西南交通大學
Southwest Jiaotong University

Air-high Speed Rail (AHSR) Intermodal Transport Network Design Problem of China

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Outline

1. Introduction

2. Design of Operation mode of AHSR

3. Planning of the AHSR network

4. Conclusions

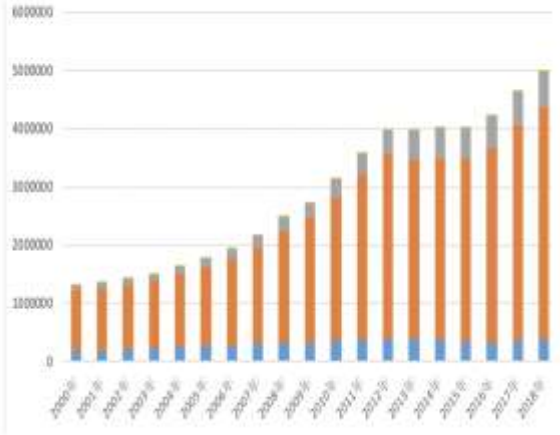
1. Introduction

Introduction

Background

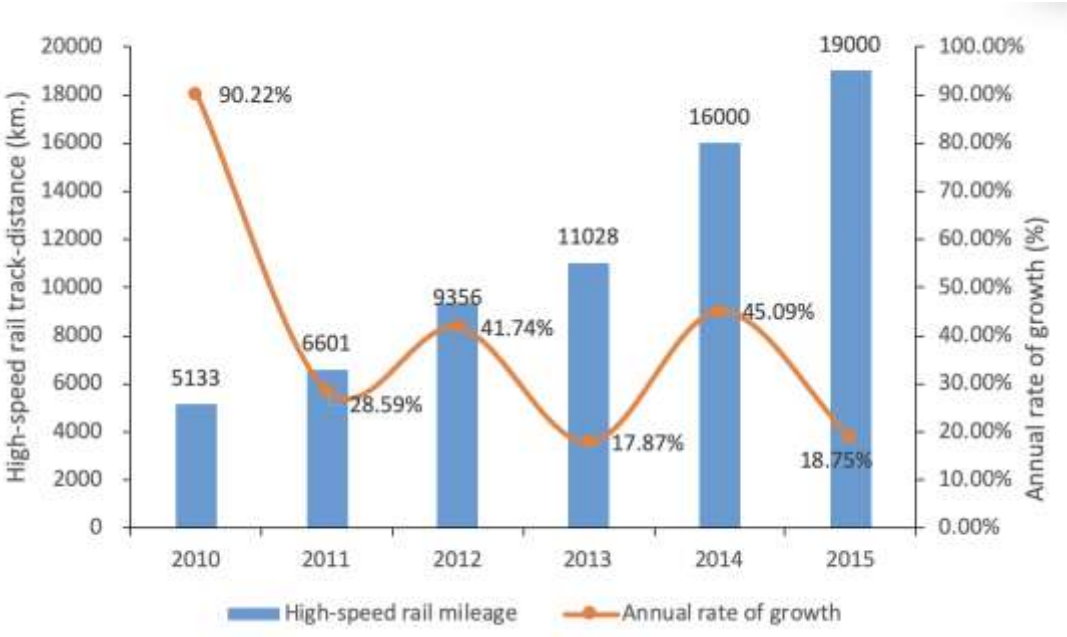
Transportation modes

- Rail:
- Road
- Waterway
- Air



Introduction

Background



China has become the world's greatest high-speed rail country,

The spatial-temporal distribution of passengers occupancy rate of the HSR is diversity.

There are some idle capacity existed in China's HSR system.

The HSR is environmental-friendly compares with air and highway transport.

Introduction

The meanning of Air-high Speed Rail (AHSR) ?

The rapid growth of e-commerce and the existed idle capacity of high-speed railway in China result in a novel intermodal transport pattern for express delivery, which is air-high speed rail freight transport(AHSR). In this research, the design of the Air-high speed rail network in China is studied.

