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Collecting staples by the Hustadvika Biokraft AS planned biogas plant from local farms

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Abstract

The real-world vehicle routing problem with pick-up (VRPP) for Hustadvika Bioekraft AS is presented. The collection of manures from the farms is made. The objective is to reduce the total transportation in terms of time. The model presented in this paper is nontrivial and analysed using the firm's selective data using a CPLEX linear solver. The delineated model handles a fraction of the complete problem. Thus, it can be a foundation for real-world problems with extended constraints. The mathematical model is developed and tested on companies' data. The results are given. The paper aims to develop a model that offers an optimal solution and can be a foundation for similar vehicle routing problems. The model presented in this paper can be used for future research and may be extended by adding more constraints like rolling horizon and loading/unloading time.

Keywords: vehicle routing problem, inventory routing problem, vehicle routing problem with pickups, vehicle routing problem with backhauls

1 Introduction

Norway is among other countries focusing on bioenergy and wants to be carbon neutral until 2030 (Miljøverndepartementet, 2012). By 2030, 30% of manures must go in a biogas reactor (Landbruks-og matdepartementet, 2009). In Norway, there are approximately forty biogas plants,

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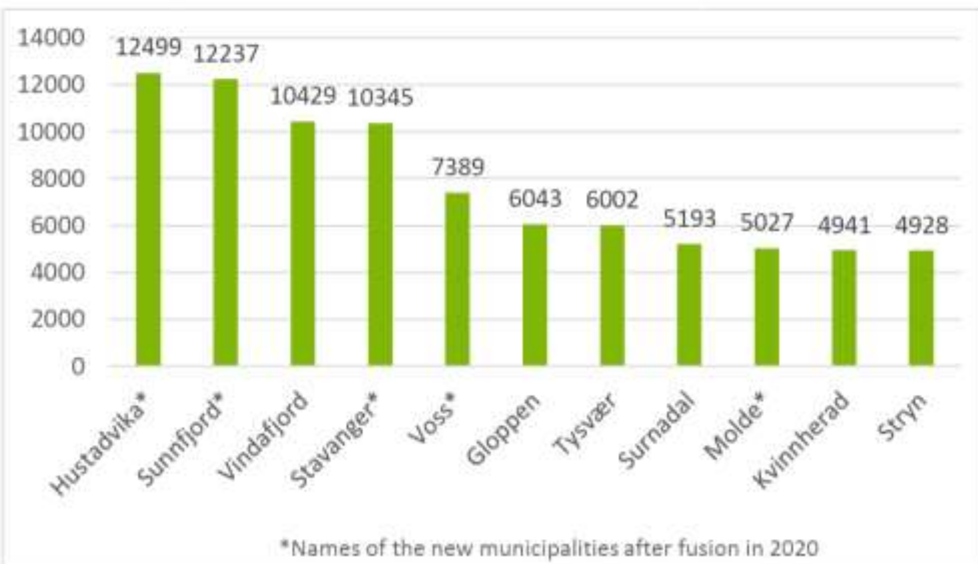
and manures as a staple are used by some of these plants (Norges Bondelag, 2011). It is expected that the number of biogas plants will increase soon, according to the Norwegian policy for bioenergy (Berg et al., 2023).

Figure 1: Hustadvika municipality Map

The Hustadvika became one of the largest municipalities after merging the two municipalities Eide and Fræna in January 2020 as shown in figure 1 and in western Norway among three municipalities, Vestland, Rogaland, Møre and Romsdal, and Trøndelag between Trondheim and Stavanger can be seen in Graph 1 in terms of cattle (Statistisk Sentralbyrå, 2017).



It is a potential location for using staples as raw material in a biogas plant (Raha et al., 2014). The company Hustadvika Biokraft AS is preparing to operate at Harøysundet. To heat the bioreactor, it plans to get fish slurry from local fish farms and wood waste from Romsdal Interkommunale

Renovasjonsselska (RIR) and staples. The end products are excess heat, biogas, and decomposed residue used as fertilizer (Awafo & Agyeman, 2020). The process to produce biogas at the plant takes, on average, 20 days after the arrival of fish slurry and staples from farms.

