South Asian Journal of Management Sciences
Vol. 10, No. 1, (Spring 2016) 38 – 47
DOI:10.21621/sajms.2016101.04

Using Excel Solver to Solve Braydon Farms' Truck Routing Problem: A Case Study

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ABSTRACT

This case study is based on Braydon Farms LLC, floral distribution complexity analysis in Alabama, US. This study utilized excel solver to determine effective distribution to the 14 stores at least cost for Braydon Farms clients. The integer programming model was used to estimate the optimal configuration for the distribution to 14 stores for seven daily routes. Furthermore, for the 14 stores, the total shortest distance was configured that the record of sales in the floral distribution truck should be loaded by store and flower types for the first full season. It is recommended to the company to further optimize the distribution with one big truck for all stores coverage versus two small trucks for the upcoming season.

Keywords: Floral industry logistics and distribution, excel solver, Travelling Salesman problem (TSP), Truck Dispatching Problem (TDP), Vehicle Routing Problem (VRP).

Introduction

Decision Dilemma

Braydon Farms LLC is a floral supplier for Marvin's Building Materials, a multi-store chain of medium size hardware/lumber retailers. It has distribution agreement with Marvin's covering several floral products. With limited resources, Brad Garrott, the owner of Braydon Farms LLC, has contracted to deliver floral products to 14 of their stores within Alabama. He realized that there is a distribution scheduling issue and decided to get professional consultation from Sorrell College of Business, Troy University. The floral supplier's primary concern was how to supply the 14 stores in the most timely and efficient manner and with the least cost. A visual map of those 14 store locations is presented in Figure 1.

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Figure 1: Distribution map for 14 stores

Notes: Number 1 represents Braydon Farms location; Letters A-N represents 14-store locations

Braydon Farms LLC

Braydon Farms LLC, a floral grower and wholesaler in Troy, AL, has three greenhouses and five employees in total. Brad Garrott started the business in 2013. Since the beginning of 2015, first contract was signed with Marvin's Building Materials. This was extremely significant because the supplier finished his transition from a grower/retailer to a grower/wholesaler. He expected to generate approximately $300,000 revenue for this spring season and another $200,000 for the fall.

The main suppliers for Braydon Farms LLC include BWE, GROSouth, and Express Seed. Since there are multiple suppliers in the floral industry, the bargaining power of suppliers is relatively low, which is an advantage to Braydon Farms. However, Braydon farms' size is small, so the bargaining power of Braydon Farms is low compared to other competitors from this perspective.

On the other hand, Marvin's is the only retail operation Braydon farms now supplies and therefore, Marvin's bargaining power is much stronger than his. However, in the future, Braydon Farms has potential customers such as Lowe's, Wal-Mart and other big-box stores. As a startup business, Braydon will be confronted with competition from competitors such as Young's Nursery & Greenhouse and Bonnie Plant Farm, both in the same logistical area. Therefore, the rivalry among competitors in floral industry is intense. Finally, the threat from new entrants is moderate due to the fact that the industry is growing with enticing new players but it is offset due to the expense and expertise needed to invest in this business.

Braydon Farms' strategy is product and service differentiation due to product uniqueness and strong personal service. Braydon Farms supplies over ten categories of flowers including Petunias, Million Bells, Gerber Daisy, and others over spring and fall seasons. Flowers are nurtured inside the greenhouse. The blossoming plants are then placed on trays and later loaded onto wheeled racks ready to be shipped by truck, as showed in Figure 2. Primary weaknesses of the company are its size and the lack of historical data for decision making.

Figure 2: Potted Flowering Plants Stored on Loading Racks

Currently, Braydon Farms has only one truck available for distribution. The spring season lasts from March to July with a peak being the beginning of April to the end of May. During this period, plans are to supply two stores out of a single load. While for the month of March, it is assumed that one truck is good enough for three stores' supply. For the month of June and July, one truck can distribute five stores as demand diminishes. A summary of distribution information is presented in Figure 1 and Table 1.

