Article

Consolidation centers strategy for the distribution of prickly pear in Mexico

Rafael Granillo Macías[1§]
Isidro Jesús González Hernández[1, 2]
Francisca Santana Robles[1]
José Luis Martínez Flores[2]

[1]Autonomous University of the State of Hidalgo-Higher School of Ciudad Sahagún. Highway Otumba-Ciudad Sahagún S/N, industrial zone, Ciudad Sahagún, Hidalgo. CP. 43998. (profe-7739@uaeh.edu.mx).
[2]Popular Autonomous University of the State of Puebla. Street 21 south no. 1103, col. Santiago, Puebla, Puebla. CP. 72410. (isidrojesus.gonzalez@upaep.edu.mx; joseluis.martinez01@upaep.mx).

[§]Corresponding author: rafaelgm@uaeh.edu.mx.

Abstract

The cultivation of the prickly pear (*Opuntia* spp.) has positioned Mexico as the world leader in the production of this agri-food product. Because the harvest is sent to different markets throughout the country, distribution and marketing operations represent a challenge in this supply chain. This research was conducted based on the national production obtained in 2016, with the objective of developing a distribution network that maximizes the profits of the producers. The hypothesis was that based on a consolidation center strategy, it is possible to design a model for a distribution network that selects optimal routes based on transport costs and sales prices in the demanding markets. Mixed integer linear programming with continuous variables was used to determine the quantities of products to send and integer variables to select the consolidation centers. The proposed model was implemented; through, an algorithm programmed in Matlab which applies mathematical optimization techniques to evaluate the best feasible solution. The results indicate that four consolidation centers should be used in the state of Guanajuato, ten in Zacatecas, one in Hidalgo and Puebla respectively, two in the State of Mexico and six in San Luis Potosí. With this proposal, the state of Zacatecas concentrates at least 50% of the harvest, so this location is key to optimize the profit in the supply chain of the prickly pear.

Keywords: *Opuntia* spp., consolidation centers, logistics network, mixed whole linear programming, optimization.

Reception date: December 2018
Acceptance date: January 2019

Introduction

As the world leader in the production of prickly pear (*Opuntia* spp.), Mexico has 20 000 producers who annually harvest an average of 352 000 t in 48 000 ha available for planting (SIAP, 2017). The main producers at a national level are the State of Mexico, Zacatecas, Puebla and Hidalgo, followed by the states of San Luis Potosí and Guanajuato (Mexico Produce, 2016). The behavior of prickly pear production during the period 2007-2016 according to data from SIAP (2017) shows slight variations with an accumulated value in thousands of pesos of 12 704 617. Of the four main states, the lowest production is Hidalgo and the one with the highest production during the period studied is the State of Mexico. The state of Puebla is the one that has achieved the highest yield per hectare planted during the same period, except for the years 2009 and 2010 whose state with the highest yield was Durango.

The national production of the prickly pear is generally dispersed in diverse climates and lands with average areas per producer of five hectares, with the State of Mexico and Zacatecas contributing approximately 64.4% of the total area available for planting.

One of the challenges in post-harvest operations is distribution and commercialization, which are fundamental processes that affect profitability in the prickly pear agroindustrial sector in Mexico (Pinedo-Espinoza *et al*., 2010; Ramírez *et al*., 2015), where mainly producers from the central zone of the country participate who supply the different markets at the national level (Ayllón *et al*., 2015). In the marketing process, 90% of the production is concentrated in a short period of time, which corresponds to the harvest cycle of the prickly pear. In addition, there is strong competition with other seasonal fruits that are harvested in the same period as grapes, mango or guava (Barrera *et al*., 2011).

The perishable nature of this product with a post-harvest life that varies between nine and fifteen days means that the time and distance traveled to deliver the product to the customer are factors that directly affect the sale price. Due to these conditions of decline in quality and the seasonality with which it occurs mainly in the months of June to November this supply chain includes too many intermediaries for distribution, resulting in low prices for producers and high prices at consumer (Ramírez *et al*., 2015). The production in this chain is usually done in complex networks characterized by being developed in one or two levels of distribution; that is, from producer to the market or through an intermediary.

