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A STUDY ON HIGHWAY NETWORK PLANNING METHOD IN RAPIDLY URBANIZING AREA IN CHINA

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Abstract: This paper aims to develop highway network planning method to match the special demands of the rapidly urbanizing areas in China. Based on the properties of rapidly urbanizing regions, the authors analyze different effect of highway traffic at the beginning and ending of the region's urbanization progress. To fulfill the co- appeal of economy and highway traffic development, the authors pay attention to the following aspects: (a) arrange highway route depending on network model and regional geographical-economy model in rapidly urbanizing region, (b) harmonize urbanizing skeleton highways with other rural lines, and (c) improve line and node position precision and land control precision to match the special demands of the region. The planning method is applied in Yinzhou District highway planning as an example.

Key Words: rapidly urbanizing area, highway network planning, layout

1. INTROUDUCTION

With the industrialization process going rapidly, some rural areas have much potential to be the process industry zone, so those zones will own some features of urban area and will turn into cities if the process industry is gradually massing. Hereunder we specially define those rural areas as Rapidly Urbanizing Area (RUA). Highway network as the main infrastructure in the RUA should be planned based on the strategy of adapting to and driving the process of the urbanization and industrialization, in mean time the demands for the development of the neighbor areas should be considered during the highway network planning process. The traditional planning methods that just determine the probable routes according to the nodes important or the area lines couldn't meet the demands of RUA. RUA needs the more exact

planning trunk lines which not only reduce the anon cost of rebuilding but also can improve the development of areas. This paper takes YinZhou that is a district in ZheJiang province, PRC as an example to study and analyze the planning process for the highway network in those areas.

2. RUA DEVELOPMENT FEATURES ANAYSIS

The rural areas gradually turning into cities has two different categories of processes: one is the local economy (whether related to the city economy or not) transition process from the agriculture to industry and service as trigger industry by aggregating a series of element factor; The other is the urban land resource can not cater for the urban development so that the nation or state invests to develop the new urban district and new city. The latter is mainly droved by the political factors and the development regularity is easily found out, so this paper focuses on the former. The former generally is marked by the following attributes:

- Having the special resource or location advantages. Such as harbor; district next to the metropolis; port or some kind of industry as the main part of economy.
- Economy and population growing fast droved by resource or location advantage and policy mix, in corresponding to those, employment structure changing and the employment quantity growing.
- Agriculture land use converting into urban land use. Due to the economy development and population massing generating multi-demand, the land use for industry, housing, business and education increases fast. This makes the agriculture land converting into urban land quickly.
- Industry structure changing rapidly. Industry and service industry becoming the main industry.

3. RUA HIGHWAY DEMANDS ANALYZE IN DIFFERENT DEVELOPMENT STAGE

"Who wants to be rich, where constructs road first". The speed-up effect of highway to economy development has been commonly cognized by the common people, but this effect is more significant in RUA than that in others. Highway construction in different development stage has different function: it is the foundation for early development, the important part of middle development advantage and the support element for upper development result of the region. At the beginning of the development, the key concerned part for the investors is the accessibility of the RUA. This accessibility attracts the investors' attentions, only when the investors ensure that the accessibility can guarantee economic gain, the investment decision, which is the exterior impetus for area development, can be made; In the period of expansion, when there have been output from the investment, the investors pay more attention to the quality of the transportation, for example the time limited efficacy, security and economical efficiency, those can strengthen the location advantage and make the investors advantage in the market competitions so that the RUA can implement the sustainable development; In the mature period, the RUA almost complete the urbanization and the traffic condition is mostly related to the early highway network, to a great extent, the urban function is generally based

on the early trunk highway network. So based on the features of RUA, the highway network in RUA puts forward the special demands as follows:

In the starting period, the planning of trunk highway lines and transport hubs, the construction and reserved land should be considered well. The trunk lines is quite important to display the location advantages, so the trunk lines should be planned based on the strategic plan of development area, and the layout of highway network should be adapted to the transport demands. For the current highway construction, highway gradation may not be very high but the land for upgrading should be reserved. Those requirements demandthe higher precision of highway network layout and land use control than others.

In the expansion period of the RUA, the highway should be upgraded according to the task undertaken by highway. In the urban road with conflict among the pedestrian, non-motorized vehicle, the separating and supporting facilities should be installed. Based on the highway serving as the urban road and satisfying the different level users' demands, the technical standard can be flexibly adopted.

