Evaluation of High-speed Railway Construction Priority in B&R Area Based on Bilateral Trade and International Cooperation

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Abstract

Since December 2013 when the Chinese government has made the Silk Road Economic Belt and the 21st-Century Maritime Silk Road (the Belt and Road initiative, B&R) major decision, some policies about B&R, developing directions and steps are emerging in an endless stream. Based on the bilateral trade volume, national stability and international cooperation index, the B&R high-speed railway priority construction model (HSRC) is put forward in this paper. In order to improve the efficiency, a parallel ant colony algorithm is introduced to calculate the partial betweenness index of international logistics transportation network. This paper also introduces the trade share amount index of road section based on international trade to depict the importance degree of each section in the traffic network, and finally calculates the priority construction index of each road section. Results show that 23 sections in B&R area have priority conditions to build high-speed railway in current situation. Compared the evaluation results with projects under construction or to be put into construction in B&R area, we find that road sections and cities covered by these high-speed railway projects have a great coincidence which demonstrates the accuracy of HSRC Model and corresponding algorithm from the empirical aspect.

Keywords

The Belt and Road initiative, high-speed railway construction priority, bilateral trade volume, international cooperation, partial betweenness.

1. Introduction

In December of 2013, the Chinese government has made a "speed up the construction of infrastructure interconnectivity with neighboring countries and regions, to promote the silk road economic belt, maritime silk road construction, and form a new pattern of all round opening" big decisions, this is the famous the Belt and Road initiative (B&R). In the increasingly fierce international competition situation, if dealing with external pressures through a new model of regional cooperation (such as TPP and TTIP), Chinese will bring new opportunities for their own development. The implementation of the Belt and Road initiative, build a full range of foreign development pattern and international cooperation in the new framework, through more effective foreign policy, not only can promote the economic development of the country, but also is of great significance in the construction of infrastructure to neighboring countries, energy cooperation and other aspects of the real economy. Traffic transportation is the main power which can shape and lead the economic space pattern, and the construction process of transportation system is the prerequisite and significant foundation of carrying out B&R strategy. Although it comes to an agreement on constructing high-speed railway in B&R area at present [1][2], because of the limit of several factors the railway's construction must follow the gradual principle. That is to say, we should construct the most important and nuclear line at first, and then to confirm the next project of construction according to the development of new situation [3][4].

Based on the above ideas about current situation of road infrastructure construction, national stability, national cooperation between countries and the types, and levels of import and export trade volume,

this paper proposes a high-speed railway section model -HSRC model in B&R area according to literature. In order to quickly evaluate each section a high-speed railway construction order optimization algorithm (HSRCO^{2}A) based on parallel ant colony optimization algorithm is introduced in this article. In the logistics transportation network defined by many hub cities in B&R area, this algorithm gives full consideration of import and export logistics cost factor and combines with the characteristics of countries or regions. After obtaining the shortest paths from domestic hub cities in China to hub cities in Asia, Europe and Africa using parallel ant colony optimization algorithm, the proposed HSRCO2A algorithm would figure out the partial betweennesses of all hub city vertexes and road sections in B&R area by adding up the number of times they are passed by all shortest paths. Finally, the algorithm is used to calculate the priority construction of the road sections between the hub cities and then determine the priority order of high-speed railway construction.

2. HSRC Model

To be clear, one of the most important intentions of Chinese government putting forward the Belt and Road initiative lies in its high-speed railway technology output. During the rapid development times of international exchange and international trade, constructing long high-speed railway with more than 350 kilometers per hour has becoming the first choice in improving logistics efficiency and reducing logistics costs. Moreover, if Chinese government brings together closely with most Eurasian and African countries and regions, integrates these countries and regions as a world class super economic union through technical cooperation, trade and non-governmental exchanges, it will be not only China's important contribution to promoting stability, regional cooperation and regional development area, but also an important contribution to the world economy and stability. The Belt and Road Initiative is a relatively new concept. Many scholars have finished some researches of high-speed railway construction and management from the policy level in the B&R area but few people carry on the thorough theoretical analysis from the data level. The transportation infrastructure of railways and highways is the most critical factor during the construction of B&R. However, it is more difficult to mobilize funds enthusiasm. The type of logistics transportation from China to Europe and African countries/regions is by land in most cases especially when transporting steel, coal, oil and other bulk materials. So, evaluating of high speed rail priority construction in B&R area to ensure smooth development of B&R area is very useful for countries and regions along the lines. Based on the above thoughts, in order to evaluate the feasibility and urgency of the construction of high-speed railway among cities in B&R area, this paper constructs a high-speed railway construction model: HSRC model. This model considers not only the physical characteristics of the logistics network, such as road length, travel time of road section, but also the external environment characteristics of the logistics network such as national stability, the level of cooperation among countries, and the volume of trade import and export undertaken by some certain road section. The purpose of constructing the HSRC model is to study the characteristics of each road section of the logistics network and each hub city from several aspects, which is the significance of constructing the HSRC model. For convenience sake, several concepts are defined below.

