SUPPLY MANAGEMENT THROUGH NETWORK ROUTE OPTIMIZATION[1]

by

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Abstract

Supply management commonly has a geographic dimension, i.e., materials, people, or information constantly flows between many locations (called "nodes") through connections such as roads (called "links"). Sugarcane fields and sugar mills, for example, can be considered as nodes and the roads connecting them, the links. This collection of nodes and links can be termed as a "network".

It often happens that in large geographic networks there are many alternative links that interconnect the nodes. Thus, it is crucial for an organization to move equipment, supplies, products or people within its network such that the total cost of transport is optimized by finding the shortest route (chain of links) through the network. Planning the routes when obtaining or distributing materials and supplies can reduce costs, time, distance and business risks immensely. Many organisations fail to save on logistical expenses due to lack of scientific network route planning.

*The challenge is to find a method (algorithm) which can easily find this optimal route. This is important because manually listing all possible routes and choosing which one produces the minimum transport distance/cost is impractical. For example, if there are merely 5 nodes in the network, the number of possible routes to choose from is 4*3*2*1=24 which could still be patiently done manually. However, if there are 6 nodes, there are 5*4*3*2*1=120 possible routes, with 7 nodes 720 routes and if there are 10 nodes there are 362,880 routes to choose from!*

This paper discusses the rudiments of this method of network optimization using the Traveling Salesman Problem Solver and Generator (TSPSG) software that can be downloaded for free from the Internet, then illustrates its possible application in a renewable energy project that uses sugarcane leaf biomass as fuel for its boiler. The cane biomass is collected daily from different cane fields (nodes) interconnected by roads (links).

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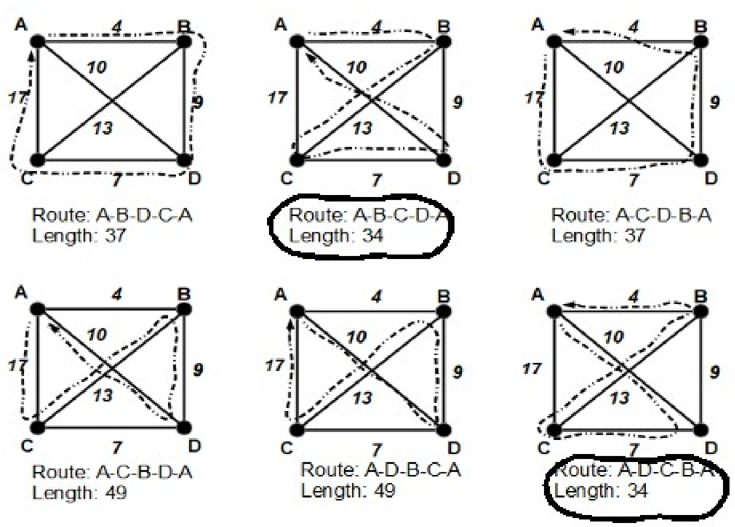
INTRODUCTION

Supply Management is the process of obtaining and managing products or services needed to operate a business or other type of organization. Elements of supply management include materials/products, equipment, information, budgets, and personnel. The purpose of supply management is to keep costs stable and use resources effectively to maximize the profits and efficiency of the business or organization.

Supply management in organizations of agricultural nature usually involves geographic networks. A network may be defined as a set of points, or “nodes,” that are interconnected by lines, or “links.” In real-life situations these nodes can be geographic units such as cities, towns, farms, etc., that are connected to each other by roads (links). A specific chain of links that connect several nodes can be termed as a “route” or “path.” Links are usually characterized as having values of distance, time, or cost when traversing them. In supply management it is important to utilize an optimum route between two or more nodes in relation to total time consumed, costs incurred, or distance traversed.

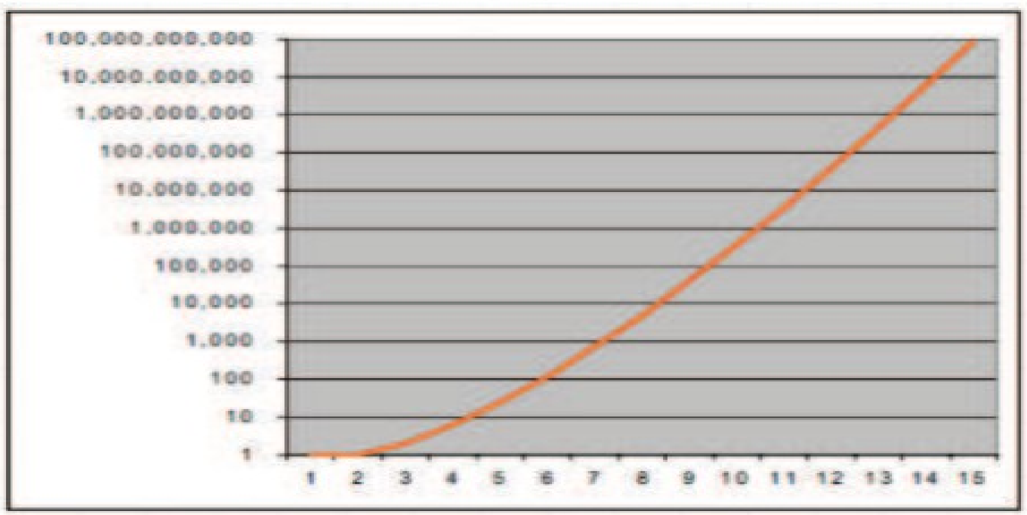
One type of “problem” concerning networks is how to visit all the nodes using a route that has a shortest distance (or cost, or time elapsed) compared to the many other routes that can be taken. As example, the illustration below shows a network with 4 nodes (A,B,C,D) connected by links of varying distances. If starting out from node A and the objective is to visit all the other nodes and return to A, there are 6 possible routes of varying total lengths, as shown.



