Routes Planning at Animal Husbandry Department

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Case Article

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Abstract:

The case demonstrates and provides an opportunity to undergraduate, graduate, and doctoral students a practical application of supply chain modeling in the area of livestock management for a group of rural communities in India. The animal husbandry department needs to ensure timely replenishment of liquid Nitrogen to several livestock locations to preserve the semen straws which are frozen for artificial insemination. The department wishes to explore the possible route redesign for cost reduction. The description in the case including the presented data is produced as a real project undertaken by authors. The case provides students to conceptualize and design sample routes manually to meet the cost objective. However, the main objective is to make students understand and implement the solution heuristics for large scale vehicle routing problems. It also allows students to compare the various designs not only trying possible vehicle capacities but also three solution heuristics. Nevertheless, students also realize the importance of the spreadsheet as a decision support tool for evaluating several options by integrating the chosen heuristic. The important milestone of the case project was the implementation of our recommendations by the animal husbandry department.

Keywords: Logistics, agricultural logistics, supply chain management, vehicle routing problem (VRP), animal husbandry, spreadsheet

1 Introduction

The case presents a real project undertaken by authors for an animal husbandry department to introduce students to a large-scale vehicle routing problem (VRP). The key motivation for the authors was to demonstrate and convince the animal husbandry department about the applicability of management science principles, esp. operations research (OR) tools in planning the various stages of animal husbandry supply chain and practices that indirectly benefits the agricultural/rural economy of a country. The current case is an outcome of the series of such planned projects that deliver the liquid Nitrogen to several livestock locations of the rural community for artificial insemination. It would be interesting to know that the case is presented as a reality without compromising the current scale and available data. While evaluating the possible alternatives, students are expected to develop skills that will be useful for dealing with the practical situations encountered in their corporate careers. This includes dealing with large-scale data, applying the right VRP heuristics, and dealing with the large structure of the problem using a spreadsheet. The presented case deals with only one district of the state. Nonetheless, students appreciate the impact of the analysis significantly once extended to several districts as a perfect decision support system for the animal husbandry department. The students are delighted to know that the solution proposed by the team was finally implemented. The most significant impact of the project outcome was the openness of the department to identify and offer managerial problems to researchers with ease and confidence.

2 Literature Review

The optimization models such as VRP and its variations have been extensively discussed in the literature and found numerous applications in businesses. Hence, we focus mostly on the pedagogical literature on logistics management and VRP published in INFORMS Transaction on Education.

Drake et al. (2011) present a case that focuses on network design to optimize the logistics of parcel delivery. The students are expected to propose an optimal design that considers servicing either directly or by zone skipping. However, the case also questions the issue of ethics wherein the best design may be required to consider zone skipping to disguise the identity of freight to a third party. The goal is to encourage students to reflect on the business implications of an ethical decision in the corporate world, despite a mathematical model suggesting an alternative solution. Sundaravalli and Ravichandran (2017) introduce a case that allows students to use a simple but powerful transportation programming model to plan the monthly movement of food grains in a cost-effective manner subject to demand and supply limitations. It further develops the alternative plan to destination in the absence of a direct rail connection. Nevertheless, both cases do not require the students to design the vehicle movement routes.

Depuy (2009) describes a puzzle that helps students to handle the modeling intricacies of an integer programming model applied to an instance of the traveling salesman problem (TSP). Students are required to write the formulation to find a route through the puzzle board that visits each symbol exactly once with few additional constraints. But they must not make cyclic routes like TSP and should end the tour on the last symbol.

Among the cases in the journal, we find two cases that are worth mentioning here. The distance matrix preparation is the most time-consuming but important input for solving a VRP. Huggins's (2019) work addresses the issues of converting the zip code automatically into distances from any default location efficiently. However, we used the name of addresses including zip code (i.e. pin code) to locate the livestock node on Google map and found the distance from the required location. It included therefore over 15000 data points to finally create the distance matrix. The case published by Milburn et al. (2017) is somewhat directly related to our present work. The case describes the delivery of home furnishings to 123 stores in a retail chain from a single warehouse. The design of the route is required to meet store delivery time windows with additional considerations to transportation drive and driver's duty regulations. The students are expected to understand and use heuristics related to a capacitated VRP to find the routes with subsequent customization to check the feasibility of transportation rules. However, the authors claim to present a fictional case based on a problem faced by a real organization.