The outputs are biogas, decomposing residue, and excess heat to be utilized as compost (Kamp & Bermúdez Forn, 2016). The total time required on average for producing biogas is approximately 20 days from the arrival of fish slurry and the manure at the biogas plant until the procedure is completed, as presented in figure 2.

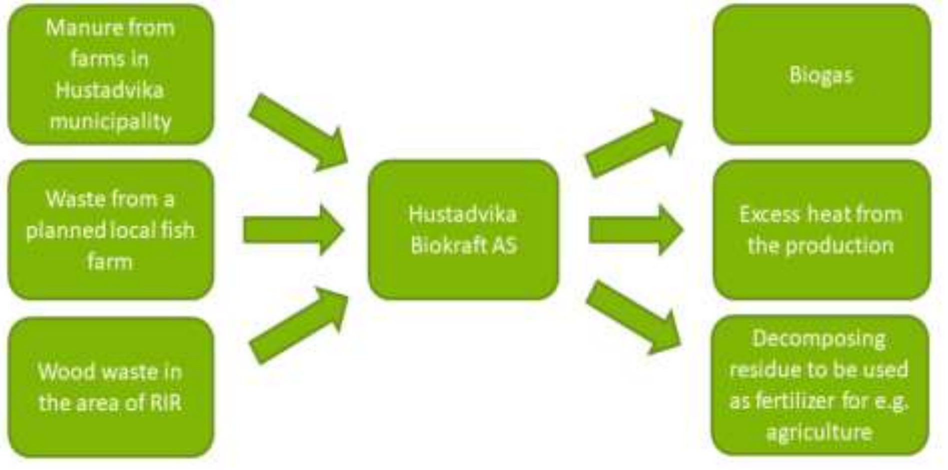


Figure 2: The biogas production process

It can be seen as a transportation problem for delivering residue and picking up manures /staples to and from farms. These farms are located within 2.6 – 50 kilometers of the planned biogas plant. It produces 150 – 200(000) tons of manures per year. Each farm's minimum and maximum production is 500 and 7000 tons, which requires, on average, 15 semi-trailers. The company is seeking a cost-efficient transportation solution with a vehicle routing plan (Berhe et al., 2017).

The following constraints and the above information make this problem more complex and harder to solve.

The first constraint is that the delivery amount of residue (from the fish slurry) will be more than the pickup amount of staple to and from the farms. Therefore, delivery requires more vehicles than pickups. As it is not allowed to mix staple and decomposed residue, many vehicles first deliver the residue and then start picking up the staples from the farms (Li et al., 2018).

The second constraint is related to storage facilities for staples on the farms. There are two types of farms. The type I farm has a tank in the same building as cattle and one to three storage facilities a bit away from the farm. The type II farm only has a tank on the existing building with cattle and one storage facility. The number of type I farms is 36, and the type II farms are 48, making it 84 farms total (Wassie & Adaramola, 2020). Since the type II farm has a single facility, the company will have to concentrate on emptying the tanks as much as possible before the residue delivery. It is not required to extend time by the farmers to fertilize fields. The company Hustadvika Biokraft AS intends to load the staple facility with decomposed deposits even by draining the staple containers throughout the year (Schoeber et al., 2021). Each facility can store from 500 tons up to 6000 tons.

The company is planning to build a residue storage facility at the plant (Lwiza et al., 2017). It is also possible for the farms to cooperate with neighboring farms on storage facilities where one farm is responsible for storing residue and staples (Brahma et al., 2016).

The third constraint deals with the inaccessibility of roads throughout the year. It is related to the type II farm storage facility located slightly far from the farm. A separate road is used to reach that storage facility, which is impossible to access using vehicles and is often blocked due to snow in winter. Usually, when ground ice is defrosting in spring, some roads have a restriction for heavy vehicles. So, the company must pick up the staple before this period and prioritize the delivery of residue somewhere in April so it is available at the end of April or the beginning of May for the farmers to spread the fertiliser on fields.