Definition 1 Transportation network of B&R Refers to the logistics transportation network which consists of many hub cities and highway/ railway roads within the range of B&R area, defined as graph G.

Define G= (N, L), symbol N is the set of nodes representing all hub cities and symbol n is the number of nodes. Suppose that all roads are bidirectional and symbol L is the set of all road sections in B&R area, l is the number of road sections. The symbol di represents China domestic city node and symbol oj represents foreign city node in B&R area excluding China. According to the actual needs of this article, the node set N is divided into two subsets D and A, which represent the set of domestic urban nodes and the set of foreign urban nodes respectively. And we define $D = \{d_i | i = 1,2, \dots, C_1\}$, $A = \{a_j | j = 1,2, \dots, C_2\}$, where C1 and C2 represent the number of domestic cities and foreign cities respectively and C1+C2=n. Define $G_D = (D, L')$ where $L' = \{< i', j' > | i', j' \in D\}$ and $G_A = (A, L'')$ where $L'' = \{< i'', j'' > | i'', j'' \in A\}$. Symbol GD is a subgraph of G which consists of node set D and road section set L', symbol

GA is also a subgraph of G which consists of node set A and road section set L''. Obviously we have $G_D \subset G, G_A \subset G$ and $G_D \cup G_A \subset G$.

Definition 2 Country comprehensive cooperation index (CC) Refers to the level or depth of cooperation between China and countries or regions along the B&R.

Parameter CCk represents the kth country cooperation index with China which is related to the country cooperation evaluation index ce, country non-stability index ns and the volume of import / export between China and country k ie. Country cooperation evaluation index ce is positively correlated with five factors between China and country k as: policy communication degree pcd, infrastructure connectivity degree icd, trade unimpeded degree tud, fund flow degree ffd and popular sentiment degree psd, which are positively correlated with volume of import and export too. Define a country's national instability index $ns^k \in [0,1]$ .The greater the value is, the more unstable the country is. Based on the above parameters, we define

$$CC^k = (1 - ns^k)(\varphi_1 ce^k + \varphi_2 ie^k) \quad (1)$$

In equation (1), we have $ce^k = f(pcd^k, icd^k, tud^k, ffd^k, psd^k)$, where $f(\cdot)$ is the function of country cooperation evaluation index ce. Obviously, the higher the country cooperation evaluation index, the more stable the political situation of the country, the greater the value of import and export with China and the higher the country's comprehensive cooperation index with China, or vice versa. As the index ranges are diverse from each other, it is needed for normalization when calculated. The national instability indexes are shown in Table 1. When calculating the national instability index for each country in B&R region, it is necessary to comprehensively consider and accumulate the corresponding values of various unstable factors, and then normalize them. For a stable country k, we define $ns^k = 0$.

Definition 3 Weighted logistics time of road section. Refers to the logistics time between two adjacent nodes in B&R region. The weighted logistics time comes from the traditional travel time, taking into account the transport mode, the country's comprehensive cooperation index and the length of the road and other factors. When $\forall d_i \in D$ and $\forall a_j \in A$, if $< i, j > \in L$, the weighted logistics time of road section <i,j> is defined as

$$t'_{ij} = \tau(1 - CC_j^{kj})t_{ij} \quad (2)$$

In formula (2), t_{ij} is even travel time of road section <i,j> under current transportation mode, $\tau > 0$ is an adjustable parameter, and CC_j^{kj} is the comprehensive cooperation index of country kj. If two city hubs are from outside China, that is to say, when $\forall a_i \in A, \forall a_j \in A$,if $< i, j > \in L$, the weighted logistics time of road section <i,j> is defined as formula (3) below.

$$t'_{ij} = \tau(1 - \frac{cc_i^{ki} + cc_j^{kj}}{2})t_{ij} \quad (3)$$

In formula (3), both city hubs a_i and a_j are not come from China. Using the theory of complex network and link prediction mechanism [5][6], according to the known network structure we can predict the unknown relationship between nodes. Based on the above theories, we believe that the possibility of cooperation among cities in countries with good relations with China is also greater considering China's strong leadership in B&R area. Accordingly, if use the mean value of the two countries' comprehensive cooperation index with China as the two countries' comprehensive cooperation index, we may obtain the weighted logistics time of road section <i,j>.

