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Location selection of dry port based on AP clustering - the case of southwest China

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Abstract: Due to the increasing freight volumes passing via seaports checkpoints, and increasingly reported delays in customs clearance procedure, dry port, emerged as one kind of solution to such situation, instead of extending the port scale under limited land use. The place located with dry port (sometimes inland port) can solve not only the congestion embarrassment faced by connected seaport, but also can improve economic development of the hinterland by integrating the logistics network and ameliorating the access between dry port and seaport. Hence, the location planning of dry port has been a pivot in this research field. In this paper, AP (Affinity Propagation) Clustering method is proposed to solve this location problem of dry port (number and location), and it is applied in a case study which is to select the optimal dry port location for Shanghai port from its 8 hinterland provinces. And the result that Hunan province is chosen to be the optimal dry port construction location is being proved credible with AP Clustering method in this paper.

Keywords: Location, Dry Port, AP Clustering Method, Shanghai Port

1. Introduction

Along with the increasing size and capacity of container vessels, seaports have been reported facing drastic problems of inability to handle import and export containers in an regular rate, which would definitely result in the congestion and delay of lorries and other kinds of haulage vehicles at the finite seaport terminal space (Woxenius et al., 2004), and influence shippers' transportation cost indirectly, and lots of other chain reactions, like inhibiting the ports' productivity due to less and less ships' calling at it, and the invisible but great carbon dioxide emission produced from those blocks, and road accidents due to drivers' boring and tired morale about congestion, etc. One solution to this problem is expanding the physical port area (McCalla, 1999). However, sea ports are among the most space extensive consumers of land in metropolitan areas (Jaržemskis & Vasiliauskas, 2007) which means such kind of expansion will occur at the cost of expensive land occupation, and even without promising benefit from it (Pellegram, 2001). What's more, the solution can't help resolve the environmental effect brought by the whole transportation in supply chain, from the origin of cargos, through inland access routes, to destinations, especially in the environmental friendly years. As a result, to ameliorate such situation, attention has to be paid on the hinterland, and then dry port is approached.

In this paper, a literature review about kinds of characteristics of dry port is illustrated including definition discrepancy, and functions of dry port. And then the location selection method is followed as the third part, describing methods used before and the AP clustering location method applied in this paper. In the fourth part, a case study is offered with real-value data to choose dry port for Shanghai port based on the AP clustering method. Finally are conclusions which are calculated out with Hunan province as the optimal dry port location within the hinterland of Shanghai port.

2. Dry Port Concept

2.1 Terminologies

Among those amount of definitions of dry port, the most used one is conducted by Woxenius (2004) that the dry port concept is based on a seaport directly connected by rail with inland intermodal terminals, where consignees (called shippers in this paper) can leave and/or collect their goods in intermodal loading units as if directly at the seaport. The term "dry" is subject to contention of excluding inland terminals serviced by barges. However, Roso (2007) stresses that the inland access between the dry port and seaport is not necessarily made of rail, high capacity of traffic mode like barge is also a feasible alternative. Rodrigue et al. (2010) suggest the term inland port is more appropriate than dry port since it considers terminal activities as well as the crucial logistics activities taking place in co-location or in proximity of inland terminals.

In this paper, dry port definition is adopted.

Table 1: Discrepancies among several definitions

	Definitions
Inland Container Depot	A common user facility with public authority status, equipped with fixed installations and offering services for handling and temporary storage of import/export stuffed and empty containers.
Inland Freight Station	An inland freight station is nothing more than a railroad owned warehouse type structure set away from the piers or offline terminals for storage of freight. They were used to relieve congestion at the waterfront piers and offline terminals.
Intermodal Freight Center	A terminal specialized in the handling operations for the HfreightH transportation in an Hintermodal containerH or HvehicleH, using multiple modes of HtransportationH (HrailH, HshipH, and HtruckH), without any handling of the freight itself when changing modes.
Inland Clearance Depot	A place approved by HM Revenue & Customs to which goods imported in containers/vehicles may be removed for entry, examination and clearance, and at which goods intended for export in container/vehicles may be made available for export control.
Integrated Logistics Multi-Zone	A place where kinds of logistics activities of different transport modes converge, including not only the logistics facilities, but also with those logistics companies which can offer lots of service function sit within a centralized area.
Inland/Dry Port	An extended gateway of the seaport, with shippers viewing the dry port as an interface to the seaport and shipping lines, as a result, shippers can leave and/or collect their goods in intermodal loading units as if directly at the seaport