2. The Design of Operation mode of AHSR

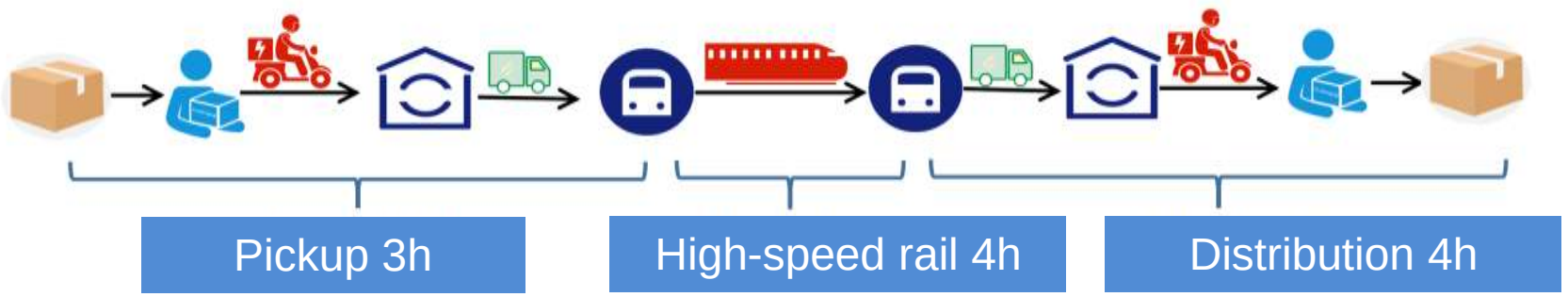
High-speed Railway Express(HSRE)

- Same Day Delivery
- Next Morning Delivery
- Next Day Delivery
- Economic Express

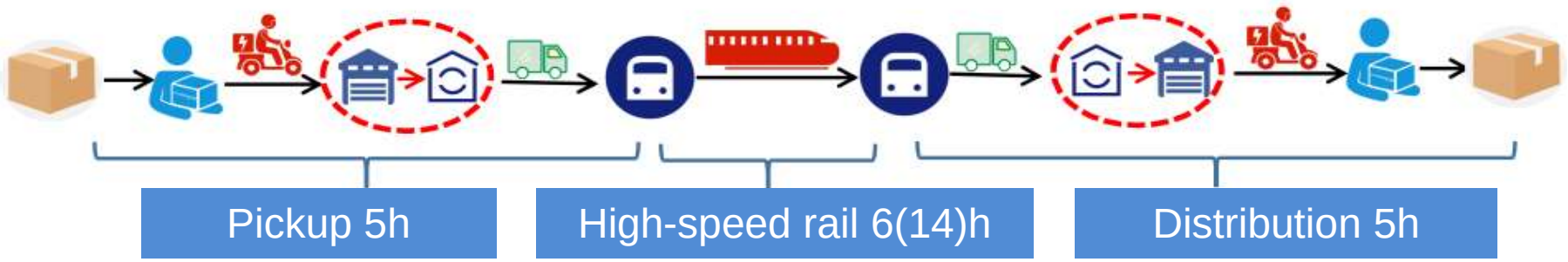
China Railway High-speed Express (CRHE) is a “Door-to-Door” small parcel delivery service with high efficiency, quality and standard, and provide a wide range of customers with Time-limited Services (Same Day Delivery, Next Morning Delivery, Next Day Delivery) and Standard Services (Economic Express, Intra-city Express)

High-speed Railway Express(HSRE)

Same Day Delivery



Next Morning Delivery and Next Day Delivery



High-speed Railway Express(HSRE)

High-speed Railway Express(HSRE)