In the field of Management Science, such network optimization objective is called the “Traveling Salesman Problem” (TSP) and may be formally stated as:

“Given a list of destinations (nodes) and the distances between nodes (length of the links), find the shortest possible route that visits each destination only once, and returns to the starting node.”

In a network with 'n' number of nodes, there are (n-1)! routes that visit each node only once and returns to the starting node (origin). The symbol “!” Is called “factorial” which means that the number must be multiplied by all the smaller numbers before it. Hence, for 6 nodes, (6-1)! = 5! = 5*4*3*2*1= 120 routes to choose from. Fig. 1 shows that the number of routes rises exponentially with every node added. With 7 nodes there are 720 alternative routes, but with 8 nodes in the network there would already be 5,040 possible routes!



Source: Caplice, C. Logistic Systems, MIT Center for Transportation & Logistics

Fig. 1. Number of possible routes (vertical axis) in relation to number of nodes (horizontal axis) in a network.

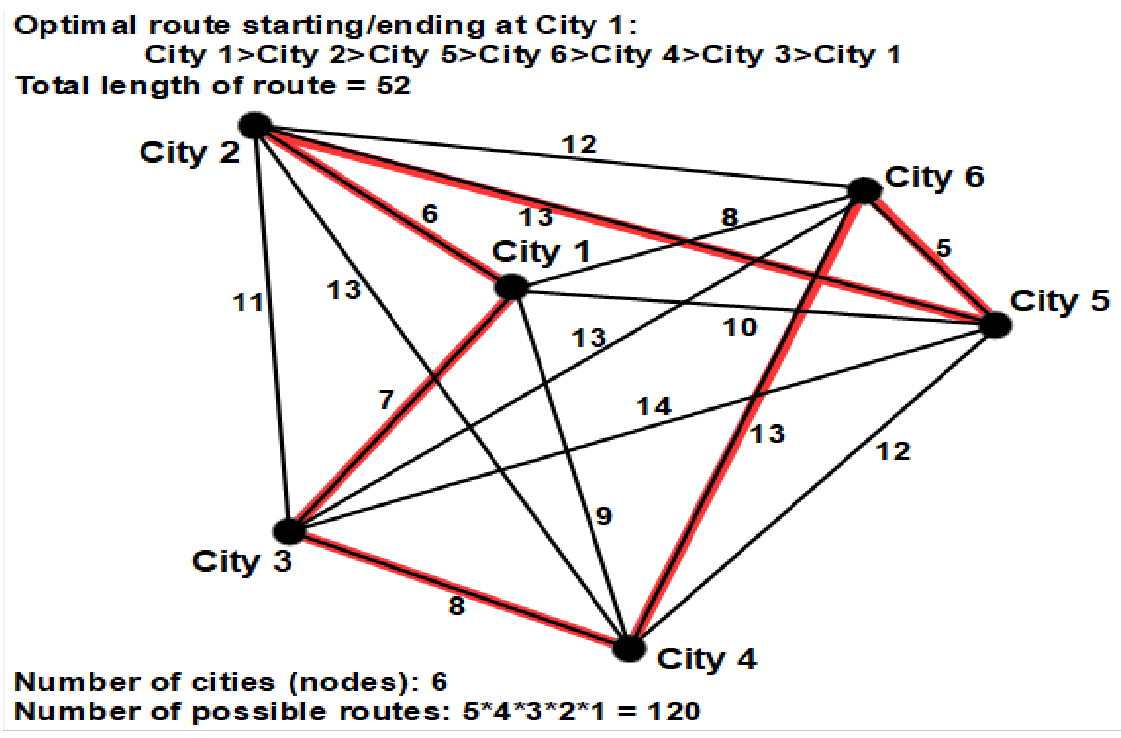


Fig. 2. Sample network with six nodes, distances between nodes, and the optimal route traced in red.

Fig. 2 shows a sample network with 6 nodes (Cities) and the distances between Cities. If starting out from City 1 and the objective is to visit all the other Cities then go back to City 1, there are 120 possible routes. This is a classic Traveling Salesman Problem. If solved using an appropriate algorithm, the shortest route would be City 1>City 2>City 5>City 6>City 4>City 4>City 1.

The Traveling Salesman Problem was defined in the 1800s by Irish mathematician W.R. Hamilton and by British mathematician Thomas Kirkman. The general form of the TSP appears to have been first studied by mathematicians during the 1930s in Vienna and at Harvard University, notably by Karl Menger. American mathematician Hassler Whitney of Princeton University, who described the challenge of finding the shortest route to visit one city in each of the US states, introduced the name *Traveling Salesman Problem* soon after.

REVIEW OF LITERATURE

The Traveling Salesman Problem is often found in many real-world problems, including many in the agricultural area. In agricultural logistics, especially in field logistics, the TSP... often occurs in the planning of the movement of machines to undertake multiple agricultural tasks (Wood, 2018).

The book “Precision Agriculture: Technology and Economic Perspectives” edited by Pedersen and Lind (2017) discussed the application of TSP in controlled-traffic farming by optimizing the sequence of working tracks of mechanicized fertilizer applicators. This is to minimize the non-working distance traveled while turning at headlands. Results showed that by implementing the traveling salesman approach for field coverage optimization, the savings achieved in non-working traveled distance amounted to 15.7%, 43.5%, and 23% for three fertilizing operations examined. These numbers correspond to savings in the total traveled distance of 5.8%, 11.8%, and 11.2%, respectively.