The fourth constraint focuses on farms' yearly demand for decomposed residue. The farm's annual cycle for fertilization and harvesting fields is shown in figure4. Three fertilization periods can be seen in a year: spring, summer, and autumn. The first period for fertilization starts once ground ice has defrosted in spring. Once the harvesting is done for the first period, the second fertilization phase occurs. The third fertilization period starts when the second harvest is completed and is used to dispose of surplus staples or decomposed residue in the future, resulting in enough space in the storage facility throughout the winter. The third fertilization was optional and may not be needed by all farms. While there are excessive tons of delivery of residue than tons staple pickup at farms, it can be expected that most farms will be using a third fertilization period. It is seen in figure 4 that this third fertilization phase is longer than the first two phases. The second harvesting period usually finishes by September 1st, and by law, farmers are allowed to fertilize the field by October 31st, except if the ground ice is not softened.

Therefore, the company should ensure that all farms will have the required residue before the fertilizing period. Approximately 60% and 40% of its storage capacity of decomposed residue will be needed and delivered beforehand to each farm for the first and second fertilization periods, respectively. The exact time for fertilization and harvesting depends primarily on the weather as it differs year to year.

The appropriate time for pollination and reaping times depends on the weather conditions, and due to global warming, it varies from year to year.

The company Hustadvika Biokraft AS is determined to have two vehicles. The routes at the farms are planned from Mondays to Fridays to make pickups and deliveries with four drivers from 7:00 am to 9:00 pm to 10:00 pm and perhaps on Saturdays from 9:00 am to 4:00 pm. It may deliver more decomposed residue and pick up more manure on Mondays than Fridays, as it is heaped up all over the weekend. The manure demand for Sunday must be covered by the amount picked up between Monday and Saturday.

It combines vehicle routing problems (VRP) with inventory, various vehicles, and backhauls. While considering the diverse constraints related to the problem, it may be classified as a rich VRP.

1.1 Research questions

This paper intends to build a base where the main aim is to develop a mathematical model for obtaining the right routing solution by Hustadvika Biokraft AS for collecting manure at local farms and delivering decomposing residue. The main research question is:
1.0 The minimum time to calculate the shortest route?
With the subsequent sub-problems:
1.1 When is each farm served?
1.2 How often is each farm served?
1.3 How much staple is picked up from each farm on each route?

1.4 How much-decomposing residue is delivered at every farm for each route?
1.5 Are two vehicles capable of operating all the routes?

The problem is devised based on manures pickup from the farms. The issues related to this research are highlighted above. The central concern is understanding this complex real-world problem and developing a mathematical model. The data received from the company is used to test and analyse this model.

The remaining paper is structured as follows: The literature related to this research is presented in section 2. Section 3 describes the problem along with the development of the model. Section 4 gives the testing and analysis of the model. The conclusion is done in section 5.

2 Literature review

The capacitated vehicle routing problem is finding the number of ways each route starts at the source location, visits the number of customers, and returns to the source location (Khan et al., 2023). The total delivery on that route doesn't exceed the vehicle capacity. The objective is to minimize the transportation cost. The classical vehicle routing problem and its variants are presented by Toth and Vigo (2002). The vehicle routing problem (RVRP) is a general area within the optimization field. This problem includes single or multiple products being transported from the source (the facility) to various destinations (customers' locations) by a set of vehicles. The objective is to decrease total shipping costs or maximize profit. The vehicle routing problems are diverse and vary in nature based on different assumptions, as given by Toth & Vigo (2002a).

The inventory routing problem (IRP) and the inventory management and routing problem are explained in the literature survey (Andersson et al., 2010). The VRP with backhauling is used for both pickup and delivery of goods. VRPs with heterogeneous vehicles are used for delivery as an alternative to one vehicle. In the VRP with time windows routing problems, delivery or pick up where the transport has to occur within specific time windows at the customer's locations. Vehicle routing problems (VRPs) have multiple objectives and routing problems consider numerous objectives, such as reducing the number of routes and freight costs (Koç & Laporte, 2018).

In literature, numerous variations of vehicle routing problems exist, and the constraints related to real-world problems make this problem unique and very complex. The problem presented in this paper is also a combination of many vehicles, inventory and backhauling

2.1 The inventory routing problem (IRP)

Inventory combined with vehicle routing problems are generally known as inventory routing problems. The purpose is to lessen the freight cost by guaranteeing no stock-out at the customer's site (Bard et al., 1998). The Inventory Routing Problem (IRP) is seen as an expansion of the Vehicle Routing Problem, which integrates two aspects of supply chain management, one focusing on the amount of inventory and the other on the routing of vehicles. Often, these aspects are dealt with separately, but including and integrating several aspects in a single problem makes it complex to solve but results in better performance for a system. The primary three decisions are considered: 1) amount of goods delivered to a customer, 2) time to serve a customer, and 3) delivery routes.