Table 2: Discrepancies of similar terminology in details

Category	Facilities	Functions	Purpose
Inland Container Depot	Container handling facilities	Storage and offering container	To centralize container in one location effectively and safely to make the obtainment and repair of container is possible and convenient.
Inland Freight Station	Cargos handling facilities	Consolidation and deconsolidation, cargos distribution, integration, etc	To relieve congestion and offer storage besides usual functions, which is to help complete the freight delivery process according to clients' requirements.
Intermodal Freight Center	Container handling facilities	Transshipment between different traffic modes	To supplement the transshipment service cargos need in different transport areas in order to arrive the destinations.
Inland Clearance Depot	Container and cargos handling facilities	Clearance, storage, etc	To handle cargos in the process of import and export under customers' control.
Integrated Logistics Multi-Zone	Facilities related to all the logistics activities	All kinds of logistics activities	To integrate and optimize local logistics network through improving the operation efficiency in the logistics park.

Inland/Dry Port	Container and cargos handling facilities	Integration, transshipment, temporary storage, consolidation and distribution, customers clearance, etc	To relieve connected seaport's pressure of overcapacity of freight and space limitation, to improve the inland-port access, to help develop local region's trade economy, and to reduce contaminated emissions and accidents from road transport and congestion

2.2 Functions

2.2.1 Advantages

As the effects of dry ports, besides obviously relieving seaport congestion or improving seaport inland access, the idea that improving seaport productivity also constitutes a significant component in the implementation of the dry port is proposed by Roso (2008), because a high efficiently operated seaport without congestion and delay will definitely attract more vessels to call at. In addition, from an environmental prospective, Roso (2007) has proved that the city with the dry port implementation is 25% lower in carbon dioxide emission than the city without, while congestion and truck waiting at the terminal are significantly reduced. In the inter-modal transport system with dry port as the inland intermodal terminal, the whole transportation cost can be drastically saved, from the prospective of scale effect of integration process of large volume of goods. The transshipment from road to rail would not only reduce transportation cost, but also cut down the pollution emission and accidents from multiple road vehicles. Comparing to the conventional transport, the new system with dry port can eliminate or reduce empty containers movements (Dadvar and Ganji, 2010), due to empty container storage in both of the dry port and its connected seaport terminal.

2.2.2 Shortcomings

Despite those important roles dry port takes in transport network, the terminal sometimes impede the development of intermodal transport with additional transhipment costs at road-rail terminals or due to a shippers' lack of freedom to choose transport mode once their business are moved to trans-modal freight centre (Woxenius, 1997), which means the origin customer has no option to lower transportation cost and do other things flexibly, besides driving to the seaport by itself. Furthermore, because the process of customer clearance has been advanced than traditional transportation, cargos related insurance and other fees change accordingly, which may not always bring benefit to customer.

2.2.3 Implementation Impediments

The dry ports emerge in a variety of geographical settings, and are serving a variety of functions and involve a variety of actors (Rodrigue, 2010), composing public authorities and private institutions, like rail/road operators, terminal operators, freight forward, etc. Different actors have different interests toward the co-operating terminal, dry port (Roso, 2008), in which, public side expect the fundamental effects realized by dry ports, including relieving seaport pressure, reducing contaminated emissions, improving hinterland development, etc; In this way, the planning strategies of different sides will not come in a line successfully, which results in the impediments of implementation of dry ports. Roso (2008) indicates fours factors' inhibiting the dry port's being put into operation, regulations, environment, land use, and infrastructure. Dadvar (2010) points out the dry port implementation challenges and impediments exist as the inconsistency among several different but exactly related sectors and organizations, interfering of benefits of different parts of transportation chain, unable and inappropriate infrastructures to achieve inter-modal transportation needs, etc. In order to realize the dry port's effect to the greatest, multiple sides' co-effort is very much necessary.