In the mature period of RUA, the role of highway must be emphasized on the demand of urbanization. The lands along the highway almost are urban land use, so the highways also become the urban roads. Not only the cross section but also the green belt and parking should be arranged according to the requirement of the urban traffic system.

4. HIGHWAY PLANNING FEATURES IN RUA

Due to the transition from the country to city and the highway construction leading the development, those factors make the planning with some following specialties:

Skeleton network layout is to establish the transport corridor in RUA and convert the hinge location. The skeleton layout should consider the location of the joint of framework, the-state-of-art and planning of land use and connecting with high efficiency and smoothness based on the survey for availably existing road and hinge and the survey for planning. The process of making out the skeleton layout contains the following steps:

- Using the method combining the node significance and traffic zone analysis to set up the preliminary layout
- On the large-scale map (1:50000 or 1:10000), the location of highway can be laid out. This process also considers the possibility of lines, influence analysis on the land use.

In addition, the alignment on the large-scale map is beyond the working range of the highway network planning and almost reaches the demand of the urban road planning and possibility study of highway, but the similar practices have been done in Guangdong and Zhejiang province and show its necessity. This process also needs to balance the contradiction between the construction cost and the quantities.

The layout of junction hinge. Due to the area nearby the trunk lines developing fast, the highway network planning has to consider reserving the land for the future junction hinge facility construction. This work basically contains two steps:

First, access junction facility planning needs to consider the planning of the interstate highway or national trunk lines, so this kind of planning has to negotiate with other planning authority or refer to the strategic planning.

Second, the junction facility planning inside the RUA is necessary to analyze the junction and function of each road to decide the location of the overpass facility. After determining the location, the land use planning must comply with this planning in order to reserve enough land for future land construction.

Due to it is unnecessary to make sure the model of the junction facility, once determining the separating or interchange model, the land use for the facility almost can be controlled.

Branch line network planning. After skeleton network and hinge hub have been planned, the secondary network is very necessary to be planned based on the land use. For the districts intended to develop totally we just choose the link points, limit the boundary and hand it over the concerned department to install the branch line based on the city planning. There are no details involved in highway planning. For the existing village and country land, we can proceed the homologous layout programs according to trunk network planning [3], village network planning methods [4], and bring the layout result into the planning.

The planning of cross-section. In order to make the convenience to reserve the land for the highway construction, the scope of land use for trunk lines and junction hub must be defined, so the planning of the highway cross-section becomes very necessary in order to set out the width of the highway land use (in urban planning, this width called “red line” means no more construction can be inside the scope). The traffic volume decides the driveway width of highway cross-section generally. To RUA, the indeterminable factors of future traffic volume are so many that it is not proper to regard the current traffic volume excessively. Either the city transportation estimate(the future land usage is definite)or the road function analysis（the future land usage is not definite）can be used to decide the driveways from 4 to 6. For the consideration of pedestrian, non-motorized vehicle, green belt and future municipal works, the planning can contain the cross-section design drawing for all highway included in the planning scope according to the Code for Transport Planning on urban road. The result of cross-section design can be used to control land use as a condition.

Balancing technical standard and construction cost. In RUA, the prospect traffic volume is big, but corresponding to that, the current traffic volume is very small, in addition, the invest capital at the beginning may be not enough to support the all construction at the high grade. In case of that, the technical standard can be different in the different stage. For example, in the beginning period, the highway might only be constructed by traffic lane and the supporting

facilities can be constructed step by step according to the traffic demand and invest capital.

Urbanization demand. After the RUA converting to city, the interchange for transit and the parking outside the road require land to satisfy those demands. But in highway planning stage, those works can not be done accurately and impossible to study profound, so the planning can mention the conceptual plan and management idea to advice the related authority to pay attention to land reserving in the development.

5. THE SYSTEMATIZED NETWORK PLANNING METHOD FOR RUA

The above discussion analyzes the characteristic of rapid-urbanizing area network planning. We should still systematize the planning steps and process so that this method can be easily applied in practice.

5.1 The Working Steps and Process of Network Planning in RUA

This planning process contains seven steps, the detail information can be found from the following flow chart.

Step1: Planning target ascertainment. Based on the social economy, the-state-of art of the traffic system, the social and economic development characteristic in RUA, analysis of the minimum scale of highway that can lead the economy development, the planning target can be ascertained, the index for time limited efficacy and percentage of coverage can be ascertained too.