The strategic decisions for the location of storage and distribution centers become of great relevance for the design of the supply chain of perishable products (Sanabria *et al*., 2017), especially due to the difficulty in modeling the different variables that intervene length of the chain.

The problems in the design of distribution networks for perishable products are generally based on determining the number of locations of the raw material, the plants where it is processed and the warehouses where the inventory will be kept, as well as selecting the marketing channels among the suppliers and customers (Granillo-Macías *et al*., 2017).

A strategy to improve distribution and commercialization is to resort to consolidation centers, as a low-cost alternative that allows cooperatively to consolidate the harvest of different producers and later distribute it in the demanding markets (Reina and Cortés, 2015). A consolidation center is defined as a geographical location which is used to transfer products between different origins and destinations. The main objectives of a consolidation center are to extend the coverage of a distribution network, improve the performance of the supply operation and reduce transportation costs (Hamidi *et al*., 2014). In distribution logistics systems, a consolidation center is used mainly when the product flows come from multiple suppliers (Figure 1).

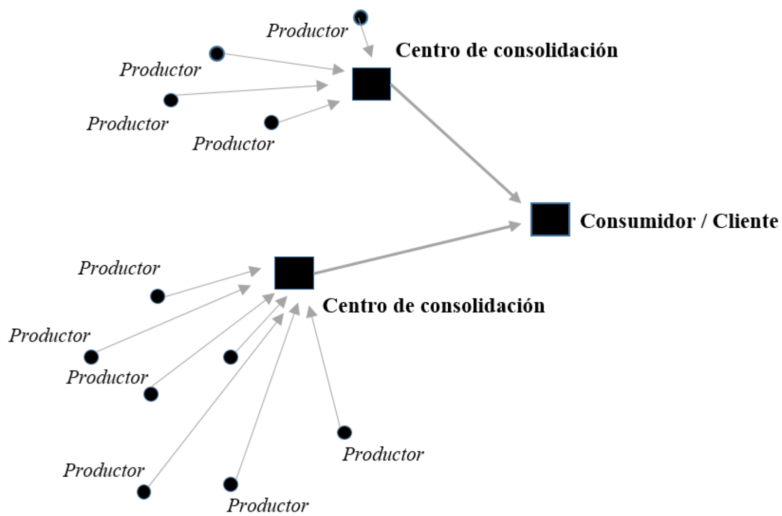


Figure 1. Graphical representation of consolidation centers.

The adequate configuration and allocation of flows in the design of a network based on consolidation centers allows to reduce the transfer time and the cost of maintaining the inventory in the supply chain (Agustina *et al*., 2014), being especially useful in the distribution of large volumes of products which are transported between different points of origin and destination (Ghaffari-Nasab *et al*., 2015).

Kreng and Chen (2008) develop two models to coordinate both production and distribution to reduce the most relevant costs in a supply chain. They evaluate two strategies, one of consolidation centers and one of traditional storage, the researchers conclude that the first strategy allows large savings in total costs. These authors make two main contributions, the first is with respect to expanding the applications of consolidation centers where they incorporate a combinatorial study, the second one refers to the evaluation of computational performance with the strategy of consolidation centers.

Küçükoğlu and Öztürk (2017) implement a mixed whole linear programming model in two stages for a transport problem, to design a distribution network based on consolidation centers, which minimizes transport costs from suppliers to customers, also considers the loading plans of incoming and outgoing trucks and the assignments of products in the consolidation area with respect to dimensional physical restrictions. Vasiljevic *et al*. (2013) point out that by implementing consolidation centers in agriculture it is possible to improve the distribution of products and increase competitiveness not only in one company but in the entire supply chain.