3. Methodology

3.1 Location Selection Methods Review

Location selection is always being one of the hot topics within the dry port construction area, among which the literatures applying methods of fuzzy system take the majority. For instance, Zhong et al. (2008) used a fuzzy c-means clustering algorithm to find suitable cities for Dalian port among 34 inland hinterland areas as candidate dry port location. Hua (2005) developed a Multiple-Attribute Decision Making (MADM) method based on the TOPSIS dedicated to change fuzzy data into crisp data for selecting the most acceptable inland port sites among a set of candidate sites under multiple potentially conflicting objectives in a group decision-making environment and then the inland port selection from a investment perspective is considered with solution method of the Multiple-Objective Decision Making (MODM) method, Fuzzy Factor Rating System and Fuzzy Logic(Ou and Chou, 2009; Kuo et al.， 2009) are also proposed to locate international distribution center. Besides, many other methods are also used to solve the location problem of inland multi-modal terminal, such as ANP (Lu and Li, 2009), P-median in use of changing network (Daniel and Vladimir, 1998). A fuzzy multi- objective model is developed to optimize fire station location through genetic algorithm (Yang et al., 2007). Above all, the spatial location problem of facility can be divided into discrete (Multi-dimension Logit), concrete, and network model. Most of them are designed to solve planning problem with multi-objective under limited resources.

3.2 AP Clustering Approach

In order to solve the large scale location problem in a tolerable time and get the optimal output from the whole base, clustering analysis is offered to be an effective tool to do this kind of analysis, which is also widely used to do pattern discerning, data mining, text processing, voice processing, biology information and image processing, and so on.

Because of its simplicity, general applicability, and performance, affinity propagation proves to be of broad value in science and engineering. Affinity propagation clustering algorithm is used to solve large scale location problem by Tang, et al. (2010). AP clustering is also proved to be more effective and accurate than k-means clustering and other clustering methods, and helpful in saving operation time as well (Dueck et al., 2007).

3.3 AP Clustering Model

Input N Data Points as The Origin Decision Matrix X:

Data point XBi Bis expressed as an n-dimension vector, like XBiB= (xB1B, xB2B, xB3B......xBnB), i = 1, 2.... N, in which xBiB means the value and quality one candidate location of dry port gets under influencing factor i.

Matrix Normalization:

X: Decision matrix;

xBijB: Numerical outcome of the iPthP alternative with respect to the jPthP criterion;

xP*PBj B: The maximal value across all alternatives;

x PminP BjB : The minimal value across all alternatives;

rBijB : Normalized numerical outcome of the iPth Palternative with respect to the jPthP Criterion;

$$r_{ij} = \frac{x_{ij} - x^{\min}{}_j}{x^*{}_j - x^{\min}{}_j} \quad (1)$$

- Criteria Weight Calculation:

wBjB is computed by the entropy measures (Hua, 2005) designed to construct reliable criteria weights.

$$e_j = -k\sum_{i=1}^{|I|} r_{ij} \ln r_{ij} \tag{2}$$

$$k = 1/\ln|I| \tag{3}$$

$$d_j = 1 - e_j \tag{4}$$

$$w_j = \frac{d_j}{\sum_{k=1}^{n} d_k} \tag{5}$$

- Input N×N similarity matrix S for N Data Points Based on The Criterion Weights:

$$R_{ij} = \left[w_j * r_{ij}\right] \tag{6}$$

The similarity of the pair data point i and j are measured by the Euclidean distance, S(i, j) = −||RBiB − RBjB||P2P, i, j = 1, 2......N, and i ≠ j. Then the N×N similarity matrix S are constituted with elements S(i, j), and in the diagonal of similarity matrix S lies with the preferences P(i), i = 1, 2....N, (its initial value is negative) which indicates the preference that data point i be chosen as a cluster center, and influences output clusters and the number of clusters (NC).