Matai et al. (2010) mentioned the application of TSP in order-picking tasks in warehouses. At a warehouse orders arrive for a certain list of the items on storage. Personnel using materials-handling vehicles have to collect the items for delivery preparation. The relation to the TSP is immediately seen. The storage locations of the items correspond to the nodes of the network. The distance between two nodes is given by the time needed to move the vehicle from one location to the other. The problem of finding a shortest route for the vehicle with minimum pickup time can be solved as a Traveling Salesman Problem.

Cummings (2000) reported about a work by P. C. Mahalanobis ("A sample survey of the acreage under jute in Bengal") which discussed aspects of TSP solutions in connection with a survey of farm lands in Bengal, where one of the major costs in carrying out the survey was the transportation of men and equipment from one survey point to the next.

SAMPLE PROBLEM AND THE TSPSG SOFTWARE

Suppose Field Technicians need to make a visit to sugarcane fields listed below to gather certain data. From their Head Office, they need to visit each of the fields only once, return to HO within the day making sure their total vehicle mileage (distance traveled) is kept to a minimum. This is to reduce cost and to make sure they can go back to HO as early as possible to make their report, and to prepare for the next day's itinerary. This is a problem that can be set up as a TSP and can be quickly solved by the TSPSG software which can be downloaded for free from the Internet (see Appendix). The procedure is given below.

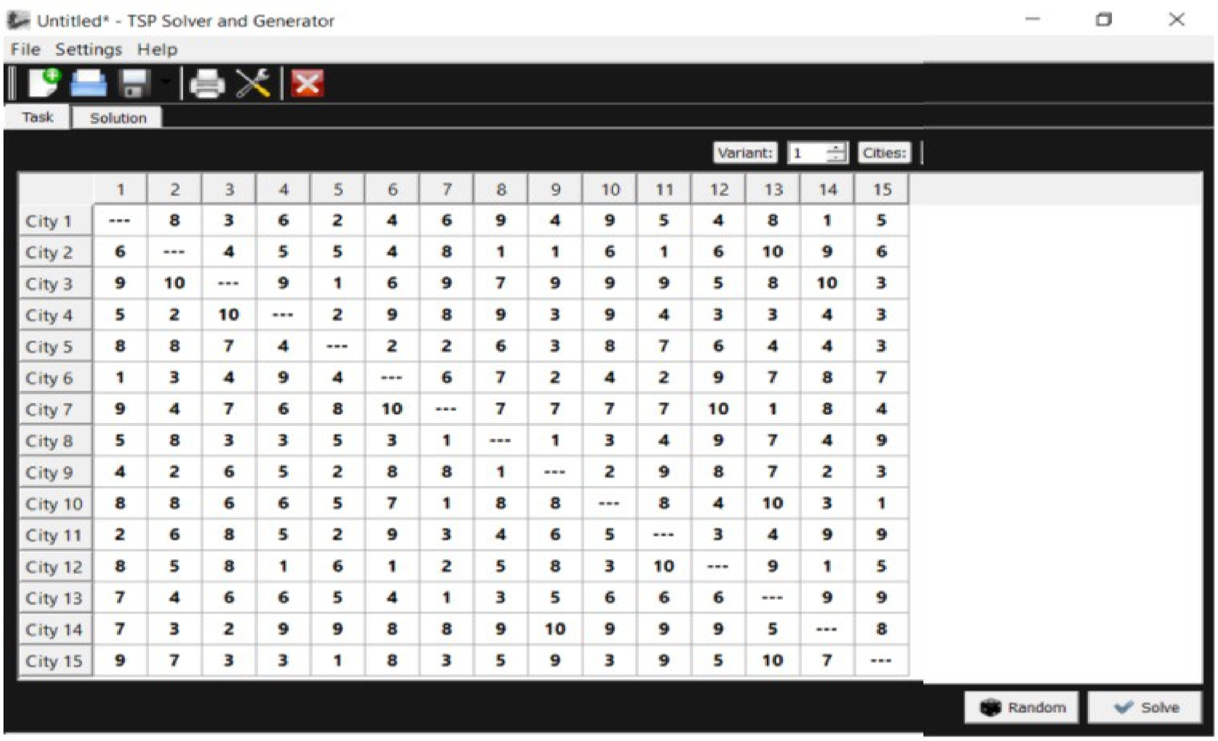
Number	Field Code
1	ADE4
2	ADE51
3	COL1/49
4	COL2/4
5	CAB2
6	LAS35
7	CULB46
8	PUY2
9	PAN24A
10	SAG3/19
11	SAG1/19-21
12	CAF12C
13	BIN12A
14	BIR1/30-35
15	MAT/3-6
16	CEL/14A
17	MAT/32
18	SAJ/4.65A
19	BON/48

1..The first step in using the TSPSG software is to create in a spreasheet (e.g. Microsoft Excel) a matrix or table of the distances (in this case, in kilometers) between each and all fields in the list. In the example above, it would look like this:

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1		ADE4	ADE51	COL1/49	COL2/4	CAB2	LAS35	CULB46	PUY2	PAN24A	SAG3/19	SAG1/19-21	CAF12C	BIN12A	BIR1/30-35	MAT/3-6	CEL/14A	MAT/32	SAJ/4.65A	BON/48
2	ADE4	0	1.58	4.72	8.24	15.8	7.8	11.2	10.4	11.5	15.3	13.9	11.5	13.9	13.7	16.8	18.4	18.4	18.8	20.5
3	ADE51	1.58	0	11.7	8.5	14.3	6.23	9.58	8.79	9.93	13.7	12.3	9.89	12.3	12	15.2	16.8	16.8	17.2	19
4	COL1/49	4.72	11.7	0	4.83	12.6	7.67	8	10.2	11.4	15.2	13.7	11.3	13.7	13.5	16.6	18.2	18.2	18.7	20.4
5	COL2/4	8.24	8.5	4.83	0	9.37	4.47	4.88	7	8.15	12	10.5	8.11	10.5	10.3	13.4	15	15	15.4	17.1
6	CAB2	15.8	14.3	12.6	9.37	0	10.2	10.6	12.8	13.9	17.7	16.3	13.9	16.3	16	19.2	20.8	20.8	21.2	23
7	LAS35	7.8	6.23	7.67	4.47	10.2	0	5.53	7.73	8.93	12.73	11.23	8.83	11.23	11.03	14.23	15.83	15.83	16.23	19.33
8	CULB46	11.2	9.58	8	4.88	10.6	5.53	0	8.1	9.25	13.1	11.6	9.21	11.6	11.3	14.5	16.1	16.1	16.5	18.2
9	PUY2	10.4	8.79	10.2	7	12.8	7.73	8.1	0	1.74	6.74	5.24	2.85	5.24	5.2	8.14	9.74	9.74	10.14	11.84
10	PAN24A	11.5	9.93	11.4	8.15	13.9	8.93	9.25	1.74	0	8.83	7.33	4.94	7.35	7.15	10.55	12.15	12.15	12.55	15.35
11	SAG3/19	15.3	13.7	15.2	12	17.7	12.73	13.1	6.74	8.83	0	1.5	3.89	6.3	6.1	9.2	10.8	10.8	11.2	14
12	AG1/19-2	13.9	12.3	13.7	10.5	16.3	11.23	11.6	5.24	7.33	1.5	0	2.39	4.8	5	8.1	9.7	9.7	10.1	12.9
13	CAF12C	11.5	9.89	11.3	8.11	13.9	8.83	9.21	2.85	4.94	3.89	2.39	0	2.41	2.21	5.4	7	7	7.4	10.2
14	BIN12A	13.9	12.3	13.7	10.5	16.3	11.23	11.6	5.24	7.35	6.3	4.8	2.41	0	3.38	6.57	8.17	8.17	8.57	11.37
15	IR1/30-3	13.7	12	13.5	10.3	16	11.03	11.3	5.2	7.15	6.1	5	2.21	3.38	0	5.17	6.77	6.77	7.17	9.97
16	MAT/3-6	16.8	15.2	16.6	13.4	17.1	14.23	14.5	8.14	10.55	9.2	8.1	5.4	6.57	5.17	0	1.6	1.6	8.86	7
17	CEL/14A	18.4	16.8	18.2	15	20.8	15.83	16.1	9.74	12.15	10.8	9.7	7	8.17	6.77	1.6	0	1.1	10.46	8.6
18	MAT/32	18.4	16.8	18.2	15	20.8	15.83	16.1	9.74	12.15	10.8	9.7	7	8.17	6.77	1.6	1.1	0	11.56	9.7
19	SAJ/4.65A	18.8	17.2	18.7	15.4	21.2	16.23	16.5	10.14	12.55	11.2	10.1	7.4	8.57	7.17	8.86	10.46	11.56	0	12.7
20	BON/48	20.5	19	20.4	17.1	23	19.33	18.2	11.84	15.35	14	12.9	10.2	11.37	9.97	7	8.6	9.7	12.7	0

Thus, pertaining to cell D2 in the spreadsheet, the distance from Field ADE4 to Field COL1/49 is 4.72 kilometers, cell H9- PUY2 to CULB46 is 8.1 km., cell R20- BON/48 to MAT/32 is 9.7 km. and so on.

2.. The data of field-to-field distances is then entered into the TSPSG matrix as shown below. Note that the label “City” is a built-in feature of the software and cannot be changed, hence, in the sample list above, City 1 would be field Number 1 which is Field ADE4, City 2 is Field ADE51, City 3 is COL1/49 and so on. Note further that the TSPSG screen can display only up to 15 rows vertically, but it can be scrolled up to enter more data.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
City 1	---	8	3	6	2	4	6	9	4	9	5	4	8	1	5
City 2	6	---	4	5	5	4	8	1	1	6	1	6	10	9	6
City 3	9	10	---	9	1	6	9	7	9	9	9	5	8	10	3
City 4	5	2	10	---	2	9	8	9	3	9	4	3	3	4	3
City 5	8	8	7	4	---	2	2	6	3	8	7	6	4	4	3
City 6	1	3	4	9	4	---	6	7	2	4	2	9	7	8	7
City 7	9	4	7	6	8	10	---	7	7	7	7	10	1	8	4
City 8	5	8	3	3	5	3	1	---	1	3	4	9	7	4	9
City 9	4	2	6	5	2	8	8	1	---	2	9	8	7	2	3
City 10	8	8	6	6	5	7	1	8	8	---	8	4	10	3	1
City 11	2	6	8	5	2	9	3	4	6	5	---	3	4	9	9
City 12	8	5	8	1	6	1	2	5	8	3	10	---	9	1	5
City 13	7	4	6	6	5	4	1	3	5	6	6	6	---	9	9
City 14	7	3	2	9	9	8	8	9	10	9	9	9	5	---	8
City 15	9	7	3	3	1	8	3	5	9	3	9	5	10	7	---