The objective of this study was to develop a distribution network for the prickly pear supply chain through a mixed whole linear programming model (MILP) that maximizes the producers profits.

The hypothesis was that based on a strategy of consolidation centers it is possible to design a distribution network that selects the optimal routes when considering the logistics costs of transportation and the sale prices in the demanding markets.

Materials and methods

A tool for planning in distribution and transport operations are mathematical optimization techniques, which are formulated based on an objective function and restrictions focused mainly on reducing costs and time (Badole *et al*., 2012). Some of these techniques include linear and non-linear programming depending on the nature of the study problem. In this proposal, mixed whole linear programming was used, which uses continuous variables to determine the quantities of products to be shipped and integer variables (between 0 and 1) to select the consolidation centers that should be used in order to optimize the distribution network.

For the modeling optimization techniques were applied such as: ‘branching and boundary’, which uses a method based on dividing the feasible solution into small subsets of solutions to systematically evaluate the best solution found; also used the mathematical optimization ‘plane of cut’ which is a technique that allows iteratively refine the set of feasible solutions, which is widely used to find an entire solution in linear programming problems.

The software selected for the implementation of the modeling was Matlab which uses algorithms based on mathematical programming to locate parameters that minimize or maximize an objective function under certain restrictions. The Microsoft Excel software was used as the interface between the database used and Matlab.

Formulation of the model

The objective of the MILP model is to determine the distribution network that maximizes the producers' profit. In this case, the strategy of consolidation centers is considered, so the objective function is expressed as.

$$\sum_{j\in J}\sum_{k\in K}P_k X_{jk} - \sum_{i\in I}\sum_{j\in J}C_{ij}X_{ij} - \sum_{j\in J}\sum_{k\in K}C_{jk}X_{jk} - \sum_{j\in J}f_j Y_j \quad 1)$$

In the objective function (1), $i \in I$ represent the set of prickly pear producers located in the producing states of Puebla, Zacatecas, San Luis Potosí, State of Mexico, Hidalgo and Guanajuato, $j \in J$ represents the set of consolidation centers available and $k \in K$ represents the set of consumer markets. The decision variables X_{ij}, X_{jk} indicate the amount in tons to be transported from producer *i* to consolidation center *j*, from consolidation center *j* to market *k*. In addition, Y_j is a binary variable that indicates which consolidation centers should be used and which not for the purpose of optimizing the distribution network. The parameters C_{ij}, C_{jk} in (1) incorporate transport costs ($/ton) from producer *i* to consolidation center *j* and from consolidation center *j* to market *k* and finally P_k and f_j indicate the sale price in the market *k* and the fixed opening cost of the consolidation center *j* respectively.

Regarding the restrictions for this model, expression (2) indicates that the quantity sent from consolidation center *j* to market *k* must cover at least the demand in *k*.

$$\sum_{j \in J} X_{jk} \geq dem_k \quad \forall \; k \in K \tag{2}$$

Restriction (3) guarantees that the production of prickly pear that is sent from producer *i* to the consolidation center *j* is not greater than the available crop in *i*.

$$\sum_{j \in J} X_{ij} \leq sum_i \quad \forall \; i \in I \tag{3}$$

The restrictions (4) and (5) relate the quantity sent X_{ij} and X_{jk} with the available capacity in the consolidation center *j*.

$$\sum_{i \in I} x_{ij} \leq cap_j \quad \forall \; j \in J \tag{4}$$

$$\sum_{k \in K} x_{jk} \leq Y_j cap_j \quad \forall \; j \in J \tag{5}$$

The flow (inputs-outputs) in the consolidation center is expressed in (6) as a balance equation.

$$\sum_{i \in I} X_{ij} = \sum_{k \in K} X_{jk} \quad \forall \; j \in J \tag{6}$$

Finally, (7) guarantee the non-negativity of the variables and the type of each one.

$$x_{ij} \geq 0; \; x_{jk} \geq 0; \; Y_j \in \{0,1\} \quad \forall \; i \in I, \; \forall \; j \in J, \; \forall \; k \in K \tag{7}$$

Implementation of the model

The highest volumes of prickly pear production in 2016 according to SIAP (2017) were concentrated in Zacatecas, State of Mexico, Puebla, San Luis Potosí, Guanajuato and Hidalgo (Table 1).