- Responsibility R(i,k) and Availability A(i,k):

"Responsibility" R(i, k) represents how well-suited for point k to serve as the exemplar for point i;

"Availability" A(i, k) represents how appropriate for point i to choose point k as its exemplar;

Larger the R(:,k)+A (:,k), more probability the point k as a final cluster center.

Formula of AP Clustering Algorithm:

R(i,k) = S(i,k)–max{A(i,j)+S(i,j)}, where j∈{1,2,…,N} but j≠k;

A(i,k) = min{0, R(k,k)+sum{max(0,R(j,k))}}, where j∈{1,2,…,N} but j≠i and j≠k;

P appears in R(k,k)=P(k)–max{A(k,j)+S(k,j)}, the number of identified clusters is increased or decreased by adjusting P correspondingly, and usually a good choice is to set all the P(i) to be the median (pm) of all the similarities between data points;

RBiB = (1-lam) ×RBiB + lam×RBi-1B, ABiB = (1-lam) ×ABiB + lam×ABi-1B, where damping factor lam∈ [0, 1] and default lam=0.5 (Frey B J, Dueck D, 2007). AP clustering searches for clusters through an iterative process. In each iterative step i, R and A are updated with the one in last iteration. Based on evidence accumulation, the iterative process moves on until a high-quality set of exemplars and corresponding clusters emerge.

Objective Function:

Max Netsim = Dpsim+Expref

Where Netsim means the total similarity of the network; Dpsim indicates the total similarity sum of an exemplar received from its attracting data points; and Expref denotes the preference of a data point to be a exemplar.

4. Case Study

4.1 Description of the Case

Shanghai port, being in the construction of international shipping center, becomes the economic support for its hinterland areas, most import and export freight volumes of which are completed through Shanghai port. In 2010, Shanghai port overtook Singapore port to become the world's busiest container port with handling 29.05 million TEUs. Since the Port of Shanghai is a critically important transport hub for the Yangtze River region and the most important gateway for foreign trade serving the Yangtze economically developed hinterland of Anhui, Jiangsu, Jiangxi and Hubei provinces with its dense population, strong industrial base and developed agricultural sector. Since these places sit within the hinterland areas of south China, together with the natural condition of craggy topography, they always develop behind of other harbor cities for worse transportation connection with outside world, which impede their economic development seriously. This paper focuses on these inland cities of Shanghai port for their being negligence by former researchers, and also by the necessity and possibility they have to be deployed as dry ports to optimize the whole transport condition.

Therefore, the candidate sites are chosen as 8 provinces in southern China, i.e. Sichuan, Chongqing, Hubei, Hunan, Anhui, Jiangxi, Jiangsu, and Shanghai. Seven factors group is adopted in this paper, they are:

X1: GRP (Gross Regional Production) per capita;

X2: total import and export value;

X3: investment in fixed assets about transport;

X4: freight traffic volume (freight volume summed by rail, water, high-way);

X5: traffic radiation (route length summed by rail, water, high-way);

X6: environment protection intention (project completed number of treating industrial pollution);

X7: policy-oriented coefficient (the proportion of combination of transport fixed asset investment and industrial pollution treatment in the total government expenditure).

In this paper, a typical AP clustering algorithm together with reliable criteria weights measurement (the Entropy Measures) is applied to the dry port location selection problem with real-value data obtained from the China Statistical Yearbook 2009.

4.2 Case Analysis

The application program is operated with Matlab software, and the relative input and output data are given as below.