Step2: Highway framework planning. After setting out the economy depending points for RUA and transport hinges, the traffic zone location theory and Critical Path Method (CPM) can be applied to ascertain the highway skeleton and the layout of nodes.

Step3: Marking the planning boundary and links. Due to the urban area and country interlacing, it is very necessary to clarify the planning boundary through investigation. The planning boundary can be defined not including the urban area.

Step 4: Branch line network planning. Using the traffic zone location theory and node importance to lay out the secondary highway network that makes the skeleton denser.

Step 5: Optimising the layout. Considering the integration of highway planning and land use planning, the cross-section of trunk lines in the future urban area must be planned and the land use must be controlled by the alignment on the large-scale map and ascertain the location of the junction, then the highway network can be optimised.

Step 6: Construction sequence. Analysing the function of trunk lines in different period and geographic condition of secondary highway, considering the development emphasis and

capital invested，those can make the construction sequence.

Step 7: Planning and target in different stage evaluation and adjustment. The proper index can be chosen to evaluate the highway network layout and scenario rationality. According to the evaluation, make some necessary adjustment.

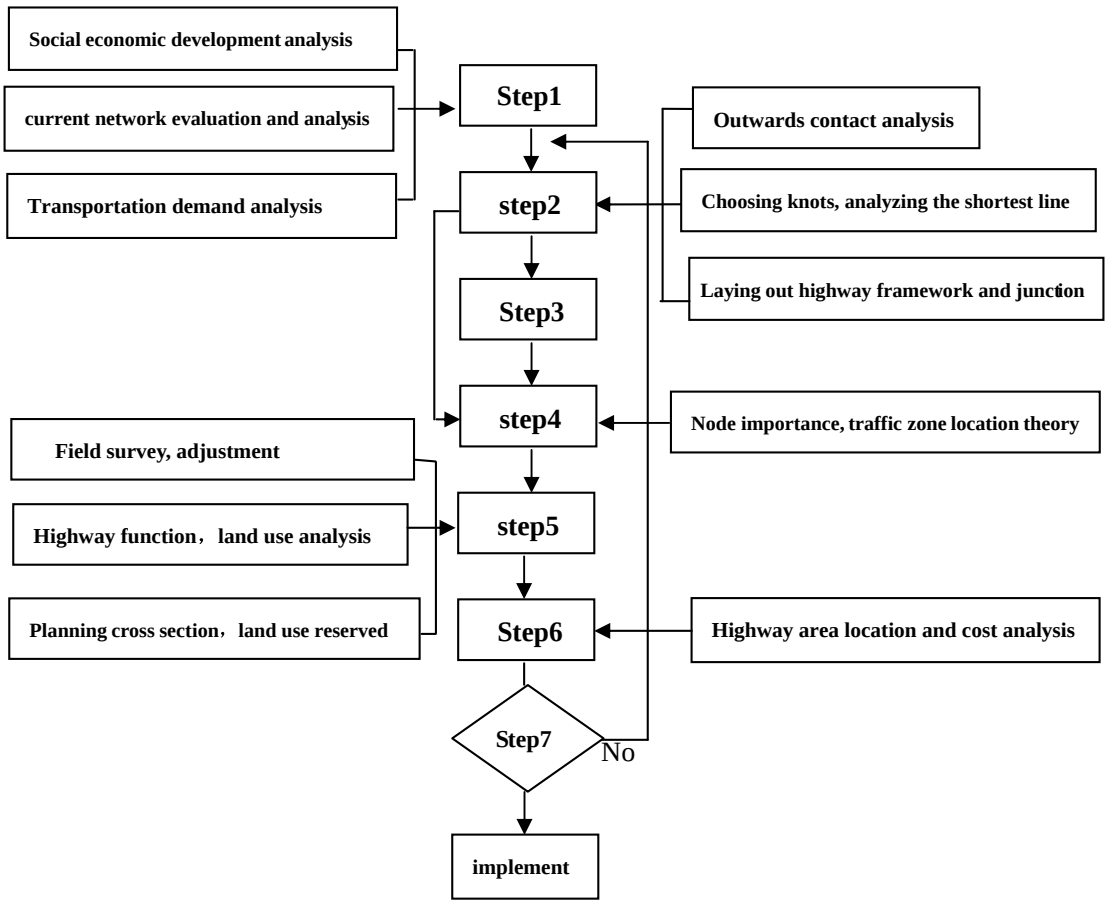

Figure 1.Flow Chart of Highway Planning Process for RUA

5.2 The Announcements of Highway Network Planning in RUA

5.2.1 Planning Target Ascertainment

The planning target shall put much emphasis on the service function of highway complying with interstate or national highway planning and ensure the highway network work properly.