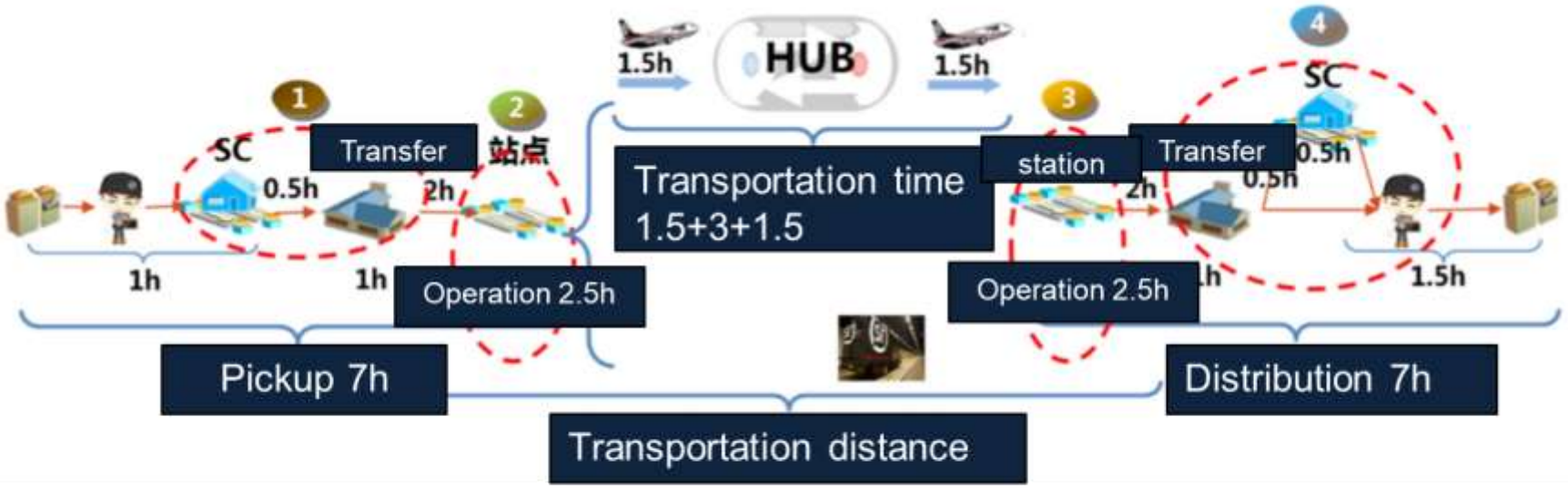
High speed railway freight train

Passenger and freight mixed train

High speed railway confirmation train

Passenger train pick up mode

Air freight operation



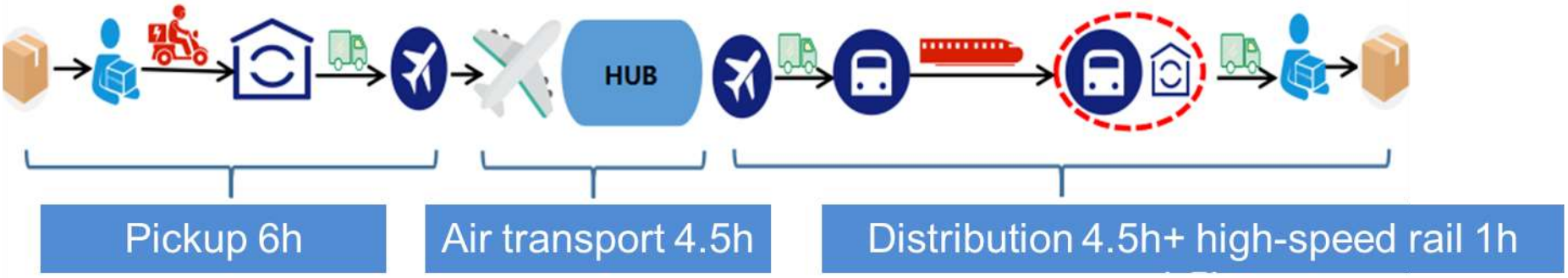
Air-freight operation procedures

Air freight operation modes

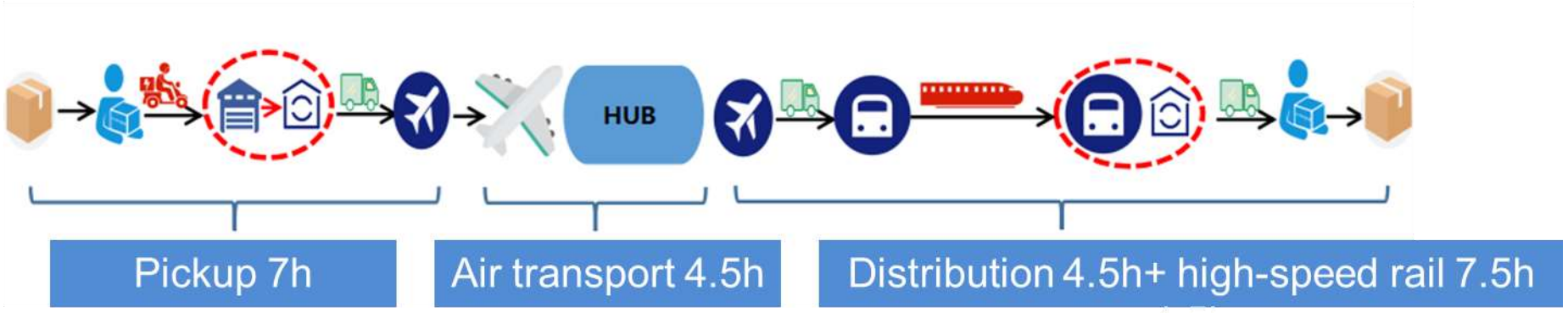
	End-to-end	Stop-over	Hub-spoke mode	Luggage compartment of passenger airline
	Direct flight from origin to destination	The plane stops over to refuel or load and unload goods	Centralize a series of routes to a hub airport, then connect and transfer flights in the shortest time, so as to obtain maximum market coverage	Transportation of goods with the spare capacity of airliner
Advantages	The main operation mode of airlines at present, with few procedures and high efficiency	High aircraft utilization	Wide coverage, high efficiency and low cost	Main operation mode, standardized operation procedures, sufficient routes, low cost
Disadvantages	Small coverage area and insufficient point-to-point cargo volume lead to difficult cargo collection, long time, less routes and low resource utilization.	Small scale, low frequency, limited flight time and slightly higher cost	Complicated operation procedures. Poor timeliness	Limited by passenger routes, the scale of freight transportation is small.