The situation in our case comprises 177 livestock locations with single delivery in a monthly planning horizon. The entire description including the given data in the case is close to reality and presented as it is without any omission. Like Milburn et al. (2017), our situation is also a large-scale vehicle routing problem that can not be solved without the use of any software and heuristics. The case shows the distinct application in agriculture and animal husbandry area which was started for the welfare of the farmers. Hence, a small improvement in the plan was deemed to be acceptable to reduce annual costs. This encourages the student's thinking for appreciating the application of learnings to the welfare of the social system despite many joining the business world later on. The case provides not only small scale as well as large

scale data for an instructor to impart learnings. The case provides data of 25 livestock locations to facilitate the students to solve it manually without the need of any software but using their logic and to develop any possible heuristic. We solved the problem using the famous Clark-Wright (1964) saving heuristic and proposed the new route design which was implemented by the organization. We also introduce students to the ability of an Excel spreadsheet to automatically solve a large-scale routing problem by incorporating the same heuristic.

Subsequently, students learn to design alternative designs using the spreadsheet for different capacities including the possible vehicle modification, and finally compare performance with the actual distribution cost of the department. Further, two more heuristics (Fisher and Jaikumar, 1981; Bramel and Simchi-Levi, 1995) are also used for comparing the plans and encourage students to explore other heuristics from the available literature. The area of VRP has been extensively dealt with in the literature and we present a general discussion on all types of modern solution approaches to solve this complex problem while keeping our focus on the classical heuristics mentioned above.

3 Case Description

The case deals with the planning manager at the animal husbandry department who has been handling the distribution of the liquid Nitrogen to 177 livestock locations in the district of Nagpur, Maharashtra, at regular intervals for several years. One of the roles of animal husbandry is to improve the genetic qualities and behavior of farm animals by artificial insemination. The initial part of the case discusses the various roles of animal husbandry in the welfare and development of the economy in rural areas. The latter part of the case focuses especially on the livestock supply chain of artificial insemination and describes the several activities of the department to meet the given objective.

The frozen semen straws of high pedigree animals are to be processed, transported, and stored at livestock locations for artificial insemination. Liquid Nitrogen is generally used to preserve the semen straws at the various livestock locations across the district. Each livestock location has two types of cryocans[1]: 50 liters and three liters. The required inventory of semen straws is generally stored in the three liters cryocan. The three liters cryocan is portable and can be moved to any nearby site of the livestock location by a veterinary doctor for artificial insemination. It is essential to replenish the three liters cryocan with liquid Nitrogen to avoid the exposure of semen straw to the environment. The required quantity of liquid Nitrogen in three liters cryocan are replenished at regular interval from the 50 liters cryocan. The 50 liters cryocan is stationary and used to store only liquid Nitrogen required for the replenishment. The significant part of the distribution in the livestock supply chain is to ensure the availability of liquid Nitrogen in the 50 liters cryocan at each livestock location. Any shortage of the liquid Nitrogen in the 50 liters cryocan may impact the replenishment of liquid Nitrogen in the 3 liters cryocan and hence the spoilage of the semen straws stored in it. The logistics team of the department, over a period, prepared nine major routes in order to facilitate the delivery of liquid Nitrogen. The objective of the given route design was to minimize the cost of transportation by reducing the total length of the trip. The overall plan was based on the subjective judgment and experience of the planner with inputs from the truck drivers, rather than based on any supply chain theory/model. Moreover, there was a

[1] A cryocan is the term used to denote container designed to store liquid nitrogen or other such material at very low temperature.

wide variation in the length of a trip on each route causing a lot of inconvenience to the drivers of the vehicles. The animal husbandry department was started for the welfare of farmers and acts as a cost center to the department. Hence, they felt that a small improvement in the distribution can significantly impact the annual cost of animal husbandry and can also be extended as a showcase project to all other 35 districts.

4 Suggested Classroom Use

The case is written to deliver an extension of quantitative models such as distribution design, network model, and transportation design in the supply chain management course. The case specially fits well in order to address the last mile delivery topic which can be contextualized to the relevant situations like online grocery/vegetable delivery, delivery of the packages by online retailers, distribution of the products to various retailers, etc. The students can easily relate the importance of these problem scenarios in order to identify the appropriate objective and constraints. This case demonstrates the opportunity to explore and relate the uses of quantitative models from operations courses to improve the supply chain activities in the animal husbandry department using a spreadsheet application. The instructor can use the case as a classroom discussion to teach the vehicle routing problem (VRP) and relate it to other business situations as stated and discussed in detail in the teaching note.

