra's spatial algorithm, that synergizes environmental, economic, and social dimensions with spatial analysis. This new method complements the classic Dijkstra algorithm by adding calculations to alternative weights and criteria. We use a non-numeric Multi-Expert Multi-Criteria Decision Making (ME-MCDM) approach. This new method uses spatial analysis on criteria that consider environmental perspectives, namely distance, cost, risk, and utilization. The results of the prototype simulation show that the most optimal route is through P (V_1, V_2, V_3, V_5) with a total alternative value (TAV) of 1,547. The results show that this new method has provided a more reasonable and meaningful solution than the classical Dijkstra algorithm results. This new method can verify that the optimal route for horticultural food commodities is not always the shortest route based on model validation. This new method can choose a more suitable distribution route for this commodity.

The simulation model in this prototype can show that logistics transparency, namely material management and physical distribution. We can predict the availability, affordability, and utilization of food compared to the actual condition of 95.86%. It shows that the factors in the sustainability dimension are involved, interact with each other. They affect the development of the "SMART" AGROLOGISTIC application prototype to develop a sustainable potato logistics agro-industry in Central Java, Indonesia. This new prototype and approach have demonstrated the balance of supply and demand in an adaptive simulation model to improve food security. In addition, this approach has also proposed a more suitable institutional structure for the potato agro-industry in Central Java. This structure plays a more significant role in the Association of Farmers Groups (Gapoktan) and small and medium industries (IKM). Finally, this approach shows that IoT collaboration in a spatially intelligent DSS framework can be an alternative solution for developing sustainable potato agro logistics. Mainly to minimize supply and demand imbalances.

Keywords: food security, IoT, ISDSS, logistics transparency, spatial Dijkstra, sustainable potato agro-industry

"SMART" AGROLOGISTICS: INTELLIGENT SPATIAL DECISION SUPPORT SYSTEM FOR SUSTAINABLE POTATO AGRO-INDUSTRY LOGISTICS DEVELOPMENT

RINDRA YUSIANTO

Dissertation
As partial fulfillment of the requirement for the degree of
Doctor in the Agro-industrial Engineering Program

STUDY PROGRAM OF AGRO-INDUSTRIAL ENGINEERING
POSTGRADUATE SCHOOL
IPB UNIVERSITY
BOGOR
2021

External Examiner on Closed Examination:

1. Prof Ir Zainal Arifin Hasibuan, MLS, PhD
2. Prof Dr Ir Titi Candra Sunarti, MSi, IPM

External Examiner on Open Examination:

1. Prof Ir Zainal Arifin Hasibuan, MLS, PhD
2. Prof Dr Ir Titi Candra Sunarti, MSi, IPM

Title : "SMART" AGROLOGISTICS: Intelligent Spatial Decision Support System for Sustainable Potato Agro-Industry Logistics Development
Name : Rindra Yusianto
Student ID : F361180081

Approved by

Supervisor:
Prof Dr Ir Marimin, MSc

Co-Supervisor:
Prof Dr Ir Suprihatin

Digitally signed by:
Suprihatin
Date: 17 Sep 2021 10.58.40 WIB
Verify at dsign.ipb.ac.id

Co-Supervisor:
Dr Ir Hartrisari Hardjomidjojo, DEA

Acknowledged by

Chair of Agro-industrial Engineering Study:
Dr Illah Sailah, MS
NIP 19580521 198211 2 001

Dean of Graduate School:
Prof Dr Ir Anas Miftah Fauzi, MEng
NIP 19600419 198503 1 002

Digitally signed by:
Anas Miftah Fauzi
Date: 19 Sep 2021 11.17.20 WIB
Verify at dsign.ipb.ac.id

Close exam date:
July 30, 2021
Open exam date:
August 19, 2021

Passed date:

PREFACE

Praise and gratitude I pray to Allah SWT for all His gifts to complete this research well. The theme I chose was Smart Agro Logistics entitled "SMART" AGROLOGISTICS: Intelligent Spatial Decision Support System for Sustainable Potato Agro-Industry Logistics Development. "SMART" AGROLOGISTICS is a prototype application of an intelligent spatial decision support system (ISDSS) based on the Android operating system. Data collection from September 2019 to June 2021.

