Southwest Jiaotong University Undergraduate Graduation Project

Location and Design of One Section of a Certain Intercity Railway

Grade: 2018

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Major: Civil Engineering

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THE PLAN FOR GRADUATION PROJECT

CLASS 2018 NAME Workineh Liyew STUDENT NUMBER 2018199124

ISSUE DATE 2022- 08- 20 DUE TIME 2022-12 - 20

Title Location and Design of One Section of a Certain Intercity Railway

1.Purpose and significance of this design

Through the graduation design, students will have a more comprehensive understanding of the railway line design process, familiar with the relevant specifications and reference books, and lay the foundation for future independent work. In addition, the ability of students to apply basic theories and professional knowledge to solve railway design problems will be cultivated. Furthermore, the ability of students' engineering drawing, theoretical analysis, scheme design, computer application and foreign language reading will be improved and trained. And students' ability to analyze and resolve practical engineering problems will be improved. Moreover, it will cultivate students' practical, meticulous, rigorous and serious working style.

2.Tasks for students

(1) Relevant data collection and collation, foreign language translation, and design software learning.

(2) The formulation of railway main technical standards.

(3) Research and comparison of railway line strike schemes.

(4) Railway plane and profile design.

(5) Calculation of the railway carrying capacity and traffic capacity.

(6) Calculation of main technical and economic indicators.

(7) Preparation of graduation design instructions and drawing of railway plane and profile.

3.The degree of achievement of this design and the training objectives of this major?

Students' ability to comprehensively apply the knowledge they have learned in railway line selection design will be trained. And students' ability to skillfully apply relevant design specifications will be cultivated. Students' engineering drawing ability and the ability to apply computer software and text expression will be trained as well. Students' ability to analyze and solve practical engineering problems will be enhanced. The quality of practical, meticulous, rigorous and serious for students will be cultivated.

4.Content and time allocation of each part of graduation project (17 weeks in total)

Part I Relevant data collection and collation and design software learning (4 weeks)

Part II The formulation of railway main technical standards and research and comparison of railway line strike scheme (2 weeks)

Part III Railway plane and profile design (5 weeks)

Part IV Calculation of railway transport capacities and main technical and economic indicators (2 weeks)

Part V Preparation of graduation design instructions and drawings (3 weeks)

Graduation Project Review and Defense and Revision (1 weeks)

Remarks

Supervisor Yong Zeng (Associate professor)

摘 要

城际铁路的设计应满足乘客的出行需求和城市之间的经济交流，确保供应满足需求，并大大分担高速公路和传统货运铁路的客运供应。城际铁路将城市连接在一起，形成快速的交通经济交流圈，优化了路网结构，提高了铁路客运服务水平。

本次毕业设计主要是设计一段设计速度为 200 公里/小时的双线城际铁路。其中包括确定拟设计方案的主要技术标准、根据现有地形等高线数据和设计规范选择三条线路走向、比较所选线路走向的优缺点、详细的平面和剖面设计以及优化（如合理布置平面曲线）、纵坡长度和坡度的优化，根据需要布置桥梁和涵洞，以及平纵断面的设计图。然后，计算通过能力和铁路能力的计算和校核，以及主要技术经济指标的计算，包括投资和运营费用以及折算的年成本，以便在三个方案中进行比较和最终选择。在本次毕业设计中，Civil 3D 2020 用于线路走向、平面和剖面以及走廊横截面的设计。

关键词： 平面和纵断面； 城际铁路；路线设计； Civil 3D

Abstract

The design of intercity railway should meet the travel need of passengers and economic exchanges between cities, ensure supply to meet the demand, and greatly share the supply of expressways and traditional freight railways for passenger transportation. Intercity railways connect cities together to form a rapid transportation economic exchange circle, optimizing the structure of the road network and improving the service level of railway passenger transportation.

This graduation design is mainly about the design of a section of a double line intercity railway with a design speed of 200km/h. which consists of the determination of the main technical standards for the schemes to be designed, the selection of three line strikes according to the existing topographic contour data and design specifications and comparison of advantages and disadvantages for selected line strikes , the detailed plane and profile design as well as optimization such as the reasonable arrangement plane curves, the optimization of length and slope of the longitudinal slope , the arrangement of bridge and culvert according to the needs, and the design drawing of flat longitudinal sections. Then, calculation and checking of carrying and railway capacity as well as the calculation of the main technical and economic indicators which include the investment and operation expenses and converted annual cost are calculated for comparison and final selection among the three schemes. In this graduation design, Civil 3D 2020 is used for design of the line strikes, plane and profile as well as the corridor cross sections.

Key words: Intercity railway; alignment design; plane and profile; Civil 3D

Contents

Chapter 1 Introduction

In a world of increasing population and economic growth, transportation systems like railway, highway, air and water transport systems are of great significance. Among those transportation systems, railway is rapidly increasing in China and all over the world currently. In this graduation design, the location and design of one section of a certain intercity railway which is one of the transportation systems is explained and designed step by step.

A railway is a terrestrially guided mass transportation system on which trains move independently using diesel traction or with the aid of remotely transmitted power or electrical traction using steel wheels rolling on a specific steel guideway delineated by two parallel rails. A railway line is a communication path made up of rails that are only used by railway vehicles or it can be defined as any parallel running tracks that connect two points. Where a section of a railway line comprises of two or more lines running parallel to one another, there are as many lines as routes to which exclusive tracks are allocated. In order to carry people or goods between stations or sites designated in tariffs as separate points of departure or arrival, a track must have end-to-end line continuity.

Intercity railway lines are lines which are designed for serving the passengers in urban areas[1,2]. As a link between urban and mainline railroads, the intercity railway provides medium- and short-distance passenger transportation, as well as commuter service. In other words, it refers to the fast, convenient and high-density passenger dedicated railway that specially serves urban agglomeration with the design speed of passenger train ranging from 120km/h to 200km/h.

When compared to the intercity railways, highway transportation for long-distance travel has limited sustainability due to its lower safety performance, convenience, speed, eco-friendliness, and capabilities. Meanwhile, intercity rail transit is the best option for integrating regional transportation and transporting a large number of passengers. This is due to the fact that intercity railway transportation system has exceptionally high safety, high speed, a small environmental imprint, sustainability, high efficiency, and a strong service capacity.

Intercity rail transportation can accommodate large numbers of passengers and is favorable to fostering the transition of the regional economic growth mode. Furthermore, intercity rail transit system will promote industrial construction, spatial arrangements, and allocation of resources, as well as increase land utilization efficiency, therefore boosting regional integration and urbanization growth. As a result, by solving issues like as traffic congestion, pollution, and energy shortages caused by the enormous expansion of vehicles, intercity rail transit will serve as an absolute under pinner for speedy and punctual passenger transport in urban clusters and metropolitan regions. Intercity rail transit is a quick, comfortable, and high-capacity passenger rail transportation system created between core cities which are densely populated.

There are many uses for the railway, making it a desirable means of transportation. To name a few applications, it is utilized to link cities with comfortable high-speed services that give quick travel times from city center to city center, provide large capacity local travel of passengers in big cities, convey vast amounts of ore from interior mines to seashore ports, and more. As more people become aware of the problems related to air pollution and climate change, their interest in it is only going to grow since it is energy efficient and can be operated by renewable sources of energy.

Recently due to the rapid urbanization and increasing of the population in cities and metropolitan areas, enabling rapid and convenient intercity travel became mandatory. When there is a region with accelerating urban agglomeration and industrial integration, cities in the region will have a high need for passenger and freight transportation. To make better use of the area's land resources, safeguard the ecological environment, and spread the burden of road traffic and urban hubs, a high-speed, high-capacity public transportation system, known as an intercity rail system, must be built.

Inter-city railway is generally built in some developed economy zone, linking main cities in the zone. Trains can run with speed of 160 km/h, 200 km/h or over on main sections. Intercity rail lines still operate commuter trains and provide suburban services in the zone. The intercity railways can be classified into single intercity railway and duplex intercity railway. For single intercity railway, only two terminations have the economy passenger traffic demand; a duplex intercity railway connects several cities and there is the demand of economy passenger traffic between each two cities.[1]

In this design, a certain section of a double line intercity railway with a design speed of 200km/h is designed. Three line-strike schemes are selected and finally they are compared with each other according to the technical and economic standards to which line strike is the best among them. In addition, the plane and profile design, calculation of the railway carrying capacity and traffic capacity and calculation of main technical and economic indicators are done for each design scheme.

This design is done with the help of one of the software developed by Autodesk, Autodesk Civil 3D 2020, which is a highly versatile software for railway and highway design. Autodesk Civil 3D is a creative and easy to understand civil engineering design and documentation software that supports computer aided design (CAD) and Building Information Modeling (BIM) workflows on a vast range of civil infrastructure projects, including roads and highways, land development, rail, airports, and water which helps to organize project data, create and analyze surfaces, alignments plane and profile views of the created alignment, create assemblies and corridors of railways and roads.

It allows a us to freely create horizontal and vertical alignments, adjust any variables desired, including design velocity, radius of curves, length of transition curves, railway cross slopes, cut and fill slopes, thickness of subgrade of the railway track, etc.

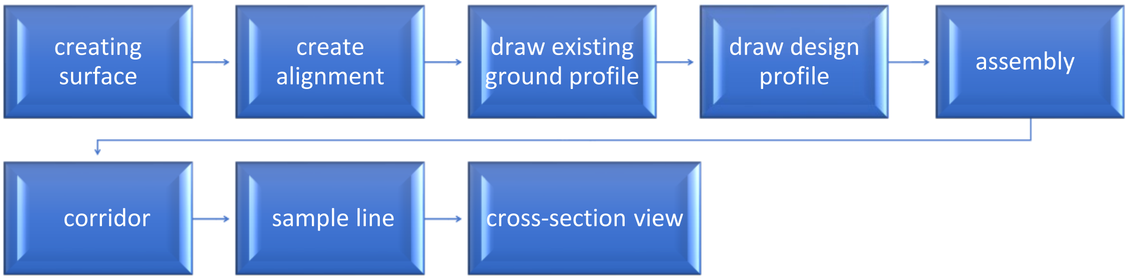

Figure 1-1 Flow chart for workflow of Autodesk civil 3D in railway design.

What are the outputs of Autodesk civil 3D?

- Plane and profile views of alignments
- Cant view: the super elevated view of the railway track along curved sections.
- Rail line data excel sheet – used for setting out the railway line for surveyors
- Section view
- Amount of earthwork.

Purpose and significance of the thesis

The aims of this thesis are:

✓ a comprehensive understanding of the railway line design process,

✓ a proper use of the relevant specifications and reference books,

✓ laying the foundation for future independent work.

✓ applying basic theories and professional knowledge to solve railway design problems.

✓ Improving the engineering drawing ability, theoretical analysis, scheme design and computer application like the usage of Civil 3D.

✓ improving analysis and resolution of practical engineering problems.

In this chapter, the design task and method of railway alignment as well as the Purpose and significance of the thesis are expounded; furthermore, the working principle and steps of Civil 3D software for railway line design is introduced. In the second chapter, railway main technical standards are defined and explained in detail and finally summarized in a table. In the third chapter, techniques and process of line strike selection are explained in addition fundamental requirements of a railway alignment is explained and the three proposed alignments are compared.

In the fourth chapter, the basic requirements of the plane and profile design of an intercity railway is elaborated and the elements of the plane design like the circular curve transition curve tangent etc., and profile design vertical circular curve and slope section etc., are explained and designed for the proposed three line-strikes. In the fifth chapter, the running time, carrying and traffic capacity are explained and calculated for the proposed alignments. In the last chapter (chapter 6), the main technical and economic indicators are calculated and compared to select the best alignment for the intensity railway in the given section.

Chapter 2 Determination of intercity railway main technical standards

The railway main technical standards are those which the designed railway line should meet and usually they depend on the function of the railway line. When the line is expected to serve transport of passengers with the shortest possible time, the design speed of the line should be higher and the technical standards should be at a level where they can provide the required safety since higher speeds are more susceptible to accidents. Railway main technical standard are established for the purpose of ensuring safety, maintaining of railway network and ensuring of railway transport characteristics, ensuring of convenience for users and environmental countermeasures[1].

2.1 Determination of main technical standards

The main technical standards of intercity railway shall be determined by comprehensive comparison based on its role in relevant railway networks, topography, geological conditions, transport capacity and transport demand along the line.

These technical standards can be classified as engineering standards and facility standards. Engineering standards are hard for reconstruction and should be studied thoroughly before the design and construction of the railway line. Engineering standards include the number of main tracks, the maximum grade (or ruling grade), the curvature's minimum radius, and the length of the arrival and departure line that may be used. With changes in traffic, facility standards such as EMU type, train operation control mode, train operation command mode, and minimum headway may simply be altered. Each main technical standard of intercity railway is explained in detail below.

1. Design speed

Design speed is the maximum allowable operating speed for all sections of a railway line which is represented by Vmax (km/h), and it also serves as a fundamental design criterion for associated structures and infrastructure. Traffic demand, project condition and significance of an intercity railway are the major factors affecting the design speed.

2. Number of main lines

The railway connecting and passing through each station is referred to as the main line. Railways can be classified as single line, double line, or multiple line railways depending on how many major lines they have. But for intercity railways, the line is designed as a double line as specified in the code. This is due to the fact that intercity railways are links between cities with a higher population that needs a high transport capacity, so using a double line can maximize the carrying capacity usually 3 to 4 times the capacity of a single line railway; it maximizes the running speed and reduces the construction and operation cost.

3. Distance between main lines

When a railway is constructed with two or three main lines, the straight section of the main line should be designed as a parallel double track with a constant distance between centers of lines, and the curves of the main line in section should be designed as concentric circles. The distance between centers of lines shall be determined to meet the safety requirements. When the design speed of the intercity railway is slow (≤160km/h), the distance should be widened which is influenced by factors including railway clearance, aerodynamics, and wheel-rail contact geometrical relation.

4. Minimum curve radius

Minimum plane curve radius is the smallest allowable radius that can be used in intercity railway which influences the safety of operation since it is inversely proportional to the centrifugal force i.e., the smaller the radius, the higher the centrifugal force which may cause overturning in train operation. Minimum curve radius also affects the riding comfortableness, running quality and some engineering economy indicators, such as running speed, running time, investment, income of operation, and expenditure of operation. When we say minimum curve radius affects the running time, expenditure of investment and operation cost, it is because, the curve resistance which is one of the additional resistances is affected by the curve radius inversely. So, the shorter the radius, the higher the resistance which increases the operation cost and the running time and on curves to assure the total grade doesn’t exceed the maximum allowable, we should reduce the grade which in turn increases the earthwork that increases the construction cost.

The minimum horizontal curve radius is be decided according to factors such as railway grade, intended operating speed, traffic organization method, level of ride comfort and safety, and engineering working circumstances, etc. So, for this thesis a minimum horizontal curve radius of 2200m is specified in general conditions and 2000m for difficult conditions.

5. Maximum gradient

The steepest grade that can be utilized on a railway line is called the maximum gradient. Along with alignments, line lengths, and station distribution, the maximum gradient has a direct impact on traffic safety, running speed, traffic capacity, construction cost, operating costs, and the financial success of the system. It is a technical standard that applies to all aspects of railway engineering.

Calculating the maximum gradient requires consideration of factors such as the anticipated operating speed, locomotive power, form of traffic organization, level of rider comfort and safety, and annual traffic volume. Since intercity railways use a light weight and high power electric multiple units (EMU_s), they can adopt steep slopes, so the maximum allowable gradient for intercity railways can be as steep as 20‰.

6. Available length of arrival and departure lines

Arrival and departure lines are lines built at stations to assure the safety of traffic. The longest length that may be utilized for train stopping without affecting the operation on nearby lines is the available length of the arrival and departure line.

When CTCS2 train control mode is adopted and 8-car multiple units are parked, the effective length of arrival departure track of lean type station shall not be less than 400m; The effective length of the arrival departure track of the terminal station shall not be less than 325m under general conditions and 290m under difficult conditions.