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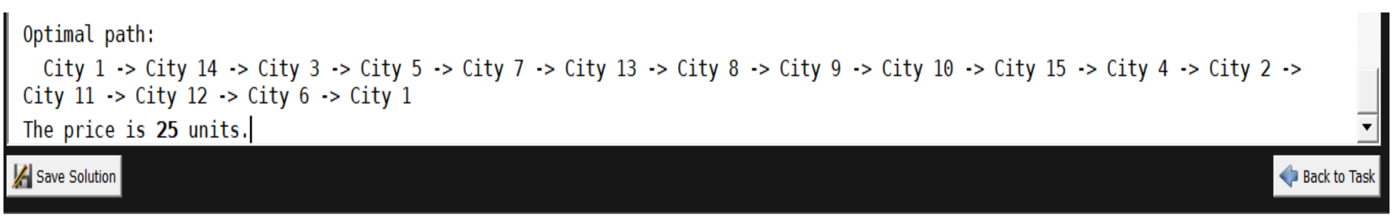
3.. Click the “Solve” button on the lower right corner of the software's screen, and the optimal (minimum total distance) route is quickly generated, as shown below.



Optimal path:

City 1 -> City 14 -> City 3 -> City 5 -> City 7 -> City 13 -> City 8 -> City 9 -> City 10 -> City 15 -> City 4 -> City 2 -> City 11 -> City 12 -> City 6 -> City 1

The price is **25** units.

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Transcribed in proper labels, the optimal route is:

ADE4 > BIR1/30-35 > COL1/49 > CAB2 > CULB46 > BIN12A > PUY2 > PAN24A > SAG3/19 > MAT/3-6 > COL2/4 > ADE51 > SAG1/19-21 > CAF12C > LAS35 > ADE4

4.. The process is repeated for the next day, with a new list of fields to visit, again starting off at the HO and going back to it at the end of the field visits.

APPLICATION IN SUGARCANE BIOMASS COLLECTION

A biomass-fired powerplant is currently under construction in Manapla, Negros Occidental. When operational, it will have a generating capacity of 24.99 megawatts, enough electricity for the needs of 265,000 people in the region's urban centers and rural areas.

The plant will be primarily fueled with sugarcane leaf materials ("cane trash") left in the field after harvesting, to be collected by specialized machinery in farms in Cadiz, Manapla, Victorias, EB Magalona, Silay and Talisay. After the cane has been harvested and transported to the mill, a tractor-mounted rotary rake unit is first to enter a field, windrows the trash and proceeds to the next field that is on RFR (Ready for Raking) status (Fig. 3). A tractor-pulled wagon follows in its wake, picks up the windrowed trash until some 4 tons is on board, unloads it at the edge of the field, repeats the process until all windrowed trash in that field is collected, and follows the rake in the succeeding fields (Fig. 4). The unloaded trash at the field edge is then loaded by grab loaders to tractor-pulled trailers and taken to bailing-transloading stations (Fig. 5).

Fig. 3. Rotary rake, for windrowing cane trash.

Fig. 4. Wagon, picks up the windrowed trash and unloads it at field edge.

Fig. 5. Tractor-pulled trailer is loaded at field edge, then transports the cane trash to a bailing/transloading station.

The rake unit, being the lead collection equipment, determines to route of the trailing collection equipment, the wagon. Hence, finding the optimal (least-cost) route is essentially finding the route that the rake must take, as the wagon merely will follow the rake.

The Traveling Salesman Problem may be applied to the least-cost routing of the rake and wagon in the process of cane trash collection, but with modifications. This is because in the classic TSP, the route must be a closed loop, i.e., the "Salesman" returns to the origin node (Fig. 2, Fig 6). In the case of cane biomass collection, when the rake reaches the last field destination in the optimal route, it will not go back to its starting field (origin), unlike in classic TSP. Instead, it will proceed to the first field ready for raking (RFR) in the next-day network of fields to be optimized. Thus the last field of the preceeding network will be the first field in the next network to be optimized (Fig. 7). This process in repeated as long as there is collection operation.

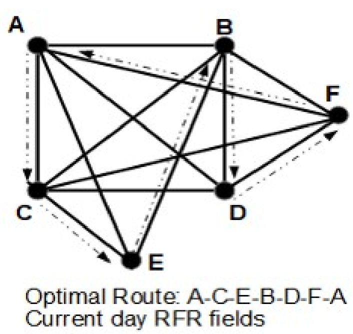


Fig. 6. In the classic Traveling Salesman Problem, the optimal route is a closed loop which starts and returns to the origin node.

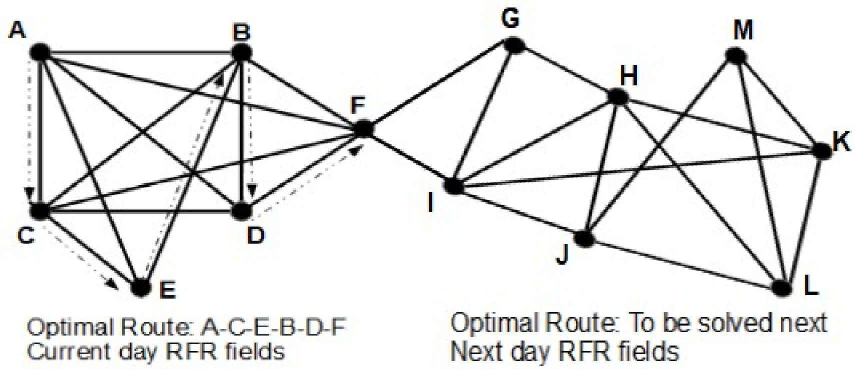
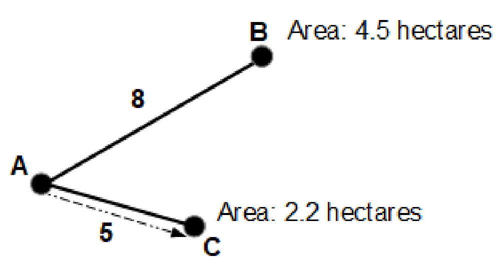


Fig. 7. If applied to biomass collection, the optimal route will not be closed, i.e., the last destination field in the optimal route of the current list of RFR fields will be the origin of the next-day set of fields whose optimal route will be solved next.