Definition 4 Optimal path in Logistics transportation. Here refers to the logistics and transportation optimal paths between the hub cities in China and the country's key cities in B&R area. When $\forall d_i \in D$ and $\forall a_j \in A$, we define the symbol LOPij as the optimal path of road section <i,j>. The optimal path in logistics transportation is calculated by weighted logistics time of road sections. It is generally known that there are so multiple feasible paths between two city hubs in different countries or regions that we need to choose the best path among them. Based on the above, we may define the shortest logistics transportation time as $\text{Min } T_{ij} = \sum_{m=0}^{M-1} t'_{q_m q_{m+1}}$, where q0=i , qM=j, vertexes q1 till qM-1 are intermediate nodes and M>0 is the number of road sections in optimal path LOPij.

Definition 5 Partial betweenness (pb). Includes partial vertex betweenness and partial edge betweenness, means the number of times that each city node (vertex) or each road section (edge) is passed by all optimal paths, named pbv(partial betweenness of vertex) and pbe(partial betweenness of edge). The term betweenness comes from the field of complex networks which reflects the importance of nodes or edges in the whole network topology[1] . In this article partial betweenness (pb) is redefined because of our specific structure of graph G: the former is obtained by considering all shortest paths of every vertex, whereas the latter is calculated by considering all shortest paths of every vertex from sub-graph GD to every vertex from sub-graph GA and not including the shortest paths within Sub-graph GD or GA. The larger the value of the parameter pb, the more important the vertex or edge. From the point of view of the construction of high-speed railway, those road sections determined by high-scoring regional transportation hubs and logistics road sections may be more suitable for beginning high-speed railway construction as soon as possible in order to promote the rapid development of B&R.

Definition 6 Trade share amount of road section (ts). In the course of import and export trade with China, the logistics cost is allocated to the road section according to the length of the road section. As shown in Fig. 1, when $n_i, n_j \in N, < i,j > \in L$, there are several Chinese domestic city hubs in the right dashed frame and several city hubs of other countries or regions in B&R area. Suppose there are P optimal routes named Route1 until RouteP through road section <i,j>. Define the logistics cost of optimal path p equal as lcp, the length of the road as llp,$p \in [1,2,\dots,P]$, and dij is the real length of road section <i,j>, then we may calculate the trade share amount of road section <i,j> as

$$ts_{ij} = d_{ij} \cdot \sum_{p=1}^{P} \frac{lc_p}{ll_p} \tag{4}$$

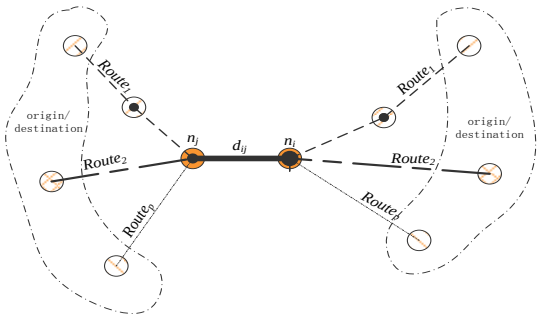

Fig. 1 Diagram of trade share amount of road section <i,j>

To a certain extent, the trade volume explains the importance of the road section in the whole logistics transportation network. Formula (4) indicates that the more the number of optimal lines is, the higher the cost (lcp/llp) of the optimal line itself bears, and the road section would be more likely to play an important role in the constructing process of B&R infrastructure.

Definition 7 Importance of road section (si). It means the importance of one certain road section <i,j> in B&R area during the process of import and export trade. This index is closely related to the partial betweenness of road section <i,j>, the partial betweenness of vertex i and j, and the trade share amount of road section <i,j>. When $n_i, n_j \in N, < i,j > \in L$, the importance of road section is defined as

$$si_{i,j} = \beta_1 pbe(i,j) + \beta_2 (avg(pbv_i, pbv_j) + \beta_3 ts_{ij} \tag{5}$$

In formula (5), parameters pbe, pbv and ts are positive to variable si, where β_1, β_2, $\beta_3 > 0$ and $\beta_1 + \beta_2 + \beta_3 = 1$. It's obvious that he bigger the values of betweenness, the greater the trade volume of the road section, the higher the urgency of the construction of high-speed railway.