An instructor can organize the case discussion in the sequential stages to introduce the last mile delivery models in the supply chain course. In order to enrich the discussion, instructors can use student teams in the course to make a presentation. The various stages that can be used for the discussion are presented one by one.

a. Case description: The instructor may ask a group to make a general presentation about the case covering the animal husbandry role, its general objectives in the development of the rural areas. Another group may describe the supply chain of artificial insemination focusing on the current structure, distribution network, major routes, alternatives, few issues, and possible direction for improvement. This may set a tone for introducing the importance of the given problem is not only animal husbandry but also identifying other contextual situations of similar problems in other industries.
b. A brief review of the VRP: At this stage, the instructor may introduce the importance of VRP as the last-mile delivery problem by giving few examples to identify the important parameters such as distance, time, and capacity.
c. Related business situations: The instructor may ask the students to identify similar business problems in the real world and its implications to the business goals. Further, it is also possible to discuss the different possible variants of VRP for the various business context. Eksioglu et al. (2009) published a work classifying the VRP literature in the form of taxonomy to cover the broader range. This taxonomy lists the many important factors such as capacity consideration, the number of vehicles, single depot vs multiple depots and static vs dynamic scheduling, etc.
d. Introducing VRP sample /toy problem and methodology: The scale of the current problem is large enough and cannot be solved manually without the use of computer software and heuristics. Students need to learn a few such available methodologies to solve the given problem. This can generally be facilitated by solving a small problem (Chopra and Meindl, 2003; as cited in Segerstedt, 2014) which is included in the teaching note or as a toy example as listed in Table 3 of the case. The teaching note discusses and explains the famous Clark-Wright (Clarke and Wright, 1964) saving heuristic step by step manually using the simple problem. However, the instructor is free to use other heuristics or ask

students to explore them further from the VRP literature. This would help the students to understand and use the available VRP heuristics.

e. Solving the large-scale animal husbandry problem: Given that students are aware of Clark-Wright saving or other heuristics and understand the need for some computer program to handle the large problem of the case, the instructor may introduce the Excel-based spreadsheet model to solve the VRP. We have developed an Excel spreadsheet model using the Clark-Wright saving heuristic using MACRO to solve different scenarios of the current situation and available with the teaching note. Further, teaching note discusses and uses the Fisher and Jaikumar (1981) heuristic as known as the cluster-first, route-second algorithm, and Bramel and Simchi-Levi (1995) heuristic as known as a location-based algorithm. The instructor may like to compare the summary of these three heuristics with the original plan to make students aware of the fact that the heuristics provide a good solution but may not guarantee the optimal solutions.

The students can use the Excel spreadsheet tool to explore the different scenarios as given in the case and prepare the route designs for each one of them. This includes presenting the route design for the vehicle with different capacities and comparing it with the current plan and resulting cost tradeoffs finally leading to the best cost-effective route design.

5 Pedagogical Coverage

The case is comprehensive enough to cover the given supply chain topic to address various participants that not only include undergraduate, graduate, doctoral students but also the industry executives. Students attending the basic course can map the current livestock supply chain and identify the key concerns of the animal husbandry department. Further, instructors can ask them to adopt some ad-hoc heuristics to design routes without the need for computer programming or software. Students can use the data of 25 livestock locations (Table 3) and propose route design for a smaller capacity vehicle (i.e. 5, 10 cryocans). Instructors can facilitate students to compare these solutions with the solution provided in the teaching note using the *Routes Planning Excel Spreadsheet.xlsx* and discuss the development of heuristics and its importance in solving such real problems in the supply chain.

Instructors for graduate and doctoral students attending advanced courses can assign additional tasks other than those discussed above. However, students still may be asked to propose routes for 25 livestock locations for a higher capacity vehicle (i.e. 20 cryocans). Courses may require students to develop further expertise in managing software and coding heuristics to solve real supply chain problems. Instructors can introduce the heuristics to solve such problem and present the complete routes that can be obtained by the *Routes Planning Excel Spreadsheet.xlsx* for different vehicle capacities (i.e. 20, 25, 30 cryocans) for a large problem given in *RPAHD Data Files.xls* (available as supplemental materials). The teaching note provides route designs for different scenarios for three classical heuristics (Clarke and Wright, 1964; Fisher and Jaikumar, 1981; Bramel and Simchi-Levi, 1995). For developing expertise, students can be asked to explore other heuristics (Laporte et al, 2000) and write software code for comparing the performance with the discussed heuristics in the teaching note.