5.2.2 Highway Network Layout and Optimization

Basic theory for layout. Traffic zone location means that some traffic zone may produce or attract the traffic flow by the location advantages endowed by geographic position. This advantage owns the property of constant in a long period. Traffic zone location line is the links of the point owns the traffic location advantage. Traffic zone location application in

highway layout is to summarize the basic regularity and align the highway near to the traffic zone location line. Some researches have indicated:

- The center of the region exists the traffic zone location line with the largest potential
- The quartile of the region also exists the traffic zone location line with larger potential
- The shortest traffic zone location line exists near to the political point, economy point and transport node
- Ridge route, hill-side route, hill-slope route and river route is the traffic zone location line in the constrained topographical condition
- In the conjugation site and the border of the administration, the loop traffic zone location line exists with largest economic interest

Layout by node importance is first to select the node that is connected by the highway network, then quantify the importance of node and connecting lines among nodes by some economic index related to the transport, finally frame the highway network based on the largest quantified importance. This way considers the energy of economy of the node, but some nodes without the economic index have to be connected, its quantified importance can be acquired by quantifying the energy of location or analogical method.

Highway skeleton layout. Highway skeleton planning must correspond to the trunk lines of upper network planning. The skeleton planning is first to select the nodes, which includes the depending city, entrance-exit of access road, transport hinge, harbor, airport, free way junction, defied trunk lines, boundary of RUA, then analyze the traffic connection demand and determine the critical path among the nodes have connection demand and the primary traffic zone location lines as the skeleton layout. Because the network of this level plays a very important role, the highway technical grade is usually planned as expressway, the first class highway or speedway.

Skeleton network is the key point to drive the economy development in RUA, but it needs the support from the branch line network to connect the other area except the RUA, so it is necessary to define the joint between the planning scope of general highway network and RUA.

Branch line network layout. The task at this stage is to plan the highway network in the non-RUA area in the planning scope. The branch line network planning must outstand the collection and distribution function of the skeleton, service the economy development. This process almost is the similar to that mentioned in the references [3][4][5] except the depending skeleton planning.

Cross-section planning and reserved land. Cross-section selection must be based on the highway or urban road technical code, the principle of “putting people first” should be reflected. For the highway with pedestrians demands, non-motorized vehicle, the cross-section can be set as the one block (without median strip), two blocks (with median

strip), three blocks (two dividers) under the circumstance of guaranteeing the service level of trunk lines, at the same time, the land use for green belt land use on the both sides of highway must be reserved and controlled. For the junction, the land use for the overpass facility must be also reserved for the convenience of future intersection canalization and intersection widening.

Intersection model planning. For the hinge at the intersection of the trunk lines and freeway, trunk lines and urban road, the road connecting to development district, the junction facility model can be chosen as interchange or separating model; for the highway with land use development along its both sides, the intersection can be set as common crossing. Trunk line and branch line can be separated.

5.2.3 Construction Sequence

The short-term highway construction first considers the access road of RUA and the feeder highway network to the trunk lines to lead the RUA development. The early investment benefit can be increased by stage operation in different development period. For example, the express lane can be completed in near period and the whole road can be perfected in next periods.

5.2.4 The Evaluation and Adjustment of Network Layout and Stage Target

It can be preceded based on the function pulling and moving the RUA development, the sustainable development and technique evaluation.

6. CASE STUDY－THE HIGHWAY NETWORK PLANNING OF YINZHOU DISTRICT IN NINGBO CITY

6.1 Planning Target Ascertainment

Yinzhou District lies in the eastern of Zhejiang province along the sea and the southeast part of Changjiang economic circle --- Shanghai is the core. Hu-Hang-Yong expressway passes through Yinzhou District that encircles closely the center of Ningbo City, connecting the Hangzhou Bay Crossing conveniently. There has been certain scale of economy in Yinzhou District, It is one of first-100-county in China. The economic society development target of Yinzhou District is to develop the process industry and the service industry strongly, become the modern and strong county with prosperity economy, high-performance social management and service system, the harmonious relation between city and country and perfect ecosystem and environment.