Air-high Speed Rail (AHSR) Intermodal Transport

Air-high Speed Rail (AHSR) Same Day Delivery



Air-high Speed Rail (AHSR) Next Day Delivery



Air-high Speed Rail (AHSR) Intermodal Transport

Intermodal Transport modes	capacity	Operation conditions	Technical feasibility	economic feasibility
Air-Passenger train pick up mode	small	Fast loading and unloading, with standard cargo package, combined with high-speed railway timetable to optimize air cargo scheduling	easy	Increase a small amount of railway freight variable cost
Air-confirmation train	Medium	Standard package, organizational load and unload, use railway time-window to optimize the cargo assembly	Need to Strengthen Railway Freight Organization	Increase a small amount of railway freight variable cost
Air-Passenger and freight mixed train	Large	Reconstruct the luggage train, optimize the air arrangement considering high-speed railway timetable	Need to redesign luggage train, rebuild the railway station	Increase fixed asset investment and variable cost
Air-freight train	Large	Need specialized freight station	rebuild the railway station	Increase fixed asset investment and variable cost

3. Planning of AHSR network

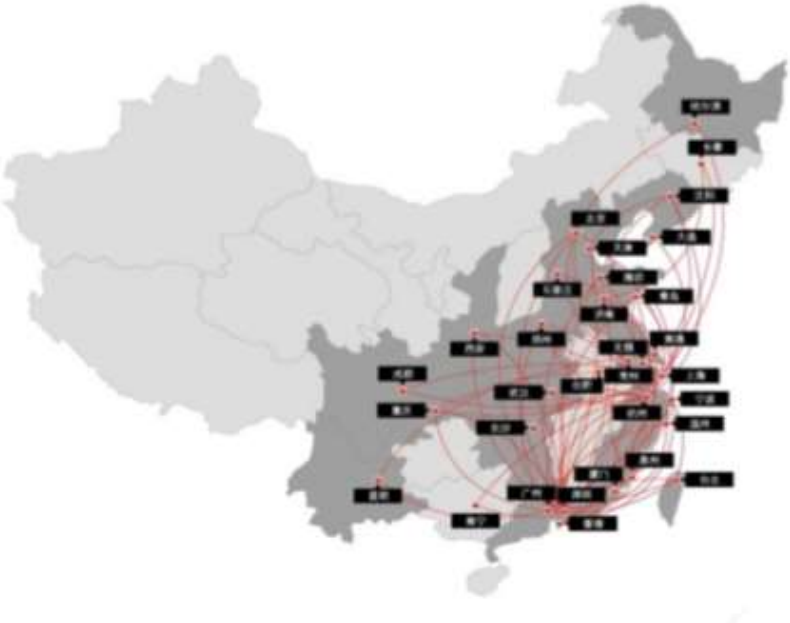
Background

High-speed Rail Network Of China

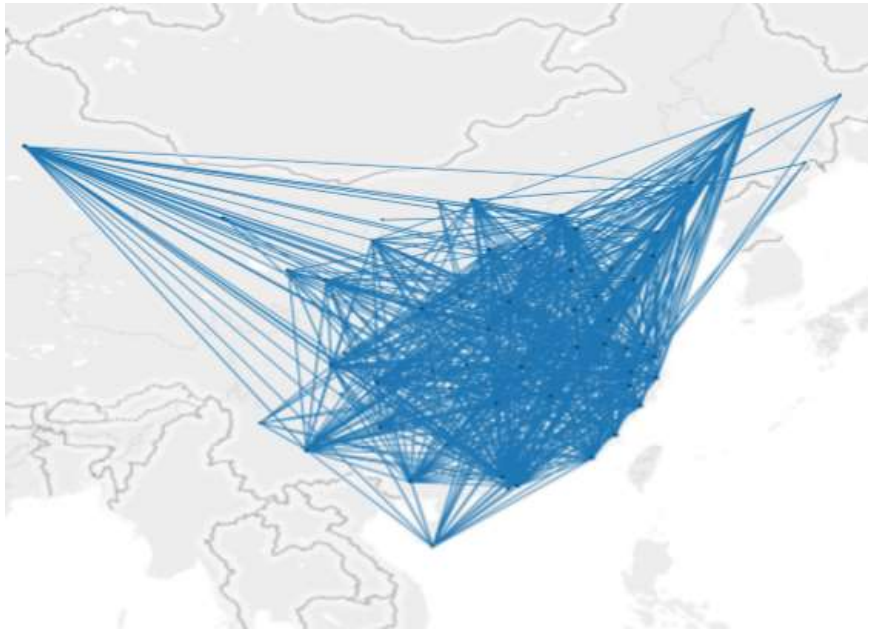
High-speed Rail Network Of China

Background

The Air-cargo network of China



SF Air-cargo **Freighters** network



SF Combi Aircrafts network

Determination Of Hub City

At present, there are a large number of cities with airports and high-speed rail stations. It is necessary to preliminarily select cities that meet the requirements of hub city from these cities.

Selection Criteria：

(1) GDP ranked first

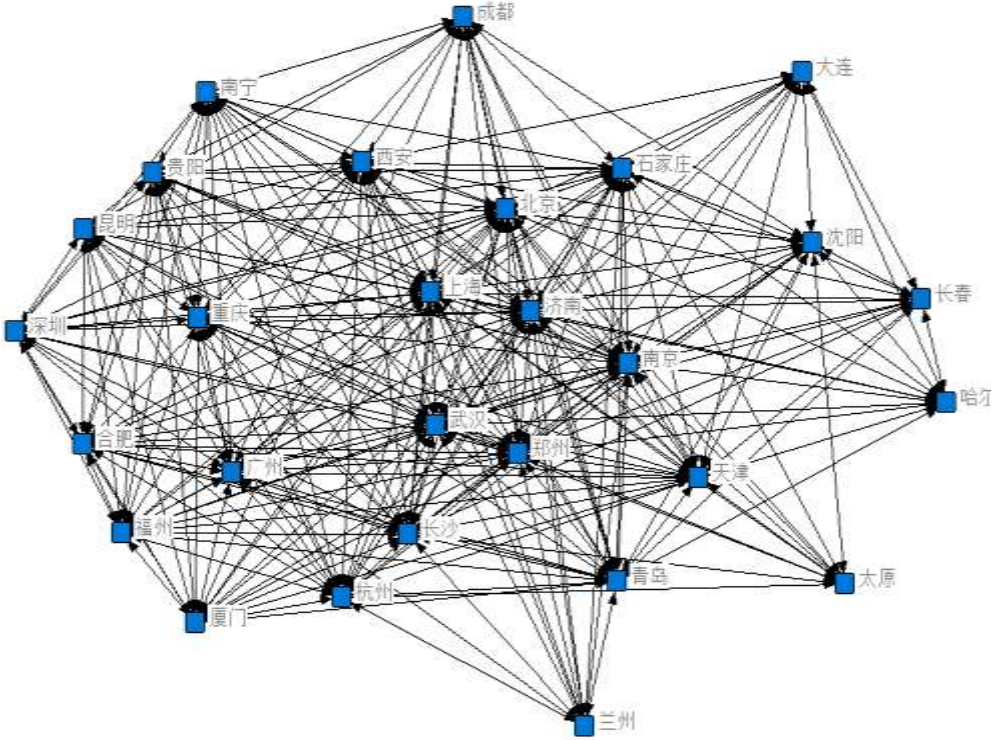
(2) With policy support

(3) Provincial capital city

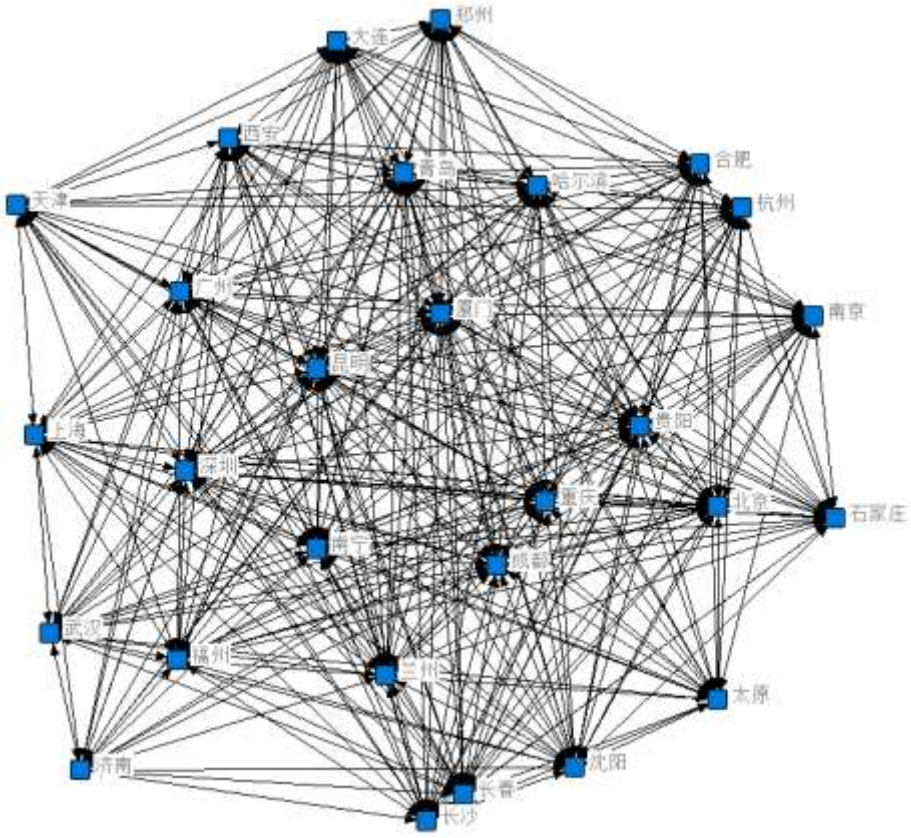
Preliminary selection results:

Harbin, Changchun, Beijing, Tianjin, Shijiazhuang, Nanjing, Hangzhou, Taiyuan, Zhengzhou, Wuhan, Changsha, Nanning, Xi’an, Chengdu, Chongqing, Guiyang, Lanzhou, Kunming, Dalian, Qingdao, Xiamen, Shenzhen, Shenyang, Jinan, Fuzhou, Guangzhou, Shanghai, Hefei

Determination Of Hub City



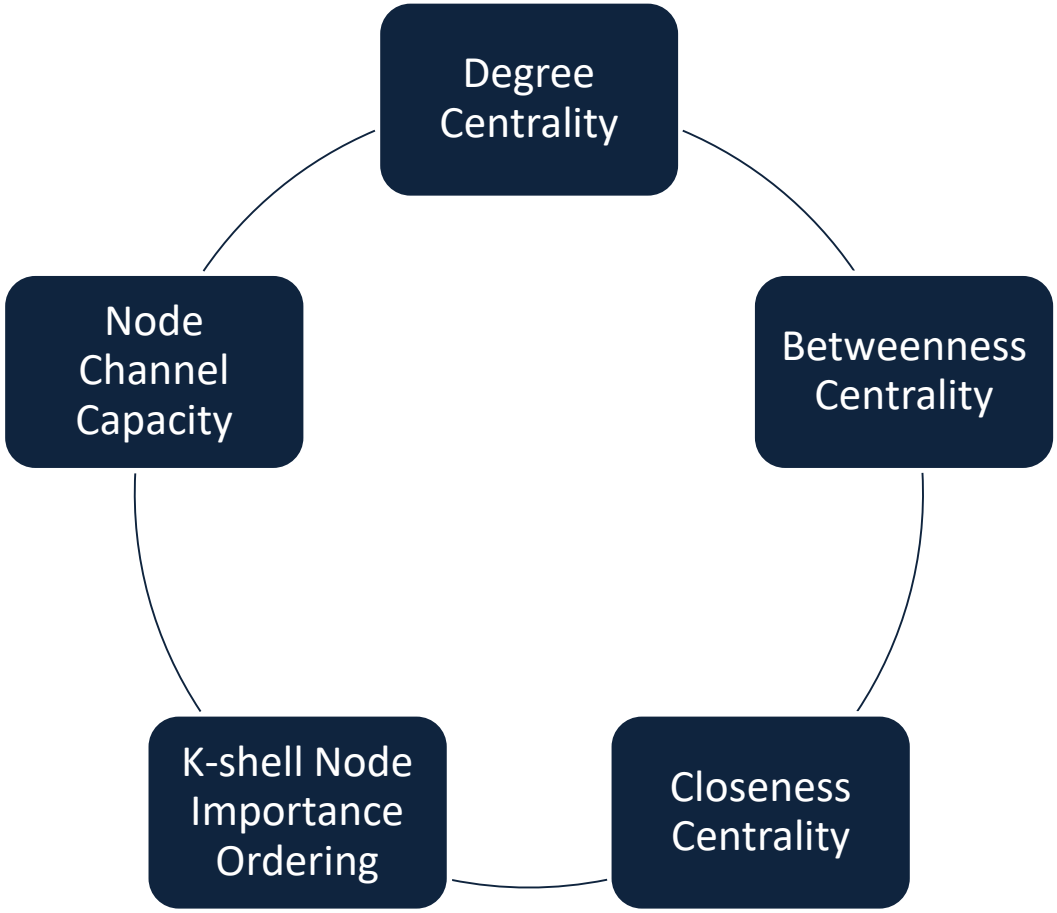
High speed rail connection graph



Air connection graph

Determination Of Hub City

Assessment of node city centrality



Determination Of Hub City

Assessment of node city centrality

Rank	City	Score	Rank	City	Score	Rank	City	Score
1	Beijing	0.644851	11	Tianjin	0.455876	21	Qingdao	0.424113
2	Shanghai	0.637877	12	Hangzhou	0.455179	22	Fuzhou	0.420628
3	Zhengzhou	0.593471	13	Taiyuan	0.450304	23	Harbin	0.420605
4	Wuhan	0.589851	14	Shenzhen	0.442475	24	Nanning	0.420097
5	Nanjing	0.578281	15	Chongqing	0.436431	25	Changchun	0.416104
6	Guangzhou	0.561747	16	Kunming	0.435915	26	Shenyang	0.41507
7	Xi’an	0.559934	17	Changsha	0.434153	27	Hefei	0.412178
8	Chengdu	0.508316	18	Xiamen	0.428543	28	Dalian	0.410621
9	Shijiazhuang	0.486835	19	Guiyang	0.427595			
10	Jinan	0.456165	20	Lanzhou	0.424567			

Freight Volume Forecasting

Freight Volume Forecasting

	Beijing	Shanghai	Guangzhou	Nanjing	Wuhan	Zhengzhou	Chengdu	Xi’an
Beijing	0	37306.84	21431	10857	13750	18035	8822	14042
Shanghai	33736	0	35374	17316	20675	15498	8871	12946