The case is appropriate for industry executives while delivering a training module on supply chain or logistics. Given the limited time, instructors may encourage discussion to map and to identify the key concerns of the livestock supply chain. Further, an instructor can introduce one classical heuristic's concept for the data given for 25 locations. Nonetheless, the *Routes*

Planning Excel Spreadsheet.xlsx can be used to automatically solve a large-scale routing problem by incorporating the same heuristic. Furthermore, the case encourages the possibility of identifying similar situations from their respective companies to broaden the application.

Finally, the case discussion can further be extended beyond using heuristics to solve the route designs. Teaching note provides two such possible extensions as given below. An instructor can initiate a discussion about the possible impact of these extensions and invite more suggestions if possible.

- The decision on order level (Cryocan's capacity) at livestock location: The impact of increased order size on performance such as the number of routes, cost of new designs, ordering frequency, and average inventory level at livestock locations.
- New supply chain structure of artificial insemination: Designing the few strategic points for inventory positioning for the small cluster of livestock locations and its impact on route design.

6 Classroom Experiences

The version of the case has been used related to supply chain topics not only in the electives for one/two-year MBA programs but also in one to two weeks programs for training different executives of various companies. Generally, MBA students are familiar with basic courses in operations management, quantitative model, statistics, and spreadsheet before studying electives. The executives in a week program from the companies typically work in domains such as logistics, warehousing, supply chain and usually are interested in knowing various / management concepts/ theories available in supply chain management.

The case was extensively used as a pedagogical tool in supply chain distribution planning topics across various programs run in our institute. The case has received appreciation from all respondents. The case has been mostly used in the latter part of the supply chain course especially for the topics on distribution design, network design, transportation design including the challenges and approaches in managing the last-mile delivery. Initially, we faced difficulty in handling such a large-scale problem. However, we first explained and developed the concept with a simple problem and later explained how one can use the spreadsheet modeling to incorporate the same heuristic to solve such a real big problem.

It is common among the students to relate their learning from different courses to the real environment. The case provides the opportunity to incorporate the supply chain model in a spreadsheet to evaluate the various route design scenarios. Students were able to identify the various related business situations which can be analyzed using supply chain theories. Most of the students not only liked the case due to the real-life application, real data but also developed confidence in handling real business situations and relate their learnings to companies such as online retailers, online groceries, retail distribution, etc. In addition to learning from the last mile delivery topics, students were able to identify other supply chain issues in the animal husbandry supply chain given the case context. Few identified areas were inventory management of semen straws, demand analysis of various semen straws, performance analysis of artificial insemination, etc. Recently, a student from the course talked about the application of his learnings on routing the vegetable/grocery delivery during COVID time. Moving the vehicle for delivery to various clusters of residents may cause more administrative inconvenience. Generally, the residents place the order once a week randomly for delivery to one of the daily available four slots. This made the vehicle move long distances covering the resident in all the clusters. The suggestion was to restrict the

movement of the vehicle within the cluster by asking the residents from the same cluster to place an order in the identified slot. This was expected to reduce vehicle distance per week, administrative inconvenience, and the number of visits to campus meeting the same demand. The executives from the companies were excited to find the real application of the concept, final implementation by the department, and significant savings after extension to other remaining districts. They even tried to identify the situations from their respective companies to apply the supply chain learnings. Especially, with respect to VRP, they were able to provide other contextual constraints and probable changes in the model. One executive commented that they need to always finish the delivery within the five hours to the last delivery point once started.

A batch of students from the one-year MBA program has more than five years' experience before joining the course. One student recalled his experience of working with a large printing press that has many customers. He was working in the planning department handling deliveries. In one of his assignments, he was delivering various inventories such as checkbooks, withdrawal slips, etc. to various retails locations of a nationalized bank at regular intervals. He found the concept to be interesting, relevant, and appropriate to apply in his previous work experience and commented that his planning was mostly on intuition and judgment.

7 Conclusion

The case creates an exciting opportunity to integrate supply chain concepts using a quantitative model and spreadsheet modeling to solve a real-life problem in the animal husbandry department. Considering the given situation present in several companies, the MBA students and executives found it interesting to apply the concept to many contemporary business problems. More specifically, students liked the practical applicability of the course learnings and found it valuable knowing the company implemented the solution.

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