BAB 5

KESIMPULAN DAN SARAN

Bab ini berisikan kesimpulan dari hasil penelitian yang telah dilakukan dan saran untuk penelitian selanjutnya.

5.1 Kesimpulan

Berikut merupakan kesimpulan dari penelitian "Pengembangan Model *Green Time Dependent Vehicle Routing Problem* untuk Meminimasi Emisi Gas Rumah Kaca".

1. Model *green time dependent vehicle routing problem* (G-TDHVRPTW) telah berhasil dikembangkan. Model ini merupakan kombinasi dari 4 buah batasan VRP yaitu *time dependent*, *time window*, *heterogeneous*, dan *multi-depot* yang dikembangkan dengan mempertimbangkan konsep *green* VRP. Batasan-batasan pada model dimodifikasi sedemikian rupa sehingga bisa mencakup ke-4 batasan utama tersebut. Model ini dibentuk untuk meminimasi biaya sekaligus meminimasi emisi gas rumah kaca yang diterjemahkan ke dalam salah satu komponen biaya.
2. Hasil pencarian solusi dengan menggunakan metode optimasi berhasil dilakukan, begitupula dengan menggunakan metode heuristik. Terdapat perbedaan sebesar 15% dimana solusi dari metode heuristik menghasilkan biaya yang lebih tinggi dibandingkan hasil solusi optimal. Hasil rute yang terbentuk berbeda, dimana rute hasil metode heuristik bersifat *greedy*,

karena *improvement* yang dilakukan berfokus pada rute yang telah terbentuk. Dengan kata lain hanya dilakukan eksploitasi, sementara tidak terdapat eksplorasi.

3. Analisis sensitivitas dilakukan terhadap komponen-komponen biaya, jumlah waktu hari, jumlah kendaraan, dan jumlah permintaan. Perubahan nilai parameter untuk analisis sensitivitas ditetapkan sebesar -50%, -30%, +50%, dan +100%. Berdasarkan hasil analisis sensitivitas, perubahan pada komponen biaya dan jumlah waktu hari tidak mengubah solusi optimal. Sementara perubahan jumlah kendaraan dan jumlah permintaan mengubah rute yang terbentuk.

5.2 Saran

Berikut merupakan beberapa saran yang dapat diberikan untuk penelitian selanjutnya berdasarkan penelitian yang telah dilakukan.

1. Pengembangan model G-TDHVPRTW dengan menggunakan data stokastik untuk permintaan ataupun kecepatan kendaraan. Hal ini memungkinkan model untuk semakin dekat dengan kondisi realistis.
2. Pengembangan model G-TDHVRPTW dari segi tingkat kompleksitas model, yaitu penambahan batasan yang dapat dipertimbangkan seperti batasan *multi-trip* yang memang terjadi pada kondisi nyata.
3. Pengembangan metode heuristik dengan menggunakan metode heuristik yang lebih kompleks seperti *neural network algorithm* ataupun menggunakan metode metaheuristik.

DAFTAR PUSTAKA

Azis, Z., & Mawengkang, H. (2017). Time Dependent Heterogeneous Vehicle Routing Problem for Catering Service Delivery Problem. *Journal of Physics: Conference Series*, *890*(1). https://doi.org/10.1088/1742-6596/890/1/012103

Badan Pusat Statistik. (2020). *Statistik Transportasi Darat 2019* (Subdirektorat Statistik Transportasi (ed.)). BPS RI. https://www.bps.go.id/publication/download.html?nrbvfeve=ZGRjZTQzNGM5MjUzNjc3N2JmMDc2MDVk&xzmn=aHR0cHM6Ly93d3cuYnBzLmdvLmlkL3B1YmxpY2F0aW9uLzIwMjAvMTEvMjAvZGRjZTQzNGM5MjUzNjc3N2JmMDc2MDVkL3N0YXRpc3Rpay10cmFuc3BvcnRhc2ktZGFyYXQtMjAxOS5odG1s&twoadfnoarfeauf

Barceló, J., Orozco, J. A., & Grzybowska, H. (2013). Making Real-Time Fleet Management Decisions Under Time-Dependent Conditions in Urban Freight Distribution. *Freight Transport Modelling*, *January 2016*, 453–484. https://doi.org/10.1108/9781781902868-022

Bretzke, W. R. (2013). Global urbanization: A major challenge for logistics. *Logistics Research*, *6*(2–3), 57–62. https://doi.org/10.1007/s12159-013-0101-9