In VRP, customers have demands to be fulfilled. The transport company assigns the total amount of goods to the delivered vehicles while minimizing the total cost required for these routes. Meanwhile, in IRP, the company decides on delivering the number of goods. The problem studied in this paper can be related to the inventory routing problem. The plant decides on pickup from each farm each day in the extended horizon as it deals with repeated distribution or picks up of a single product. In IRP, it is assumed that an unlimited product is available to deliver or pick up while it is not valid, and it is different when it comes to a real-world problem.

Andersson et al. (2010) and Coelho et al. (2014) have written a detailed literature review on inventory routing problems. A basic description of having a mathematical model for IRP is given by Coelho et al., 2014). Archetti et al. (2007) created this model first, which was expanded by Coelho & Laporte (2013) and Adulyasak et al. (2013). It is defined as the one-to-many model where several vehicles drive a route from the plant to the location of various customers to meet their demands.

3 The vehicle routing problem with backhauls (VRPB)

3.1 Model description and assumptions Sets

Vertices represent plants and farms. Remember that the staple/ slurry warehouses are located slightly away from the farm's locations. The company Hustadvika Biokraft AS agreed to assume the warehouses are located at farms and staple tanks accessible throughout the year to streamline the problem. The eighty-four potential farms are to be considered for the delivery of staples. By the time the company is up and working, the number of farms may be decreased. This problem is NP-hard due to its nature.

The selected number of farms is considered for testing a mathematical model. The four farms are chosen based on the following criteria: various storage amenities, travel distance from the plant, ease of use of storage location (Hassan et al., 2023), and the number of staples to be picked up. These four farms are chosen based on short, medium, and long-distance, and the rate of staple production is represented based on low and medium. The average distance and production are calculated for all the farms. The farms are selected for testing and given below in Table 1.

The inventory carrying capacity is the number of manures accumulated at each farm. Each farm has fixed storage for manures, but the total farm storage capacity data is not available.

Table 1: Selected farms for testing mode

Farm no.	**Farm**	**Distance from the plant (kilometres) (hours)**		**Production (year) (daily)**		**Min. inventory carrying (capacity) (slurry facility)**	
	7	0.07	14.6	2.8	5333	3000	**3555.3**
2	**21**	0.46	4.1	18.4	1483	**1000**	988.7
3	**50**	0.61	8.9	24.5	3250	1400	**2166.7**
4	**81**	0.74	19.2	29.5	7000	**6000**	4666.7

According to the law, the minimum requirement for the farm's storage is eight months of manure production. Therefore, it is calculated by multiplying 23 by annual farm production. While testing the model of how this amount is calculated, the inventory holding capacity of a few farms is less than in reality. Others may have more inventory holding capacity than the required level. The farm's inventory holding capacity (IHC) is computed by dividing its demand by the number of days (365) in the year when it is running and fully utilized (200,000 tons/year) to obtain the farm's daily capacity.

The daily capacity is calculated.

The farms' initial inventory level depends on when Hustadvika Biokraft AS starts picking up manure. So, it is kept at zero for all the farms while testing the model, as it is hard to tell the exact amount of manures stored at each farm. The yearly production rate is divided into 365 days to determine the daily manure produced at each farm. The amount paid on Monday (the first day of the week) is doubled in the model, as no route is driven on Sundays for pickups. Initially, the plant's annual manure demand was 150 thousand tons. We have chosen to keep the index for vertices on the demand parameter, though it could easily be removed since there is no demand for manure at the farms.
The research questions to be addressed in our model are the following:

1. Find the number of vehicle routes that minimize the driving time.
2. When should farms be visited?
3. how often each farm should be visited?
4. How much manure should be picked up for every visit to each farm?
5. what is the inventory level at each farm's end of the day?