7. Traction type

It is the type of locomotive traction power or MU power. Railway can use three kind of traction sources. These are electric, diesel and steam traction. The kind of traction should be chosen in accordance with the distribution of power supplies, railway features, and natural circumstances along the route. Electric traction should be prioritized on main lines with high traffic volumes, lines with steep slopes, and lines that are near to or on lengthy tunnels.

For intercity railway electric traction is used for three main reasons: it is environment friendly, it saves transportation resources and meets the power demand of trains running at high speeds. Using electric traction, for intercity railway increases the power of locomotive, speed, traction, which can significantly increase the rail capacity without noise and pollution to the environment.

8. Type of block

Train spacing points divide a railway line into many sections or block sections. Section and station are separated on a double-track railway line by house signals or station limit signs. A station section is additionally separated into numerous block sections by the automated through signals in order to maximize the carrying capacity of the section, taking the pillars of through signals in the same direction as demarcation points. Block time, which aims to increase rail line capacity by decreasing the train headway, is the time from when a train first enters the block until it departs. The capacity of a railway line can be impacted by a strategic train sequence and reduced block lengths. The maximum capacity of a railway can be achieved by two trains moving at the same speed. Blocking can be realized in three ways. Manual block, Semi-automatic block and automatic block.

Manual block arrangement only allows one train to remain in the block at a time and it is rarely used on mainlines in China. Automatic block can interchange the through signals showing in terms of status of train running and block sections. Drivers manage the train running by looking at the signal display. The inter-station distance between two subsequent stations is automatically broken into numerous block subsections, reducing the delay between trains traveling in the same direction. It is an automated block system because the train with the track circuit completely controls the signal change.

A double line intercity railway should utilize an automatic block mode in accordance with Chinese specifications. This helps to shorten the duration between two trains traveling in the same direction to 8 to 10 minutes while increasing daily carrying capacity to at least 100 per day.

9. Minimum headway

When two or more trains are planned to travel on the same section and in the same direction by the block district intervals in an automated block district, the method of operation is referred to as a tracking operation. The time gap between trains that is automatically spaced is known as the minimum headway. The automatic block signal system, train length, train speed, block section length, and other factors all play a role in determining track train intervals. When trains with similar characteristics ran on sections with different block lengths, the longest block served as the critical block and set the required minimum headway. Depending on the need for transportation, the minimum headway should be 3–4 minutes. For intercity railways, 3 min is taken as the minimum headway.

10. Train operation control mode

To guarantee the high safety and efficiency of intercity railway with a speed of 200km/h, it is necessary to employ modern highly automatic signal equipment to keep the interval of the trains by fixing block sub-section. This is because we can’t meet the requirements of railway by using block signals since the speed of trains is increasing and the traffic interval is decreasing on main line railways. According to the current railway development in China, passenger dedicated railways like intercity railways usually employ CTCS-2 “goal – distance” continuous speed control mode.

11. Dispatching means

Dispatching is the management of traffic in the command center to monitor the daily production and transport of intercity railway. Intercity railway as one type of passenger dedicated railway, should adopt CTC (centralized dispatching system), an advanced technology equipment and a modernized transportation organization.

Automatic blocking and centralized scheduling together enable dispatchers to remotely operate all turnouts and signals, enhancing the flexibility and strength of the traffic organization plan and resulting in safer operations and increased through capacity.

12. Minimum and maximum radius of vertical curve respectively (m)

For the trains running through a given alignment, the values of the minimum and maximum radius of curves used at the gradient change points is specified so that the no coupler separation, no derailment conditions for the trains, comfort conditions for passengers and maintenance conditions of the track are met. Therefore, to satisfy the above requirements, the minimum and maximum radius of vertical curves are 10000m and 30000m respectively for intercity railway alignment design.

2.2 Summary

Because there are so many of the railway main technical standards, comparison and selection of the main technical standards is a complex task; so, it should be roughly done in the prefeasibility stage and should be compared and selected in the feasibility stage of a railway line design.

Each main technological standard of a railway should work in coordination with other standards to ensure that the train's running speed, quality, and quantity are all compatible. In addition, the development of the railway network should be taken into account while designing new lines, and the coordination of railway network capacity, point-line coordination, and the smooth transition between the design line and the current line should all be maintained.

So, in this chapter, the main technical standards for a double line intercity railway with a design speed of 200km/h are thoroughly studied, selected and summarized in the table below.

Table 2- 1 Intercity railway main technical standards

Main technical standard type	Requirement for intercity railway
Railway grade	Intercity railway
Design speed	200km/h
Number of main lines	2 (double line)
Distance between main lines (m)	4.2
Minimum plane curve radius (m)	General condition 2200 difficult condition 2000

Maximum plane curve radius (m)	12000
Maximum gradient	20‰
Traction type	Electric traction
Type of block	Automatic block
Number of EMU marshalling cars	8
Effective length of arrival departure track	400m
Train operation control mode	CTCS-2
Dispatching means	Centralized dispatching system (CTC)
Minimum radius of vertical curve (m)	General condition 15000 and difficult condition 10000
Maximum radius of vertical curve (m)	30000
Minimum headway	3 minutes

Chapter 3 Comparison of intercity railway line strike schemes

The most important semantic component of every linear infrastructure asset such as highway and railway is an alignment which stands for the backbone of the geometric form and the linear positioning of other elements[3]. A railway route is not a temporary infrastructure rather it has a high degree of permanence involving costly structures [4]. So the best possible optimization to the alignment should be done so that future serviceability of the railway line will not be compromised.

Railway lines are usually designed from the whole(general) to the detailed(specific) passing different number of stages according to the complexity of topography and available information. But generally, railway location selection procedures can be divided into three stages. These are strike selection, route selection in narrow strip area, and alignments design of the selected route.

Many political, social, and economic factors affect the decision to build the new railway line in order to meet the growing demand of the new population center. The principle and process of determining route alignment are essentially the same regardless of which driver makes the request, though the standards differ. The reasons for choosing a specific route alignment should be based on reasonable engineering principles, while also taking into account construction and future operation and maintenance issues.

3.1 Principles of the railway line strike selection

Railway line strikes are defined as approximate alignments within the selected strip of land that are compared with one other in order to select the preferred option according to different circumstances. It is used to define the fundamental path connecting the start and end terminals, as well as the main intermediate traffic hubs.

Topographic factors, particularly the typical natural ground slopes, have a significant impact on the positions and strategies for locating railway alignments. We can classify the natural ground slope condition in to two cases; the sufficient and easy grade[1].

i. Sufficient grade:

it is when the average natural ground slope is steeper than the maximum allowable gradient of the proposed line. In this case, both plane and elevation barriers limit the alignment and the profile design of the selected line is the major source of problems. Route is developed by using the maximum gradient in order to reach the desired elevation and to avoid a huge earth work or the construction of tunnels. Depending on the actual terrain condition in sufficient grade section of a railway route, we can use round abouts, spiral curves or bulb shaped curves etc., by being consistent with one other and the actual terrain situation, since there is no standard mode of route development.

Leading line method of railway location can be used for sufficient sections by which the line strike is chosen by a broken line having maximum gradient and zero cut and fill at the crossing with the contour line is used. It is a rough route design that has the highest gradient, the least amount of cut and fill, and is appropriate for the terrain.

ii. Easy grade

Easy grade refers to a flat, open area where a railway may follow an aviation line as its principal direction or an area where the maximum designed gradient is greater than the typical natural ground slope. The railway is not constrained by elevation obstacles in this grade segment. So, by planning the route in a short, straight way and avoiding plane barriers, it is feasible to acquire a reasonable line position. Since a curve will only be supplied to pass these sorts of plane barriers, we should divert the barriers early to lessen the curvature depending on the importance of the line, traffic volume, geography, geological conditions, the railway network trunk, and other considerations.

In order to position the barrier on the inside of the curve and reduce its deflection angle, the point of junction of curves must line up with the primary barriers when the route avoids spurs, passes valleys, or encounters other barriers. Stations are not allowed to veer off the line's short, straight course and they should be positioned as convexly as possible to optimize the train operation as an upgrade helps the train to decrease its speed while entering the station to stop and a downgrade helps the train to accelerate as it leaves the station. To minimize earth work, the landscape should be level and broad. Since the terrain is flat, easy grade is used in this design.

Route selection involves many steps from project identification to construction.

The first one is project identification and it involves the investigation for the need of a new railway between certain destinations according to the social, economic and political as well as other determining factors. The second one is pre-feasibility stage by which the selection of strip of land or corridor is undertaken after the route is classified as necessary. Then feasibility study follows, including the selection of available routes and on table design and comparison of the cost, length, type of topography, geology is done.

The design stage: which includes the detailed design of subgrades track, bridges and tunnels as well as other ancillary components like drainage ditch and retaining walls.

Finally, the railway is constructed and become open to operation during which maintenance will be needed. So, our design should be in such a way that the future maintenance is reduced.

When selecting the line strike, the location of bridge sites, agglomeration points and location of intermediate stations should be chosen in advance so that the line can inevitably pass through these points. Seriously unfavorable geology areas, historic reservation, reservoirs, and major project areas should be considered as location exclusion areas.

When selecting an alignment, we need to make sure that the distance of the design line is far enough from highways, rivers, or ponds etc. if they are present in the vicinity of the design line. When bridges are to be built, the site should be selected according to the geology and hydrological condition. In addition, it must also choose the narrowest part of the barrier and should be perpendicular or nearly perpendicular to the course of the river or the route of highway to be passed by bridge so that the length of the bridge can be reduced which affects the construction cost.

If there is an existing highway or railway, the new design line should be selected near and nearly parallel to the existing line, because along the existing line the number of buildings is small and the buildings are often of low importance, the scheme design is easy and especially in big cities the right of way should be along existing lines to avoid the demolition and reconstruction as well as the disturbance of residents. If the distance is large, it will be difficult to use the land between the newly designed line and the existing highway or railway that causes un professional use of land which is uneconomic.

When we design the line around hilly regions, the line should pass beside the hill so that we can save land for cultivation.

3.2 Fundamental requirements of the railway line strike selection

A new railway line needs to be correctly aligned after careful study, since an inaccurate alignment may end up being more expensive and may not be able to achieve the required goals So, the alignment of an intercity railway should meet different kinds of requirements such as the following listed below.[4]

Purpose of the New Railway Line

The new railway line's alignment must be consistent with the intended use for building new railway lines, including strategic and political objectives, the development of underdeveloped areas, the linking of fresh commercial hubs, and the shortening of existing railway lines.

Integrated Development

The new railway line must follow the master plan and be integrated into the nation's overall growth.

Economic Considerations

Railway line building should be as cost-effective as possible. The new railway line's intended use should conform to the following.

Shortest route

The shortest path is the one that takes you directly connecting from one point to the next. The costs of construction, maintenance, and operation are lower for the shorter length of the railway line. However, there are additional pragmatic factors that could cause a detour from the shortest path.

Construction and maintenance cost

To reduce construction costs, the line alignment must take maintenance and construction costs into account. By balancing earthwork excavation and filling, reducing rock excavation, aligning the alignment on the watershed line, and taking other technical considerations, this can be accomplished. Because, steep slopes and abrupt bends can seriously damage rails and rolling stock, avoiding them can cut down on maintenance expenses.

Minimum operational expenses

The route with the lowest operating costs must also guarantee the lowest transportation or operation costs. This can be accomplished by maximizing cargo transport for a given locomotive and traction system power level. This in turn can be accomplished by an easy gradient, avoiding abrupt curves, and adopting a straight path.

Maximum Safety and Comfort

Passengers should be as safe and comfortable as possible when traveling the route. This can be done by integrating other technological characteristics, constructing curves with the proper transition lengths, giving vertical curves for gradient change points with a change of gradient greater than the defined value in the code, etc.

Aesthetic Considerations

Aesthetics should also be considered when choosing the path which should be visually pleasing to the passengers taking the train. This can be accomplished by avoiding the borrow pit terrain and traveling through attractive areas, natural and lovely sceneries.

In general, the design of intercity railway route selection must adhere to the following concepts.

By passing through important cities to boost passenger flow and facilitate travel, it should be in accordance with the overall railway network design. It should also improve project quality and transit efficiency while cutting maintenance costs. Additionally, it should establish a fair layout, work in tandem with other engineering projects, local transportation, farming water conservation, and general urban planning.

When it is necessary for the line to pass through unfavorable geology, all forms of unfavorable geological bodies must be diverted away, and soil treatment techniques must be used to raise the subgrade's bearing capacity. This is necessary to ensure operation safety.

In order to optimize the line's plane and profile sections, choose the best project scheme, and define the project type, the railway route selection and overall design must take slope protection, waterproofing, and drainage works into account from a system engineering perspective. The route should be chosen to prevent high filling, deep cutting, and improper regulation of the subgrade filling height in certain geotechnical and unfavorable geological sections.[1]

We can see the figure below as a sample from the drawing to see how line strikes can be chosen according to sites for bridges on rivers, towns etc., The line strikes in green, red and yellow are line strike 1,2 and 3 respectively.

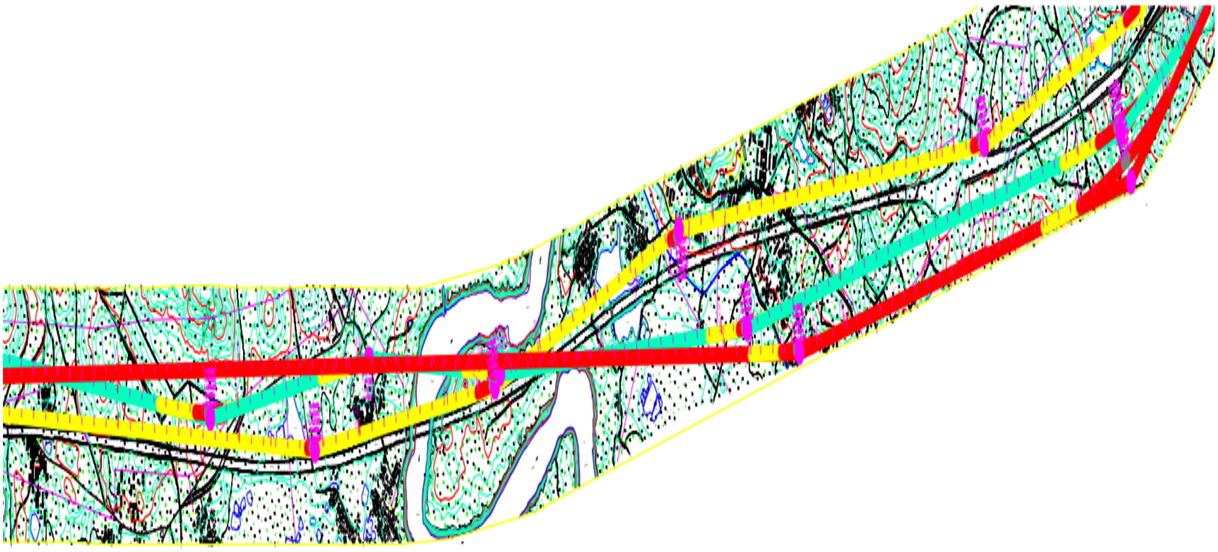

Figure 3-1 Part of the three line-strikes

3.3 Comparison of advantages and disadvantages of line strike schemes

Railway route selection is a complicated process which requires the comparison of many schemes according to their vertical and horizontal geometry, investment, suitability for operation and the position of the railway line with in the given area which may consist of companies, people's houses, schools, existing roads and railways, other restrictions like rivers, mountains, etc.

Designing a railway alignment is an immensely challenging procedure. The railway route designers in this procedure frequently deal with a wide range of variables and a vast array of options. Based on geography, soil quality, environmental effects like noise and air pollution, socioeconomic variables, and the expected level of service from the railway in terms of freight or passenger transit, a railway alignment designer should choose an economical route.

When we compare the advantages and disadvantages of the alignment, we can consider the radius R of curves, the exterior deflection angle (α), number of curves and other parameters as listed in the table 3-1.