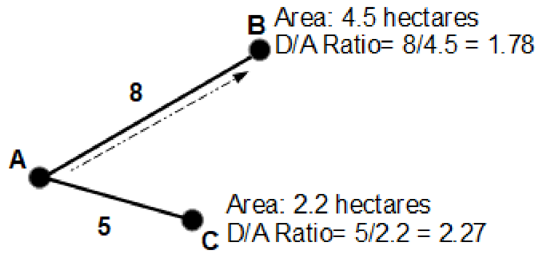
Another modification is to factor-in the area (in hectares) of each cane field, in addition to the distance between fields, area being a determinant of the yield (volume) of trash that can be collected for a field (around 15 tons/hectare being the average). This is in consideration of the fact that it may be more productive for the rake to proceed to a larger field (higher trash volume) even if it is farther than go next to a nearer field which is smaller. Thus, instead of using solely distance between fields to compute for the optimal route, the concept of "D/A Ratio" is introduced in determining the optimal route. D/A Ratio is herein defined as:

$$\text{D/A Ratio} = \frac{\text{Distance in kilometers between Node 1 and Node 2}}{\text{Area in hectares of Node 2}}$$

In classic TSP algorithm which considers only the minimization of distance travelled, a short-distance travel is often (but not always) chosen over a longer-distance travel, as in the example below where Field C is chosen over Field B as the next collection destination from Field A because it is nearer.



If the area of the next field destination is factored-in in the form of the D/A ratio, the result could be different but more appropriate, as shown below:



In the second case, in proceeding from Field A to Field B the collection team travelled only 1.78 kilometers for every 1 hectare collected from, whereas, it would have been 2.27 kilometers for 1 hectare if the collection team proceeded to Field C.

Expressed inversely, a smaller D/A ratio means a bigger collection of trash for every kilometer travelled. Assuming 60% of the trash in a field can be collected, Field B has a trash yield of (4.5*15)*.60= 40.5 tons and trash/distance ratio of 40.5/8= 5.06 (5.06 tons per kilometer) while Field C has (2.2*15)*.60= 19.8 tons or a lower trash/distance ratio of 19.8/5= 3.96 tons per kilometer.

SETTING UP THE BIOMASS DATA FOR THE TSP SOFTWARE

Assume that below are the fields ready for Raking (RFR) for the following day of cane biomass collection. The first column “Number” is simply the order of the fields as printed in the list and does not indicate the sequence for raking. This raking sequence is actually what the Collection Supervisor needs to detemine for his rake unit, assuming that the first field to be raked is Number 1 (SAG3/19). Since there are 14 fields in the list, there are 14-1! or 6,227,020,800 routes possible starting from ADR14, visiting each of the 13 remaining fields in the list. Since it is impossible to list all these many alternative routes manually (at least in, say, a 1-hour period that the Supervisor needs to determine the optimal route), this optimal route can be determined using the TSPSG software, in a procedure outlined as follows.

Number	Field Code	Area (ha.)
1	ADR14	0.7
2	AURB15	2.8
3	BUE8/9	0.9
4	CABS2AB	3.2
5	CABL56-57	2.3
6	CAT22A	2.0
7	DAG27AB	5.6
8	JEA31B	1.4
9	LIL49	1.1
10	MATB5.29	5.3
11	NACA6B	0.4
12	NORJ8	1.0
13	PUYL2-7-8	2.5
14	PUYG6/9	5.0
	Total (ha)	34.2

1..The first step in using the TSPSG is to create in Excel a matrix (table) of the distances in kilometers between each and all fields in the list. In the example above, it would look like this:

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
	ADR14	AURB15	BUE8/9	CABS2AB	CABL56-57	CAT22A	DAG27AB	JEA31B	LIL49	MATB5.29	NACA6B	NORJ8	PUYL2-7-8	PUYG6/9
ADR14	-	3.28	7.95	9.53	10.96	9.45	3.68	5.87	2.85	6.09	10.41	4.93	5.39	4.79
AURB15	3.28	-	6.94	9.27	10.7	8.43	5.72	4.86	2.49	5.06	9.39	4.24	4.37	3.79
BUE8/9	7.95	6.94	-	11.29	12.72	8.59	9.15	2.95	7.2	8.37	9.55	4.06	3.98	5.71
CABS2AB	9.53	9.27	11.29	-	5.4	8.04	10.73	7.39	9.53	10.76	9	6.48	8.02	8.15
CABL56-57	10.96	10.7	12.72	5.4	-	9.5	12.16	8.82	10.96	12.17	10.46	7.93	9.41	9.56
CAT22A	9.45	8.43	8.59	8.04	9.5	-	10.65	6.5	8.73	9.87	0.96	5.33	7.13	7.26
DAG27AB	3.68	5.72	9.15	10.73	12.16	10.65	-	7	4.1	7.27	11.61	6.1	6.59	5.98
JEA31B	5.87	4.86	2.95	7.39	8.82	6.5	7	-	5.09	6.27	7.46	2	1.93	3.68
LIL49	2.85	2.49	7.2	9.53	10.96	8.73	4.1	5.09	-	5.4	9.69	4.26	4.75	4.02
MATB5.29	6.09	5.06	8.37	10.76	12.17	9.87	7.27	6.27	5.4	-	9.96	5.29	5.79	3.23
NACA6B	10.41	9.39	9.55	9	10.46	0.96	11.61	7.46	9.69	9.96	-	5.58	7.37	8.22
NORJ8	4.93	4.24	4.06	6.48	7.93	5.33	6.1	2	4.26	5.29	5.58	-	2.55	2.64
PUYL2-7-8	5.39	4.37	3.98	8.02	9.41	7.13	6.59	1.93	4.75	5.79	7.37	2.55	-	0.86
PUYG6/9	4.79	3.79	5.71	8.15	9.56	7.26	5.98	3.68	4.02	3.23	8.22	2.64	0.86	-