Table 1: Distribution information

Season	Period	No. of stores per day
1	03/01-04/01	3
2	04/01-06/01	2
3	06/01-07/31	5

The time spent each day in delivery is another issue for the Company. It takes at least two hours for the driver to unload for each store. The average speed limit for the truck is around 40-45 miles per hour. The time constraint is very critical since the driver is allowed to drive only 11 hours maximum daily and the total mileage has to also be controlled as the driver travels each day. The aim for this research case analysis is to minimize costs with limited time and human resources.

Background and Literature Review

In the fast-paced and overwhelming world of logistics, fresh floral industry logistics is a special challenge due to its specialized needs and requirements. The nature of fresh produce does not allow them to be stored for even short periods. Transportation, without any doubt, brings much stress for fresh flowers. It may not only affect the appearance, but also disturb the interior performance of potted plants. Consumers are not willing to pay for non-lasting flowers. However, with certain shipping practices, one can reduce or even eliminate that stress (Nell, 1990). Therefore, the methods of keeping potted plants free from damage play a significant role in keeping high quality products.

One significant factor for fresh goods logistics is physical injury. Due to its fragile nature, fresh produce is vulnerable to vibration, compression and impact. Therefore, proper packaging and correct placement are especially crucial in minimizing the physical damage which may caused by transportation (Vigneault, Thompson, Hui, & LeBlanc, 2009).

When transported by a moving vehicle, plants are prone to experience vibration damage in consequence of the large amount of vibrating motion. One way to reduce this damage dramatically is to install steel-spring-suspended axles. A trailer equipped with an air ride suspension system will absorb the shock and reduce vibration damage considerably. Nowadays most long haul tractors in North America have air-ride suspension (Vigneault, Thompson, Hui, & LeBlanc, 2009). Floral transport rack is another common method used to improve the transportation service. Usually, the rack has multi-level configuration and may be hung on a wall peg through a hole at one end. This special approach not only reduces the physical damage, but also increases the number of plotted plants to be loaded. What's more, it enables workers to easily remove one floral stand without disturbing others (Domurat, 1993).

The travelling salesman problem (TSP) intends to answer the following question: given a list of customer sites (vertices) and the distances (edges) between each pair of the vertices, what is the shortest possible route that a salesperson can visit each city exactly once and returns to the original base (depot)? It is an NP-hard problem in combinatorial optimization, important in the fields of operations research and computer science. In terms of Graph Theory, TSP can be modeled as an undirected weighted graph, such that sites are represented as the graph's vertices, paths connecting pairs of cities are modeled as the graph's edges, and a path's distance is the edge's length. It is a minimization problem starting and finishing at a specified vertex (v_0) after having visited each other vertex exactly once. Often, the model is a complete graph (*i.e.* each pair of vertices is connected by an edge). If no edge exists between two vertices, adding an arbitrarily long edge will complete the graph without affecting the optimal tour length.

Dantzig and Ramser (1959) first introduced and formulated the classic Truck Dispatching Problem (TDP). By imposing additional constraints, TDP is considered as a generalization of the famous and notorious Traveling Salesman Problem (TSP). The TSP is concerned with the shortest traveling route for a salesman to visit a given set of customers. The TDP differs from TSP in that after contacting *m* of the *n* customers (*m* being a divisor of *n*), the salesman must return to a central terminal to start his next trip visiting a new set of *m* customer. The TDP was later extended and generalized to VRP – vehicle routing problems to incorporate real world constraints and circumstances (Schneider, Stenger, & Goeke, 2014). Further, capacitated VRP considers the limited freight capacity of the delivering vehicle and VRPTW (VRP with Time Windows) includes the extra constraint of time window at each site that the delivering truck can reach (Gendreau & Tarantilis, 2010). Since the problem size in this case is relatively small (n = 14), VRP of such magnitude can be solved completely with little consumption of computing power. Thus, we deem that reviewing the variety of algorithms and heuristics related to VRP is beyond the scope of this case analysis.