As we know, there are many types of additional resistance that act on at train while moving; among those curvature resistance is the resistance a train will experience while moving on a curved section of a given alignment. This curvature resistance can be expressed by the formula below.

$$r_r = \frac{600}{R} \times g\ (N/t) \text{ or} \tag{3-1}$$

$$r_r = \frac{10.5\alpha}{L_C} \times g\ (N/t) \tag{3-2}$$

Where, r_r- curvature resistance (N/t)
R- radius of the curve (m), α-curve deflection angle (°)
L_c- length of curve (m), g- gravity (9.81m/s^2)

So, as we can see in the formulas above, we can conclude that the curvature resistance r_r, is directly related to the curve deflection angle (α) and inversely proportional to the radius R. This shows that the alignment which utilizes a larger radius R and smaller curve deflection angle (α) is safer and more comfortable for driving. From table 3-1 below, we can see that alignment 1 with the highest number of curves (9) has its most unfavorable combination of R=2200m and α_1=18°25′03″ and alignment 2 with the smallest number of curves (3) has its worst combination of R=2200m and α=21°57′08″ while alignment 3 with eight curves has R=2200m and α=11°48′08″.

Table 3- 1 Comparison of curves and their exterior deflection angle and transition curve length

PI	Alignment 1			Alignment 2			Alignment 3		
	R(m)	α(° ′ ″)	Length of transition curve	R(m)	α(° ′ ″)	Length of transition curve	R(m)	α(° ′ ″)	Length of transition curve

	2200	6 24 43	300	3000	5 44 37	250	2400	3 03 13	300
	3000	5 48 13	250	2200	21 57 08	300	3000	5 28 56	250
	3400	2 41 29	220	3000	3 36 25	250	2200	4 05 15	300
	3000	3 10 40	250				2200	4 43 04	300
	2200	7 58 47	300				2200	10 12 15	300
	2200	8 04 22	300				2200	3 56 48	300
	2800	16 01 18	270				2200	11 48 08	300
	2200	18 25 03	300				2400	3 47 01	300
	2200	6 53 27	300						

We can compare and contrast the three schemes according to the following table.

Table 3- 2 Comparison of the three alignmenets

Items	Alignment 1	Alignment 2	Alignment 3
Total length (km)	20.43	20.45	20.32
Number of curves	9	3	8
Number of bridges	13	13	11
Length of bridges (km)	1.975	1.315	1.245
Number of tunnels	0	0	0
Number of places where parameters for difficult conditions used	0	0	0

Table 3- 3 Technical Index of Plane Design

Items	Unit	Alignment 1	Alignment 2	Alignment 3
		Index		
Total length of main line	km	20.460	20.451	20.322
Number of curves	item	9	3	8
Total length of curves	km	3239.428	1332.488	1908.077
Ratio of curve to total line length	%	15.83	6.52	9.39
Maximum curve radius	m	3400	3000	3000
Minimum curve radius	m	2200	2200	2200
Maximum external deflection angle α	° ′ ″	18 25 03	21 57 08	11 48 08

3.4 Summary

To summarize, the selected line strikes should fulfil the requirements and also should be compared with respect to different parameters as illustrated below.

With respect to the ratio of length of curves to the total line as shown in table 3-3, we can say that alignment 2 is the best. But since all the schemes are operationally safe and up to the requirements in the specification, we should instead check for other parameters. Even though this comparison and selection might not be the final, alignment 3 with the smallest deflection angle and also the shortest route is the best route. But the final decision of scheme comparison should be done according to the technical and economic indicators calculated in the last chapter of this design.

Chapter 4 Railway plane and profile design

For transportation infrastructure like highways and railways, and others, geometric design include designing geometric cross sections, horizontal and vertical alignments, crossings, stations, and different design features. In every situation, geometric design seeks to optimize economy, comfort, and safety while reducing environmental effect like environmental pollution and noise and vibration. The requirements for railway alignment and intercity railroad in particular are presented in accordance with Chinese codes in this chapter, which concentrates on the principles of geometric design.

There is a certain order in which activities must be accomplished in a normal design project, with the construction of a preliminary horizontal centerline typically coming before the establishment of vertical alignment (profile design). This is caused by the fact that while determining the vertical alignment, the height of the existing ground along the centerline is crucial. Plotting a profile of the existing ground level is the primary step in creating the design profile, and to achieve this, a rough horizontal centerline must already be determined.

The plane and profile design for railways or highways is done in order to assure the smooth transition in the longitudinal direction. By combining the plane and profile of a certain alignment, we can see that the alignment meets the requirements of safety and comfort as well as the economic considerations altogether. If one of the requirements is compromised, it helps us to improve the route condition by changing the whole or part of the alignment's location or by using a suitable value of the main technical standards.

4.1 Basic requirements for the railway plan and profile design

The railway alignment must be as smooth as possible, with minimal variations in both the horizontal and vertical directions. A smooth alignment with few and modest changes in direction improves appearance, ease of maintenance, and ride quality. All alignment element segments (vertical curves, grade lengths, horizontal curves, transition curves) must have a minimum length adequate to dampen fluctuations in train motion. This length is directly proportional to the duration of time spent on the segment and so varies directly with design speed.

In this design, the plane and profile of all the three proposed schemes should meet the specifications from the design code. From the code of railway line alignment in China, the following parameters should be fulfilled while designing plane and profiles of an intercity railway line.

The minimum radius of curve in the mainline plane of an intercity railway shall be selected in accordance with the following provisions:[5]The minimum curve radius in plane to match the design speed shall be as specified in Table 4-1.

Table 4- 1 The minimum curve radius (m) for plane design

Design speed (km/h)		200	160	120
Engineering condition	general	2200	1500	900
	Difficult	2000	1300	800

When the topography or other barriers are difficult and do not let us design our intercity railway line meeting the standards, speeds limits can be applied while using a value of curve radius that is smaller than the those in the design code. In this case, the minimum curve radius of the plane in the speed limit section can be chosen according to Table 4-2.

Table 4- 2 The minimum curve radius of the plane in the speed limit section

Design speed (km/h)		100	80	60
Engineering condition	general	600	500	400
	Difficult	500	400	300

The minimum length of circular curves and intermediate straight lines shall be calculated according to the following formula and in accordance with the requirements of Table 4-3.

General conditions:

$$L \geq 0.6v \tag{4-1}$$

Difficult conditions:

$$L \geq 0.4v \tag{4-2}$$

In the formula, L is the length of a circular curve or an intermediate straight line(m), and v is the design speed(km/h).

Table 4- 3 The minimum length of circular curve or straight line (m)

Design speed (km/h)		200	160	120
Engineering condition	general	120	100	80
	Difficult	80	70	50

The maximum gradient of the intercity railway should not be greater than 20‰ under general conditions and not be greater than 30‰ under difficult conditions. The mainline is preferably designed for longer slope sections. The minimum slope section length should not be less than 400m under general conditions and 200m under difficult conditions, and should not be used continuously.

4.2 plane design

The plane geometry of a given railway or highway alignment is composed of tangents (straight lines), circular curves and transition curves.

Any railway may be operated most effectively on a straight, level track. Unfortunately, the majority of railway lines are neither level nor straight. In order to securely drive the train, ensure that the passengers are comfortable, and ensure that the cars and track work well together, tangent sections of track must be connected in a way that steers the train safely[6]. With regard to overall operations, maintenance, and vehicle stability, the fundamental objectives of geometric requirements for intercity railway are to offer affordable, effective, and comfortable transportation while ensuring appropriate levels of safety. Generally, design criteria standards are produced based on experience with comparable operational rail transportation systems and accepted engineering practices.

The key factor influencing the comfort and safety of train operation which limit the running speed is the minimum curve radius; which is determined by superelevation cant and unbalanced lateral acceleration of the moving train on the curve. In the plane design, we should fulfill the requirements of minimum length of intermediate straight line, length of transition spiral and minimum curve radius of 2200m. The minimum curve radius is extensively affected by the physical characteristics of the vehicle such as the distance between vehicle truck centers and truck axle spacing. The minimum curve length L_c, is determined by ride comfort unlike the minimum tangent length which is related to vehicles' physical characteristics.

The use of absolute minimum criteria for plane design of a certain alignment could induce many potential risks, such as increased maintenance, wear of wheel and rail, noise and shorter service life of track components, so we should avoid using absolute minimum criteria in our design.[6]

4.2.1 Horizontal curve, transition curve and intermediate straight-line design

Horizontal circular curves are curves with radius of fixed or constant dimension.[7] An acceptable curve radius must be determined based on the industry minimum curve radius, taking curve passing performance, train running speed, cant, etc. into account., to ensure a smooth operation of rolling stock.

A moving vehicle produces forces at the point of contact between the wheel and rail, which can cause sideways rail stress. The lateral force acting on the rails varies with track curvature, cant, and speed. A curved track with a limited radius of curvature experiences significantly larger lateral stresses on the high rail than a track with a big radius of curvature. In addition, the static vertical force is substantially bigger than the dynamic vertical forces, and the lateral forces on curves are significantly greater than those on tangent components.

The lateral pressures on the tangent track are directed in both directions and oppose each other, but there is always a strong static vertical force owing to the vehicle weight. This explains why the vertical degradation of railway track is greater than the lateral deterioration. Railway track deteriorates faster on bends due to increased lateral stresses caused by vehicles moving with cant deficiency or cant excess.

The lateral degradation of track geometry is often stronger on curves, and the lateral irregularity increases exponentially as the curve radius decreases.

For an intercity railway with a design speed of 200km/h, the minimum permissible horizontal curve radius is 2200m and the maximum curve radius is 12000m. Here we can see that the maximum radius is also limited to a certain value of 12000m; this is because, maintenance will not be easy at a larger curve radius. To facilitate easy boarding/ landing and the safety of passengers, a curve along a station must have a radius as big as possible. For curves in the same direction, compound curves with or without transition spirals are preferable to a short length of a tangent between curves.

$$T_i = R_i \tan(\frac{\alpha_i}{2}) \tag{4-3}$$

$$L_c = \pi\alpha R/180 \tag{4-4}$$

$$E_c = R \times (\sec\frac{\alpha}{2} - 1) \tag{4-5}$$

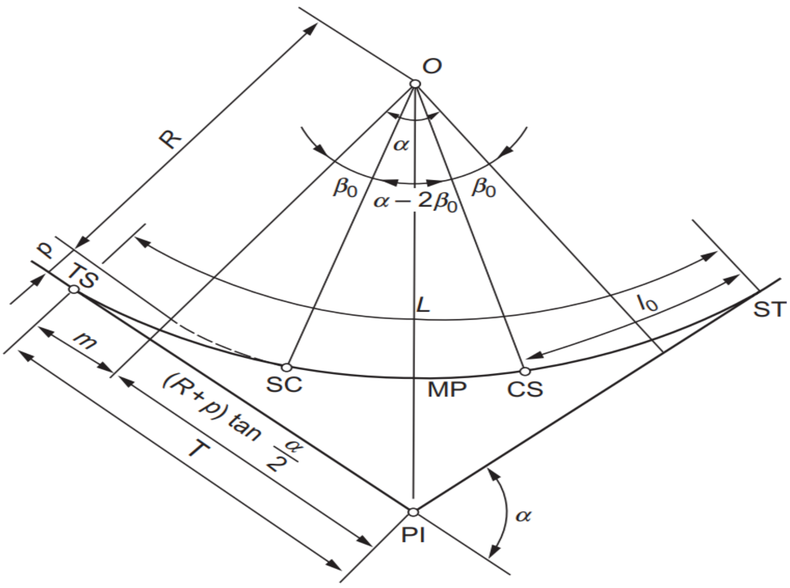

Figure 4-1 Common horizontal curve

Transition curves are those curves applied between a straight line and curve section of a route with varying radius of curvature that varies from infinity at the end of the tangent to R at the start of the curve. According to [8], a cubic parabola transition curve which is most often used in railway engineering shall be used between the straight line and the circular curve of an intercity railway unlike highway lines which most frequently use a clothoid which is characterized by the linear relationship between its curvature and curve length. In railway engineering, cubic parabola type of transition curves with a small vehicle lateral acceleration is more suitable for easement curves with shorter length; but for long spirals typically longer than 150m, other types of transition spirals with a higher order should be used.[9]

In the two graphs below, we can see the difference in vehicle body lateral acceleration when cubic parabola and a polynomial transition spiral with 9th degree is used on a short (100m) and long (200m) transition length.[10]

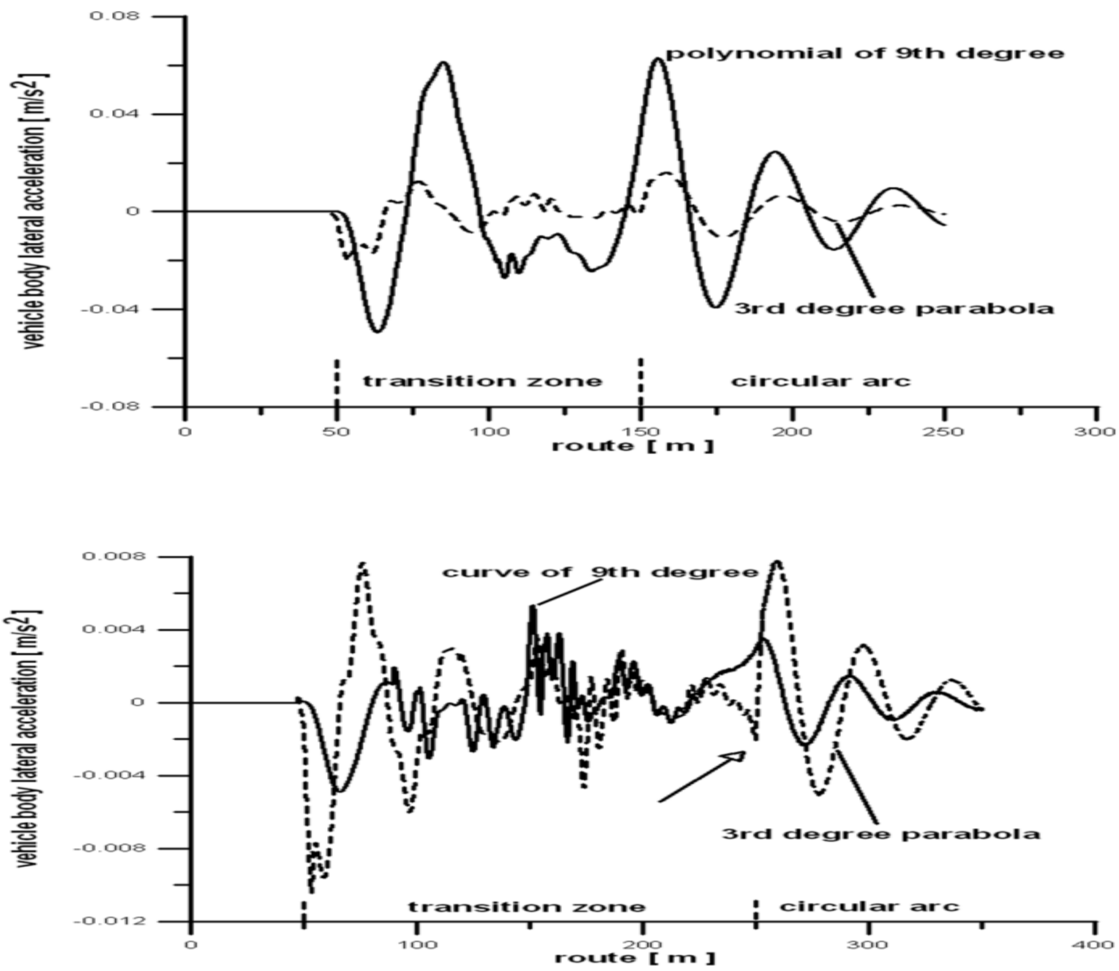

Figure 4-2 Vehicle body lateral acceleration on a cubic and 9th degree transition curve

Transition curves should be perfectly tangential to the straight and the circular curve, in addition its length should be in such a way that curvature changes at the same rate with the superelevation and it should be long enough to attain the required superelevation at the curved section. The length of the transition curve can be calculated according to the following formulas which are related to the design speed, curve radius and terrain conditions, and the maximum value should be taken[1].

$$L_1 \geq \frac{h}{i_{max}} \tag{4-6}$$

$$L_2 = \frac{hv}{3.6f} \tag{4-7}$$

$$L_3 = \frac{h_q v}{3.6\beta} \tag{4-8}$$

Where, L1, L2, L3 and curve length are in m;

h- design superelevation value, in mm;

hq -Design under superelevation value (in mm)

imax-The maximum superelevation gradient meeting the safety conditions is generally 2 ‰;

v- Design speed (in km / h)

f - super high time-varying rate, 28mm / s under general conditions and 35mm / s under difficult conditions;

β -superelevation time-varying rate, 23mm / s under general conditions and 38mm / s under difficult conditions

Where do we use transition spirals?