Chu, C. W., & Hsu, H. L. (2019). A heuristic algorithm for multiple trip vehicle routing problems with time window constraint and outside carrier selection. *Maritime Business Review*, *4*(3), 256–273. https://doi.org/10.1108/MABR-04-2019-0018

Cinar, D., Gakis, K., & Pardalos, P. M. (2017). Sustainable Logistics and Transportation: Optimization Models and Algorithms. In *Springer Optimization and Its Applications* (Vol. 129). http://link.springer.com/10.1007/978-3-319-69215-9

Departemen of Economic and Social Affairs United Nation. (2018). World Urbanization Prospects 2018. In *The United Nations*. https://population.un.org/wup/

Desrochers, M., Lenstra, J. K. J. K., Savelsbergh, M. W. P., & Soumis, F. (1988). Vehicle routing with time windows: optimization and approximation. *Vehicle Routing: Methods and Studies*, *16*(January), 65–84.

Direktorat Jenderal Perhubungan Darat. (2018). Perhubungan Darat Dalam Angka 2018. In *Direktorat Jenderal Perhubungan Darat*.

Ericsson, E., Larsson, H., & Brundell-Freij, K. (2006). Optimizing route choice for lowest fuel consumption - Potential effects of a new driver support tool. In *Transportation Research Part C: Emerging Technologies* (Vol. 14, Issue 6,

pp. 369–383). https://doi.org/10.1016/j.trc.2006.10.001

Fan, W., Xu, H., & Xu, X. (2009). *COMPEL Int J for Computation and Maths in Electrical and Electronic Eng Volume 28 issue 6 2009 [doi 10.1108_03321640910992056] Hu Li, Bo; Fan, Wenhui; Xu, Huayu; Xu, Xin -- Simulation on vehicle rou.pdf* (pp. 1516–1531). Emerald Group. https://www.emerald.com/insight/content/doi/10.1108/03321640910992056/full/html

Figliozzi, M. (2010). Vehicle routing problem for emissions minimization. *Transportation Research Record*, *2197*, 1–7. https://doi.org/10.3141/2197-01

Glock, C. H., & Kim, T. (2015). Coordinating a supply chain with a heterogeneous vehicle fleet under greenhouse gas emissions. *International Journal of Logistics Management*, *26*(3), 494–516. https://doi.org/10.1108/IJLM-09-2013-0107

Ho, W., Ho, G. T. S., Ji, P., & Lau, H. C. W. (2008). A hybrid genetic algorithm for the multi-depot vehicle routing problem. *Engineering Applications of Artificial Intelligence*, *21*(4), 548–557. https://doi.org/10.1016/j.engappai.2007.06.001

Hosny, M. (2011). Heuristic Techniques for Solving the Vehicle Routing Problem with Time Windows. *International Conference on Future Informaion Technology*, *13*(March), 19–23.

Jharkharia, S., & Das, C. (2019). Vehicle routing analyses with integrated order picking and delivery problem under carbon cap and trade policy. *Management Research Review*, *43*(2), 223–243. https://doi.org/10.1108/MRR-01-2019-0013

Kementerian Lingkungan Hidup dan Kehutanan. (2019). Inventarisasi Gas Rumah Kaca dan Monitoring, Pelaporan Verifikasi Tahun 2018. In *Direktorat Inventarisasi Gas Rumah Kaca, Monitoring, Pelaporan dan Verifikasi*.

Li, Y., Lim, M. K., & Tseng, M. L. (2019). A green vehicle routing model based on modified particle swarm optimization for cold chain logistics. *Industrial Management and Data Systems*, *119*(3), 473–494. https://doi.org/10.1108/IMDS-07-2018-0314

Lightner-Laws, C., Agrawal, V., Lightner, C., & Wagner, N. (2016). An evolutionary algorithm approach for the constrained multi-depot vehicle routing problem. *International Journal of Intelligent Computing and Cybernetics*, *9*(1), 2–22. https://doi.org/10.1108/IJICC-06-2015-0018

Lombard, A., Tamayo, S., & Fontane, F. (2012). International MultiConference of Engineers and Computer Scientists, IMECS 2012. *Lecture Notes in Engineering and Computer Science*, *2196*.

Malandraki, C., & Daskin, M. (1992). Time Dependent Vehicle Routing Problems:

Formulations, Properties and Heuristic Algorithms. *Transportation Science*, *26*, 185–200.