Thanks to Prof Dr Ir Marimin, MSc, Prof Dr Ir Suprihatin, and Dr Ir Hartrisari Hardjomidjojo, DEA, who has guided and provided many suggestions. We also thank the chairperson of the session and external examiners of the supervisory commission. In addition, our appreciation to:

1. Dr Heri Hermansyah, ST, MEng as Director of Research and Community Service Ministry of Research and Technology/National Agency for Research and Innovation of the Republic of Indonesia, which has provided funding support for this research through the Indonesia Bangkit scheme 2020, and the Applied Research scheme 2021.
2. Prof Dr Ir Edi Noersasongko, MKom, as Rector of Dian Nuswantoro University and Prof Dr Arif Satria, SP, MSi, as the Rector of IPB University, who supports this research.
3. Prof Ir Zaenal Arifin Hasibuan, MLS, PhD (Dian Nuswantoro University and chairman of APTIKOM Indonesia), Prof Dr Ir Titi Candra Sunarti, MSi, IPM (IPB University), an external examiner in closed and open examinations.
4. Dr Pedro Manuel Villa (Federal University of Vicosa Brazil), Dr Hj Mohammad Nabil Almunawar (Universiti of Brunei Darussalam), Prof Dr apt Sundani Nurono Suwandhi (ITB and Chairman of FlipMAS Indonesia), Prof Dr Supriadi Rustad, MSi (Dian Nuswantoro University), Prof Dr Ir Sukardi, MM (IPB University), Prof Dr Eng Taufik Djatna, STP, MSi (IPB University), Dr Endang Warsiki, STP, MSi (IPB University), Prof Dr Ir Hari Purnomo, MT (UII), Dr Ir Illah Sailah, MS (IPB University), Prof Dr Ir Agus Buono, MSi, MKom (IPB University), Prof Ahmad Fauzy, SSi, MSi, PhD (UII), Prof Dr Ir Darsono, MSi (UNS), Dr Ir Syamsul Bahri Agus, MSi (IPB University), Dr Irman Hermadi, SKom, MS (IPB University), Dr Ir Elisa Kusrini, MT, CPIM, CSCP (UII) Prof Budi Santoso (ITS), Prof Dr Ir Ellyza Nurdin, MS (UM Bandung), Prof Dr Revolson Alexius Mege, MS (UNManado), who provided support in this research.
5. Prof Dr Ir Mauridhi Hery Purnomo, MEng (ITS Surabaya), Prof Dr Ir I Nyoman Sucipta, MP (UNUD), Prof Dr Tukiran, MSi (UNESA), Dr Muhammad Asrol, STP, MSi (UBINUS), Dr Rina Fitriana, ST, MM (Trisakti University), Dr Casnan, MSI (STKIP Muhammadiyah Kuningan), Dr Rahmat Pramulya, STP, MM (Universitas Teuku Umar), Dr Nova Rijati, SSi, MKom (Dian Nuswantoro University), and Dr Budiharjo, MKom (Dian Nuswantoro University) for reviewing our publications and this dissertation report.
6. Sidik Widagdo, SSos, MSi as Head of Plantation and Horticulture Division of Food, Agriculture, and Fisheries Service Wonosobo, Central Java.
7. Beni Hermawan, SIP, and the entire Division of Development and Extension Program, Wonosobo, Central Java, provided the data for this research.
8. Parmin as the Enggal Makmur Garung Wonosobo farmer group and all farmer group members, Adhi Nurcholis, MSc as the Adhiguna farmer group,

Adhiguna Laboratory Kejajar Wonosobo, and all staff who have helped during data collection.

9. Pak Wagino, Pak Aris, Pak Nur, Pak Hargiono, Pak Baito, and all potato farmers and collectors in Wonosobo and Banjarnegara, Central Java, Indonesia, have helped with this research.
10. Pak Rahmat is the owner of the Pakuwojo potato industry, and Pak Handoyo is the owner of the Melati potato industry. Bu Ety Tamir is the owner of the Albaeta potato industry.
11. Dede Solehudin, SE and all staff of PT. Indomarco Prismatama, and Mba Ayu and all staff of Indofood Fritolay Makmur Denpasar and Semarang.
12. Agro-industrial Engineering class 2018, Dedi Wahyudi, Endang Suhendar, Sambas Sundana, Tikuk Kuswandi, Rizki Dorojatun, Dwindrata Basuki Aviantara, Paduloh, Kartika Okta Purnama, Ratna Ekawati, Putti Retno Ali, Desi Novianti, Nurul Umi, Safriyana, and Amalia Afifah which is extraordinary.
13. Dr Yesi, Dr Agnes, Dr Petir Papilo, Dr Nunung Nur Hasanah, Dr Ririn, Dr Noveria, Taufik Baidawi, MKom, and all friends "bimbingan rutin."
14. Sri Martini, SKom, MSi, Pak Chandra and all TSI laboratory staff of IPB University.
15. Muhammad Saifur Rohman MCs, Rahmat, and Oki Candra, along with the SMART AGROLOGISTIC development team, helped develop the website and android-based application prototypes.
16. Arga Dwi Pambudi MT, Atiek Prawira ST, and all staff of the Faculty of Engineering, Dian Nuswantoro University, assisted in this research.
17. I also thank my father, Warsono (deceased), and my mother, Sri Sutji Rahayu, my beloved wife Neni Fajarwati, ST, my sons Anindra Muhammad Azka, Rasya Affiq Maulana, and Rivanda Shafy Avisennsa, given their support, prayers, and love.