They are used at both ends of a superelevated circular curve and between compound curves to provide a gradual increase or decrease of centrifugal force and to avoid sudden application so that the chance of derailment is gently lowered[11].

For compound curves the radius of the first curve R_1 is different from the radius of the second curve R_2, which causes a sudden change of centrifugal force at the radius change point.

$$F_c = m\frac{v^2}{R} \tag{4-9}$$

$F_{c1} = m\frac{v^2}{R_1}$, and $F_{c2} = m\frac{v^2}{R_2}$. Since $R_1 \neq R_2$, $F_{C1} \neq F_{c2}$, which results in an abrupt change of centrifugal force, therefore, to smoothen the transition, we use a transition curve with a radius changing from R_1 at the end of $curve_1$ to R_2 at the beginning of $curve_2$.

The length of easement curves should be reasonably chosen according to the design speed, curve radius and engineering conditions in accordance with the table below[12].

Table 4- 4 The length of transition curve

Design speed(km/hr)	200		160		120	
Curve radius(m)	(1)	(2)	(1)	(2)	(1)	(2)

3400	220	180	120	90	50	40
3300	230	190	120	90	50	40
3200	240	200	120	100	50	40
3100	240	200	120	100	60	50
3000	250	200	130	110	60	50
2900	260	210	140	110	60	50
2800	270	220	140	110	60	50
2700	280	230	150	120	60	50
2600	290	240	160	130	60	50
2500	300	240	160	130	70	60
2400	300	250	160	130	70	60
2300	300	250	170	140	80	60
2200	300	250	180	140	80	60
2100	300	250	180	140	80	70
2000	300	250	190	150	90	70

In the table (1) and (2) correspond to superelevation time-variable rate of f=28mm/s and f=35mm/s, respectively.

In order to guarantee alignment continuity and the smooth operation of the trains, the straight line between two consecutive curves in segments of curve adjoining curve should be sufficiently lengthy[1]. The intermediate straight line is the straight line that joins the beginning of the back curve (TS2) and the end of the front curve (ST1), alternatively it may be viewed as a straight line connecting these two points as shown in the figure below.

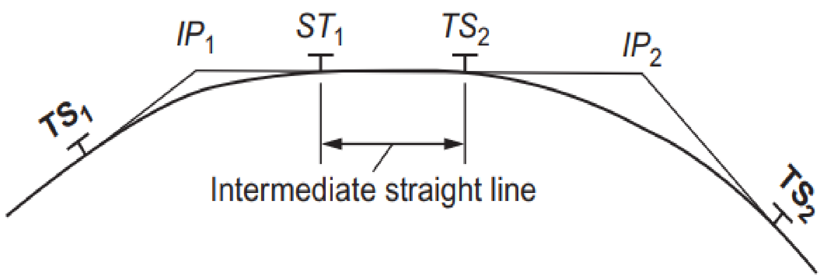

Figure 4-3 Intermediate straight line

In order to guarantee continuity and optimum riding experience on a railway line, a straight line of a specific length should be installed between two successive curves. The non-superposition theory of vehicle vibration is applied to calculate the length of an intermediate straight line. The fundamental idea is that when a train travels in an intermediate straight line, vibration of the train is caused by the impact of the wheel on the rail at spiral to tangent (ST) and tangent to spiral (TS).

As a result, the intermediate straight line must be lengthy enough as to prevent vibration superposition and assure driving comfort, in order that the train's traveling time (t) in the intermediate straight line at the maximum riding speed does not fall below the vibration vanishing time of the bogie spring.

The maximum vertical vehicle vibration acceleration in the transition curve at the back of the intermediate line increases with traveling speed when a train travels in the same-sense or reverse curve of the most severe alignment configuration at different speeds. Increased driving speed does not always result in increased vertical vehicle vibration, and longer intermediate straight lines may not help minimize the superposition effect of vehicle vibration within a specific length[13]. The maximum vertical vibration acceleration of a train attenuates in accordance with the natural vibration period and mostly stabilizes after two cycles when it travels through a curve, whether in the same sense or in reverse.

Additionally, at the same riding speeds and superelevation grades, the train's maximum vibration accelerations remain constant. The maximum vibration acceleration of the vehicle after stabilization increases with increasing the riding speed and the superelevation gradient of the transition curve in the rear of the intermediate straight line.

The minimum length of intermediate straight line should meet requirements of track maintenance, prevent the lateral swaying of train from influencing a train's smooth travel and it should prevent the influence of vibration of rolling stock on riding comfort. For the intermediate straight line, we have the formula

$$L_j = L - T_i - T_{i+1} - \frac{l_{oi}}{2} - \frac{l_{oi+1}}{2} \geq L_{j\,min} \tag{4-10}$$

4. 2.2 superelevation (cant), distance widening and gauge widening

Superelevation is the difference in elevation of the outer and inner rails of a railway track on the curved section, which is established usually by lifting the outer rail while taking the inner rail as a reference rail and maintaining its original level called banking effect which helps to increase the speed of a train negotiating a curve.[6]

Superelevation must be added to a circular curve and transition curve in accordance with the gauge, curve radius, speed of the rolling stock, etc. In the design, we must make sure that the highest value of the cant won't negatively impact the stability, etc., of rolling stock that is either stationary or moving at a slow speed. Superelevation is applied to curves for three main reasons. These are:

- Reducing passenger discomfort.
- Decreasing stress on the outside rails of curves by ensuring a relatively even distribution of load on the two rails, so that cost of maintenance can be reduced by reducing the wear and tear of both wheel and rail.
- Minimizing the centrifugal force which decreases the chance of overturning of trains.

As explained by Newton's 1st law of motion, a train tends to move in a straight line which induces a centrifugal force when entering in curves which is directly related to the square of the speed and inversely related to the radius. So, this induced centrifugal force which acts away from the center should be counteracted not to detract the smooth and safe operation of trains and reduce comfort of passengers.

Superelevation is added linearly varying from '0' at the tangent side of the transition curve to 'h' at the circular curve side and continues with 'h' to the end of the circular curve and then decreases to '0' at the end of the transition curve on the other side.

The value of cant at which the load on both wheels is distributed equally and there is no leaning of passengers in either direction is called equilibrium cant. For a standard gauge railway with s≈1500mm,

$$h = 11.8\frac{V^2}{R} \tag{4-11}$$

where h -is the equilibrium cant;

v - is the average speed;

R - the radius of curvature

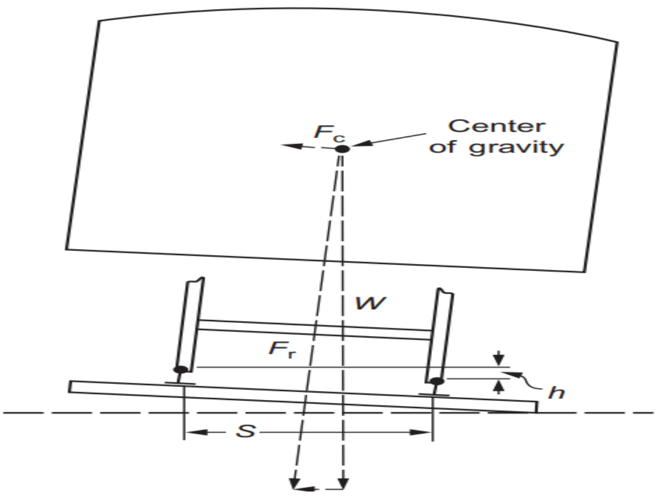

Figure 4-4 Schematic diagram of superelevation

For 'n' number of trains with running speed of v_1, v_2, v_3, …, v_n, the average speed for the calculation of superelevation can be calculated as

$$v = \sqrt{\frac{n_1 v^2{}_1 + n_2 v^2{}_2 + n_3 v^2 + \cdots + n_n v^2}{n_1 + n_2 + n_3 + \cdots + n_n}} = \sqrt{\frac{\sum n_i v^2{}_i}{\sum n_i}} \tag{4-12}$$

The outer rail will experience greater than usual wear from trains moving faster than equilibrium speed, whereas the inner rail will experience greater than normal wear from trains moving more slowly than equilibrium speed. Additionally, when the train travels faster than the equilibrium speed, the centrifugal force and elevation are not perfectly balanced, which causes the train to lean toward the outside of the curve.

Since all the trains on the route do not run at the equilibrium speed, there will be cant deficiency for those trains running with a speed faster than the average speed and cant excess for trains running with a speed slower than the average. Cant deficiency is the disparity between the cant necessary for the allowable maximum speed on the curve and the actual applied cant. However, cant excess is the difference between the actual cant provided and the cant necessary for slow speed trains.

The minimum line spacing for straight sections should not be less than the standards in the table below.

Table 4- 5 Minimum line spacing

Design speed (km/h)	200	160 and below
Minimum line spacing (m)	4.2	4

Currently, the minimum safety space between centers of line required by the Chinese code has more than needed to fulfill the need of aerodynamics, and in general, it is around 200 mm for railway with speed not lower than 200 km/h, so the line spacing may not be widened for curved sections of such lines. But for design speeds of 160km/h and below, curve line spacing widening values for lines should be selected according to Table 4-6.

Table 4- 6 Widening value of line spacing in curve section

Curve radius(m)	Widening value (mm)	Curve radius(m)	Widening value (mm)
12000~3500	0	1200	70
3000	30	1000	85
2500	35	900	95
2200	40	800	110
2000	45	700	125
1800	50	600	145
1600	55	500	170
1500	60	400	215

1400	60	300	285
1300	65	--	--

However, in this design, the design speed of the intercity railway is 200 km/h, so distance widening at curves is not applied.

Curves create stresses that exacerbate track deterioration and derailment danger while trains pass over them[14]. The ideal strategy to alleviate these pressures is to build the curve with the longest feasible radius, coupled with one or more of the additional measures listed below, if necessary: super-elevating the outer rail, placing check rails on the inner rail, and/or enlarging the gauge.

For the rolling stock to run on the curve safely and smoothly, as well as to lessen driving resistance, rail wear, and the dynamic effect of the rolling stock on the track, gage widening is necessary on small-radius curves[15,16]. The gage widening value is influenced by the rolling stock's wheelbase, the curve's radius, and the distance between the wheel flange and the gage line. With a smaller curve radius and rail gap, a wider wheelbase and gage are required.

While an excessive gage widening value expands the rail gap and decreases train stability, an insufficient gage widening value rises the dynamic impact of the rail, driving resistance, and rail wear. So, using the correct gage widening values on curves can lessen the lateral load on the wheel or rail, which reduces wear on the wheel and rail and enhances the performance of trains when crossing curves[16].

But in this thesis, gauge widening is not necessary since the smallest radius used (2200m) is far bigger than the radius of the curve that needs widening.

Station Design

Stations are centers of transit or nodes of railway transportation where there are various types of concentrated technical equipment. A railway station can be stated as any location on a railway line built as a hub that can perform one or more of the following tasks: picking up or displacing passengers; loading or unloading goods or packages; controlling the movement of trains; allowing trains to cross one other in the case of single line sections; or allowing faster trains to pass slower trains; and allowing locomotives to take fuel in the case of diesel traction, water, or other supplies[17].

In addition, it can be used for attaching and removing coaches or wagons from the trains, offering facilities for the changing of engines and crew/staff, arranging wagons and bogies to form new trains, and offering facilities and holding the passengers in case of emergencies like floods and accidents when traffic is disrupted.

The station's site selection shall take into consideration the city's transportation requirements and urban planning, as well as the topography and geology of the area, the demolition of any existing structures, and extensive land development and urban growth. The intermediate station must be adjacent to the towns along the line to facilitate the urbanization development, and the departure station should be situated at the same site as the urban comprehensive transportation hub and existing or proposed railway passenger station[1].

For a double track intercity railway, overtaking stations or intermediate stations can be set. The station spacing of intercity railway should be 5 km ~ 20 km so that the running time will not influence the carrying capacity of the whole designed line.

The design of the slope of the main line within the station yard of an intercity railway shall be in accordance with the following provisions:

1. The main line within the effective length of the arrival and departure line should be designed as a slope section.
2. The main line within the effective length of the arrival and departure line should be set on flat slopes. When it is set on the ramp, the slope should not be greater than 1‰, and the slope of the underground station should not be greater than 2‰.
3. The slope of the main line of the overtaking station and the station without sidings should not be greater than 6‰.
4. The gradient of the main line in the throat area of the station should be the same as the gradient in the effective length of the arrival and departure line. Under difficult conditions, the gradient should not be greater than 2.5‰ at the departure station and 6‰ at the intermediate station.

4.3 The Profile design of Intercity Railways

Vertical alignment is defined by simple basic data: the station, elevation and length and radius of vertical curve for a series of vertical PIs.

Gradient is the amount of slope along the longitudinal direction of a railway track provided to negotiate the rise and fall in level of existing ground to provide a unform rate of rise and fall and reach stations of different elevation as well as reducing the earthwork volume.

4.3.1 Slope section design

The maximum allowable slope for intercity railway line should be 20‰ and the minimum gradient should not be smaller than 2‰ to assure drainage requirements. To design an optimum longitudinal section of intercity railway, the maximum gradient, elevation constraints like bridge and culvert sections, power lines etc., and the maximum allowable gradient change should be considered.[12]

In this design, we have three alignments selected and as each alignment passes through different topography the number and length of bridges and culverts is different, so we should first identify the station of those constraint conditions and we should fulfil these conditions in the profile design. Bridges or culverts should be set to span a physical obstacle (such as a body of water, valley, road, or rail) without blocking the way underneath. They are built to allow passage over the obstruction, which is typically something that would be difficult or impossible to cross otherwise.

The length of grade section shall be determined to comply with the requirements of safety and riding comfort. For a grade section with a gradient of 15‰ and 20‰, the length of the section should not exceed 9km and 5km respectively. We should avoid long steep grades, because there will be a high amount of speed reduction when the train moves upgrade and it will need a high braking force when the train moves downgrade, especially for mixed passenger freight railways. But for grade sections with gradients not larger than 12‰, it is not necessary to limit the maximum length of the grade sections.

According to Chinese passenger dedicated railway construction practice, the appropriate maximum gradient should generally be within the range of 12-30‰.

The minimum slope section length should not be less than 400m under general conditions and 200m under difficult conditions, and should not be used continuously. But the minimum length should be the larger of 400m or l_p under general and difficult conditions depending on the coefficient of V [8].

$$l_p = (\Delta i_1 + \Delta i_2)/2 \times R_v + (0.4 \sim 0)V \tag{4-13}$$

Where: l_p - minimum slope section length (m).

Δi_1,Δi_2- Gradient difference of slope sections at both ends of slope sections (‰).

V- design speed, in km/h: the coefficient of V can be 0.4 under general conditions and 0 under difficult conditions.

R_v- vertical curve radius (m).

When we design our profile of each alignment, we should consider the maximum height of cut and fill as well as the height of bridges and culverts. So, the maximum value of cut and fill should be with in 8m. This is because of the following main reasons

i. The stability of slopes: when we design the subgrade of a railway line, we need to control the slope of the cut or the fill. If the slope is too steep, the stability of the slope is compromised and when the slope is too gentle, both the volume of earthwork and the width of right of way increase. The factor of safety of the slope should be greater than the minimum allowable i.e., $F_s \geq [F_s]$.

ii. Amount of earthwork and height of retaining wall: when the height of the slope is increased and the slope is also steep, the slope being designed will be more unstable. So, the height of cut and fill slopes (engineered slopes) should be lowered as much as possible to reduce the construction cost and maintenance cost during failure. During construction retaining structures can be constructed to attain the maximum possible stability of the slope and the height of the slope section determines the type, height and cost of retaining structures.

iii. The right of way (the land use): Railway right of way is the property on which railway track is placed which varies in width according to the steepness and height of the slope which in return depend on the existing ground and design profiles.