Guangzhou	27830	50799	0	43089	26666	13979	13708	14730
Nanjing	3650	18405	7714	0	6331	4543	2033	3152
Wuhan	9365	15572	13986	6468	0	6733	3486	5764
Zhengzhou	11456	10886	6838	3341	6279	0	2881	5662
Chengdu	9422	10477	11274	5681	5467	4844	0	9491
Xi’an	9701	9891	7836	3892	5847	6158	6139	0

AHSR network models

$$C = \min \left(\begin{array}{l} \sum_k \left(C_k + WC_k \bullet \sum_i \sum_k \sum_m \sum_j D_{ij} X^l_{ikmj} \right) + \sum_i \sum_j \sum_l D_{ij} C^l_{ij} X^l_{ij} \\ + \sum_i \sum_j \sum_k \sum_m \sum_z D_{ij} \left(\rho C^l_{ik} + \gamma C^l_{km} + \rho C^l_{mj} \right) X^l_{ikmj} + \sum_i \sum_j \sum_l D_{ij} TC^l_{ij} X^l_{ij} \\ + \sum_i \sum_j \sum_k \sum_m \sum_l D_{ij} X^l_{ikmj} \left(TC^l_{ik} + TC^l_{km} + TC^l_{mj} + ZT \bullet X_{km} \right) \end{array} \right) \quad (5\text{-}1)$$

s.t:

$$\sum_k y_k = P \quad (5\text{-}2)$$

$$X^l_{ikmj} \le y_k, \forall i, j \in I, l \in L, k \in K \in I, m \in M \in I \quad (5\text{-}3)$$

$$X^l_{ikmj} \le y_m, \forall i, j, k, m \in I, l \in L \quad (5\text{-}4)$$

$$\sum_k \sum_m \sum_l X^l_{ikmj} + X_{ij} = 1, \forall i, j \in I \quad (5\text{-}5)$$

$$X^l_{ikmj} \le Y_k + Y_m, \forall i, j \in I, l \in L, k \in K \in I, m \in M \in I \quad (5\text{-}6)$$

$$\sum_i \sum_k \sum_m \sum_j D_{ij} X^l_{ikmj} + \sum_i \sum_j D_{ij} X^l_{ij} = \sum_i \sum_j D_{ij} \quad (5\text{-}7)$$