Hopefully, this research can be helpful for all of us and contribute to the development of science, especially potato agro-industry development.

Bogor, August 2021
Rindra Yusianto

TABLE OF CONTENT

LIST OF TABLES xvi

LIST OF FIGURES xvii

APPENDIX LIST xix

GLOSSARY xix

I INTRODUCTION 1
- 1.1 Background 1
- 1.2 State of The Art 2
- 1.3 Research Questions 5
- 1.4 Objectives 5
- 1.5 Benefits 5
- 1.6 Scopes and Structure 6
- 1.7 Novelty 6

II SYSTEMATIC LITERATURE REVIEW 7
- 2.1 Smart Agro Logistics Systems 7
- 2.2 Traceability System using Smart Agro Logistics 9
- 2.3 Intelligent Agro Logistics DSS 10
- 2.4 Trust in Agro Logistics 11
- 2.5 Multi-Criteria in Agro Logistics using Spatial Perspectives 12
- 2.6 Logistics Transparency in Sustainable Food Security 13

III METHODOLOGY 17
- 3.1 Time and Location 17
- 3.2 Research Framework 17
- 3.3 Data Collection 19
- 3.4 Data Analysis 20
- 3.5 DSS Software Prototype Development 20

IV GENERAL ANALYSIS OF SITUATION AND EXISTING CONDITIONS 23
- 4.1 Potato Production 23
- 4.2 Potato Logistics 30
- 4.3 Potato-based Agro-industry 31
- 4.4 Post-Harvest Handling 33
- 4.5 Existing Potato Institutional Structure 35

V CROPLAND SUSTAINABILITY AND HARVEST PREDICTION USING IOT 37
- 5.1 Abstract 37
- 5.2 Introduction 37
- 5.3 Method 39
- 5.4 Result and Discussions 45
- 5.5 Conclusions and Recommendations 51

VI DETERMINING LC AND DISTRIBUTION ROUTES USING SPATIAL DIJKSTRA 53

6.1 Abstract 53
6.2 Introduction 53
6.3 Method 54
6.4 Result and Discussion 61
6.5 Conclusions and Recommendations 69
VII TRACKING AND TRACING USING ANDROID-BASED NAVIGATION SYSTEMS 71
7.1 Abstract 71
7.2 Introduction 71
7.3 Method 72
7.4 Result and Discussion 77
7.5 Conclusions and Recommendations 86
VIII LOGISTICS TRANSPARENCY USING NON-NUMERIC ME-MCDM WITH TRUST MODEL 87
8.1 Abstract 87
8.2 Introduction 87
8.3 Method 88
8.4 Result and Discussion 96
8.5 Conclusions and Recommendations 106
IX GENERAL DISCUSSION 107
9.1 Intelligent Spatial Harvest Prediction using IoT 107
9.2 Optimization of Distribution Routes using Spatial Dijkstra 108
9.3 Tracking and Tracing using Smart Agro Logistics 108
9.4 Sustainable food security with Logistics Transparency 109
9.5 Novelty 110
9.6 Research Limitation 111
9.7 Managerial Implication 111
X CONCLUSIONS AND RECOMMENDATIONS 113
10.1 Conclusions 113
10.2 Recommendations 114
REFERENCES 116
APPENDIX 133
CURRICULUM VITAE 146