3.2 Model development

A simple version of the IRP model by Coelho et al. (2014) is further developed to solve this NP-hard problem. The model was designed to solve the inventory routing problem with delivery (IRPD), where the route starts from the depot and serves a set of customers on each route and returns to the depot. While the current model is written where a vehicle is driving an empty vehicle and pickup is made from many farms and returning to plant as seen as many to one problem. Relevant constraints are kept and modified; on the other hand, few are dropped as they do not apply to the existing pickup problem. The inventory constraints are defined at the farms and plants (constraints (2) and (4) in Coelho et al., (2014)).

The manures are produced at the farm's location, and manure demand is at the plants located in this given problem. The delivery is made to the plant after pickup is done from farms. It is essential to mention that an additional parameter is added as an extra indicator as the production takes place in more than one location. The delivery should not exceed the customer demand and is covered by constraints (7), which are written as a pickup by a vehicle cannot exceed the stock at each farm. A farm cannot have pickup without visiting it is defined by constraints (9) and is kept the same. The sets, variables, and parameters notations are given below, along with the mathematical model for the IRPP.

Objective function

1. $\sum_{i\epsilon F}\sum_{t\epsilon T} h_a\, II_{at} + \sum_{(ab)\epsilon A}\sum_{v\epsilon V}\sum_{t\epsilon T} c_{ab}\, U_{abvt}$

Subject to:

2. $II_{0t} = II_{0t-1} + \sum_{a\epsilon F'}\sum_{v\epsilon V} M_{avt} - d_{0t}$ $\quad \forall\, t\epsilon T$
3. $II_{at} = II_{at-1} + r_{at} - \sum_{v\epsilon V} M_{avt}$ $\quad \forall a\, \epsilon F', t\epsilon T$
4. $II_{a0} = l_a$ $\quad \forall a\, \epsilon F$
5. $II_{at} \le g_a$ $\quad \forall a\, \epsilon F, t\epsilon T$
6. $\sum_{v\epsilon V} M_{avt} \le II_{at-1} + r_{at}$ $\quad \forall a\, \epsilon F', t\epsilon T$
7. $M_{avt} \le g_a Z_{avt}$ $\quad \forall a\, \epsilon F', v\epsilon V, t\epsilon T$
8. $\sum_{a\epsilon F'} M_{avt} \le qZ_{0vt}$ $\quad \forall v\epsilon V, t\epsilon T$
9. $\sum_{b\epsilon F, a<b} U_{abvt} + \sum_{b\epsilon F, a>b} U_{bavt} = 2Z_{avt}$ $\quad \forall a\, \epsilon F, v\epsilon V, t\epsilon T$
10. $\sum_{a\epsilon S}\sum_{j\epsilon S, a<b} U_{abvt} \le \sum\ Z_{avt} - Z_{mvt}$ $\quad \forall S \subseteq F, v\epsilon V, t\epsilon T, m \in S$
11. $II_{at} \ge 0$ $\quad \forall a\, \epsilon F, t\epsilon T$
12. $M_{avt} \ge 0$ $\quad \forall a\, \epsilon F', v\epsilon V, t\epsilon T$
13. $U_{a0vt}\, \epsilon \{0,1\}$ $\quad \forall a\, \epsilon F', v\epsilon V, t\epsilon T$
14. $U_{abvt}\, \epsilon \{0,1\}$ $\quad \forall (a,b)\epsilon F', v\epsilon V, t\epsilon T$
15. $Z_{avt}\, \epsilon \{0,1\}$ $\quad \forall a\, \epsilon F, v\epsilon V, t\epsilon T$

3.3 Description

The objective function (1) minimizes the overall transportation costs, a sum of inventory carrying and transportation costs (measured in time, i.e., hours). Constraints (2–3) tell about the inventory level at the plant and the farms, respectively, but constraints (4) give the initial inventory level of the plant and the farms. Constraint (5) confirms that the inventory level does not exceed the capacity at each pant and farm. Constraints (6) make sure that a vehicle cannot pick up more manure than what is in stock at each farm each day, though constraint (7) ensures that there is no pick up at a farm by a vehicle one day without the same farm being visited by that vehicle on that exact day. Constraints (8) ensure that the total vehicle load on a vehicle one day does not exceed the vehicle capacity and make sure the exact vehicle visits the plant that day. Constraints (9) ensure a vehicle arriving at a farm also leaves that farm (opposite to the plant), while constraint (10) eliminates sub-routes. Constraint (11-12) says that it is non-negative. Constraints (13) and (14-15) indicate that the variables as integer and/or binary, respectively.