Table 4: Decision Matrix

Provinces	X1 (10000 RMB)	X2 (10000 USD)	X3 (100 million RMB)	X4 (10000 tons)	X5 (km)	X6 (unit)	X7 (%)
Sichuan	15367.72	2211365	628.5	114719	238208.1	540	22.1
Chongqing	17952.31	952139	449.2	63763	114140.5	170	23.4
Hunan	17486.90	1254719	513.4	116145	198957.8	375	18.1
Hubei	19839.57	2070567	538.6	71900	199258	345	18.5
Jiangxi	14728.02	1361793	255.1	80932	142103.5	223	13.8
Anhui	14464.82	2018385	346.1	180169	157274	158	14.4
Shanghai	72553.76	32205531	783.3	84400	14039.1	230	28.5
Jiangsu	39484.97	39227193	730.4	139711	166183	761	10.7

Table 5: Calculation Results

Number	1	2	3	4	5	6	7	8
Province	Sichuan	Chongqing	Hunan	Hubei	Jiangxi	Anhui	Shanghai	Jiangsu
Idx	3	3	3	3	3	3	7	8

Figure 6: Map with dry port location

Calculation results show that three dry ports need to be constructed. Hunan becomes the optimal choose to build dry port for its adjacent cities, which is just accordant to real planning of Hunan province, in which "Qizhou" city is being under dry port construction. Hence, the method used in this paper is proved to be valid and credible. For Jiangsu, according to this result, a direct connection with Shanghai seaport is more efficient than transshipment through other locations, which also is Shanghai seaport is more efficient than transshipment through other locations, which also is in line with the real administrative plan.

In addition, sensitive analysis in one alternative with one factor change has been done to this result. When the factors of traffic volume and route length decrease to 50%, respectively, the optimal selection goes to Hubei province. When the same change happens to other factors, result comes out to add a dry port location in Jiangxi Province.

However, this method is lack of consideration about the roundabout route between origin and destination place, because the relative distance in geography among those candidate cities cannot be efficiently quantified into the calculation. About this, manual revision on the basis of computed result is necessary. For example, freight from Anhui province can go to Shanghai port directly without transshipment through Hunan province as described above.

Besides, we find the recommended location computed by AP Clustering is not always the one exactly with kinds of optimal condition. For instance, in this paper Hubei province is considered as the best choice for dry port construction, because it is dominant in most of the criteria value, but instead Hunan province is suggested. Discussion on this difference proves that AP Clustering method is not designed to point out the best one, but the one can represent the rest. And this makes sense in the prospective of economic development, government needs to coordinate different situation, rather than increase the gap between strong and poor cities. As a result, dry port construction can be a measure to help city with proper conditions to improve, which is even not the best. In this case, AP clustering method can still give us fresh ideas when facing large amounts of candidates.

In order to compensate the comparison evaluation, fuzzy C-clustering method has been applied. In given condition, similar results are gotten: the later method picks up Shanghai and Suzhou province as their respective exemplar, and classifies other provinces in one cluster. Since the candidates number studied in this paper is small, difference between such two methods are not that large.

5. Conclusions

In this paper, we disregard the administrative impediments from different participants with conflicts of interest, and the priority of this paper would be offering a comprehensive analysis for the chosen southern cities to construct dry ports in an extensive range, mainly from a perspective of public benefit rather than the commercial profit. The Affinity Propagation (AP) Clustering method presented together with the entropy measures proves to be a creative and credible method to solve location selection problem, as the results of this paper conforms to the real situation of dry port construction. In addition, other summaries referred in this paper can also offer decision support for relative parts as well as appropriate supervision and urge of dry port implementation.

Except the location selection research of dry port, to work in a systematic and sustainable way, deep investigation is still needed in its development process, such as public regulation, cooperation of public and private sectors, legal and financial framework, operative manners, impact to relative industry, logistics and supply chain optimization, seaport selection, influencing factors and sensitive analysis, etc.

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