$$Y_k, X^l_{ikmj}, X^l_{ij} \in \{0,1\} \quad (5\text{-}8)$$

$$X_{km} \in \{1,2\} \quad (5\text{-}9)$$

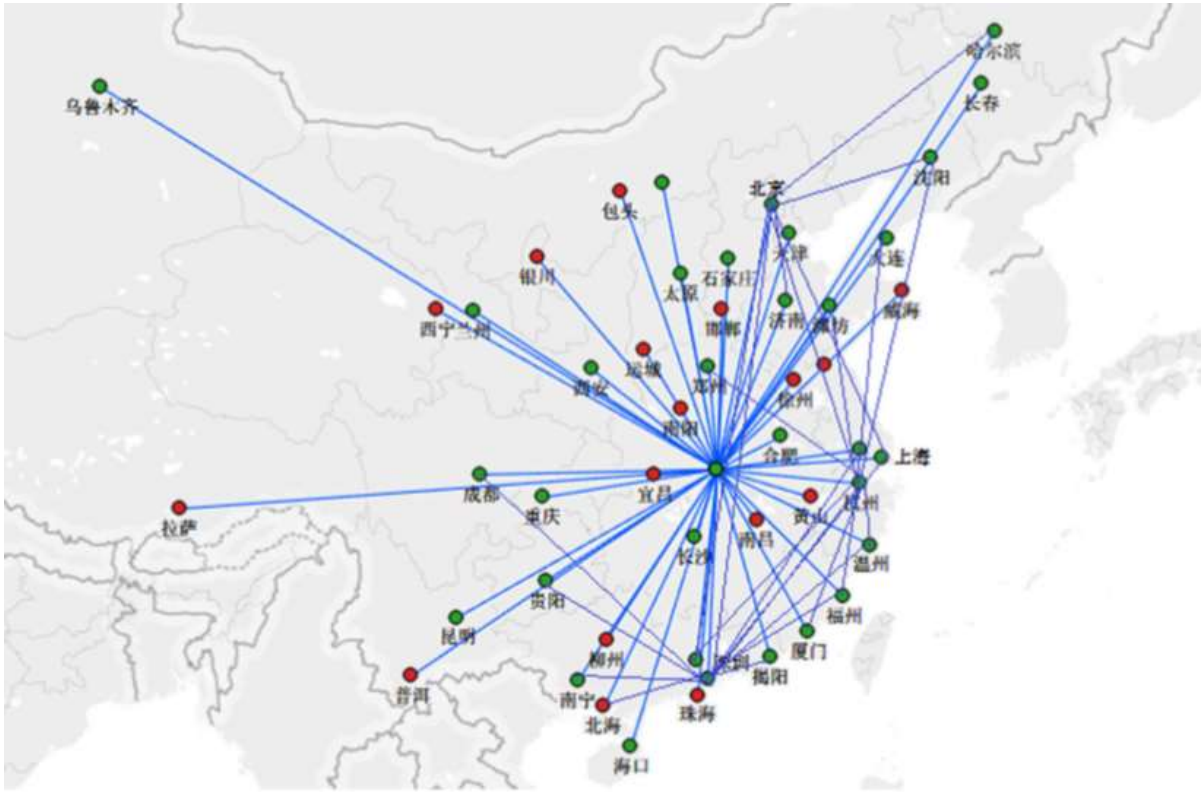
Numerical results of AHSR network

Assessment of node city centrality

	beijing	shanghai	zhengzhou	wuhan	Xi'an	chengdu	xiamen	guangzhou	shenyang
Beijing	0	1	1	1	1	2- Xi'an -1	2- Wuhan -1	2- Wuhan -1	1
Shanghai	1	0	1	1	2	1- Wuhan -2	1	1	2- Beijing -1
Zhengzhou	1	1	0	1	1	1- Wuhan -2	1	1- Wuhan -2	2- Beijing -1
Wuhan	1	1	1	0	1	1	1	1	2- Beijing -1
Xi'an	1	1	1	1	0	1	1- Wuhan -2	2- Wuhan -1	2- Beijing -1
Chengdu	1- Xi'an -2	2- Wuhan -1	2- Wuhan -1	1	1	0	2- Wuhan -1	2-v-1	1- Xi'an -2- Beijing -2
Xiamen	1- Wuhan -2	1	1	1	1- Wuhan -2	1- Wuhan -2	0	1	1-Wuhan-2- Beijing -2
Guangzhou	1- Wuhan -2	1	1	1	1- Wuhan -2	1- Wuhan -2	1	0	1-v-2- Beijing -2
Shenyang	2	2- Beijing -1	2- Beijing -1	2- Beijing -2	2- Beijing -2	2- Beijing -2- Wuhan -2	2- Beijing -2- Wuhan -1	2- Beijing -2- Wuhan -1	0

1: High-speed rail 2:Aircraft

Numerical results of AHSR network



Air cargo network planning

4. Conclusions

Conclusions

- The Air-High Speed Railway inter-modal transport can integrate railway transport's stability, low price and air transport's rapid characteristic, it will be an important development direction in the field of freight transportation. .
- The Air-High Speed Railway inter-modal transport meets the requirements of low-carbon and efficient development of China's freight transport.

THANKS