To determine the production volumes available from the bidding states (origins) and the quantities requested by the claiming states (destinations), the methodology proposed by Ayllón *et al*. (2015).

Table 1. Production of prickly pear.

State	Municipalities producers	Production (t)
Guanajuato	7	22 577
Hidalgo	31	21 337
Mexico	9	190 530
Puebla	22	100 866
San Luis Potosi	23	15 138
Zacatecas	21	94 092

SIAP data (2017).

The consolidation centers present the particularity that their use is not restricted to a particular supply chain, but rather serves a wide variety of products that can be distributed through this network that connects the supply (producers) with the demand (clients). Considering this particularity, the consolidation centers were selected based on the available infrastructure of warehouses and collection centers at the national level according to data from ASERCA (2017). In total, 53 possible locations were located (Table 2), which have the highest storage capacities available by state.

Table 2. Selected locations.

State	Consolidation centers	Total capacity (t)
Guanajuato	10	324 000
Hidalgo	7	76 825
Mexico	9	237 662
Puebla	10	120 356
San Luis Potosí	7	73 200
Zacatecas	10	162 020

Data from ASERCA (2017).

When considering that the objective function seeks to maximize the profit of the producers, the database of the National System of Information and Market Integration (SNIIM, 2017) was consulted with the purpose of identifying the behavior of the prices of the prickly pear that are commercialized in the different demanding states. Altogether 27 potential markets were selected for the distribution of the prickly pear located in the cities of Aguascalientes, Tijuana, Campeche, Torreón, Colima, Tuxtla Gutiérrez, Mexico City, Tapachula, León, Celaya, Irapuato, Guadalajara, Morelia, Cuautla, Tepic, Monterrey, Oaxaca, Querétaro, Chetumal, Cancun, Reynosa, Jalapa, Minatitlán, Veracruz and Mérida.

In order to calculate the distance between the producers, consolidation centers and selected demand markets, the Google Matrix Distance application programming interface was used, which allows the distance between locations to be reliably obtained (Fahui and Yanqing, 2011). This tool calculates the optimal route for transport from the infrastructure of available roads, the best travel time between a set of origins and a set of destinations.

Transportation is an important component of supply chain and logistics operations since it is intended to comply with time constraints and meet customer demands on the agreed dates, avoiding delays and minimizing freight transportation costs or products. In addition, distance is another important dimension in the transport of cargo. The cost of the product transport service varies according to the distance to which the load must be transferred.

This is reasonable because the amount of fuel used depends on the distance and the amount of work is a function of distance. Tsao and Lu (2012) mention that, the greater the distance to transfer the products, the lower the cost of transportation per kilometer traveled, also explain that an easy way to calculate the cost of transportation is considering a fixed cost and a variable cost additional that must be paid per unit (kilometers) of distance traveled. However, there are other factors or components besides the fixed costs and distance traveled that must be taken into account to determine the price of the freight transport service.

For example, the Secretariat of Communications and Transportation of Mexico presented a conventional methodology to generate price indices; that is, it identified the inputs that carriers use to produce the service and establish the cost of the service (Moreno, 2014). On the other hand, Hajghasema and Abbas (2016) mention that transport costs are a main part of logistics costs, therefore, it is reflected in the final costs of the products, the authors explain that around 5% to 6% of the price of the products corresponds to transportation costs. In some products such as food, this rises up to 30%.

To calculate the logistics costs of transport in our case study, we rely on the approach of Tsao and Lu (2012) where only fixed costs are considered and an additional cost that must be paid for each kilometer traveled, besides the methodology of The Ministry of Communications and Transportation to estimate the transportation costs that were established is this study. Table 3 shows the logistic costs incurred when transporting a ton of prickly pear from a producer to a consolidation center.