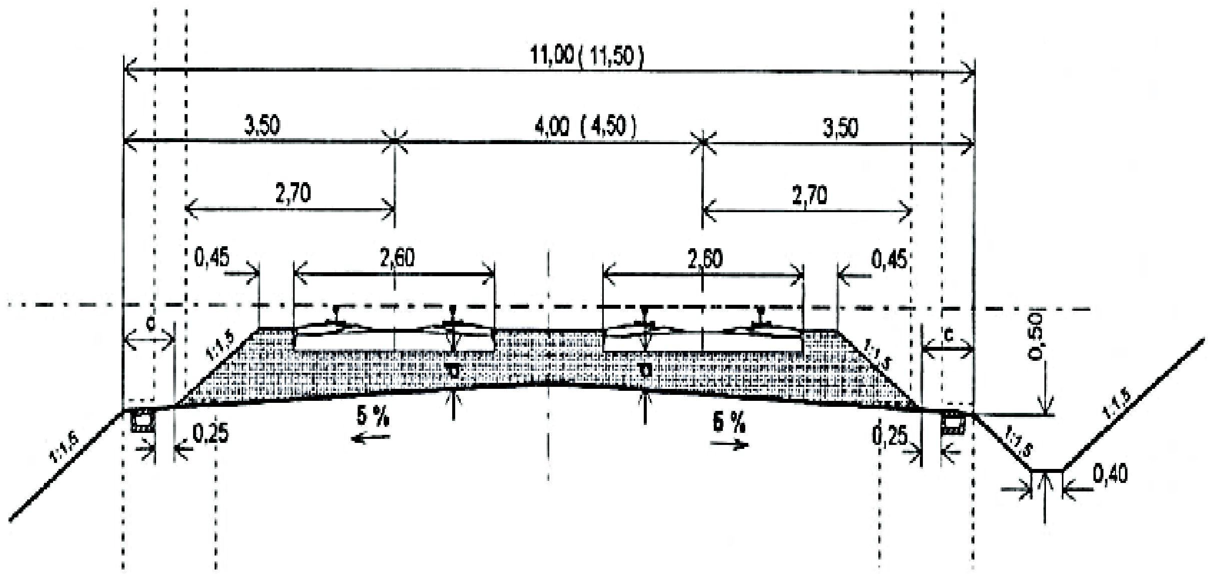

Figure 4-5 Right of way of a double track railway line

As an example, we can see the profile design from civil 3D for scheme 1 in the figures below.

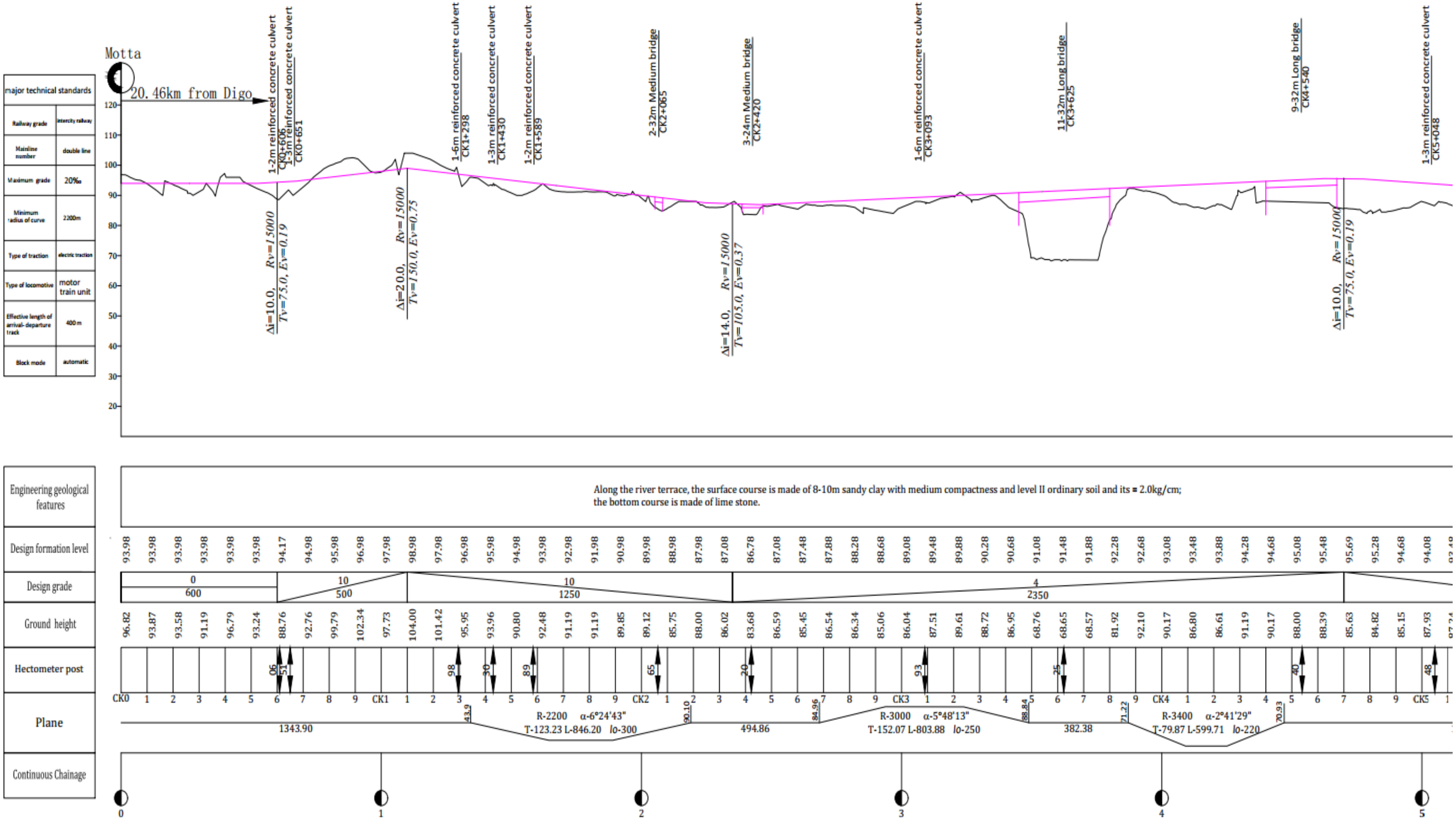

Figure 4-6 Profile design of scheme 1

Gradient compensation

It is the reduction of gradient on curves or tunnels to avoid the total resistance being beyond the allowable limit. When a train runs on a route with a curved section or a tunnel, the train is applied by additional resistance[1]. A train with a tonnage rating determined by maximum grade will run at a speed lower than estimated speed in lengthy, steep sections where grades should be built as the maximum gradient if the total of the designed gradient and curve or tunnel equivalent grade exceeds the given maximum grade. If so, the train will start moving more slowly causing a delay in the running of the train which increases the running time and reduces the traffic capacity. The maximum grade section should be reduced at curves or tunnels in order to ensure that the resistance under a train does not exceed the equivalent grade of the ruling grade. So, we should express the curve and tunnel resistance as an equivalent grade resistance and reduce the design grade in the profile design.

A compensated curve can be created to allow for a smoother passage over each secondary section of track with a rising gradient with less gear shifting from the locomotive engine, allowing the train to continue operating smoothly and conserving part of the engine's energy. The proposed line's elements will be overcome with less energy required by the train, and the engine power will remain constant without gear changes. There are several design options, such as[18]

- reducing the grade of the route,
- designing the track without lost gradients;
- When the track's axis is aligned in a directional solution, it indicates that the radius of the circles and the easement curves of various forms are increasing spirals.
- At rising gradients that are closer to the maximum gradient or standard gradient i_{max}, the track section can be designed as a portion of the constant gradients resistance (CGR). Since it is well known from railroad operation that trainsets must overcome obstacles like circles and tunnels, etc., lowering the longitudinal profile in these areas is suggested so that the train can pass through them using the same locomotive engine power and the necessary traction force.
- If the train enters the transition spiral at point TS, the running resistance in the circle rises until the transition spiral's ending point SC (of course, this also depends on how lengthy the vehicle is), and this resistance r_i continues until the same circle's end point CS. As the curvature k shifts from a line to zero, $k = 1/r$, it gradually starts to fall in the transition spiral near the end of the track circle.

The compensated curve is only solved for the track axis in the ascending gradients and not in the opposite direction in the descent, where the Earth's gravity acts positively. Gravitation force helps the engine of the locomotive in a downhill run and there is an opposite problem with the braking.

$$\Delta i_R = \frac{600}{R}\ (‰) \tag{4-14}$$

$$\Delta i_R = \frac{10.5\alpha}{L_i}\ (‰)\ \text{or} \tag{4-15}$$

$$\Delta i_R = \frac{10.5\sum\alpha}{L_i}\ (‰) \tag{4-16}$$

where α is the deflection angle of curve (°);

R is the radius of curve (m); and

L_i is the length of design grade section (m).

For a tunnel with a length more than 400 m, its additional resistance increases but adhesion coefficient reduces, leading to the design gradient of profile plus the equivalent gradient of additional aerodynamic drag in tunnel greater than the maximum gradient[1,19]. Reduced traction force in tunnels is brought on by reduced rail-wheel adhesion, which is mostly caused due to the existence of moisture in tunnels. In addition, it is generally known that the amount of resistance of air depends on the relative velocities of the wind and train in the tunnel where the air is relatively compressed and not free to flow, with upwind air resistance being larger than downwind air resistance, as well as the cross-sectional areas of the tunnel and train. Particularly in a very narrow tunnels on a single-track railway line, resistance is significant.

Therefore, in the profile design, compensating the maximum gradient is necessary to ensure the general passenger or freight train to pass through this location with speed no less than the calculated minimum. In tunnels, we can calculate the design gradient value by using the following equation.

$$i=\beta_T.i_{max}(‰) \tag{4-17}$$

where β_T is the tunnel gradient coefficient which depend on the length of the tunnel and type of traction used by the locomotive. The value of $\beta_{T\ can}$ be taken from the table below according to the Chinese specification.

Table 4- 7 Tunnel gradient coefficient β_T for electric and diesel traction

Tractive effort type	Electric traction	Diesel traction
Length of tunnel (m)		
$400<L_T\leq1000$	0.95	0.9
$1000<L_T\leq4000$	0.9	0.8
$L_T>4000$	0.85	0.75

Total Converted Grade

The total converted grade i_{con}, refers to the sum of grade of profile i and the equivalent grade of curve resistance and equivalent grade of tunnel resistance in the same section, that is,

$$i_{con} = i + i_r + i_T \,(‰) \tag{4-18}$$

4.3.2 vertical curve design

In railway alignment design, mostly circular and sometimes parabola type vertical curves with a curve length as long as practicable is used to assure a gradual change of transition from one grade to the other so that there will be a uniform rate of change of gradient, which controls the rotational acceleration for smooth riding quality and attractive appearance.[20,21]

For a railway with a design speed of 160km/h and above, vertical circular curves should be provided for adjacent grades with a gradient change of 1‰ and above[1]. For passenger dedicated lines as the intercity railway in this design, vertical curves are designed when the change of gradient at a gradient change point is greater than 1‰. So, in this design a vertical circular curve is applied at each gradient change point with a gradient change of 1‰ for all the three schemes.

When vertical curves are needed at grade change points, the grade change point should be at least a length of Tv farther from the beginning or the end of the transition curve so that the vertical circular curve and the transition curve do not coincide[1]. But we can design vertical and horizontal curves in the same region by increasing the radius of both curves.

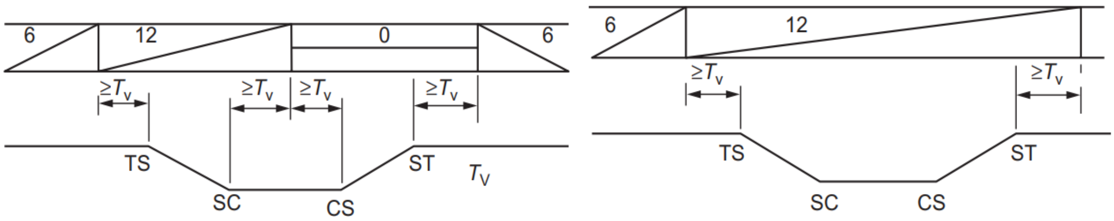

Figure 4-7 Relation between location of grade change point and transition curve

The radius of vertical circular curve should be controlled with in a certain range so as to provide passenger comfort, no coupler separation, no derailment and ease for track maintenance.

The maximum radius of the plane curve should not be larger than 9000m when a vertical circular curve and a planar curve overlap. When this kind of overlapping line occurs and the vertical curve is a convex type, it reduces the safety of train operation and passenger comfort, but when it is a concave type, although rail wear and maintenance workload increase, train operating safety and passenger comfort actually get enhanced. The vertical acceleration and the body's vertical Sperling index are two of the most obvious impacts of the vertical-planar curve overlapping line. The stability of the train's operation is significantly impacted when the body's vertical acceleration is superimposed at the intersection of the plane's gentle circle and the vertical curve's commencement.

The minimum vertical curve radius (m) shall be selected in accordance with Table 4.8.

Table 4- 8 The minimum vertical curve radius (m)

Design speed (km/h)		200	160	120	Below 120
Engineering condition	general	15000	15000	10000	5000
	Difficult	10000	8000	5000	3000

As mentioned in the Chinese design code of alignment of railway, the radius of the vertical curve should not be greater than 30,000m and the length of the vertical curve should not be shorter than 25m.

The minimum distance between the start and end of a vertical curve (or change of grade) and the start and end of a flat curve on an intercity railway should not be less than 20m.

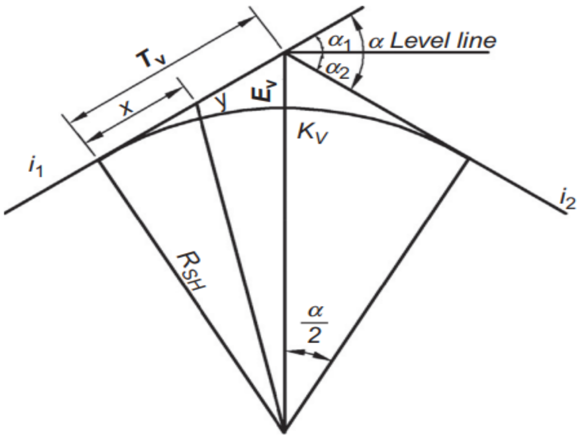

Figure 4-8 Diagram of vertical curve

Vertical curves should not be set within easement curves, mainline turnouts, rail expansion joints and open bridge decks. If the design speed of the section is greater than 120 km/h, no change of slope points should be set within the above section.

For a vertical curve formed by a change of gradient from i_1 to i_2, we can have the following relationships.

$$T_v = R_v \times \tan\frac{\alpha}{2} \approx \frac{R_v}{2}\tan\alpha = \frac{R_v}{2} \times \tan|\alpha_1 - \alpha_2|$$

$$T_v = \frac{R_v}{2}\left|\frac{\tan\alpha_1 - \tan\alpha_2}{1 + \tan\alpha_1 \times \tan\alpha_2}\right| \approx \frac{R_v}{2}\left|\frac{i_1}{1000} - \frac{i_1}{1000}\right|$$

$$T_v = \frac{R_v \times \Delta i}{2000} \tag{4-19}$$

Whereas the length of the vertical curve K_v can be calculated by applying the following formula.

$$K_v = 2T_v \text{ (m)} \tag{4-20}$$

The external secant E_v, which is the distance from the gradient change point to the curve is calculated as,

$$E_v = \frac{{T_v}^2}{2R_v} \tag{4-21}$$

The external secant E_v, is used to calculate the additional value of cut or fill from the design profile to the actual construction elevation on sections with vertical curves only.

From the figure below which I took from my design in Civil 3D, we can see the parameters like R_v, E_v, Δi and E_v.