3. Evaluation Algorithm of High-speed Railway Construction Priority: HSRCO²A

3.1 Introduction of Parallel Ant Colony Algorithm

Ant colony optimization algorithm is a heuristic search strategy and it works well when solving various combinatorial optimization problems. Because of the characteristics of randomness of the

traditional ant colony optimization algorithm, the optimization time is very long. In order to solve the shortcomings of the traditional ant colony optimization algorithm, in addition to the initial solution for a variety of optimization, as well as pheromone for a variety of dynamic updates, more and more researchers have parallelized ant colony algorithm [7]. The parallel model of ant colony algorithm is divided into 3 categories: independent parallel ant colony optimization algorithm, master-slave parallel ant colony optimization algorithm and coarse-grain parallel ant colony optimization algorithm. Taking into account the relative independence of the optimal paths in this research, an independent parallel ant colony optimization algorithm can be used to solve it. The so-called independent parallel ant colony algorithm, that is, a large ant colony is divided into multiple sub-groups, each ant independently maintain their own ant colony pheromone matrix. And independent commitment to a search task, its purpose is to make full use of the parallel advantages of multi-core to improve the system optimization.

3.2 HSRCO²A algorithm based on parallel ant colony optimization algorithm

The main purpose of the HSRCO2A algorithm is to evaluate the possibility of building high-speed railway between adjacent city hubs within the B&R network G. Based on the target and the parallel ant colony algorithm, the algorithm of HSRCO2A is given below.

Algorithm

Step1 Initialization. Input the national instability index *ns*, cooperation evaluation index *ce* and the value of import and export trade with China *ie*. Construct logistics transportation network *G* and input length of each road section, type of road section (highway or railway) and even travel speed of each road section. Determine the value of the following parameters as φ_1, φ_2, τ, β_1, β_2, *and* β_3.

Step2 Normalization. Normalize such parameters as cooperation evaluation index *ce*, the national instability index *ns* and the value of import and export trade with China *ie*.

Step3 Calculation of the important indicators. Calculate comprehensive cooperation indexes (CC_k, $k=1,2,\ldots,K$) of all overseas countries and regions in B&R area with formula (1) after that obtain the travel time t_{ij} of each road section, calculate weighted logistics time of road sections t'_{ij} between the hub cities in China and other urban hub cities in B&R area according to formula (2), and calculate the other weighted logistics time of road sections t'_{ij} between urban hub cities of other countries and regions (excluding China) on the basis of formula (3).

Step 4 Solution of optimal path. Based on the weighted logistics time of road section t'_{ij}, calculate *P* optimal paths from *Set D* (which includes several Chinese hub cities) to *Set A* in B&R area using parallel ant colony optimization algorithm.

Step5 Solution of importance index of road section. Based on the above *p* optimal paths and the volumes of import and exports between other countries / regions and China, figure out partial betweennesses (*pbv* and *pbe*) of all vertexes and road sections in graph *G*, synchronously obtain the logistics cost and length of every path (lc_p, ll_p, $p=1,2,\ldots,P$) . Figure out the trade share amount (*ts*) and importance index (*si*) of each road section in graph *G* according to formula (4) and (5).

Step 6 Evaluation of high-speed railway construction priority. Sort all road sections <*i*,*j*> in descending order according to their importance indexes (*si*). Based on the above operation, obtain a priority road section set in which the road section need to be constructed firstly.

The above algorithm adopts parallel ant colony optimization algorithm to solve the optimal path p (Step4). According to the idea of ant colony optimization algorithm, the key steps include pheromone dynamic updating mechanism and transition probability solving strategy. In this article, define the initial value for road section $< i,j > \in G$ as $\tau_{ij}(0)$, and we have the following pheromone updating formula

$$\tau_{ij}(t+1) = (1-\rho)\tau_{ij}(t) + \Delta\tau_{ij} \tag{6}$$

In formula (6), $\rho \in (0,1]$ is called evaporation parameter and $(1-\rho)$ means the remaining ratio of pheromone in one certain road section from time t to t+1. Parameter $\Delta\tau_{ij} = \sum_{q=1}^{Q} \Delta\tau_{ij}^{q}$ is the pheromone increment in road section <i,j> and $\Delta\tau_{ij}^{q}$ is the pheromone increment of ant q on the section where Q is the number of ants. Hence, the transition probability of ant q from hub city i to j is

$$p_{ij}^{q}(t) = \begin{cases} \frac{[\tau_{ij}(t)]^{\alpha}\cdot[\eta_{ij}]^{\beta}}{\sum_{r\in allowed_q}[\tau_{ir}(t)]^{\alpha}\cdot[\eta_{ir}]^{\beta}} & j \in allowed_q \\ 0 & otherwise \end{cases} \tag{7}$$

In formula (7), parameters α and β are greater than 0, parameter $\eta_{ij} = \frac{1}{t'_{ij}}$ is so-called visibility parameter. Parameter $allowed_q = \{N - tabu_q\}$ is the city set which ant q is allowed to enter into, where $tabu_q$ is called tabu list of ant q (the list is also a city set which ant q has already passed through.).