Table 3. Transport logistics costs.

Load	Distance	Fixed cost	Cost x ton	Cost x km additional route (after 30 km)
1< t < 28	1 < km < 30	$0.00	$575.00	$25.00
29 < t < T	1 < km < 30	$3 500.00	$575.00	$20.00

In the case of transport logistics costs from a consolidation center to a market, only the option that adds the fixed cost of $3 500.00 was considered. For the development of this model it is also assumed that.

The production of prickly pear that is obtained in the harvest by the different producers located in the bidding states is consumed totally by the demanding markets, being considered as the only potential customers. The consolidation centers function as meeting points of the obtained harvest and likewise as temporary warehouses of the producers, so when selecting a center there will be a fixed opening cost and associated operation.

The losses associated with post-harvest handling within transport operations are considered to be minimal. In transport it is assumed that it has sufficient capacity for the transfer of the prickly pear. The transport costs of a consolidation center to a market are lower due to the possibility of using transports with greater capacity which reduces the cost per ton shipped.

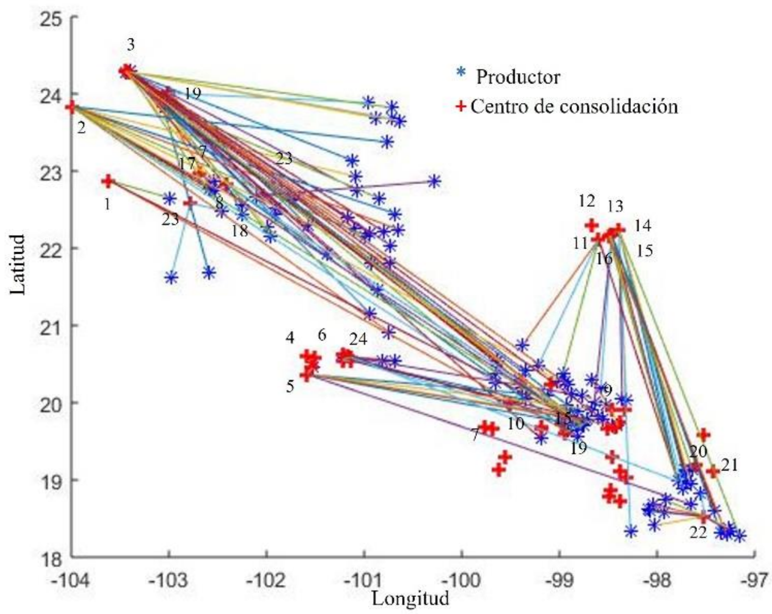
Results and discussion

To find a feasible solution, the mixed whole linear programming model was solved by coding in Matlab software using an algorithm which applies the quantitative methods of branching and boundary, cutting plane and heuristics. The programming was carried out by means of an algorithm that obtains information from databases in Microsoft Excel and later they are processed by matrix arrays. The Matlab solver used in this case was 'intlinprog' which is based on mixed whole linear programming. The proposed model considered a supply chain defined by 113 producers, 53 possible consolidation centers and 27 markets representing a total of 7 473 decision variables in their objective function.

Based on the computational results obtained, the optimal solution indicates that four consolidation centers should be used in the state of Guanajuato, which can collect 86 676 t, the state of Hidalgo and the State of Mexico should open one and two consolidation centers with a reception capacity of 61 and 43 t respectively. In the state of Puebla, San Luis Potosí and Zacatecas, one, six and ten consolidation centers must be considered for the design of the distribution network with a reception capacity of 45, 67 663 t and 162 019 t of prickly pear, respectively.

The resulting allocation of the amounts X_{ij} that are sent from the producers to the different consolidation centers indicates that approximately 50% of the total production obtained in the different bidding states must be delivered through the consolidation centers located in the state of Zacatecas in this connection, 72 producers from the bidding states of Hidalgo, State of Mexico and San Luis Potosí converge.