LIST OF TABLES

1	Number of scientific articles on spatial digital agro logistics	8
2	Potato growth rates in Asia	23
3	Producer potatoes in Indonesia	24
4	Potato production in Central Java	24
5	Potato production in Banjarnegara and Wonosobo district	25
6	Total Indonesian potato exports	25
7	Total Indonesian potato imports	26
8	Average yield potential of potato varieties	26
9	Potato quality standards according to SNI-01-3175-1992	28
10	Potato grade by weight, size, and price	28
11	Potato grade based on SNI 01-3175-1992	28
12	post-harvest yield loss percentage	30
13	Storage in existing conditions	31
14	Collector's capacity in existing conditions	31
15	Quality requirements of potato chips according to SNI 01-4031-1996	32
16	Potato quality standard for french fries	32
17	Industrial potato raw material needs in Central Java, Indonesia	42
18	Specification of sample point location	42
19	Classes and criteria for potato plants	43
20	Cropland sustainability level interval	44
21	The values of the altitude, soil texture, slope, rainfall, and temperature	44
22	Cropland sustainability classification	46
23	The existing production	47
24	The result of weighing harvest data	49
25	The total harvest comparison	50
26	Prediction of potato production of industrial raw materials	50
27	Scenario of alternative strategy	51
28	The sample nodes coordinates	58
29	The distribution route of agro-industrial products in Central Java	59
30	Temporal congestion classes and criteria	60
31	Risk hazard-zone classes and criteria	60
32	Average elevation classes and criteria	60
33	Average slope classes and criteria	60
34	Road infrastructure classes and criteria	60
35	Spatial variable score result	61
36	Coordinate, capacity, and spatial conversion values	61
37	Latitude (X) coordinates result	61
38	Longitude (Y) coordinates result	62
39	The five-dimensional scale	63
40	The criteria importance level	63
41	Matrix for assessment of alternatives and criteria	63
42	Negation the importance criteria level	64
43	Ratio Spatial variables	65
44	Spatial variable score	65
45	Expert assessment for alternative 1 (A_1)	66

46 Summary of aggregation results 66
47 Weighting of aggregation results 66
48 Alternative's value 67
49 Method comparison 68
50 Mandatory data in the traceability of horticulture food safety 73
51 Optional data in traceability of horticulture food safety 73
52 The coordinates of each node 74
53 Layer in the ISDSS concept 79
54 Algorithm comparison 85
55 Alternative routes 93
56 The criteria importance level 95
57 Matrix for assessment of criteria and alternatives 95
58 The negation of importance level 96
59 Expert assessment for alternative 1 (A_1) 96
60 The average value of trust behavior (CC) 98
61 Matrix results in pairwise comparison criteria 101
62 Matrix of eigenvalues from alternatives with the weighting criteria 101
63 The composite weight of criteria for each alternative using AHP 101

LIST OF FIGURES

1 Research gap 4
2 Publication percentage category based on a field of a subject 7
3 Agro logistics systems classification based on various methods 7
4 The total number of smart agro logistics publications 8
5 Year of publication articles 8
6 KDD in SDSS 11
7 Information flow in agrologistic 12
8 Rich Picture: An overview of the overall research activities 17
9 Research framework 18
10 Research stages 19
11 Strategy Map 21
12 Business Workflows 21
13 Primary Use Case Diagram 22
14 Vegetable potatoes varieties 27
15 Industrial potatoes varieties 27
16 Seed G1 series 27
17 Vegetable potato grade at wholesaler level 29
18 Industrial potato grade at wholesaler level 29
19 Potato industrial tree 29
20 Potato industrial tree development 30
21 Stages in agricultural activity 33
22 Potato post-harvest handling 34
23 Potato trading line 36
24 Trading system in agro-industry development 36
25 Research framework in this chapter 40