In the algorithm, C1 ant populations are generated according to Chinese hub Cities set D (C1 is the amount of Chinese Cities). Each ant population is put on a Chinese city vertex and execute ant colony

optimization algorithm in parallel. All ants want to find their destination vertex (a hub city in B&R area excluding China) as soon as possible and every population manages its own change of pheromone and transition probability. Moreover, the maximum number of iterations is needed to setup. When all ant populations finish all P shortest paths would be output.

4. Experiments and Analysis

4.1 Data preparation and parameters

For verifying the feasibility of constructing high-speed railway in B&R area, we design the following experiment. The road network G and parameters of road sections in G are shown in Fig. 2, where there are 67 hub city vertexes and 288 road sections and all the sections are connected by highway or railway. Experimental data come from literature [8] and official websites of Chinese state council. The contents in Table 1 describes the stability characteristics of countries along the B&R area, Table 2 contains evaluation data of cooperation between China and other countries / regions within B&R area. From Table 2 we find that the cooperation types can be divided into four types: deep cooperation, rapid promotion, gradually expanding and to-be-strengthened. And the volume of import and export trade between China and other countries / regions in B&R area in 2015 is shown in Table 3. Data of a handful of countries count only the first 11 months of 2015 and in Table 3 we marked these countries with an asterisk. According to the actual needs of the system, we let $\varphi_1 = \varphi_2 = 0.5$, $\tau = 1$ and $\beta_1 = \beta_2 = 0.3, \beta_3 = 0.4$. In parallel ant colony algorithm, parameter PopSize equals 8 (the number of populations), parameter population equals 20 (amount of ants in an ant population), parameter ρ equals 0.10 (evaporation coefficient), and parameter MaxI equals 1000 (the maximum iteration number). Other parameters can be adjusted according to the current situation.

Table1 Unstable countries in B&R area

country/region name	Unstable factor	score
Russia (with China), USA (with China)	geopolitical game of great powers	0.2
Kyrgyzstan, Tajikistan, Uzbekistan, India, Palestine, Israel	territorial dispute	0.5
Philippines, Vietnam, Malaysia	Sovereignty dispute with the South China Sea	0.5
Kyrgyzstan, Afghanistan, Burma, Thailand, Pakistan, Yemen, Egypt, Greece	Political instability	1.0
Kazakhstan, Uzbekistan, Tajikistan, Kyrgyzstan, Turkmenistan, Afghanistan, Syria, Iraq, Thailand, Myanmar	Facing non-traditional security problems	0.2

Table 2. Cooperation evaluation index between China and other countries / region in B&R area

Ranking	Country / region	Score	Type	Ranking	Country / region	Score	Type
1	Russian	85.09	*deep cooperation*	33	Israel	39.98	*to-be-strengthened*
2	Kazakhstan	81.25		34	Maldives	38.63	
3	Thailand	74.01	*rapid promotion*	35	Jordan	38.39	
4	Pakistan	72.40		36	Turkmenistan	37.71	
5	Indonesia	71.33		37	Romania	37.43	
6	Vietnam	70.74		38	Kuwait	36.81	
7	Malaysia	69.89		39	Azerbaijan	36.66	
8	Singapore	69.22		40	Georgia	35.94	
9	Mongolia	67.62		41	Bulgaria	34.17	

10	Laos	65.98		42	Brunei	33.27	
11	Turkey	62.45		43	Slovakia	32.42	
12	Poland	61.82		44	Bahrain	30.82	
13	Myanmar	61.43		45	Armenia	30.34	
14	Sri Lanka	61.34		46	Afghanistan	30.00	
15	Cambodia	60.98		47	Oman	27.10	
16	The United Arab Emirates	58.26		48	Iraq	25.83	
17	Egypt	57.99		49	Slovenia	25.22	
18	India	57.74		50	Croatia	24.89	
19	Kyrgyzstan	57.22		51	Lithuania	24.87	
20	Belarus	56.58		52	Albania	24.50	
21	Iran	56.43		53	Timor-Leste	24.33	
22	Tajikistan	53.40		54	Estonia	23.79	
23	Saudi Arabia	51.66		55	Montenegro	22.31	
24	Hungary	51.49	*gradually expanding*	56	Lebanon	22.20	
25	Qatar	49.32		57	Latvia	21.67	
26	Uzbekistan	49.10		58	Macedonia	21.52	
27	Nepal	47.73		59	Syria	20.75	
28	Czech	47.05		60	Moldova	19.26	
29	The Philippines	46.33		61	Yemen	18.73	
30	The People's Republic of Bangladesh	46.32		62	Bosnia and Herzegovina	16.83	
31	Ukraine	43.75		63	Palestine	13.66	
32	Serbia	42.68		64	Bhutan	8.67	
Average	43.55						