4 Testing and Analysing the Model

The language used to model, test, and implement the mathematical model using CPLEX Linear Optimizer is an Algebraic Modelling Language (AMPL). The model presented in section 3 is executed, and the solution obtained is optimal. The results are shown in figures 5 and 6, respectively.

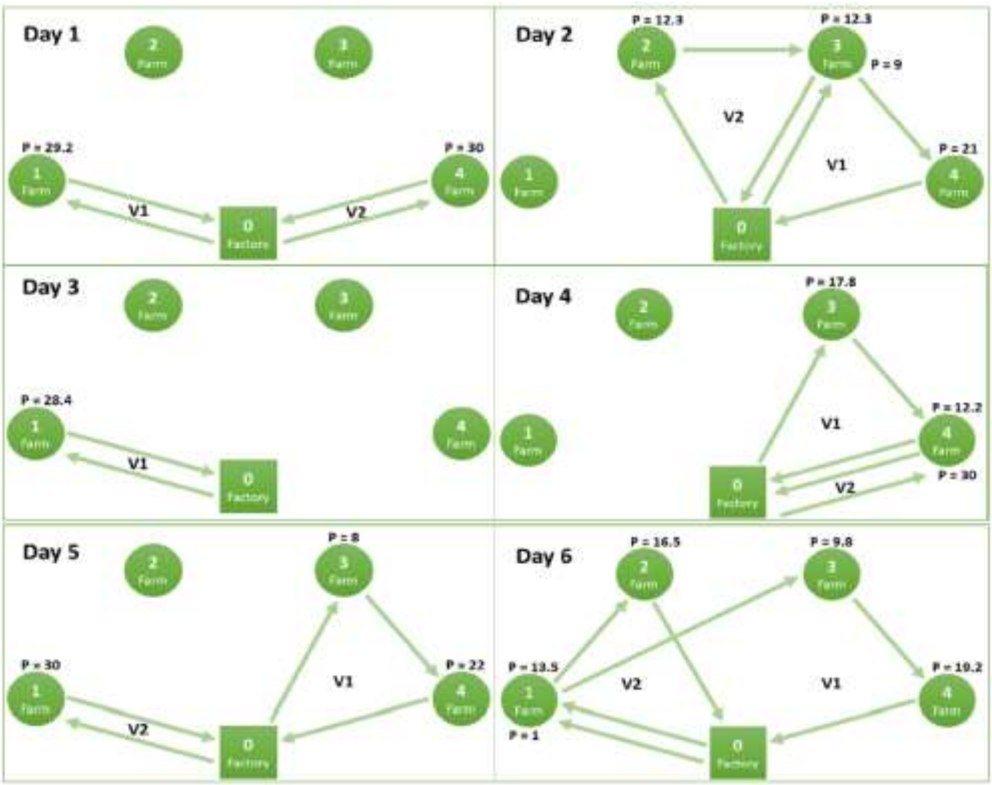


Figure 5: Each day the amount of manures picked up by vehicles

Figure 6: Inventory level on plant and farms each day

The total time is 10.644 hours is calculated as the total transport cost. In a day, some farms are visited many times by different vehicles. There are overlapping routes due to which one driver must wait for manure pickup until the other is finished picking up. It can be solved by an additional constraint which ensures that the farm will be served maximum in a day. The constraint will be as follows

- $\Sigma Z_{akt} \in V \leq 1 \ \forall \ a \in F', t \in T.$

Additional time costs

The time estimated by the company is 10 minutes each visit. Consequently, it may be added up to the objective function: $\Sigma\Sigma\Sigma Z a k t * 10 t \in T$, v∈V, a∈F.

Load constraints

The loading constraints for the vehicles are considered which can be modified for delivery of decomposing residue. Inventory level constraints by Coelho et al. (2014) can be regarded as for delivery.

Multiple routes and shifts

From Monday to Friday, the single route is driven by two vehicles each day.

Longer time

In the model above, the planning horizon is small-scale. It would be better for the company to plan at least two weeks. The rolling horizon is best suited and relevant for such types of problem by Bard et al. (1998).