2..The second step is to create in a second matrix indicating the areas (in hectares) of each field in the list:

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
	ADR14	AURB15	BUE8/9	CABS2AB	CABL56-57	CAT22A	DAG27AB	JEA31B	LIL49	MATB5.29	NACA6B	NORJ8	PUYL2-7-8	PUYG6/9
ADR14	-	2.75	0.85	3.24	2.33	2	5.56	1.4	1.1	5.29	0.4	1	2.5	5.03
AURB15	0.73	-	0.85	3.24	2.33	2	5.56	1.4	1.1	5.29	0.4	1	2.5	5.03
BUE8/9	0.73	2.75	-	3.24	2.33	2	5.56	1.4	1.1	5.29	0.4	1	2.5	5.03
CABS2AB	0.73	2.75	0.85	-	2.33	2	5.56	1.4	1.1	5.29	0.4	1	2.5	5.03
CABL56-57	0.73	2.75	0.85	3.24	-	2	5.56	1.4	1.1	5.29	0.4	1	2.5	5.03
CAT22A	0.73	2.75	0.85	3.24	2.33	-	5.56	1.4	1.1	5.29	0.4	1	2.5	5.03
DAG27AB	0.73	2.75	0.85	3.24	2.33	2	-	1.4	1.1	5.29	0.4	1	2.5	5.03
JEA31B	0.73	2.75	0.85	3.24	2.33	2	5.56	-	1.1	5.29	0.4	1	2.5	5.03
LIL49	0.73	2.75	0.85	3.24	2.33	2	5.56	1.4	-	5.29	0.4	1	2.5	5.03
MATB5.29	0.73	2.75	0.85	3.24	2.33	2	5.56	1.4	1.1	-	0.4	1	2.5	5.03
NACA6B	0.73	2.75	0.85	3.24	2.33	2	5.56	1.4	1.1	5.29	-	1	2.5	5.03
NORJ8	0.73	2.75	0.85	3.24	2.33	2	5.56	1.4	1.1	5.29	0.4	-	2.5	5.03
PUYL2-7-8	0.73	2.75	0.85	3.24	2.33	2	5.56	1.4	1.1	5.29	0.4	1	-	5.03
PUYG6/9	0.73	2.75	0.85	3.24	2.33	2	5.56	1.4	1.1	5.29	0.4	1	2.5	-

3..Create a third matrix in which each cell contains the formula for computing the D/A ratio as discussed in Page 9. For example, the distance from field ADR14 to AURB15 in Step 1 is 3.28; the area of field AURB15 in Step 2 is 2.75 ha., hence the D/A ratio of the link from ADR14 to AURB15 is 1.19, meaning 1.19 km travel to reach a field with 1 ha. area.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
	ADR14	AURB15	BUE8/9	CABS2AB	CABL56-57	CAT22A	DAG27AB	JEA31B	LIL49	MATB5.29	NACA6B	NORJ8	PUYL2-7-8	PUYG6/9
ADR14	-	1.19	9.35	2.94	4.70	4.73	0.66	4.19	2.59	1.15	26.03	4.93	2.16	0.95
AURB15	4.49	-	8.16	2.86	4.59	4.22	1.03	3.47	2.26	0.96	23.48	4.24	1.75	0.75
BUE8/9	10.89	2.52	-	3.48	5.46	4.30	1.65	2.11	6.55	1.58	23.88	4.06	1.59	1.14
CABS2AB	13.05	3.37	13.28	-	2.32	4.02	1.93	5.28	8.66	2.03	22.50	6.48	3.21	1.62
CABL56-57	15.01	3.89	14.96	1.67	-	4.75	2.19	6.30	9.96	2.30	26.15	7.93	3.76	1.90
CAT22A	12.95	3.07	10.11	2.48	4.08	-	1.92	4.64	7.94	1.87	2.40	5.33	2.85	1.44
DAG27AB	5.04	2.08	10.76	3.31	5.22	5.33	-	5.00	3.73	1.37	29.03	6.10	2.64	1.19
JEA31B	8.04	1.77	3.47	2.28	3.79	3.25	1.26	-	4.63	1.19	18.65	2.00	0.77	0.73
LIL49	3.90	0.91	8.47	2.94	4.70	4.37	0.74	3.64	-	1.02	24.23	4.26	1.90	0.80
MATB5.29	8.34	1.84	9.85	3.32	5.22	4.94	1.31	4.48	4.91	-	24.90	5.29	2.32	0.64
NACA6B	14.26	3.41	11.24	2.78	4.49	0.48	2.09	5.33	8.81	1.88	-	5.58	2.95	1.63
NORJ8	6.75	1.54	4.78	2.00	3.40	2.67	1.10	1.43	3.87	1.00	13.95	-	1.02	0.52
PUYL2-7-8	7.38	1.59	4.68	2.48	4.04	3.57	1.19	1.38	4.32	1.09	18.43	2.55	-	0.17
PUYG6/9	6.56	1.38	6.72	2.52	4.10	3.63	1.08	2.63	3.65	0.61	20.55	2.64	0.34	-

4..Next step is to enter the D/A ratios in Step 3 in the TSPSG data screen. Again, note that the label “City” is a built-in feature of the software and cannot be changed, hence, City 1 would be field Number 1 which is ADR14, and so on.