Microsoft Excel Solver, the spreadsheet optimizer bundled with Excel, is designed to model and solve linear, nonlinear, and integer problems (Fylstra, Lasdon, Watson, & Waren,1998). The all different constraint formulation in Excel Solver enables modelers to enforce the assignment of different values to a range of cells in a spreadsheet without coding (Jiang, 2010). In the next section, first the mathematical formulation of Braydon Farm's TDP problem has been demonstrated and then how the model is set up in Excel solver in order to find the optimal delivery schedule has been studied

Methodology

As a startup business, Braydon Farms' attempt to chart the optimal delivery route was hampered by the lack of historical sales data as well as current store demand data. As such, we reduce the vehicle routing problem (VRP) to a baseline Truck Dispatching Problem (TDP). Braydon Farms' TDP is best defined as one truck departs and returns to the same central farm location each day and unloads at two different store locations seven (2 X 7 = 14 stores) days a week. The weekly delivery schedule is best illustrated in figure 3 and represented as a super graph G. G consists of a set of seven sub-graphs denoted by G_1, G_2, G_3, G_4, G_5, G_6, G_7, each of which consists of three vertices (representing loading dock and stores) and three edges (trips) connecting the vertices. Using terms in graph theory, the weekly 14-store delivery schedule is defined below:

$$G = \{G_1, G_2, G_3, G_4, G_5, G_6, G_7\} \text{ and } G_1 \cap G_2 \cap G_3 \cap G_4 \cap G_5 \cap G_6 \cap G_7 = \{v_0\} \qquad (4.1)$$

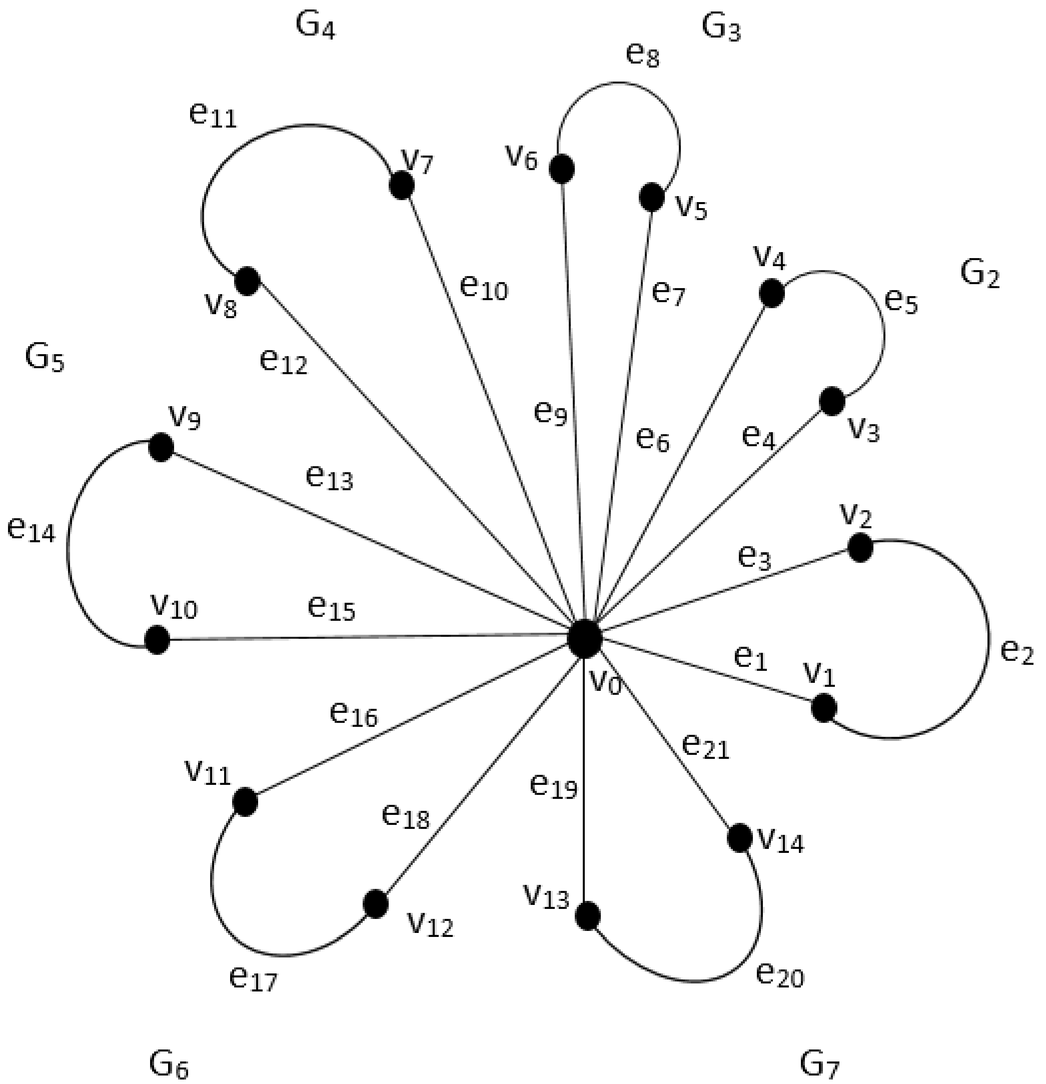
$$G_1 = \{(v_0, v_1, v_2), (e_1, e_2, e_3)\} \text{ and } e_1: (v_0, v_1),\ e_2: (v_1, v_2),\ e_3: (v_2, v_0) \qquad (4.2)$$