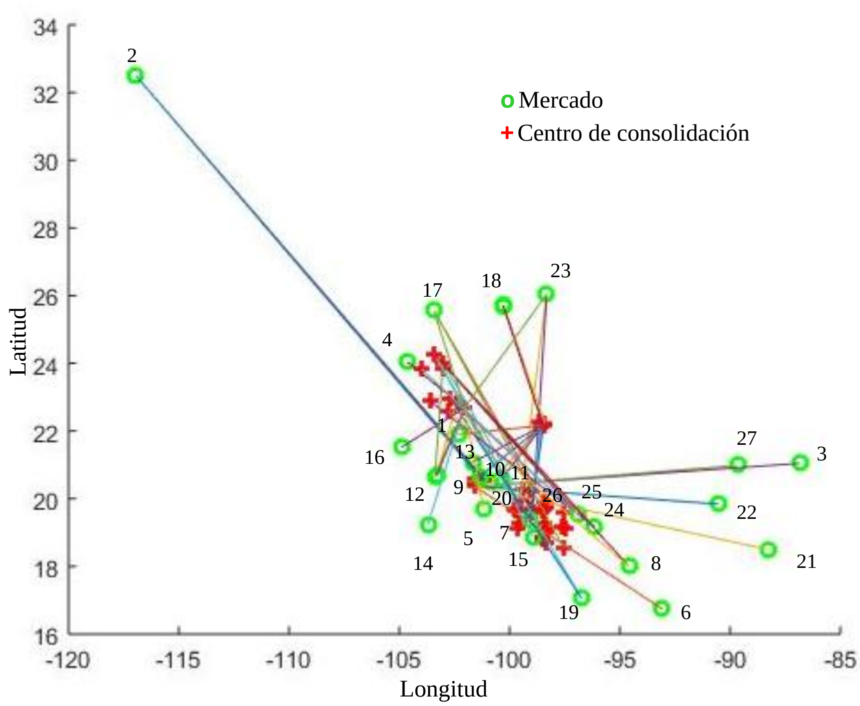
Figure 2 shows this proposed distribution network, which also considers that the producers located in Puebla send the harvest obtained; through consolidation centers located in Guanajuato and San Luis Potosí.



#	Estado	Municipio
1	Zacatecas	General F.Murguía
2	Zacatecas	Miguel Auza
3	Zacatecas	Guadalupe
4	Guanajuato	Abasolo
5	Guanajuato	Abasolo
6	Guanajuato	Abasolo
7	Zacatecas	Villa Hidalgo
8	Zacatecas	Juan Aldama
9	Hidalgo	Singuilucan
10	Zacatecas	Morelos
11	San Luis Potosí	Tamuin
12	San Luis Potosí	Ebano
13	San Luis Potosí	Ebano
14	San Luis Potosí	Tamuin
15	San Luis Potosí	Ebano
16	San Luis Potosí	Ebano
17	Zacatecas	General P. Natera
18	Zacatecas	Calera
19	Zacatecas	Sombrerete
20	México	Acolman
21	Puebla	Tlachicuca
22	México	Jilotepec
23	Zacatecas	Rio Grande
24	Guanajuato	Abasolo

Figure 2. Proposed distribution network: producers-consolidation centers.

After selecting the consolidation centers that should be used by the producers to send the harvest in order to minimize the costs associated with transportation, the model calculated the optimal allocation to the different markets that maximizes the profit for the entire chain of supply. Figure 3 shows the resulting distribution network for the connections of the selected consolidation centers and the demanding markets.