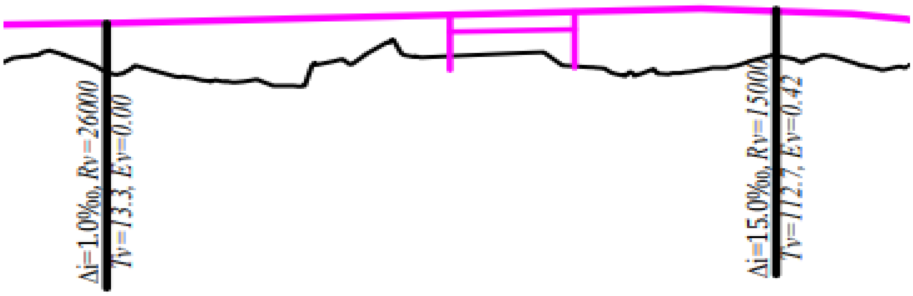

Figure 4-9 Sample vertical curve from Civil 3D

4.4 Summary

To summarize, this chapter mainly describes about the requirements, the processes and the elements of the plane and profile design of an intercity railway. In the process of the plane and profile design, the plane design which includes the horizontal curves that are used to detour unfavorable conditions, transition curves which are used to smoothen the transition from curves to straight lines and vice versa by allowing a gradual change of centrifugal force, super elevation and distance widening is designed first since the height of existing ground depend on the position of the center line of the alignment.

Secondly, the profile including the slope section and vertical curves at grade change points are designed without violating the specifications of maximum grade, minimum radius and length of vertical curve and others. The plane and profile are designed in order to assure the smooth transition in the longitudinal direction meeting the requirements of safety and comfort as well as the economic considerations altogether.

Chapter 5 Calculation of the railway carrying capacity and traffic capacity.

Prior to designing new railway lines or renewal of existing railways, economic surveys are carried out in order to meet the significance of the railway line with respect to different circumstances like defense, politics, economy etc., is determined. Since the railway route is not a temporary infrastructure i.e., it is difficult to expand or reconstruct, it is designed in accordance with the long-term traffic volume and transport characteristics so that it can adapt to the growth of the traffic volume and reduce initial investment.

The number of pairs of trains for single-track lines or the number of trains for double-track lines throughout one day and night under specific operating organization circumstances and with a specific kind of rolling stock are referred to as the railway carrying capacity.[1] It can also be stated in terms of the quantity of cars or tons of cargo for freight railways and in terms of passengers on passenger-only railways.

The number of main lines, section length, plane and profile conditions, type of locomotive, signal, interlock, block equipment, maintenance facilities, operation management, etc. all have an impact on the railway carrying capacity. The weakest of all the facilities indicated above serves as a criterion to determine the potential carrying capacity. The carrying capacity of various facilities is calculated in railway design using the sectional carrying capacity. The carrying capacity of the facilities should not be less than the carrying capacity in the section in order for them to cooperate with one another.

5.1 Calculation of carrying capacity in the section

The carrying capacity of an intercity railway is the maximum capability of handling passing, arrival or departure of trains (or pair of trains) by all the available fixed equipment in the section in 24 hours under certain operation organization conditions. It is influenced by transport mode, running speed, type of train, number and dwell time of stops, schedule of train diagram, distance between stations, and skylight set.

Intercity railways have obvious passenger peaks, and their passenger traffic levels are mainly reflected in the maximum peak hour cross-sectional passenger flow. The peak hour train operation scheme has to meet the requirements of the peak hour maximum cross-sectional passenger flow, which is the time when the maximum number of train pairs are operated throughout the day. When the peak hour throughput capacity meets the needs, all other periods can meet the needs. So intercity railways generally calculate the peak hour throughput capacity.

The inter-city railway working diagram carrying capacity of peak hour is calculated using eq 5-1.

$$N = \frac{60}{I\varepsilon} \qquad (5\text{-}1)$$

Where N is the working diagram carrying capacity of peak hour (pairs/hour);

I is the minimum time-interval between trains (min), this design takes 4min;

ε is the removal coefficient, this design takes 1.2.

From equation 5-1, the carrying capacity of an intercity railway at peak hours can be calculated.

$$N = \frac{60}{I\varepsilon},$$

$$N = \frac{60}{4\times1.2} = 12 \text{ (pairs/hour)}$$

Actual carrying capacity in section is calculated using Eq (5-2);

$$N_U = N \times K_U \qquad (5\text{-}2)$$

Where KU is the utility coefficient, generally takes 0.9.

$$N_U = 12 \times 0.9 = 10 \text{ (pairs/hour)}$$

5.2 Calculation of traffic capacity of an intercity railway

Intercity railways generally calculate the one-way transmission capacity of the line during peak hours, and the traffic capacity is calculated using Eq (5-3);

$$C = A \times N_U \qquad (5\text{-}3)$$

$$C = 600 \times 10 = 6000 \text{ (passengers/hour)}$$

where C is one-way traffic capacity of line during peak hours (passenger/hour);

A is the train capacity, in number of people per train, according to the selection of EMU to determine. For this design CRH2 with eight (8) train sets or short Emu with a capacity of 600 passengers is used.

5.2.1 Prediction of Passenger Traffic Volume

Passenger traffic volume was surveyed and foretasted along the intercity railway, to obtain the design annual peak hour cross section passenger flow forecast of short term and long term, respectively, see table 5-1 and table 5-2.

Table 5- 1 Peak hour cross section passenger flow forecast of short term

Direction of starting station ~ terminal station			station	Direction of terminal station ~ starting station		
Number of people getting on train	Number of people getting off train	cross section		cross section	Number of people getting off train	Number of people getting on train
3121			starting station			3113
		3121		3113		
110	168		intermediate station 1		172	115
		3063		3056		
154	102		intermediate station 2		99 and	134
		3115		3091		
541	397		intermediate station 3		385	459
		3259		3165		
161	136		intermediate station 4		131	136
		3284		3170		
194	104		intermediate station 5		103	195
		3374		3262		
209	130		intermediate station 6		129	204
		3453		3337		
	3453		terminal station		3337	

Table 5- 2 Peak hour cross section passenger flow forecast of long term（persons/hour）

Direction of starting station ~ terminal station			station	Direction of terminal station ~ starting station		
Number of people getting on train	Number of people getting off train	cross section		Cross section	Number of people getting off train	Number of people getting on train
4476			starting station			4463
		4476		4463		
151	234		intermediate station 1		241	158
		4393		4380		
214	142		intermediate station 2		137	185
		4465		4428		
750	553		intermediate station 3		536	636
		4662		4528		
223	189		intermediate station 4		182	189
		4696		4535		
269	143		intermediate station 5		142	270
		4822		4663		
307	189		intermediate station 6		189	300
		4940		4774		
	4940		Terminal station		4774	

5.2.2 Traffic capacity check and evaluation

From table 5-1, we can see that the required traffic capacity both ways (from the starting station to the terminal station and back from the terminal to the starting station) is smaller than the traffic capacity C of the design line i.e., ($3453 \leq 6000$) passengers/hour and ($3337 \leq 6000$) passengers/hour according to the short-term passenger flow forecast. From this we can conclude that the design meets the requirement since the traffic capacity of the design line is greater than the required traffic capacity.

For the long-term passenger flow forecast for both directions as shown in table 5-2 above, 4940 (passengers/hour) and 4774 (passengers/hour) are both less than 6000 (passengers/hour) which implies the carrying capacity of the section meets the long-term traffic capacity too. If in the future, the traffic volume increases and becomes above the carrying capacity of the section, the number of train sets can be increased to accommodate all passengers provided that the elements of the line such as bridges, tracks and curves etc. can carry the traffic.

5.3 Summary

From this chapter, we can conclude that the designed line should be able to accommodate the traffic at peak hours of passenger flow for short term and long term i.e., the traffic capacity of the deign line should be greater than the required traffic volume. The line should be designed to adapt future growth of traffic as the population is gradually increasing,

For this intercity railway, the traffic capacity of the design section meets the required traffic capacity as predicted in passenger traffic volume at peak hours for both short term and long term.

Chapter 6 Calculation of main technical and economic indicators.

It is known that the whole process of route selection is the comparison of multiple schemes so that the safest and the most cost-effective scheme can be selected. The choice of the optimal route takes many factors into consideration such as natural conditions like topography and geology, policy factors and social factors.

The economic analysis of the project aims to ensure the effective distribution of scarce resources and improve the welfare of citizens, so as to benefit the whole country. All resource investments have opportunity costs, because if resources are not allocated to projects, they will create value in other aspects of the economy. Maximizing returns from the allocated resources spend on capital items like stations, tracks or other equipment and in operation is necessary which can be accomplished by allocating resources on projects that can maximize their return[22].

The economic and technical comparison of alternative schemes is used to determine the viability and feasibility of economic and technical proposals, as well as the railway project evaluation as an important part of economic and technical schemes. When making important economic and technical decisions, different alternatives are usually proposed for railway projects for evaluation finally for ranking and selection. These values and results will be carefully compared according to the alternative calculation, in order to finally determine the best alternative scheme[23].

For mutually exclusive alignment schemes of intercity railway to be compared with one other, they should fulfill the following requirements so that they can ensure the validity of the comparison[23].

✓ Each scheme should be able to meet the project's intended objectives.

✓ Each proposed scheme should have an appropriate level of economic efficiency.

✓ Each alignment scheme should represent a consistent approach to project range and timeline specification, as well as project benefit and expense assessment.

The static technique of criterion, which doesn’t take the time value of money unlike the dynamic method of criterion, is still commonly utilized in Chinese railway projects without any possibility for reform, particularly for projects that utilize the natural environment[1].

Different routes, different gradients, different radius at different curve locations, different track joining locations, different marshalling stations, different passenger station locations, different bridge locations, different tunnel locations, different river spanning modes applied to different routes, and other technical conditions are the economic and technical alternatives involved in the pre-feasibility and feasibility study phases of railway projects in general, including intercity railway projects[23].

By analyzing the characteristics of the above alternatives, we can compare schemes with a large traffic flow differences for all factors, including benefits and costs. However, for alternatives with small traffic flow differences, only their relative costs should be compared. These alternatives are compared in order to find the best operating conditions to save transportation costs. Basically, scheme comparison data includes investment, operating expenses and so on. For this design, the investment, the operating expense and the converted annual cost are calculated and used for the comparison of the three schemes.

6.1 Calculation of the investment

In railway construction projects, investment can be defined as the total cost of civil construction plus the expenditure of purchasing locomotives and other vehicles, which reflects the overall amount of capital invested in construction period, expressed as construction cost (10,000 yuan)[1]. Investment can also be defined as the cost of installing railway fixed and operating assets. They are obtained from records of unit costs from related railway institutes and represent current values (i.e., those values present at the time of estimation).

Some of the primary cost elements include preparation, which involves land acquisition and re-settlement as well as relocation of buildings and public utilities, infrastructure, system, traction and rolling stock, design and construction supervision, and contingencies. All labor, material, and equipment costs associated with the construction of railway infrastructure, including civil structures (bridges, culverts, tunnels, and buildings), installing system equipment, and purchasing locomotives and other rolling stock, are included in investment.

In addition to the aforementioned components, investment costs should also include the following components: planning costs, such as design costs, planning authority resources, and other costs directly related to the project incurred after the initial decision to move forward; land and property costs, such as the cost of acquiring land needed for the scheme (and any associated properties), compensation payments required under national laws, and the related transactions and legal costs; and construction costs, such as site preparation costs.

In technical and economic comparison of schemes of a railway project, only direct investment is considered mostly, which only includes construction cost (civil engineering investment) and purchase expense of rolling stocks rather than other related investments.

Project investment is calculated using the approximate index method：

$$F = f_1 + f_2 + f_3 + f_4 + f_5 + f_6 + f_7 (104\ \text{yuan}) \tag{6-1}$$

where f_1，f_2，f_3，f_4，f_5，f_6 and f_7 are the subgrade engineering cost (includes retaining structure), bridge engineering cost，culvert engineering cost，tunnel engineering cost，land engineering cost， track engineering cost and railway vehicle cost of acquisition, respectively[24][1].

6.1.1 Civil Engineering investment

Commonly, engineering investment is calculated using the following formula after first determining the quantity of engineering construction and equipment and then applying the appropriate analysis of the comprehensive unit price or unit pricing.

$$\text{Engineering investment} = \sum(\text{unit price} \times \text{engineering quantity})\ \ (10^4\text{yuan}) \tag{6-2}$$

Railway engineering includes such things as buildings, communication and signal engineering subgrade engineering, bridge and culvert engineering, demolition engineering, track engineering, tunnel engineering, communication and signal engineering, other operating production equipment and buildings, other indirect costs, and so on[1].

Subgrade engineering cost

1. Calculation of earthwork cost

（a）To calculate the cost of the subgrade engineering, the main work is to calculate the number of subgrade engineering. In the design of new railway lines, the earthwork calculation methods currently used are many, but from the basic principles can be summarized as three types of methods: the average distance method, the average section method, volume formula method. Calculation can be based on some method to calculate the earthwork number of road embankment and cut, and then multiplied by the corresponding unit price, you can get the required cost of earth and rock f_1'.

The following formula can be used to calculate earthwork cost：

$$f_1' = \sum_n P_{1j} \times V_j \tag{6-3}$$

where V_j is the number of earthworks of embankment and cut in the j section (m^3)；

P_{1j} is the unit price of earthwork in different levels of soil and different sections；

n is the total number of embankments and cuttings.

This design is to simplify the calculation, without considering the influence factors of earthwork allocation. Earthwork adopts comprehensive unit price, given by cut and fill respectively：

P_{1cut} = 90.0yuan/m^3 ;

P_{1fill} =85.0yuan/m^3.

Therefore, the earthwork cost of this design is calculated as follows：

$$f_1' = P_{1cut} \times V_{cut} + P_{1fill} \times V_{fill} \tag{6-4}$$

where V_{cut} and V_{fill} are the total volume of excavation and fill of whole subgrade (m^3), respectively.

（b）Calculation of earthwork volume

In general, the volume of earth work is computed using the average cross-section method first, then estimate the subgrade engineering cost using the comprehensive unit price per cubic meter. In detailed design, the composition of the stone and soil must be distinguished based on geological data, and the quantity of earth and stone must be computed using a subgrade cross-section, and the cost must be calculated using the appropriate comprehensive unit price or unit pricing.

This design uses the average section method to calculate the amount of earthwork。If the area of each section has been calculated, then;

$$V_{cut}(V_{fill}) = \sum_{nC(F)^{-1}} 0.5 \times (A_i + A_{i-1}) \times L_{iC(F)} \tag{6-5}$$

This design subgrade section is shown in Figure 1 and Figure 2：

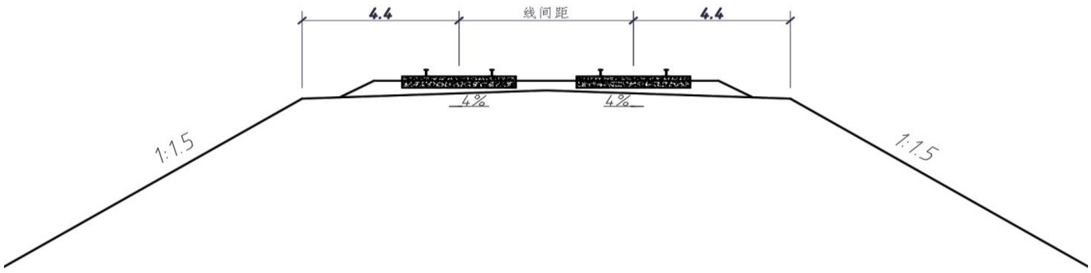

Figure 6-1 Embankment section diagram

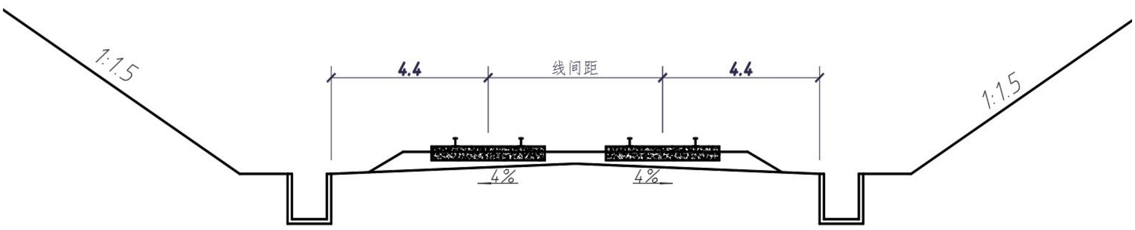

Figure 6-2 Cutting section diagram

（c）Calculation of earthwork quantity of roadbed widening

Calculation of the increased earthwork quantity of roadbed widening in curved section：

We first get the value of the outer roadbed widening ΔB at pile number I according to the curve radius check Table 6.1， then the outer roadbed widening area at this pile number is：

$$S_a = \Delta B \times H \qquad (6\text{-}6)$$

where symbol value of S_a is same as the corresponding side road base symbol. After adding S_a and the basic body of the road, it is filled into the Earthwork Quantity Calculation Table.