$$G_2 = \{(v_0, v_3, v_4), (e_4, e_5, e_6)\} \text{ and } e_4: (v_0, v_3),\ e_5: (v_3, v_4),\ e_6: (v_4, v_0) \qquad (4.3)$$

$$G_7 = \{(v_0, v_{13}, v_{14}), (e_{19}, e_{20}, e_{21})\} \text{ and } e_{19}: (v_0, v_{13}),\ e_{20}: (v_{13}, v_{14}),\ e_{21}: (v_{14}, v_0) \qquad (4.4)$$

It is noteworthy that each G_i is a simple 3-node cycle graph containing a single cycle through all 3 nodes. The weight of each edge in the 3-node cycle graph is defined as the distance between the two adjacent vertices (stores and depot). Representing the total weekly mileage to be traveled, the total weight of the G is the sum of all edge weights.

Figure 3: The Graph Representing the Weekly Delivery Schedule



Firstly, the distance matrix is defined as D = [d_{ij}], with d_{ij} being the distance between the i_{th} and j_{th} store within the n = 14 store sets. The diagonal elements of D d_{ii} represent the distance between the i_{th} store and the central farm location. Next we define the 7 x 2 matrix of decision variables X= [x_{ij}] ($x_{ij} \in \{1,2,3,4,5,6,7,8,9,10,11,12,13,14\}$), which represent the store index numbers. With D and X defined, we can formulate our truck-dispatching problem as below:

Minimize $$\sum_{i=1}^{7} d_{x_{i1},x_{i1}} + d_{x_{i1},x_{i2}} + d_{x_{i2},x_{i2}} \tag{4.5}$$

Whereas $d_{x_{i1},x_{i1}}$ is the distance between the farm and the store indexed by x_{i1}, $d_{x_{i1},x_{i2}}$ is the distance between stores indexed by x_{i1},and x_{i2} respectively, and $d_{x_{i2},x_{i2}}$ is the distance between the farm and the store indexed by x_{i2}.

Subject to:

$x_{i1} \neq x_{i2}, \forall i \in \{1,2,3,4,5,6,7\}$ (4.6)
$x_{i1} \neq x_{j1}, \forall i, j \in \{1,2,3,4,5,6,7\}\ and\ i \neq j$ (4.7)
$x_{i2} \neq x_{j2}, \forall i, j \in \{1,2,3,4,5,6,7\}\ and\ i \neq j$ (4.8)

The above three constraints ensure that one store index number appears once and only once in X.

Results

In this section, the solution of the above integer programming model in Excel was presented and the optimal configuration of the seven daily routes. To mimic the two matrices described in our proposed model, two named ranges were set-up as distance matrix and decision matrix, within the designated Excel sheet (shown in Figure 4 and 5).