Table 3. Trade volume of import and export between China and countries / regions in B&R area in 2015

Country / region	Export/import/ total volume	Country / region	Export/import/ total volume
Russia	**348.00/332.60/680.6**	Maldives	1.73/0.00/1.73
Kazakhstan*	78.28/53.38/131.66	Jordan	34.27/2.88/37.14
Thailand	**382.93/371.70/754.6**	Turkmenistan	7.73/71.09/78.82
Pakistan	164.50/24.77/189.3	Romania	31.63/12.97/44.60
Indonesia	**343.42/198.88/542.30**	Kuwait	38.00/75.00/113.00
Vietnam	**661.24/298.42/595.70**	Azerbaijan	4.39/2.23/6.62
Malaysia	**439.90/533.00/972.90**	Georgia	7.69/0.44/8.13
Singapore	**520.08/275.56/795.70**	Bulgaria	10.43/7.49/17.92
Mongolia	15.72/37.79/53.50	Brunei	14.09/0.97/15.10
Laos	12.27/15.54/27.80	Slovakia	27.90/22.40/50.30
Turkey	186.17/29.48/215.70	Bahrain	10.10/1.10/11.20
Poland	142.80/27.3/170.10	Armenia	1.14/2.16/3.30
Myanmar	96.55/56.25/152.80	Afghanistan	3.64/0.12/3.76
Sri Lanka	43.05/2.59/45.64	Oman	21.00/151.00/172.00
Cambodia	37.65/6.67/44.30	Iraq	79.11/126.78/205.89

The United Arab Emirates	**371.00/115.00/486.00**	Slovenia	20.90/2.90/23.80
Egypt	119.60/9.20/128.80	Croatia	9.85/1.12/10.97
India	**582.40/133.80/716.20**	Lithuania	12.06/1.38/13.44
Kyrgyzstan*	39.31/0.55/39.86	Albania	4.30/1.29/5.59
Belarus	7.49/10.11/17.60	Timor-Leste	1.06/0.01/1.10
Iron	**177.91/160.51/338.40**	Estonia	9.53/2.35/11.88
Tajikistan*	16.42/0.45/16.87	Montenegro	1.34/0.25/1.59
Saudi Arabia	**217.00/300.00/517.00**	Lebanon	22.9/0.10/23.00
Hungary	52.00/28.70/80.70	Latvia	10.20/1.50/11.70
Qatar	22.78/46.12/68.90	Macedonia	0.86/1.33/2.19
Uzbekistan*	20.56/11.19/31.75	Syria	10.24/0.03/10.27
Nepal	8.34/0.32/8.66	Moldova	1.00/0.21/1.21
Czech	82.30/27.80/110.10	Yemen	14.30/9.00/23.30
The Philippines	**266.73/189.76/456.50**	Bosnia and Herzegovina	0.61/0.54/1.15
The People's Republic of Bangladesh	139.01/8.06/147.10	Palestine	0.71/0.00/0.71
Ukraine	35.20/35.60/70.74	Bhutan	0.10/0.00/0.10
Serbia	4.15/1.34/5.49		
Israel	65.90/20.70/86.60		

Source: Department of general affairs of the People's Republic of China; unit: USD

4.2 Results and analysis

According to formula (1), (2) and (3), the values of comprehensive cooperation index (CCk, in Table 4) and weighted logistics time of road section (t'_{ij}) are calculated which are shown in Table 4 and Table 5 below. Results in Table 4 indicate that the following 10 countries / regions' comprehensive cooperation index are higher, including Vietnam, Russia, Saudi Arabia, the United Arab Emirates, India, Iran, Thailand, Turkey, Poland and Oman. However, the following 5 countries / region's comprehensive cooperation index are very low instead, including Kyrgyzstan, Macedonia, Moldova, Montenegro and Afghanistan. Analysis shows that countries with higher comprehensive cooperation indexes tend to have a relatively stable domestic political situation and a large scale international trade, whereas those countries with very low comprehensive cooperation indexes tend to have a more chaotic domestic political situation and the international trade volume is very small. And like Mongolia, Pakistan and other countries, although from the geopolitical point of view they are neighbors of China, because of the international trade volume is small or domestic political chaos their comprehensive cooperation indexes are only at the secondary position. Of course, the comprehensive index of cooperation is only the environmental characteristics of urban hubs and road sections. Therefore, it does not mean that they must be in the first place in the construction of high-speed railway. Topological characteristic of a road section in physical network is also taken into account when evaluating whether or not a high-speed railway should be constructed early.