26 Wonosobo administration map 40
27 Sample points based on grid interval 41
28 The system architecture 41
29 Altitude map (a), soil texture map (b), and slope map (c) 45
30 Temperature map (d), humidity map (e), rainfall map (f) 45
31 Spatial distribution cropland sustainability 46
32 The sample coordinate based on the significant production number 47
33 Kejajar sub-district map 48
34 Image acquisition 48
35 Acquisition image in the grayscale 48
36 Image segmentation using multi-thresholding 49
37 Research framework for optimization of distribution routes 55
38 Single graph network using spatial Dijkstra 57
39 The sample node coordinate in this chapter 59
40 The network of distribution routes 59
41 The optimal coordinates 7°21'38.8"S, 110°08'10.2"E 62
42 Single graph network using the Dijkstra algorithm 65
43 Single graph network using Spatial Dijkstra algorithm 67
44 Route comparison 68
45 Android-based navigation model 75
46 Connection between users and Google APIs 75
47 Dijkstra algorithm using Google APIs 76
48 Flowchart the concept of navigation radius 76
49 Program part of radians algorithm 77
50 The development of ISDSS for agro logistics systems 78
51 The Layer architecture in ISDSS 79
52 Modelling ISDSS 80
53 ISDSS block architecture 80
54 The ISDSS Concept 81
55 Network graph with Dijkstra algorithm 81
56 Network graph results of the Dijkstra algorithm 82
57 dbSmartAgro with latitude and longitude coordinates 82
58 Android-based navigation system interface 82
59 The shortest distribution route using Android 83
60 Shortest distribution route display using Android 83
61 Display nodes using navigation radius 84
62 Network graph from V_1 to V_2 84
63 Navigation system using navigation radius 84
64 The research gap framework in ME-MCDM with Trust Model 88
65 The non-numeric ME-MCDM framework 90
66 The trust model framework 91
67 An overview of the non-numeric ME-MCDM based on trust models 92
68 Route A_1 via Parakan, Temanggung District 93
69 Route A_2 via West Ungaran, Semarang District 93
70 Route A_3 via Mungkid, Magelang District 94
71 Route A_4 via Bawen-Salatiga Toll Road 94
72 Trust scale in Trust Model 96
73 Visualization of satellites on alternative route 4 (A_4) 100

74 Structural diagram for actorsactors' elements 102
75 Structural diagram for requirement elements 103
76 Structural diagram for objective elements 103
77 Structural diagram for constraint elements 104
78 Structural diagram for indicator elements 104
79 Linkages between stakeholder's chart 105

APPENDIX LIST

1 "SMART" AGROLOGISTICS application installation instructions 134
2 Operational instructions for "SMART" AGROLOGISTICS application 142

GLOSSARY

Agro-industry	=	An industry that processes raw materials sourced from agricultural products.
Agro logistics	=	Agro-industry logistics. A modern logistics related transportation for integrated industrial management function that processes horticultural food raw materials and focuses on product availability, availability, and utilization.
Agro logistics system	=	A transportation term for integrated industrial management function.
ANFIS	=	Adaptive Neuro-Fuzzy Inference Systems
ANN	=	Artificial Neural Networks.
Asl	=	above sea level.
AV	=	Alternative Value.
Bakosurtanal	=	National Survey and Mapping Coordinating Agency.
Balitbang	=	Badan Penelitian dan Pengembangan. Research and Development Agency.
Balitsa	=	Badan Penelitian Tanaman Sayuran. Vegetable Crops Research Institute.
Bapeda	=	Regional Planning Agency.
BPS	=	Central Bureau of Statistics of the Republic of Indonesia.
Cleaning	=	An activity to remove physical, chemical and biological impurities by brushing, wiping and blowing.
COG	=	Center of Gravity. Methods that take into account the equivalence of distance and volume of demand at the location of the logistics chain network.
Collectors	=	Collection centers.
Concentrate	=	A mixture of several feed raw materials, both complete and still to be completed which are specially prepared and contain sufficient nutrients for livestock needs to be used according to the type of livestock.

Contractual trust	=	A shared moral norms, such as honesty, usually requires knowledge and understanding of shared technical standards and professional and managerial behavior.
CPS	=	Cyber-Physical System.
Cropland suitability	=	Measures how the quality of the land unit complies with specific land-use requirements.
DBMS	=	Database Management System.
DC	=	Distribution Center.
DHT11	=	A sensor module that functions to sense temperature and humidity objects with an analog voltage output that can be further processed using a microcontroller.
Dinindag	=	Dinas Industri dan Perdagangan. Department of Industry and Trade of Central Java.
Dinkop UMKM	=	Dinas Koperasi dan Usaha Mikro Kecil dan Menengah. Department of Cooperatives and UMKM.
Dishanpan	=	Dinas Ketahanan Pangan. Department of Food Security.
Distanbun	=	Dinas Pertanian dan Perkebunan. Department of Agriculture and Plantation.
DSS	=	Decision Support Systems.
ERP	=	Enterprises Resource Planning.
Food security	=	Condition of fulfilling food for the state to individuals, which is reflected in the availability of sufficient food, both in quantity and quality. Safe, diverse, nutritious, equitable, and affordable, and does not conflict with religion, and community culture, to live a healthy, active, and productive life sustainably.
French fries	=	Potato wedges in the form of sticks (1 x 1 x 6-7 cm) which are fried by deep frying method at 180-200^{0}C until cooked.
Frozen potato	=	Potato that preserving by turning almost all of the water content in the product into ice.
Gapoktan	=	Association of Farmers Groups (Gapoktan)
GB	=	Giga Byte.
GCP	=	Google Cloud Platform (GCP)
GDP	=	Gross Domestic Product.
GIS	=	Geographic Information Systems. GIS provides a visual representation of a defined area and allows specific information to make more informed decisions.
GNSS	=	Global Navigation Satellite Systems.
GPS	=	Global Position Systems.
Grading	=	Sorting the size. The activity of grouping tubers based on agreed criteria or quality standards used, such as according to size or weight.
Harvest	=	The collection (picking) of the results of a field or field and marking the end of activities on land.
ICT	=	Information and Communication Technologies.
IoT	=	Internet of Things. A global network of smart devices capable of integrating the physical and digital worlds.