Figure 4: The Distance Matrix in Excel

	Unit: miles													
	Store 1	Store 2	Store 3	Store 4	Store 5	Store 6	Store 7	Store 8	Store 9	Store 10	Store 11	Store 12	Store 13	Store 14
1	222	251	24.4	284	262	103	213	23	204	155	266	29.2	246	131
2		65.4	247	76.8	47.4	148	109	235	47.9	103	58.9	218	61.5	168
3			217	279	258	98.9	247	45.1	199	151	261	32.6	242	153
4				136	31.8	181	184	267	80.4	135	41.3	251	137	201
5					115	159	162	246	59	113	38.9	230	109	179
6						119	148	87.1	101	53	163	70.9	144	139
7							47.9	189	104	102	165	205	53.4	82.3
8								206	187	139	249	35.2	230	108
9									56.5	55	62.6	171	80.9	121
10										73	117	123	98	93.1
11											119	233	120	183
12												189	214	135
13													25.2	123
14														104

Figure 5: The Matrix of Decision Variables in Excel

trip	store 1	store 2
1		
2		
3		
4		
5		
6		
7		

Next, the index (Distance Matrix, Row in Decision Matrix) function in Excel was used to create an intermediate travel distance matrix next to decision variable matrix (filled with initial values) as shown in Figure 6. The three distances in each row represent $d_{x_{i1},x_{i1}}, d_{x_{i1},x_{i2}}, d_{x_{i2},x_{i2}}$ in equation 4.5 respectively. The Objective cell required in Solver is simply the sum of all the 7x3 distances.

Figure 6: The Random 2-Store Route Configuration

Trip	Store 1	Store 2				Sum
1	14	7	222	251	65.4	538.4
2	2	13	217	279	136	632
3	4	5	115	115	119	349
4	8	1	47.9	189	206	442.9
5	12	3	56.5	54.7	73	184.2
6	10	6	119	233	189	541
7	9	11	25.2	123	104	252.2
						2940

The nonlinear nature of our model requires the use of the Evolutionary engine for Solver in Excel. To enforce the three model constraints, we simply specify the entire decision variable, which are subject to the *AllDifferent* constraint in Solver.

Discussion

Figure 7 displays the output from the excel solver. As one can observe, all those pairs of stores contained in the daily routes are grouped based on geographical proximity (low numbers in the middle column of the travel distance matrix). In the two-store route setting, the truck must either visit each store from the central location or return to the farm from that store because there is no other stop between the two stores. As far as minimization of the total travel distance is concerned, the total distance traveled between the stores and the farm remains constant. The optimization is solely applied to the distances between stores. Hence, we expect to see changes in the route pattern when work gets done on other three and five store route configurations.

Figure 7: The Optimal 2-Store Route Configuration

Trip	Store 1	Store 2				Sum
1	14	7	104	82.3	47.9	234.2
2	2	13	65.4	61.5	25.2	152.1
3	4	5	136	31.8	115	282.8
4	8	1	206	23	222	451
5	12	3	189	32.6	217	438.6
6	10	6	73	52.6	119	244.6
7	9	11	56.5	62.6	119	238.1
						2041

Since, three is not divisor of 14, there is one variable unconstrained in the corresponding decision 5x3 variable matrix. It is necessary to treat the last row as a two-store route. By the same token, the 5-store decision matrix is actually a combination of two 5-store routes and one 4-store route. Figure 8 and 9 depict the optimal configurations together with their shortest total distances. As expected, the total distance traveled decreased almost 50% from 2-store configuration to 5-store configuration.