Table 4. Comprehensive cooperation index (CCk)

Country/region	*Comprehensive cooperation index*(CC^k)	Country/region	*Comprehensive cooperation index*(CC)
Vietnam	**0.453**	Jordan	0.021
Russia	**0.323**	Laos	0.017
Saudi Arabia	**0.272**	Slovenia	0.013
The United Arab Emirates	**0.256**	Lebanon	0.012
India	**0.188**	Belarus	0.011
Iran	**0.125**	Bulgaria	0.01
Thailand	**0.119**	Uzbekistan	0.009
Turkey	**0.115**	Lithuania	0.008
Poland	**0.091**	Latvia	0.007

Oman	**0.09**	Yemen	0.007
The People's Republic of Bangladesh	0.078	Bahrain	0.007
Kuwait	0.06	Estonia	0.007
Czech	0.059	Croatia	0.006
Kazakhstan	0.05	Nepal	0.006
Hungary	0.044	Tajikistan	0.005
Egypt	0.042	Georgia	0.005
Pakistan	0.041	Azerbaijan	0.005
Qatar	0.038	Serbia	0.004
Israel	0.037	Albania	0.004
Iraq	0.032	Syria	0.004
Mongolia	0.031	Armenia	0.003
Turkmenistan	0.03	**Kyrgyzstan**	**0.002**
Slovakia	0.027	**Macedonia**	**0.002**
Cambodia	0.026	**Moldova**	**0.001**
Romania	0.025	**Montenegro**	**0.001**
Myanmar	0.025	**Afghanistan**	**0.001**
Ukraine	0.023		

According the calculated shortest paths we can obtain the betweennesses of each city and each road section within graph G, then the importance indexes of each road section are figured out. The values of road sections are shown in Table 7 in descending order. According to the importance index, we divide all sections into three levels. The first level is the most important section set which are located in the hub of the whole road network. From the urgency of the construction of high-speed railway they are the most urgent because of their abilities of connectivity and sharing the logistics flow. Because of the remote location, the common international relationship with China, and the general level of domestic political stability and other issues, road sections sets of the second and third level especially the third level sections haven't the construction conditions for high-speed railway in the present situation.

Table 5 Importance Index of Road Sections in B&R area (first level)

No.	Road Section	<Origin City, Destination City>	Origin country/region, Destination country/region	Importance Index
1	<23,27>	**<Ulan Bator, Novosibirsk >**	Mongolia, Russia	**23.2448**
2	<26,27>	**<Moscow, Novosibirsk >**	Russia, Russia	**19.6384**
3	<35,65>	**<Guwahati, Kunming>**	India, China	**19.6233**
4	<3,2>	**<Ashkhabad, Tashkent>**	Uzbekistan, Turkmenistan	**10.3901**
5	<60,1>	**<Almaty, Urumqi>**	China, Kazakhstan	**9.7328**
6	<31,29>	**<Phnom Penh, Hanoi>**	Vietnam, Kampuchea	**6.7839**
7	<38,2>	**<Ashkhabad, Tehran>**	Turkmenistan, Iran	**6.1020**
8	<61,23>	**<Erenhot, Ulan Bator>**	China, Mongolia	**5.4808**
9	<4,3>	**<Biches Kell, Tashkent>**	Kyrgyzstan, Uzbekistan	**5.0623**
10	<44,38>	**<Baghdad, Tehran>**	Iraq, Iran	**4.9581**
11	<49,44>	**<Riyadh, Baghdad>**	Saudi Arabia, Iraq	**4.6583**
12	<64,31>	**<Nanning, Hanoi>**	China, Vietnam	**4.5824**
13	<31,30>	**<Hanoi, Vientiane>**	Vietnam, Laos	**3.8709**
14	<37,35>	**<Islamabad, Guwahati>**	India, Pakistan	**3.4324**
15	<30,28>	**<Vientiane, Bangkok>**	Laos, Thailand	**2.9596**

16	<65,33>	**<Kunming, Naypyidaw >**	China, Burma	**2.8850**
17	<52,49>	**<Dubai, Riyadh>**	UAE, Saudi Arabia	**2.3909**
18	<37,36>	**<Islamabad, New Delhi>**	India, Pakistan	**2.0047**
19	<26,6>	**<Moscow, Minsk>**	Russia, Belarus	**1.9350**
20	<60,0>	**<Urumqi, Astana>**	China, Kazakhstan	**1.7149**
21	<4,1>	**<Biches Kell, Almaty>**	Kyrgyzstan, Kazakhstan	**1.3584**
22	<42,26>	**<Tbilisi, Moscow>**	Georgia, Russia	**1.1088**
23	<26,10>	**<Moscow, Kiev>**	Russia, Ukraine	**1.0179**
24	<25,6>	<St Petersburg, Minsk>	Russia, Belarus	0.8509
25	<9,6>	<Warsaw, Minsk>	Belarus, Poland	0.8127