Table 6- 1 Curved section roadbed widening value table

Design Speed(km/h)	Radius of Curve (m)	Roadbed lateral widening value (m)
200	R≥10000	0.1
	6000≤R<10000	0.2
	4000≤R<6000	0.3
	3100≤R<4000	0.4
	R<3100	0.5

Calculation of Additional Earthwork for Roadbed Widening in Station Area：

$$V_a = W_a \times H \times L_a \qquad (6\text{-}7)$$

where H is the subgrade filling height in the center of the station； W_a is the roadbed widening value, this design takes 13m； L_a is the length of widened section, this design takes 1100m。

As stated in the introduction section, one of the results of using the software civil 3D is that it can give us the type and cross-section of the railway line at different stations or mileages. For this design cross sections are created at every 50m along each alignment and as a sample we can see the cross-section of alignment 1 at the end station 20+460.13.

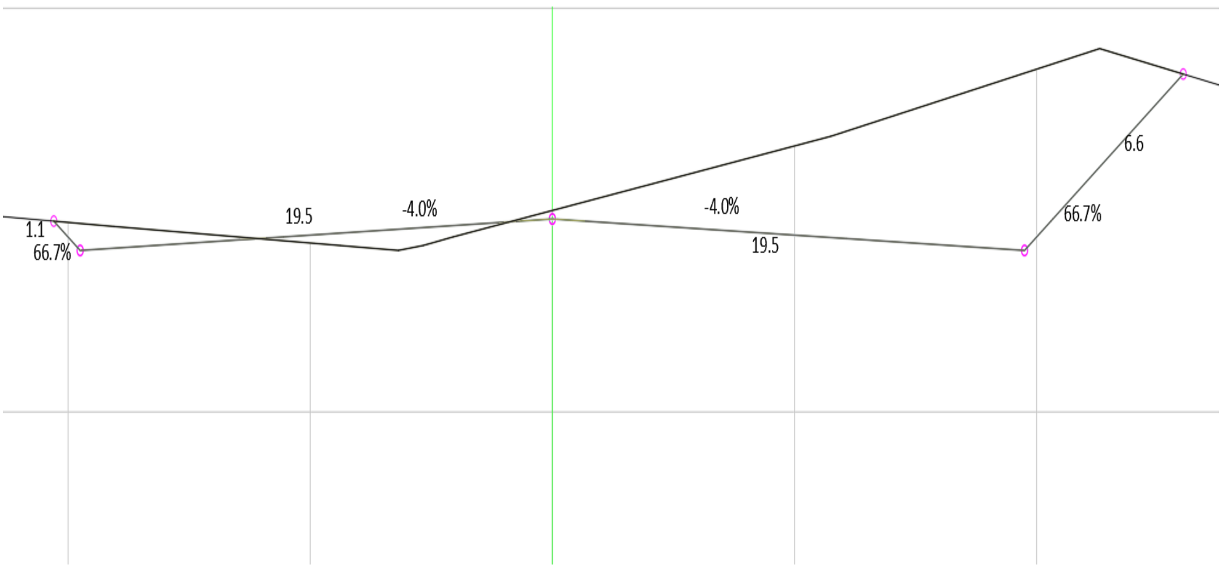

Figure 6-3 Cross-section view of alignment 1 at 20+460.13

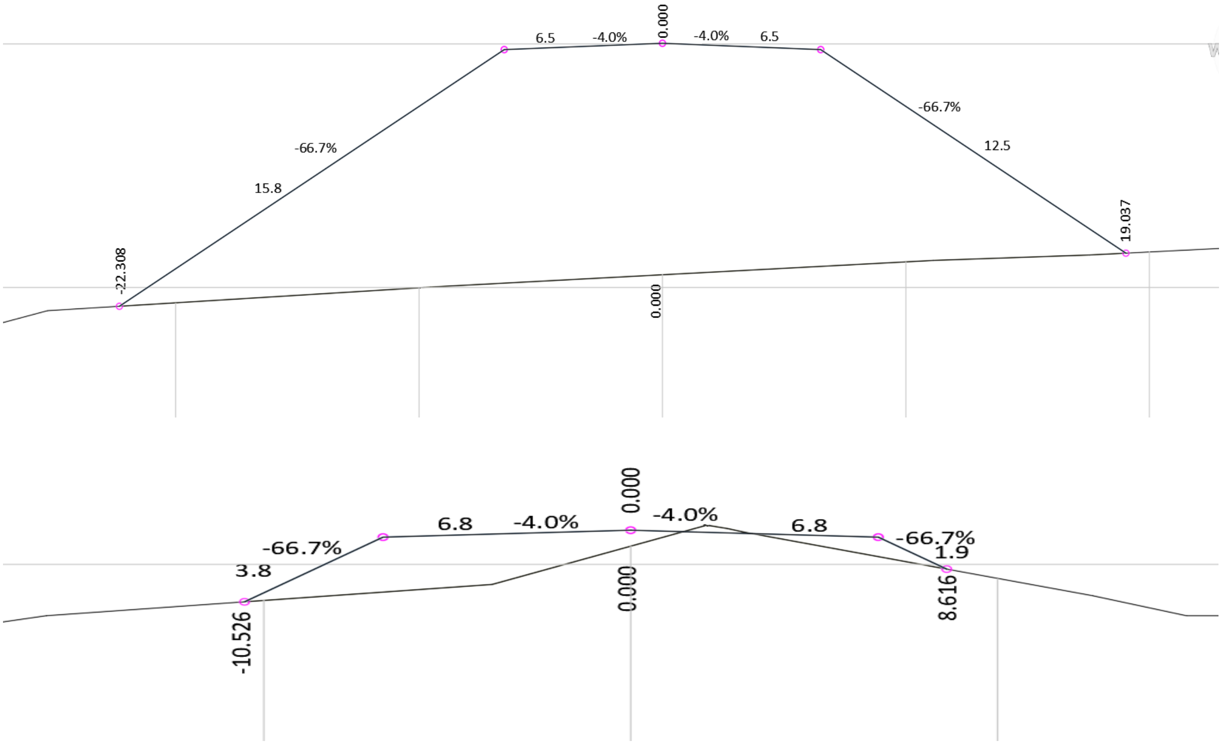

Figure 6-4 Sample cross-section views at different stations

The subgrade widening in the curve section and in the station area of a certain alignment are specified by the assemblies used in civil 3D so that they can be taken into consideration and the total volume of earthwork i.e., cut and fill is calculated. So, from the civil 3D, I have got the following values as shown in the figure directly taken from civil 3D.

Total volume at 204+60.13	
Cut area	2.79
Fill Area	62.65
Cut volume	14.15
Fill volume	823.68
Cum Cut Volume	2533662.27
Cum Fill Volume	744337.22
Net volume	1789325.05

Total volume at 204+50.61	
Cut area	0.00
Fill Area	116.32
Cut volume	0.00
Fill volume	70.99
Cum Cut Volume	2346853.32
Cum Fill Volume	610443.48
Net volume	1736409.84

Total volume at 203+22.20	
Cut area	0.00
Fill Area	3355.15
Cut volume	67.88
Fill volume	37788.12
Cum Cut Volume	1801461.66
Cum Fill Volume	782246.00
Net volume	1019215.65

Figure 6-5 Volume of cut and fill for scheme 1,2 and 3 respectively left to right

We can summarize the values in the table 6-2 below.

Table 6- 2 Volume of cut and fill for each scheme

Earthwork volume	Scheme1	Scheme 2	Scheme3
Cut volume (m^3)	2533662.27	2346853.32	1801461.66
Fill volume (m^3)	744337.22	610443.48	782246

These values in the above table consider the widening in the curved sections as well as the station sections. Then, the cost of earthwork can be calculated using the formula 6-4.

$f'_{1\text{for scheme 1}}$= 90 ×2533662.27+ 85×744337.22=29129.98 (ten thousand yuan)

$f'_{1\text{for scheme 2}}$= 90 ×2346853.32+ 85×610443.48= 26310.45 (ten thousand yuan)

$f'_{1\text{for scheme 3}}$= 90 ×1801461.66 + 85×782246 = 22862.25 (ten thousand yuan)

2. **Engineering cost calculation of retaining wall**

Railway lines are constructed by embankments and cutting sections having different soil type, magnitude of slope and slope height. Depending on the slope sliding analysis of these slopes, we provide retaining structures of different type cross section and length. But for this design, retaining wall engineering cost is estimated by comprehensive algorithm：

$$f_{1d} = (L_{ZX} \times V_{1d} \times P_{1d}) / 10^4 \text{ (ten thousand yuan)} \quad (6\text{-}8)$$

where L_{ZX} is the main line length (km)； V_{1d} is the number of retaining wall works; adopt integrated quantity, taking V_{1d} = 98.4m^3 /km； P_{1d} is the comprehensive unit price of retaining wall，taking P_{1d} = 2000yuan/m^3.

So,

f_{1d} for scheme1=20.43km×98.4m^3 /km×2000yuan/m^3/10^4 =402.06 (ten thousand yuan)

f_{1d} for scheme2=20.45km×98.4m^3 /km×2000yuan/m^3/10^4 = 402.46 (ten thousand yuan)

f_{1d} for scheme3=20.32km×98.4m^3 /km×2000yuan/m^3/10^4 = 399. 90 (ten thousand yuan)

3. **Subgrade engineering cost**

The total subgrade engineering cost f_l is the sum of the cost of earthwork f_l' and cost of retaining wall f_{1d}.

$$f_1 = f_1' + f_{1d} \quad (6\text{-}9)$$

Now, we can calculate the subgrade engineering cost f_l for each scheme using the formula above. Thus,

$f_{1\text{for scheme 1}}$=29129.98 +402.06=29532.04(ten thousand yuan)

$f_{1\text{for scheme 2}}$=26310.45 +402.46=26712.91(ten thousand yuan)

$f_{1\text{for scheme 3}}$=22862.25+399. 90=23262.15(ten thousand yuan)

Bridge Engineering Cost

When there are physical obstructions (such as a body of water, a valley, an existing road and or railway lines), bridges should be designed to cross these obstacles without impeding the path beneath. Bridges are built to provide passage over a barrier, which is generally something that would be difficult or impossible to cross otherwise.

The cost of constructing bridges can be calculated using the following formula depending on the type of bridge depending on its length.

$$f_2 = f_{2TD} + f_{2D} + f_{2Z} + f_{2X} = (L_{QTD} \times P_{QTD} + L_{QD} \times P_{QD} + L_{QZ} \times P_{QZ} + L_{QX} \times P_{QX}) \quad (6\text{-}10)$$

Where L_{QTD}, L_{QD}, L_{QZ} and L_{QX} are the total length of extra-large bridge, large bridge, middle bridge and small bridges, respectively; P_{QTD}，P_{QD}, P_{QZ} and P_{QX} are the unit price per meter of extra-large bridge, large bridge, middle bridge and small bridge respectively（ten thousand yuan / extension meter）, taking $P_{QTD} = 9$ ，$P_{QD} = 8.5$，$P_{QZ} = 8$ and $P_{QX}=8$. For this design, there are no super large bridges for all the three schemes, we only have large, middle and small bridges. Thus,

for scheme 1, we have L_{QD} =1344m, L_{QZ} =536m and L_{QX}=35m.

for scheme 2, we have L_{QD} =1248m, L_{QZ} =208m and L_{QX}=90m.

for scheme 3, we have L_{QD} =992m, L_{QZ} =240m and L_{QX}=45m.

$f_{2\text{ for scheme 1}}$ = (1344×8.5 + 536 ×8+ 35×8) = 15992(ten thousand yuan)

$f_{2\text{ for scheme 2}}$ = (1248×8.5 + 208 ×8+90 ×8) = 12992(ten thousand yuan)

$f_{2\text{ for scheme 3}}$ = (992×8.5 + 240 ×8+45 ×8) =10712(ten thousand yuan)

Culvert Engineering Cost

Culvert design is influenced by elements such as the weight of the surrounding soil and roadways, the kind of foundation soil, and the projected water characteristics and flow rates.

The cost of culvert f_3 can be calculated by the length according to the type and aperture.

$$f_3 = L_{ZX} \times L_H \times P_H \quad (6\text{-}11)$$

where L_H is the culvert extension meter per km of main line，taking 60m/km；P_H is the culvert extension meter unit price, this design takes 15000 yuan/transverse extension meter. The total length of culverts for scheme 1,2 and 3 is 129m,58m and 116m respectively.

$f_{3\text{ for scheme1}}$=0.107km×60m/km×15000 yuan/transverse extension meter =9.63(10^4 yuan)

$f_{3\text{ for scheme2}}$=0.048km×60m/km×15000 yuan/transverse extension meter =4.32 (10^4 yuan)

$f_{3\text{ for scheme3}}$=0.080km×60m/km×15000 yuan/transverse extension meter =7.20 (10^4 yuan)

Tunnel Engineering Cost

When we can't pass a hilly or mountainous topography with the maximum allowable grade (20‰ under general conditions and 30‰ under difficult conditions for this design) and a maximum allowable value of cut along the railway line, we have to construct tunnels to pass through. For this design, the cost of construction of tunnels(f_4), can be calculated using the formula given below.

$$f_4 = L_T \times P_T \quad (6\text{-}12)$$

where L_T is the total extension meter of tunnel; P_T is the unit price of tunnel extension meter according to table 6.2.

Table 6- 3 Unit price table of tunnel engineering

Tunnel	Within 1000m	115000 yuan/ extension meter
	1000～4000m	110000 yuan / extension meter
	4000～6000m	110000 yuan / extension meter
	6000～10000m	120000 yuan / extension meter

But due to the relatively flat and smoothly changing terrain of the section being designed, no tunnels are constructed. So, there is no need of calculating the tunnel engineering cost for all the three schemes.

Land Requisition Cost

The total land acquisition costs paid by the Project Company or on its behalf in order to get the right to utilize the Target Land are referred to as Land Acquisition Costs. For a dual line intercity railway projects, the land acquisition cost f_5 can be calculated using the given equation below.

$$f_5 = L_{ZX} \times S_D \times P_{SD} \quad (6\text{-}13)$$

where S_D is evenly distributed to the number of land requisition on each kilometer, the design line takes 71 mu/km, P_{SD} is the land fee, the design line takes 200,000 yuan/mu.

$f_{5\ \text{for scheme1}}$ = 20.43km ×71 mu / km ×200,000 yuan / mu=29010.6 (ten thousand yuan)

$f_{5\ \text{for scheme2}}$= 20.45km ×71 mu / km ×200,000 yuan / mu=29039 (ten thousand yuan)

$f_{5\ \text{for scheme3}}$= 20.32km ×71 mu / km ×200,000 yuan / mu=28854.4 (ten thousand yuan)

Track Engineering Cost

Track engineering includes main line track and station line track. The cost of setting the main line track might be calculated based on the length of the main track and the unit price of the relevant track type. For this design, the track engineering cost (f_6), can be estimated by the following formula.

$$f_6 = L_{ZX} \times P_{GD}\ (104\ \text{yuan}) \quad (6\text{-}14)$$

where P_{GD} is the cost of per kilometer track (ten thousand yuan / km), This design line takes 6 million yuan/km.