5 Conclusion and Further Research

This research aims to realize the complexity of the real-world vehicle routing problem with pick up and develop a mathematical model encountered by the firm Hustadvika Biokraft AS. The model presented in this paper is nontrivial and analysed by using the firm's selective data using CPLEX linear solver. The delineated model handles the fraction of the complete problem. Thus, it can be used as a foundation to real world problem with extended constraints. In the model above, the planning horizon is small-scale. It would be better for the company to plan at least two weeks. The rolling horizon is best suited and relevant for such types of problem.

The model presented in this paper can be used for future research and may be extended by adding more constraints like rolling horizon and loading/unloading time. Pasha et al. (2014) used a clustering method with tabu search has some resemblances with a problem presented in this paper. So, the technique can be used as a starting point to solve the extended problem.

6 References

Adulyasak, Y., Cordeau, J.-F., & Jans, R. (2014). Formulations and Branch-and-Cut Algorithms for Multivehicle Production and Inventory Routing Problems. *INFORMS Journal on Computing*, *26*(1), 103–120. https://doi.org/10.1287/ijoc.2013.0550

Andersson, H., Hoff, A., Christiansen, M., Hasle, G., & Løkketangen, A. (2010). Industrial aspects and literature survey: Combined inventory management and routing. *Computers & Operations Research*, *37*(9), 1515–1536.

Archetti, C., Bertazzi, L., Laporte, G., & Speranza, M. G. (2007). A Branch-and-Cut Algorithm for a Vendor-Managed Inventory-Routing Problem. *Transportation Science*, *41*(3), 382–391. https://doi.org/10.1287/trsc.1060.0188

Awafo, E. A., & Agyeman, V. K. (2020). Development of biogas resources and technologies in Ghana, a survey. *International Journal of Energy and Environment*, *11*(3), 167–178.

Berg, B. F., Pasha, U., Hoff, A., & Pasha, M. (2023). Collecting staple by the Hustadvika Biokraft AS planned biogas plant from local farms. *Journal of Excellence in Social Sciences*, *2*(2), Article 2.

Berhe, M., Hoag, D., Tesfay, G., & Keske, C. (2017). Factors influencing the adoption of biogas digesters in rural Ethiopia. *Energy, Sustainability and Society*, *7*(1), 10. https://doi.org/10.1186/s13705-017-0112-5

Brahma, A., Saikia, K., Hiloidhari, M., & Baruah, D. C. (2016). GIS based planning of a biomethanation power plant in Assam, India. *Renewable and Sustainable Energy Reviews*, *62*, 596–608. https://doi.org/10.1016/j.rser.2016.05.009

Bard, J. F., Huang, L., Jaillet, P., & Dror, M. (1998). A Decomposition Approach to the Inventory Routing Problem with Satellite Facilities. *Transportation Science*, *32*(2), 189–203. https://doi.org/10.1287/trsc.32.2.189

Berg, B. F. (2020). *An exact approach for collecting manures from local farms by the planned biogas plant Hustadvika Biokraft AS* [Master's Thesis, Høgskolen i Molde-Vitenskapelig høgskole i logistikk]. https://himolde.brage.unit.no/himolde-xmlui/bitstream/handle/11250/2754222/master_berg.pdf?sequence=1

Bondelag, N. (2011). *Fakta om biogass, Norsk kulturlandskap–det nye gassfeltet*. ISSN 978-82-7712-085-0.

Coelho, L. C., Cordeau, J.-F., & Laporte, G. (2014). Thirty Years of Inventory Routing. *Transportation Science*, *48*(1), 1–19. https://doi.org/10.1287/trsc.2013.0472

Coelho, L. C., & Laporte, G. (2013). The exact solution of several classes of inventory-routing problems. *Computers & Operations Research*, *40*(2), 558–565.

García-Nájera, A., Bullinaria, J. A., & Gutiérrez-Andrade, M. A. (2015). An evolutionary approach for multi-objective vehicle routing problems with backhauls. *Computers & Industrial Engineering*, *81*, 90–108.