The present highway network of Yinzhou has a bigger value of density and can provide a proper service level. However, the new process industry development area has obvious area location advantages. Its large-scale and developing sturdy will influence the urbanization

process of Yinzhou and Ningbo greatly. The highway transportation should drive and adapt to this new change. Based on the above analysis, the target of highway network planning is ascertained: It is through the adjustment of trunk line inside the region to enhance radiation function of highway network, come into being the fast conveyance passage which can communicate the center of Yinzhou with the other nodes of RUA, contact the main cities along the southern sea and the mid-China, east-China and south-west regions. Inside the district the half-hour-circle, which considers the center area or Ningbo City as the center, comes into being. The highway network that is convenient, unimpeded, safety, satisfied with the urbanized district demand and low investment will be achieved.

Table1. Nodes for Network Layout of Rapidly-urbanizing Regions

Line	Location	The reason for choosing
1	Dayin	Junction between S59 and Hang-Yong expressway
2、3	Gaoqiao、Wuxiang	Junction between Ring expressway and Hang-Yong expressway
4	Lirentang	Junction between Ring expressway and Yong-Jin expressway
5	Fujia	Junction between Ring expressway and Tong-San expressway
6	Panhuo	Junction between Hang-Yong expressway and Tong-San expressway
7	Hengjie	Junction of Hang-Yong expressway at WIE boundary
8	Jiangshan	Junction of Ring expressway at west MIE boundary
9	Dazhujia	Junction between Hang-Yong expressway and Tian-Tong Road
10	Duantang	Junction between Hang-Yong expressway and Airport Road
11	Export of Lianfeng Road	Link up of Lianfeng Road and Jishigang
12	Export of Chengxi Road	Link up of Chengxi Road and S34
13	Export of Dongsan Road	Link up of Dongsan Road and Yin-Jiang Road
14	Export of Tiantong Road	Link up of Tiantong Road and highway
15	Lishe Airpot	Transportation hinge
16、17	Xianxiang、Zhanqi	Economic knots along sea
18、19	Ningbocity,Yinzhou centerDistrict	Dependent city, center city
20	Sanxing	The center of east MIE
21、22	Dongqiao、Wangjiaqiao	Knot at the left boundary of west MIE, center district
23	Jishigang	Center of WIE

6.2 Highway Network Layout and Optimization

There are four rapid urbanizing areas around Ningbo: Yinzhou central District(**YCD**) lies in the center, which is the new center of administration, industry and business; Wangchun

Industry Estate (**WIE**) relying on the Hangzhou Bay Crossing has a superior position; Mingzhou Industry Estate (**MIE**), which has large land area to draw on the advantage process industry of Ningbo, is divided into two parts because the middle part belongs to Fenghua City. There are 10 trunk lines that have passage function planned by different planning organizations of country, province or city. Including: Hang-yong expressway, Tong-san expressway, Ningbo airport Road, Ningbo Ring expressway, Ningbo east-outside-ring Road, Yong-jin expressway and conjunction line, G329, S34, S59 and S71. According to the convenient of usage, the nodes the network layout of these RUAs can make us of are shown in table 1 and figure 2.

6.2.1 Framework Network Planning

The access and turning transportation demand of **YCD** can make use of Tong-san expressway, Hang-yong expressway, Ningbo around-city expressway, Hangzhou Bay Crossing, Ningbo airport Road, Ningbo east-outside-circle Road, Yong-jin expressway, S34, Dayin, Dongqiao, Dazhujia, Panhuo, Wuxiang junction of Hang-yong expressway, Lirentang, Fujia junction of Ningbo Ring expressway to satisfy the west, east, south, north, southwest five directional discrepancies and convertion. To go directly to the Lishe Airport for center area, Shiqi junction of Ningbo airport Road is ordered as link. At the internal center position, the first Yinxian Road is planned as framework highway of the starting period to drive the fast-urbanizing region development. The second Yinxian Road along the center area boundary is planned to enhance the distribution function and the framework density. Tiantong Road and Dongsan Road reserved as urban road are extended to the link eastwaid-Jiangshan Junction.

The access and turning transportation demand of **WIE** can make use of Ningbo Ring expressway, Hang-yong expressway, Yong-jin expressway and its conjunction line, Dayin, Dongqiao, Hengjie junction, S59 to satisfy with the west, east, south-west transportation needs. South-north discrepancy is not smooth, so Gulin Junction with Yongjin conjunction line is increased to satisfy north fast discrepancy. Then 23rd 24th knot connecting with export road are chosen to plan Gaoqiao~Hengzhang Highway, which connects the north to S59, southward to S34. The line locates roughly 1/2 place of west center development area; can be as the development axis of south to west. The first Yinxian Road and second Yinxian Road at the boundary of development area connect directly with the Yinzhou center District. In order to arise the function of the center city, the advantage area and link up knots-11, 25th are selected to get Ningbo~Jishigang Highway as the east-west development framework road. The line crosses the development central part.