ISDSS	=	Intelligent Spatial Decision Support System. An SDSS that integrates intelligent system techniques (expert systems) with statistical methods for spatial problem analysis.
ISM	=	Interpretative Structural Modeling.
LC	=	Logistics Centre.
Logistics	=	Comprehensive actions that integrate planning, implementation, control of raw materials, transportation, storage, loading, unloading, packaging, and shipping. More specifically, logistics can divide into two perspectives, namely internal or external perspectives. The internal view focuses on efficiency through the coordination of internal material flow (productivity, time, and cost). Whereas the external perspective explains the material flow from beginning to end in the entire logistics, it focuses on distribution efficiency.
Logistics transparency	=	A national industry based on ICT characteristics; The availability of potatoes in a spatial area, considers supply and demand information; as a material management solution in the body knowledge of logistics, is the initial foundation for the development of sustainable potato agro logistics.
Modern logistics	=	A comprehensive system that integrated transport, storage, loading, unloading, packaging, and distribution.
MCDM	=	Multi-Criteria Decision Making.
ME-MCDM	=	Multi-Expert Multi-Criteria Decision Making.
MPDM	=	Multi-Person Decision Making
NodeMCU	=	An open-source IoT platform and development kit that uses the Lua programming language to assist in prototyping IoT products, or you can use a sketch with the Arduino IDE
OLAP	=	Online Analytical Processing.
OS	=	Operating Systems.
Packaging	=	An activity to accommodate/wrap according to product characteristics.
Post-harvest Handling	=	An activity that includes cleaning, stripping, sorting, preserving, packaging, storing, standardizing quality, and transporting agricultural cultivation products.
Potato chips	=	Foods made from fresh potatoes in thin slices fried with additions and or without other permitted food additives.
QR code	=	Quick Response code.
RFID	=	Radio Frequency Identification.
RGS	=	Route Guidance Systems.
SDLC	=	System Development Life Cycle.
SDSS	=	Spatial DSS, combines spatial and non-spatial data, analysis functions and GIS visualization.
SHT15	=	Humidity and temperature sensor.
Sislognas	=	National Logistics System.

SMART	=	Simulation Model of Application Reliable and Integrated.
Smart agro logistics	=	Agro logistics that implement IoT is primarily to improve efficiency. Logistics that applies ICTs.
"SMART" AGROLOGISTICS	=	A prototype application of an intelligent spatial decision-making system for sustainable potato agro logistics development.
SNI	=	Indonesian National Standard.
Sorting	=	An activity to separate good and healthy tubers, namely tubers that are not damaged, not deformed and not attacked by pests/diseases.
Spatial data	=	Data relating to a place on earth that uses the geographic relationships contained in this data.
Spatial digital agro logistics	=	An agro logistics system that uses GIS coordinates with georeferenced IoT to optimize the facility location.
SPW	=	Spatial Perspectives Weight.
Storage	=	The activity of securing the product before it is processed or shipped.
TOPSIS	=	Technique for Other Preference by Similarity to Ideal Solution.
Transportation	=	An effort to move products from production gardens, temporary collection points, DC storage warehouses to consumers. Transport is carried out after the entire harvesting process is complete.
Trust	=	A condition where psychologically consisting of an invention to accept exposure based on the desires and expectations of the behaviors of others. An essential aspect of any relationship that can improve the quality of relationships.
Trust in logistics	=	A willingness of one party in a supply chain to be vulnerable to the behaviors and activities of other parties.
VLSI	=	Very Large-Scale Integration.
VPS	=	Virtual Private Server.