Figure 8: The Optimal 3-Store Route Configuration

Trip	Store 1	Store 2	Store 3						Sum
1	12	6	10		189	70.9	52.6	73	385.5
2	5	4	11		115	31.8	41.3	119	307.1
3	3	1	8		217	24.4	23	206	470.4
4	13	7	14		25.2	53.4	47.9	104	230.5
5	9	2	15		56.5	47.9	65.4		169.8
									1563

Figure 9: The Optimal 5-Store Route Configuration

Trip	Store 1	Store 2	Store 3	Store 4	Store 5								Sum
1	9	11	4	5	2		56.5	62.6	41.3	31.8	47.4	65.4	305
2	6	8	1	3	12		119	87.1	23	24.4	32.6	189	475.1
3	13	7	14	10	15		25.2	53.4	82.3	93.1	73		327
													1107

Conclusion, Implications and Future Research

To conclude, the weekly route configurations developed in this case study are static weekly schedules. Consequently, it does not reflect any dynamic changes from the demand side since we do not have those inputs from stores. As the owner prepares to load flowers into his truck and start deliveries for the first full season, we requested he keep a record of sales by store and flower types.

Once full season's sale data is achieved, a dynamic vehicle routing model driven by store demand and improve the accuracy of targeting flower type to market segment can be determined. Most importantly, we will run what if-analysis with the actual store sales data to compare the costs and benefits of two trucking capacity scenarios; the current one big truck for all stores vs. two relatively small trucks for next season.

Finally, it is intended to optimize the mix of flower types for each truck load based on demand and work out the best loading and unloading sequences for each trip. It was highlighted to the owner of the Braydon Farms that this is superficial analysis of the study and real data to this study can bring accurate estimations and solution to the complexities of floral logistics.

Declarations

Competing Interests

The authors declare that they have no competing interests.

Authors' Contribution

Duan, C.J. was primarily responsible for modeling the trucking routes as cycled graph in Graph Theory and proposed the mathematical formulation of the Vehicle Routing Problem (VRP). Duan, C.J., also developed the Excel Solver solution to the VRP and wrote the Methodology and Results sections of the paper. Hu, J. collected operational data, personal information from the owners of Braydon Farms including operational structure of the retail chain that Braydon Farms supplied, background on the industry, development of literature review and significant contribution to the research methodology. Whereas, Garrott, S.C. helped initiate the premise of the paper and arrangements to the site visits to Braydon Farms. Garott, S.C. also reviewed the results of the data analysis regarding the scheduling configuration and was involved in the initial review and final editing of the paper.

Acknowledgements

The authors of the paper would like to acknowledge the help and contributions of the owners of Braydon Farms, Mr. Brad Garrott and Mrs. Erica Garrott. They met with the authors on several occasions and provided the data necessary to develop the analysis in the paper. They also courteously provided personal tours of the operation of Braydon Farms and supplied photographs that further provided insights into the issues facing the organization.

Special thanks to Dr. Teng, J.K.L and Dr. Wu, D. of Troy University for their insightful suggestions that led to the final optimal solutions.

References

Dantzig, G. B., & Ramser, J. H. (1959). The truck dispatching problem. *Management Science*, *6*(1), 80-91.

Domurat, K. X. (1993). *Patents*. Retrieved 03 15, 2016, from Floral display and transportation rack : https://www.google.com/patents/US5216835

Fylstra, D., Lasdon, L., Watson, J., & Waren, A. (1998). Design and use of the Microsoft Excel Solver. *Interfaces*, *28*(5), 29-55.

Gendreau, M., & Tarantilis, C. D. (2010). *Solving large-scale vehicle routing problems with time windows: The state-of-the-art.* CIRRELT.

Jiang, C. (2010). A reliable solver of Euclidean traveling salesman problems with Microsoft Excel add-in tools for small-size systems. *Journal of Software*, *5*(7), 761-768.

Nell, T. A. (1990). Commercial transport of flowering potted plants: keeping quality beyond the bench. *GrowerTalks,* 53(9), 24-39 .

Schneider, M., Stenger, A., & Goeke, D. (2014). The electric vehicle-routing problem with time windows and recharging stations. *Transportation Science*, *48*(4), 500-520.

Vigneault, C., Thompson, J., Wu, S., Hui, K. C., & LeBlanc, D. I. (2009). Transportation of fresh horticultural produce. *Postharvest technologies for horticultural crops*, *2*, 1-24.