Ningbo Ring expressway, Yong-jin expressway and Lirentang Junction meet the transit transportation demand of the west MIE. The south-west discrepancy transportation can utilize S34. For the convenience of connection with the west neighbor city-Yuyao, The 21st knot, along the lengthways boundary, planned Dongqiao~Qishan Highway joining to S59; Dongqiao Junction is ordered to link up Yong-jin expressway for fast connection with the south-west main market.

There are Tong-san expressway, Ningbo Ring expressway, Ningbo airport Road, Fujia junction, Jiangshan junction meeting the transit and south-north discrepancy transportation

demand of the east MIE. For the convenience of east-west discrepancy, Yinnan junction with Ningbo Ring expressway is added up to support the transportation of developing area; To the transportation inside the district, along the centerline of area, the 20th 21st knot are chosen to plan Binjiang Road as the development framework road.

Synthesizing Mingzhou Industry Estate, 21st 23rd knots are selected to get Mingzhou Road to promote the development scale of areas.

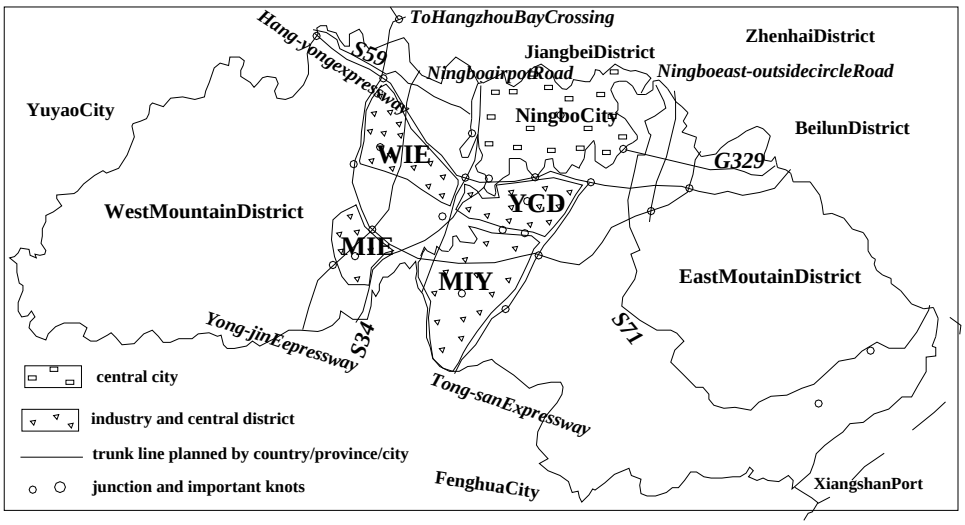

Figure2.Distribution of Trunk Line Planned by Country, Province, City, RUA and Important Knots