#	Ubicación
1	Aguascalientes
2	Tijuana
3	Campeche
4	Torreón
5	Colima
6	Tuxtla Gutiérrez
7	Iztapalapa
8	Tapachula
9	León
10	Celaya
11	Irapuato
12	Guadalajara
13	Guadalajara
14	Morelia
15	Cuautla
16	Tepic
17	Monterrey
18	Monterrey
19	Oaxaca
20	Querétaro
21	Chetumal
22	Cancún
23	Reynosa
24	Jalapa
25	Minatitlán
26	Veracruz
27	Mérida

Figure 3. Proposed distribution network: consolidation centers-markets.

The results in the allocation of consolidation centers to demanding markets were, for the locations in the state of Guanajuato, approximately 50 000 t must be shipped in the markets of Baja California, 19 000 t in Chiapas and the remaining production among the plaintiffs located in Yucatán, Campeche, Quintana Roo and Sonora.

For the consolidation centers located in San Luis Potosi the received production should be sent to the markets of Aguascalientes 3 115 t, 22 596 t in the markets of Guanajuato, for Nuevo León 19 166 t of prickly pear, Querétaro participates with 6 803 t and the remaining production is distributed in markets in Mexico City. In the case of Zacatecas, the selected consolidation centers send 11 244 t to Coahuila, for the markets of Mexico City 20 475 t, in Guadalajara 17 610 t of prickly pear, 17 909 t to be delivered to Michoacán, in Tamaulipas. 11 251 t, in Veracruz 21 079 t and the remaining production is sent to the markets located in Colima, Morelos, Chihuahua and Nayarit.

The results indicate that of the 53 possible consolidation centers it is only necessary to use 24 of these to optimize the distribution network, which represents a saving in operating costs, it was also considered that the State of Zacatecas is a strategic location to connect the demand with the supply of prickly pear.

The markets furthest away from the places where they are harvested, represent points of high demand and therefore of greater gain, in the proposed model these locations are a priority for the design of the network; however, because the consolidation centers selected in this study are located in the states where the prickly pear is harvested, the costs associated with transportation are considerably higher in those distant markets such as Baja California or Quintana Roo. The results of this study suggest centralizing production in the states with the largest area available for sowing, so that through these the prickly pear is distributed to the different markets in the country.

Conclusions

Through the proposed model, a distribution network was defined that considered the costs associated with transportation between producer locations, consolidation centers and markets. With this proposal, it is possible to identify the optimal allocation that maximizes the profit for the entire supply chain. The ideal locations according to the obtained results allow to connect the supply with the demand with a strategy of consolidation centers.

The state of Zacatecas represents a key location to ensure supply in the central and northern regions of the country, since at this point at least 50% of the crop obtained from the different producers selected in this study converge. In most cases, the capacities of the consolidation centers in the model are covered at 100%; however, as future works, restrictions can be defined on the inventory levels they receive from different producers in order to evaluate other possible locations that improve the solution obtained. With this strategy, the consolidation of other agri-food products that can be distributed through the proposed network could also be considered.

It is suggested to include within the optimization model restrictions focused on the decay of quality, aspects such as maintaining the temperature and physical appearance of agri-food products are key characteristics that should be considered to improve the modeling and design of the network.

Acknowledgments

The authors express their gratitude to the Higher School of Ciudad Sahagun of the Autonomous University of the State of Hidalgo and the Popular Autonomous University of the State of Puebla, as well as to PRODEP for the support granted to carry out this study.

Cited literature

Agustina, D.; Lee, C. K. M. and Piplani, R. 2014. Vehicle scheduling and routing at a cross docking center for food supply chains. Int. J. Produc. Econ. 152:29-41.

ASERCA. 2017. Agencia de Servicios a la Comercialización y Desarrollo de Mercados Agropecuarios. Padrón Nacional de Centros de Acopio. http://www.aserca.gob.mx /comercializacion/acopio.

Ayllon, B. J.; Omaña, S. J.; Sangerman, J. D.; Garza, B. L.; Quintero, R. J. y González, R. F. 2015. Modelo de transporte en México para la minimización de costos de distribución de tuna (*Opuntia* spp.) en fresco. Rev. Mex. Cienc. Agríc. 6(7):1615-1628.