Martínez, D. M., Ebenhack, B. W., & Wagner, T. P. (2019). Dealing with energy units, measures, and statistics. In *Energy Efficiency*. https://doi.org/10.1016/b978-0-12-812111-5.00002-0

MirHassani, S. A., & Mohammadyari, S. (2014). Reduction of carbon emissions in VRP by gravitational search algorithm. *Management of Environmental Quality: An International Journal*, *25*(6), 766–782. https://doi.org/10.1108/MEQ-08-2013-0086

Pankratz, G. (2005). Dynamic vehicle routing by means of a genetic algorithm. *International Journal of Physical Distribution and Logistics Management*, *35*(5), 362–383. https://doi.org/10.1108/09600030510607346

Potvin, J. Y., & Rousseau, J. M. (1995). An exchange heuristic for routeing problems with time windows. *Journal of the Operational Research Society*, *46*(12), 1433–1446. https://doi.org/10.1057/jors.1995.204

Poullet, J. (2020). *Leveraging Machine Learning to Solve The Vehicle Routing Problem with Time Windows*. *2018*, 125.

Qin, G., Tao, F., Li, L., & Chen, Z. (2019). Optimization of the simultaneous pickup and delivery vehicle routing problem based on carbon tax. *Industrial Management and Data Systems*, *119*(9), 2055–2071. https://doi.org/10.1108/IMDS-02-2019-0102

Rabbani, M., Pourreza, P., Farrokhi-Asl, H., & Nouri, N. (2018). A hybrid genetic algorithm for multi-depot vehicle routing problem with considering time window repair and pick-up. *Journal of Modelling in Management*, *13*(3), 698–717. https://doi.org/10.1108/JM2-04-2017-0046

Rautela, A., Sharma, S. K., & Bhardwaj, P. (2019). Distribution planning using capacitated clustering and vehicle routing problem: A case of Indian cooperative dairy. *Journal of Advances in Management Research*, *16*(5), 781–795. https://doi.org/10.1108/JAMR-12-2018-0113

Sawik, B., Faulin, J., & Pérez-Bernabeu, E. (2017). Selected multi-criteria green vehicle routing problems. *Applications of Management Science*, *18*, 57–83. https://doi.org/10.1108/S0276-897620170000018003

Setiawan, F., Masruroh, N. A., & Pramuditha, Z. I. (2019). On Modelling and Solving Heterogeneous Vehicle Routing Problem with Multi-Trips and Multi-Products. *Jurnal Teknik Industri*, *21*(2), 91–104. https://doi.org/10.9744/jti.21.2.91-104

Suthikarnnarunai, N. (2008). A Sweep Algorithm for the Mix Fleet Vehicle Routing Problem. *Lecture Notes in Engineering and Computer Science*, *2169*(1), 1914–1919.

Tan, Y., Deng, L., Li, L., & Yuan, F. (2019). The capacitated pollution routing problem with pickup and delivery in the last mile. *Asia Pacific Journal of Marketing and Logistics*, *31*(4), 1193–1215. https://doi.org/10.1108/APJML-06-2018-0217

Taniguchi, E., & Yamada, T. (2016). *The Network Reliability of Transport Article information :* 301–322.

Taniguchi, E., Yamada, T., & Tamaishi, M. (2002). Transportation and Traffic Theory in the 21 st Century . *Transportation and Traffic Theory in the 21 St Century* . https://doi.org/10.1108/9780585474601

Tidswell, J., & Raith, A. (2017). Modelling traffic assignment objectives with emission cost functions. *ATRF 2017 - Australasian Transport Research Forum 2017, Proceedings*, *November*, 1–12.

United States Envorinmental Protection Agency. (2020). Inventory of U.S. greenhouse gas emissions and sinks: 1990-2009. In *Federal Register: Vol.* (Issue). https://www.epa.gov/sites/production/files/2020-04/documents/us-ghg-inventory-2020-main-text.pdf

Wangi, Lisa Sekar, Huboyo, Haryono S, Wardhana, I. W. (2016). Kajian Emisi Gas Rumah Kaca (CO2, CH4 dan N2O) Akibat Aktivitas Kendaraan (Studi Kasus Terminal Mangkang dan Terminal Penggaron). *Jurnal Teknik Lingkungan*, *5*(4), 1–10.

Yeun, L. C., Ismail, W. a N. R., Omar, K., & Zirour, M. (2008). Vehicle Routing Problem : Models and Solutions. *Journal of Quality Measurement and Analysisi*, *4*(1), 205–218.