Hassan, N. M., Khan, S. A. R., Ashraf, M. U., & Sheikh, A. A. (2023). Interconnection between the role of blockchain technologies, supply chain integration, and circular economy: A case of small and medium-sized enterprises in Pakistan. *Science Progress*, *106*(3), 00368504231186527. https://doi.org/10.1177/00368504231186527

Khan, S. A. R., Ahmad, Z., Sheikh, A. A., & Yu, Z. (2023). Green technology adoption paving the way toward sustainable performance in circular economy: A case of Pakistani small and medium enterprises. *International Journal of Innovation Science*. https://www.emerald.com/insight/content/doi/10.1108/IJIS-10-2022-0199/full/html

Koç, Ç., & Laporte, G. (2018). Vehicle routing with backhauls: Review and research perspectives. *Computers & Operations Research*, *91*, 79–91.

Kamp, L. M., & Bermúdez Forn, E. (2016). Ethiopia′s emerging domestic biogas sector: Current status, bottlenecks and drivers. *Renewable and Sustainable Energy Reviews*, *60*, 475–488. https://doi.org/10.1016/j.rser.2016.01.068

Li, J., Yang, W., Wang, Y., Li, Q., Liu, L., & Zhang, Z. (2018). Carbon footprint and driving forces of saline agriculture in coastally reclaimed areas of eastern China: A survey of four staple crops. *Sustainability*, *10*(4), 928.

Lwiza, F., Mugisha, J., Walekhwa, P. N., Smith, J., & Balana, B. (2017). Dis-adoption of Household Biogas technologies in Central Uganda. *Energy for Sustainable Development*, *37*, 124–132. https://doi.org/10.1016/j.esd.2017.01.006

Liu, S.-C., & Chung, C.-H. (2009). A heuristic method for the vehicle routing problem with backhauls and inventory. *Journal of Intelligent Manufacturing*, *20*(1), 29–42. https://doi.org/10.1007/s10845-008-0101-9

Matdepartementet, L. (2009, May 29). *St.meld. Nr. 39 (2008-2009)* [Stortingsmelding]. Regjeringen.no; regjeringen.no. https://www.regjeringen.no/no/dokumenter/stmeld-nr-39-2008-2009-/id563671/

Miljøverndepartementet. (2012, April 25). *Meld. St. 21 (2011–2012)* [Stortingsmelding]. Regjeringen.no; regjeringen.no. https://www.regjeringen.no/no/dokumenter/meld-st-21-2011-2012/id679374/

Pasha, U., Hoff, A., & Løkketangen, A. (2014). *A hybrid approach for milk collection using trucks and trailers*. https://himolde.brage.unit.no/himolde-xmlui/bitstream/handle/11250/2470732/Pasha_2014_hybrid.pdf?sequence=1

Raha, D., Mahanta, P., & Clarke, M. L. (2014). The implementation of decentralised biogas plants in Assam, NE India: The impact and effectiveness of the National Biogas and Manure Management Programme. *Energy Policy*, *68*, 80–91. https://doi.org/10.1016/j.enpol.2013.12.048

Schoeber, M., Rahmann, G., & Freyer, B. (2021). Small-scale biogas facilities to enhance nutrient flows in rural Africa—Relevance, acceptance, and implementation challenges in Ethiopia. *Organic Agriculture*, *11*(2), 231–244. https://doi.org/10.1007/s13165-020-00329-9

Side ikke funnet / Page not found. (n.d.). Retrieved January 26, 2024, from https://www.ssb.no/statbank/sq/10014526/

Toth, P., & Vigo, D. (1997). An Exact Algorithm for the Vehicle Routing Problem with Backhauls. *Transportation Science*, *31*(4), 372–385. https://doi.org/10.1287/trsc.31.4.372

Toth, P., & Vigo, D. (Eds.). (2002). *The Vehicle Routing Problem*. Society for Industrial and Applied Mathematics. https://doi.org/10.1137/1.9780898718515

Wassan, N., Wassan, N., Nagy, G., & Salhi, S. (2017). The multiple trip vehicle routing problem with backhauls: Formulation and a two-level variable neighbourhood search. *Computers & Operations Research*, *78*, 454–467.

Wassie, Y. T., & Adaramola, M. S. (2020). Analysing household biogas utilization and impact in rural Ethiopia: Lessons and policy implications for sub-Saharan Africa. *Scientific African*, *9*, e00474. https://doi.org/10.1016/j.sciaf.2020.e00474