Based on the data and results of this article we get the following conclusions:

1) Aspect in international high-speed railway construction. Combined with the trade volume of import and export between China and other countries / regions in B&R area in 2015, the following 23 road sections needs to carry out high-speed railway construction as soon as possible: <Ulan Bator, Novosibirsk >, <Moscow, Novosibirsk >, <Guwahati, Kunming>, <Ashkhabad, Tashkent>, <Almaty, Urumqi>, <Phnom Penh, Hanoi>, <Ashkhabad, Tehran>, <Erenhot, Ulan Bator>, <Biches Kell, Tashkent>, <Baghdad, Tehran>, <Riyadh, Baghdad>, <Nanning, Hanoi>, <Hanoi, Vientiane>, <Islamabad, Guwahati>, <Vientiane, Bangkok>, <Kunming, Naypyidaw>, <Dubai, Riyadh>, <Islamabad, New Delhi>, <Moscow, Minsk>, <Urumqi, Astana>, <Biches Kell, Almaty>, <Tbilisi, Moscow> and <Moscow, Kiev>, . The following conclusions are obtained from different angles. From the political stability of the country, there are 65.22% of the road sections belonging to politically stable countries / regions. From the point of view of international cooperation with China, 78.26 % of the countries have close ties with China (CCk>=0.04, according to Table 4), and 13.03% of countries have common relations with China (CCk>=0.01, according to Table 4). From the perspective of the national economic strength, 69.56% of the road sections belong to the economically developed countries or share with China. According to the public documents, From 2015 to the end of 2016 the high-speed railway projects under construction or to be put into construction in B&R area include The Hungarian- Serbia railway (from Budapest to Belgradey), China - Laos high-speed railway project (from Mohan to Vientiane via Boten), China Thailand railway planning (from Bangkok to Nakhon Ratchasima Kh), Moscow to Kazan high-speed rail project in Russia and China Mongolia high-speed railway project (Zeck cross-border standard gauge railway project). Road sections and cities covered by these railway projects have a great coincidence with Table 7 which demonstrates the accuracy of the model and algorithm from the empirical aspect.

2) Aspect in China domestic High-speed railway construction. To promote the construction of infrastructure along the Belt and Road China has started the large-scale high-speed railway construction in recent years. In September 2015, Manchuria City has begun to build a high-speed railway which reserves entrance to Russian. In March 2016, the Chinese government decided to construct high-speed railway from Kunming City to Shanghai City, Guangzhou City and Beijing City respectively. In May 2016, a number of projects in border city Erenhot are included in "13th Five-Year" railway development plan of the Inner Mongolia Autonomous Region. In September 2016, National Development and Reform Commission approved a railway project feasibility study report from Guiyang City to Nanning City. In December 2016, Urumqi - Huoerguosi high-speed railway was included in the key construction projects of the Chinese government and to be put into construction in 2018. And Huoerguosi City is located in the central part of the Asia Europe economic plate, covering densely populated areas and economically developed areas of five Central Asian countries, she is China's best choice of opening to the west, expanding foreign trade and enhancing exchanges in Central Asia. The above projects involved Manchuria City, Kunming City, Erenhot City, Urumqi City, Nanning City and Beijing city, the capital of china. These cities are Chinese extremely important hub cities in the Belt and Road initiative. It is clear that the Chinese government has been doing massive preparatory work for the international high-speed railway infrastructure construction.

Once the layout of the domestic railway network is completed, China is bound to invest more energy in the international railway network.

5. Conclusion

Based on the situation of logistics infrastructure within B&R area and the import/export trade volumes between China and other countries/regions, this article studied the priority construction problem of high-speed railways between hub cities. In order to evaluate the importance of road sections, the HSRC model is constructed in this paper. Through using the parallel ant colony optimization algorithm, we obtained the importance indexes of all road sections in the Belt and Road area. Obviously, the higher the degree of importance index, the faster the urgency of the construction of high-speed railway. Based on the data of China's import and export trade volumes with other countries in 2015 and latest data of B&R construction, a set of road sections suitable for high-speed railway construction is obtained in this article. After comparing with the domestic and international high-speed railway engineers under construction or to be put into, the availability of the model and corresponding algorithm are verified to some extent. Of course, perhaps there are some small glitches in the conclusion because the data we have are incomplete, inaccurate, and non-real-time and so on, but this does not affect the universality of the model. The current world political and economic situation is complex and changeable [9]. As long as we pay close attention to the changes in the data the HSRC model is likely to calculate the results of the assessment of the latest data. In the future, we will conduct an in-depth research of these aspects.

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