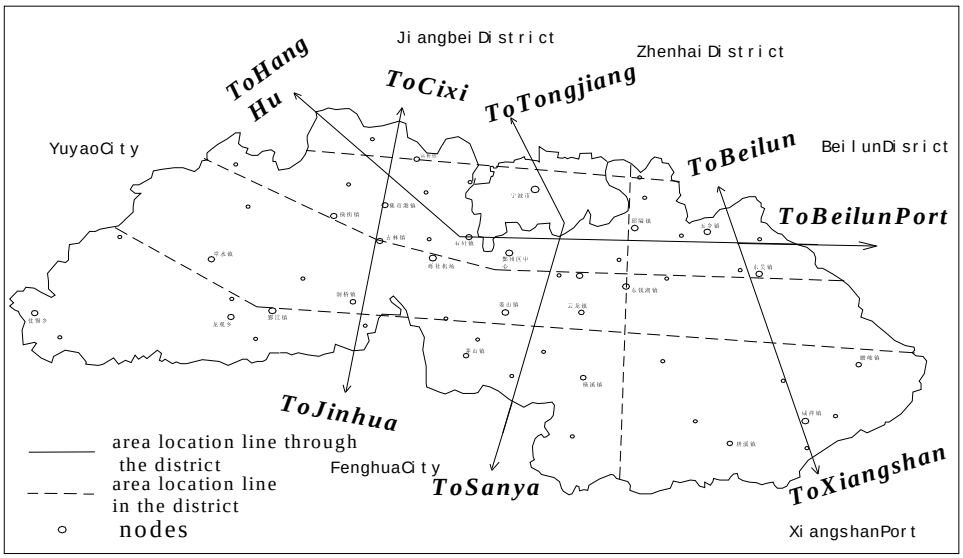

Figure3. Analysis of Transit and Transportation Area Location inside District

6.2.2 Planning of Branch Line Network

Based on the above framework RUA, we choose 55 solid nodes, including towns (for trunk line) and villages (for the normal line), add up the important 13 void nodes such as the transportation hinges connecting with outwards, analyze and compute the node important

degree, cluster and delaminate the nodes, then adopt graphic theory to get the optimal tree of the network, shape the skeleton network, combine with the heading of the main area location lines, launch the layout step by step. The link line with outwards is superior to layout. Yinzhou District east faces the Xiangshan, Beilun two seaports. The excellent area nodes— 16th 17th, which contact the east coast, are selected. Baozhan Road, Yanhai Road connecting with S71 and Mingzhou Road are planned as the most short and excellent lines contact coast in eastern region. The passage from Yinzhou center District to coast in eastern region breaks through. The area location advantage of seaport is shown through Yanhai Road.

The connection of important economic node inside the area can make use of first Yinxian Road that crosses the center. Second Yinxian Road contacts the close towns: Yunlong and Hengxi, and combines with S71 by the branch line to go to the eastern mountain region. Duantang~Liangzhu Park, Tongtu Road, Jiangnan Road are planned as the circle and radial lines of Ningbo City.Wuxiang~Lishutang, Mozhi~Fangqiao etc. are planned to encrypt framework network and plain region network, and distribute the trunk line transportation.

The highway planning method among town and village heritages [4], we leave it out for the limited space.

6.2.3 Optimize the Planning Network

The head of network has gained. We explore and settle the alignments on 1:10000 scale map. Considering the development and urbanizing areas, Dongqiao~Qishan highway goes along the outer of the west MIE; Zoumatang~CailangBridge highway in joining zone of town and city proceeds to link up the road of development areas; Based on the master planning and land use planning, the accurate alignment of highway are attained.

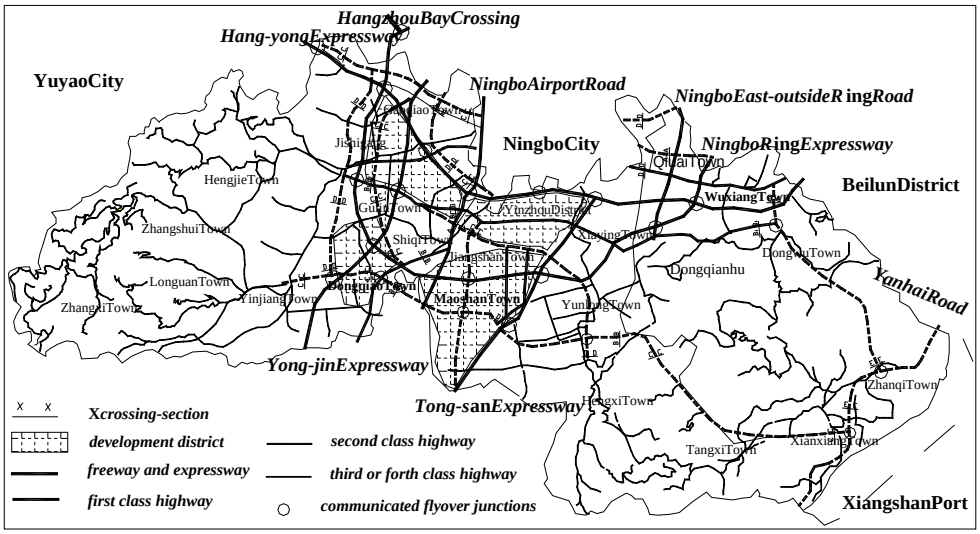

Figure 4.Main Planning of Highway Network in Yinzhou District

Analyzing the trunk line junction and its functions mutually, joining together with the existing junctions, the stronger development function, the proper distance and cost, 22 links(add up 11) are ordered as communicated flyover junctions. The layout result shows in figure 4.