$f_{6 \text{ for scheme1}}$= 20.43km ×6×$10^6$ yuan/km=12258 （10^4 yuan）

$f_{6 \text{ for scheme2}}$= 20.45km ×6×$10^6$ yuan/km=12270 （10^4 yuan）

$f_{6 \text{ for scheme3}}$= 20.32km ×6×$10^6$ yuan/km=12192（10^4 yuan）

6.1.2 The Purchase Expense of Rolling Stocks

The design line is for the operation of the high-speed train sets only, in the calculation of the total number of motor train unit considering the maintenance spare factor multiplied by the unit price of the motor train unit to obtain the total cost of vehicle acquisition, and in accordance with the mileage of the entire line, calculate the cost of vehicle acquisition apportioned to the design interval，namely：

$$f_7 = A_d = M_D \times a_d \times (1+\gamma_d) \times \frac{L_{ZX}}{L_Z} \tag{6-15}$$

where a_d is the motor train unit prices, this design line is taken 1 billion/set；

γ_d is the spare coefficient of motor train unit maintenance, this design line takes 0.16；

M_D is the number of motor train unit, calculated according to the formula (6-16)；

L_Z is the full line length of the design interval; the design line is taken as 300km.

$$M_D = \frac{\frac{t_1+t_2}{\beta_L}+\sum_{n_D} t_{Dj}}{1080} N_D \tag{6-16}$$

Where t_1 and t_2 are the train travel time going forward and backward of the train, respectively, excluding the additional time for starting and stopping. This line uses *160km/h* for estimation;

β_L is the travel speed coefficient; this design line is taken as 0.85;

t_{Dj} is the preparation time of the train set in the train section (station), this design line is taken as 18min;

N_D is the number of pairs trains in a day. In China, the train is operational for 18hrs a day.

$$M_D = \frac{\frac{t_1+t_2}{0.85}+18}{1080} N_D$$

$$t_1 = t_2 = \frac{300\text{km}}{160\text{km/hr}} = 112.5 \text{ minute}$$

$$M_D = \frac{\frac{112.5+112.5}{0.85}+18}{1080} 10\times 18$$

M_D=47.12=48 motor units

$f_7 = 48 \times 1 \times 10^9/\text{set} \times (1+0.16) \times \frac{L_{ZX}}{300}$ substituting the value of L_{ZX} for each scheme, we get the purchase expense of locomotives for each scheme.

f_7 for scheme 1=346492.8 (ten thousand yuan)

f_7 for scheme 1=346832 (ten thousand yuan)

f_7 for scheme 1=344627.2 (ten thousand yuan)

The total engineering investment cost can be calculated by equation 6-1.

$$F = f_1 + f_2 + f_3 + f_4 + f_5 + f_6 + f_7 (10^4 \text{yuan})$$

Summing up all the above investments for each scheme,

Table 6- 4 Summary of investments for each scheme

scheme	Scheme1	Scheme 2	Scheme 3
Investment A (10^4 yuan）	433295.07	427850.23	419654.95

6.2 Calculation of the operating expenses

Operating expense usually relates to the expense incurred during the operation time, and to some part it represents the merits of the scheme's operating circumstances, indicated as the expenditure of operation per year (10,000 yuan)[1]. These are the continuous costs of running railway equipment for the duration of the construction project. Railway operating expenses can generally be divided into “Operating expenses related to traffic volume” and “Fixed equipment maintenance costs” two parts for calculation, this part of the expenditure quotas refer to the Beijing-Shanghai high-speed railroad related quotas to determine.

Operating Expenses Related to Traffic Volume

At this stage of design, this part of the calculation accuracy requirement is not high, so here according to the formula (6-17) to estimate：

$$E_y = e \times L_{ZX} \times N_a \qquad (6\text{-}17)$$

where e is the operating cost which is estimated according to the operating cost per train per kilometer, and the design line is operated by 8 groups, and the cost is 7 yuan per train per kilometer, N_a is the number of moving train pairs passed in the year i.e., N_a=365×10×18=65700.

$E_{y\,1}$=7×20.43 ×65700=93.96 (ten thousand yuan)

$E_{y\,2}$=7×20.45 ×65700=94.05 (ten thousand yuan)

$E_{y\,3}$=7×20.32×65700=93.45 (ten thousand yuan)

Fixed Equipment Maintenance Costs (including depreciation)

Fixed equipment expenditure quota is divided into maintenance and depreciation, maintenance is divided into major repairs and routine maintenance, depreciation costs are generally calculated by the estimated investment budget multiplied by the depreciation rate.

Ground fixed equipment includes lines and buildings, among which lines are divided into public works and electrical services.

1. Public Works Expenses

（1）Main line maintenance cost

Main line maintenance is divided into major repairs and routine maintenance, both include materials and wages two expenditures, the unit according to million yuan/km.year, the design line main line maintenance costs are taken in Table 6-5.

Table 6- 5 Main line maintenance cost table（RMB million/mainline km-yr）

Projects	Overhaul	Daily maintenance	Total
Materials	19.06	5.33	24.39
Wages	2.53	1.49	4.02
Total	21.59	6.82	28.41

Then the annual maintenance cost of the main line of this design line is：

$$E_{Gmainline} = e_{mainline} \times L_{ZX} \qquad (6\text{-}18)$$

$$E_{Gmainline\ 1} = 28.41 \times 20.43 = 58041.63\ (\text{ten thousand yuan})$$

$$E_{Gmainline\ 2} = 28.41 \times 20.45 = 58098.45(\text{tenthousand yuan})$$

$$E_{Gmainline\ 3} = 28.41 \times 20.32 = 57729.12(\text{ten thousand yuan})$$

（2）Station track maintenance cost

Overhaul and routine maintenance of the station track are carried out together with the maintenance of the main line, and the basic work is roughly the same. The maintenance expenditure quota also includes two items of expenditure: material and wages. The unit is 10000 yuan/main line km · year. See Table 6-6 for the values of various maintenance costs of the station track of this design line.

Table 6- 6 Station Track Maintenance Cost (10000 yuan/main line km · year)

Category	Overhaul maintenance	Routine maintenance	Summation
Material	6.35	1.78	8.13
Wage	1.27	0.75	2.02
Summation	7.62	2.53	10.15

Then the annual maintenance cost of the design station track is:

$$E_{GST} = e_{ST} \times L_{ST} \times n \qquad (6\text{-}19)$$

$$E_{GST} = 10.15 \times 0.4 \times 2 = 8.12(\text{ten thousand yuan})$$

(3) Railroad switch maintenance cost

For the values of various maintenance costs of the design station track, see the table below.

Table 6- 7 Railroad Switch maintenance Cost (10000 yuan/group · year)

Category	Overhaul maintenance	Routine maintenance	Summation
Material	2.76	0.92	3.68
Wage	0.2	0.36	0.56
Summation	2.96	1.28	4.24

There are 16 groups of railway switch in two intermediate stations of the design line, so the annual maintenance cost of turnouts of the design line is:

$$E_{GRS} = e_{RS} \times n_{RS} \tag{6-20}$$

$$E_{GRS} = 4.24 \times 16 = 67.84 \text{ (ten thousand yuan)}$$

(4) Line depreciation cost

The calculation of line depreciation cost includes subgrade, bridge and culvert, tunnel and track, according to the regulations of the Ministry of Finance of the People's Republic of China, the depreciation expense is calculated by the straight-line method, the residual value rate of subgrade, bridge and culvert, tunnel is 0, the residual value rate of track is 5%, and the depreciation rate of each part of the design line is 2.2%. Therefore, the line depreciation cost is:

$$E_{GD} = (f_1 + f_2 + f_3 + f_4 + f_5 + f_6) \times \eta \tag{6-21}$$

We use $\eta = 2.2\%$ for this design.

$E_{GD1} = (29532.04 + 15992 + 9.63 + 0 + 29010.6 + 12258) \times 2.2\% = 1909.654$ (10^4 yuan)

$E_{GD2} = (26712.91 + 12992 + 4.32 + 0 + 29039 + 12270) \times 2.2\% = 1782.184$ (10^4 yuan)

$E_{GD3} = (23262.15 + 10712 + 7.20 + 0 + 28854.4 + 12192) \times 2.2\% = 1650.614$ (10^4 yuan)

2. Electric service cost

(1) Electric service equipment depreciation cost

The calculation of electric service equipment includes two parts: communication and signal. The signal includes train dispatching, automatic station management, train control system, interlocking system, etc. The design line takes 4.5 million yuan/year.

(2) Electric service equipment maintenance cost

This design line is taken to be 1.3 million yuan/year.

(3) Power supply equipment depreciation cost

Power supply equipment calculation project contains contact network, substation, civil engineering, etc., this design line is taken to be 2.6 million yuan/year.

（4） Power supply equipment maintenance cost

This design line is taken to be 1.3 million yuan/year.

The total electric service cost is 9.7 million yuan/year.

3. House building operating cost

(1)House building maintenance cost

Housing building maintenance costs are projected according to the ratio of existing maintenance costs to existing construction costs, according to the cost of new housing construction, and this design line is taken to be 1.2 million yuan/year.

(2)House building depreciation cost

According to the regulations of the Ministry of Finance of the People's Republic of China, the depreciation cost of buildings shall be calculated by the straight-line method. The design line is 800000 yuan/year.

The total house building operating cost is 2 million yuan/year.

4. Fixed equipment maintenance cost (including depreciation) E_G

The fixed equipment maintenance cost (including depreciation cost) can be obtained by summing up the above public works expenditure, electrical service expenditure and housing construction operation expenditure E_G. then, the annual operation cost of the design line is obtained by adding operation cost related to traffic volume and maintenance cost of fixed equipment. Thus,

$$E = E_y + E_G \tag{6-22}$$

It is summarized in the table below.

Table 6-8 Summary of operation cost

Scheme	1	2	3
E_y（10^4 yuan）	93.96	94.05	93.45
E_G（10^4 yuan）	61197.28	61126.61	60625.78
E（10^4 yuan）	61291.24	61220.66	60719.23

6.3 Calculation of conversion annual costs

For the comparison of schemes in this design, converted annual cost is used. When using A to express project investment, E to the annual operation expense, then the annual conversion cost K which uses a static method can be expressed using the equation given below.

$$K = E + \Delta A \tag{6-23}$$

The effective coefficient of investment Δ is related to the profit and investment policy of national economy department. It is one of the key figures in Chinese railway engineering. If Δ is stipulated on the side of smaller value, the decision will be made in favor of the alternative with expensive capital cost and lower operating costs. Otherwise, for a higher value of Δ, the alternative of less cost of investment and higher expenses of operation will be favorable. Thus, the stipulation of Δ will widely influence the railway economy and development. Currently Δ can be taken as 0.06 according to “railway construction project economic evaluation method” of Chinese railways.[1]

K_1 = 61291.24+0.06×433295.07=87288.07（10^4 yuan）

K_2 = 61220.66+0.06×427850.23=86891.67（10^4 yuan）

K_3 = 60719.23+0.06×419654.95=85898.53（10^4 yuan）

We can compare the converted annual cost using the bar graph shown in the figure below.

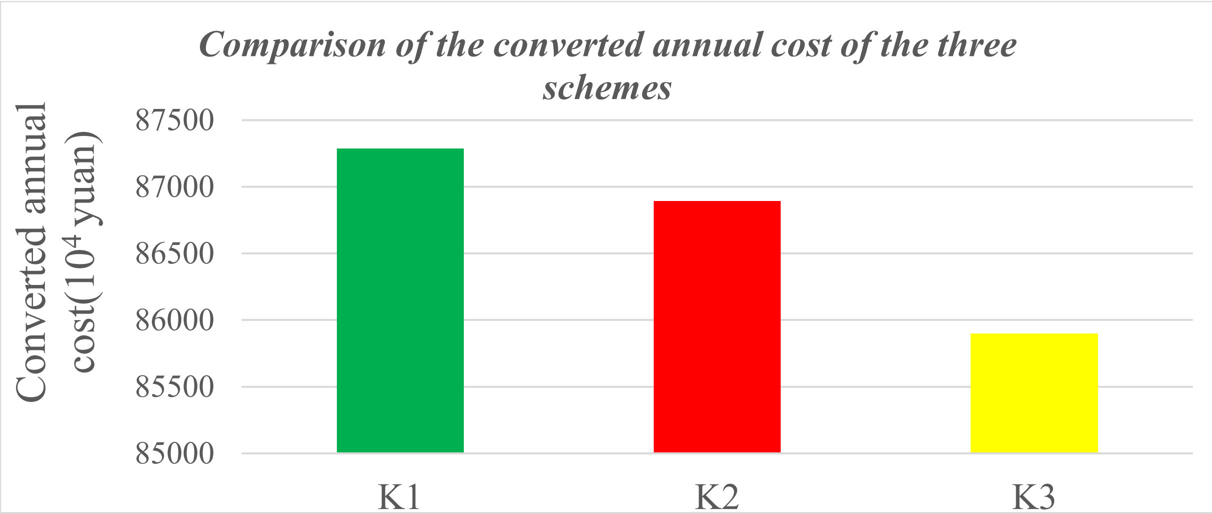

Figure 6-6 Comparison of converted annual cost of schemes

6.4 Summary

In this chapter, the economic and technical indicators including the investment and operation cost of the designed intercity railway schemes are calculated and compared in order to select the most economic scheme. This comparison is based on the converted annual cost. So, among the three alternative schemes, the scheme with the minimum annual conversion costs K is the most economic one. So, from the above calculation of the converted annual cost, we can see that scheme 3 has the smallest value of K=85898.53 (10^4 yuan). Therefore scheme 3 is the most economic scheme among the selected three schemes.

Conclusion

In the design of an intercity railway, the significance of the line with respect to politics, defense, environmental and other socioeconomic parameters should be surveyed so that the status of the design line in the railway network can be determined.

Before selecting the line strikes, the railway main technical standards are established by comprehensive comparison based on its role in relevant railway networks, topography, geological conditions, transport capacity and transport demand along the line, for the purpose of ensuring safety, maintaining railway network, ensuring railway transport characteristics, ensuring convenience for users and environmental countermeasures.

Particularly, engineering standards such as the design speed, the number of main tracks, the maximum grade (or ruling grade), the curvature's minimum radius, and the length of the arrival and departure line are hard for reconstruction and should be studied thoroughly before the design and construction of the railway line.

During an intercity railway line selection, we should choose as many line strike schemes as possible in order to avoid missing schemes at every design stage. In this graduation design, three line-strike schemes are selected on the given strip of land; each fulfilling the design specifications (such as the minimum length of intermediate straight line, the minimum radius of curvature, the minimum length of transition spiral, the minimum and maximum radius of vertical curves etc.) of an intercity railway in China.

Prior to selecting the line strikes, the location of entrance and exit of tunnels, bridge sites, agglomeration points and location of intermediate stations should be chosen in order to make the line pass through these points so that the designed line can be safe and economic as well as it can provide its expected functions. Seriously unfavorable geology areas, historic reservation, reservoirs, and major project areas should be considered as location exclusion areas to avoid affecting the natural resources, the ecosystem and the historical and cultural heritages.

The plane and profile of an alignment is a determining factor for the function of the proposed intercity railway line; therefore, it should satisfy the requirements in the design specifications and the profile also should consider the height of bridges and culverts at sites that need inevitable bridges and culverts.

Intercity rail transit is characterized by large passenger flow, limited headway, limited distant stations, and short travel time serving as a bridge between the mainline and urban railways, as well as providing medium and short-distance passenger transportation and commuting services in densely populated city clusters with developed economy, so, the traffic capacity of the design line should be greater than the required traffic capacity.

As we saw from the calculation the main technical and economic indicator of the schemes, we can conclude that scheme 3 having the smallest value of annual converted cost K=85898.53 (10^4 yuan) is the most economic scheme. In addition, this scheme is near to the existing highway line so the right of way will be the smallest and with a minimum disturbance of the community since infrastructures built at the vicinity of the highway are usually of low cost.

Since this design is in the prefeasibility stage, all the schemes should be studied further in the coming steps of the feasibility and design stage and final decision should be made.

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