Travelling Salesman Project - TSP Solver and Generator

File Settings Help

Task Solution

Variant: 1

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
City 1	---	1.19	9.35	2.94	4.7	4.73	0.66	4.19	2.59	1.15	26.03	4.93	2.16	0.95
City 2	4.49	---	8.16	2.86	4.59	4.22	1.03	3.47	2.26	0.96	23.48	4.24	1.75	0.75
City 3	10.89	2.52	---	3.48	5.46	4.3	1.65	2.11	6.55	1.58	23.88	4.06	1.59	1.14
City 4	13.05	3.37	13.28	---	2.32	4.02	1.93	5.28	8.66	2.03	22.5	6.48	3.21	1.62
City 5	15.01	3.89	14.96	1.67	---	4.75	2.19	6.3	9.96	2.3	26.15	7.93	3.76	1.9
City 6	12.95	3.07	10.11	2.48	4.08	---	1.92	4.64	7.94	1.87	2.4	5.33	2.85	1.44
City 7	5.04	2.08	10.76	3.31	5.22	5.33	---	5	3.73	1.37	29.03	6.1	2.64	1.19
City 8	8.04	1.77	3.47	2.28	3.79	3.25	1.26	---	4.63	1.19	18.65	2	0.77	0.73
City 9	3.9	0.91	8.47	2.94	4.7	4.37	0.74	3.64	---	1.02	24.23	4.26	1.9	0.8
City 10	8.34	1.84	9.85	3.32	5.22	4.94	1.31	4.48	4.91	---	24.9	5.29	2.32	0.64
City 11	14.26	3.41	11.24	2.78	4.49	0.48	2.09	5.33	8.81	1.88	---	5.58	2.95	1.63
City 12	6.75	1.54	4.78	2	3.4	2.67	1.1	1.43	3.87	1	13.95	---	1.02	0.52
City 13	7.38	1.59	4.68	2.48	4.04	3.57	1.19	1.38	4.32	1.09	18.43	2.55	---	0.17
City 14	6.56	1.38	6.72	2.52	4.1	3.63	1.08	2.63	3.65	0.61	20.55	2.64	0.34	---

5.. The “Solve” button of the software at the lower right corner of the screen (not shown above) is clicked and instantly, the optimal route solution is generated as shown below:

```
Optimal path:
  City 1 -> City 13 -> City 8 -> City 3 -> City 12 -> City 6 -> City 11 -> City
4 -> City 5 -> City 7 -> City 10 -> City 14 -> City 2 -> City 9 -> City 1
The price is 32.98 units.
```

The optimal route starts from Field 1 ADR14 and ends at Field 9 LIL49 in the following Raking Sequence:

ADR14 > PUYL2-7-8 > JEA31B > BUE8/9 > NORJ8 > CAT22A > NACA6B > CABS2AB > CABL56-57 > DAG27A > MATB5.29 > PUYG6/9> AURB15 > LIL49

Number	Field Code	Area (ha.)	Raking Sequence
1	ADR14	0.7	1
2	AURB15	2.8	13
3	BUE8/9	0.9	4
4	CABS2AB	3.2	8
5	CABL56-57	2.3	9
6	CAT22A	2.0	6
7	DAG27AB	5.6	10
8	JEA31B	1.4	3
9	LIL49	1.1	14
10	MATB5.29	5.3	11
11	NACA6B	0.4	7
12	NORJ8	1.0	5
13	PUYL2-7-8	2.5	2
14	PUYG6/9	5.0	12
	Total (ha)	34.2	

The total D/A value of the optimal path is 32.98, and if divided by 14 links in the network, the average D/A ratio is 2.35 km traveled for every 1 hectare collected from. After the rake finishes windrowing trash on LIL49, it will not return to ADR14 as in the classic TSP case, but will proceed to the first field in the next batch of fields where cane biomass will be collected.

SUMMARY

Supply management commonly has a geographical dimension involving networks, which are geographic units like towns, cities, farms or fields (called nodes) interconnected by roads (called links). One of the most important problems in supply network optimization is to find an “optimal” route that starts from a given origin node, visits each node only once, and returns to the starting node while keeping the total distance or cost (or some other factor to be minimized) of the route at a minimum. This optimization objective is called the Traveling Salesman Problem.

Since the number of possible routes increases exponentially and reaches several thousands when the number of nodes exceeds eight, solving a TSP is better achieved with the use of a computer software. This paper presented a freely downloadable (download link included) software called the Traveling Salesman Solver and Generator (TSPSG), demonstrated its use, first in a theoretical case and then its possible application in a real-life case of sugarcane biomass collection by a biomass-to-energy powerplant currently under construction in Manapla, Negros Occidental.

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Appendix

Screenshots of “About TSP Solver and Generator” Screen and the Data Entry Screen (matrix) Set at 10 Nodes

Note: TSPSG can be downloaded free from this link:

http://tspsg.info/en/download