6.2.4 Ascertain the Highway Grades and Control Land Use

According to the highway function in different stages and the degree of urbanization, the planning puts forward the highway grade shown table 2, the cross section shown figure 5. The lanes for motorized vehicle in planning lie in 2-8. We plan 6 kinds of cross sections for the first class highway according to the different district, and set up the land for green belt.

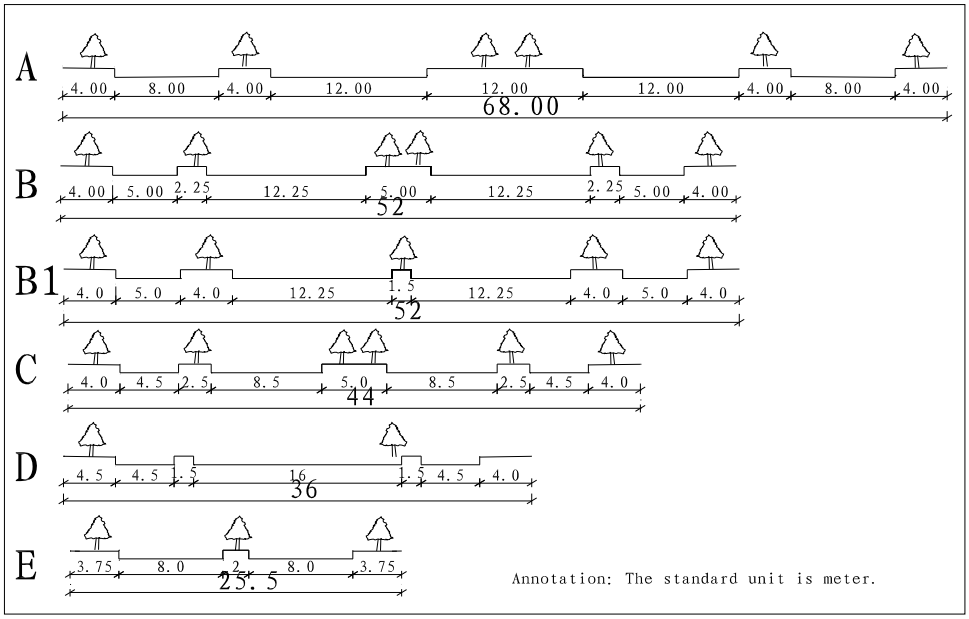

Figure 5.Highway Cross Section Planning

Table2.Detail Form for Grade and Cross Section of Main Highway in Yinzhou Districts

Type	Lines	Existing grade	upgrading	lanes	Width of sub grad(meter)	Cross section form
RUA dependent on framework highway	Ningbo—Jinhua		Expressway	Belong to Ningbo City		
	Ningbo Ring expressway		Expressway			
	First Yinxian Road		1	6	52	B1
	Second Yinxian		1	6(4)	68(36)	A、D
	Lianfeng—Hengjie		1	4	36	D
	Hengjie—Gaoqiao		1	4	44	C
	Dongqiao—Qishan		1	4	36	D
	Mingzhou Road	2	1	6(4)	52(44)	C、B
	Binjiang Road		1	4	44	C
	Ningbo—Jiangshan	2	1	4	36	D
	Yinzhong—Maoshan	2	1	4	36	D
Link up line	Yanhai Road		1	4	25.5	E
	Baozhan Road	4	1	4	25.5	E

Note: Take the value in brackets when cross section forms change.

6.2.5 Development Strategy and the Result Expected

Combining with the funds, the developments strategy is made sure that for near period (to 2005) the high speed passage contact outwards should be perfected: set up Ningbo ring expressway and Yong-Jin expressway to form the "井" framework of expressway. In second stage (to 2010): Complete outward trunk line network. In third stage (to 2015): Form framework network; complete the rebuilding of parts of urbanizing road and junctions; exterminate the road outside etc. After putting the planning network into practice, the high grade highways framework will form the network appearance of circle and emanation; build multi-level-structure, network and sustainable highway transportation system. Which will moves the development of economy and urbanization, and provide the term for economic modernization of Yinzhou District.

7. CONCLUSION

The paper presents actually the highway network planning method of rapidly urbanizing areas(RUA) according to the urbanization demand, makes points of the planned lines, land use, technique standard etc. in special period, processes the accuracy and maneuverability of planning, breaks through the depth of former planning, improves the traditional highway planning method and provides a consult for similar regions in actual work.

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