Badole, C. M.; Jain, R.; Rathore, A. P. S. and Nepal, B. 2012. Research and opportunities in supply chain modeling. A review. Int. J. Sup. Chain. Mgt. 1(3):63-86.

Barrera, J.; Aguilar, Z, A.; Ortiz, B, O. y García, L. L. 2011. Producción y comercialización de tuna en fresco bajo diferentes modalidades en Hidalgo, México. Rev. Mex. Agron. 15(38):605-614.

Fahui, W. and Yanqing, X. 2011. Estimating O-D travel time matrix by Google Maps API. implementation, advantages, and implications. Ann. GIS. 17(1):199-209.

Ghaffari, N. N.; Ghazanfari, M. and Teimoury, E. 2015. Hub-and-spoke logistics network design for third party logistics service providers. Inter. J. Manag. Sci. Eng. Manag. 11(1):49-61.

Granillo, M. R.; Olivares, B. E.; Martínez, F. J. L. y Caballero, M. S. O. 2017. Gestión de operaciones en una cadena de suministro agroalimentaria. Ciencias Holguin. 23(4):1-17.

Hajghasema, M. and Abbas, A. 2016. Optimal routing in supply chain aimed at minimizing vehicle cost and supply. Procedia Econ. Finance. 36:353-362.

Hamidi, M.; Gholamian, M. and Shahanaghi, K. 2014. Developing prevention reliability in hub location models. Proceedings of the Institution of Mechanical Engineers. Part O. J. Risk Reliability. 228(4):337-346.

Kreng, V. and Chen, F. 2008. The benefits of a cross-docking delivery strategy: a supply chain collaboration approach. Production Planning and Control. 19:229-241.

Küçükoğlu, I. y Öztürk, N. 2017. Two-stage optimisation method for material flow and allocation management in cross-docking networks. Inter. J. Produc. Res. 55(2):410-429.

México Produce. 2016. México Produce. http://www.mexicoproduce.mx/2016/10/el-nopal-y-tuna.html.

Moreno, Q. E. 2014. Índices de precios en el transporte por carretera. Instituto Mexicano del Transporte. Secretaría de Comunicaciones y Transporte.

Pinedo, E. J; Franco, B. A. y Hernández, F. A. 2010. Comportamiento poscosecha de cultivares de tuna por efecto del manejo del huerto y temperatura de frigo conservación. Rev. Iberoam. Tecnol. Postcosecha. 11(1):43-58.

Ramírez, A, O.; Figueroa, H. E. y Espinosa, T. L. 2015. Análisis de rentabilidad de la tuna en los municipios de Nopaltepec y Axapusco, Estado de México. Rev. Mex. Agron. 19(36):1199-1210.

Reina, U. M. y Cortés, A. F. 2015. Selección de una estructura de red logística de distribución para el programa mercados campesinos usando técnicas de toma de decisiones multicriterio. Rev. Cienc. Estratégicas. 23(33):89-108.

Sanabria, A. L.; Peralta, L. A. M. y Orjuela, J. A. 2017. Modelos de localización para cadenas agroalimentarias perecederas: una revisión al estado del arte. Ingeniería. 22(1):23-45.

SIAP. 2017. Servicios de Información Agroalimentaria y Pesquera. Cierre de la producción agrícola, cultivo de tuna. http://nube.siap.gob.mx/cierre_agricola/.

SNIIM. 2017. Sistema Nacional de Información e Integración de Mercados. Precios de mercados nacionales, frutas y hortalizas. http://www.economia-sniim.gob.mx/nuevo/.

Tsao, Y. C. and Lu, J. C. 2012. A supply chain network design considering transportation cost discounts. Transportation Research Part E. Logistics and Transportation Review. 48(2):401-414.

Vasiljevic, D.; Stepanovic, M. and Manojlovic, O. 2013. Cross docking implementation in distribution of food products. Econ. Agric. 60(1):91-101.