# PREFACE

 **1. Reasons for the Topic**: “Study on Rational Selection of Basic Specifications of High-speed Railway lines and Application to Ha Noi-Vinh Line”

-Each group of basic specifications of a high-speed railway line is corresponding to a transportation capacity diagram and defined socio-economic efficiency.

-The problem of selecting basic specifications of high-speed railway line is complicated and depends on many factors. The traditional methods are time-consuming and costly for data survey, calculation and comparison; however, the results are only streamlining and optimal for each separate specification but causing many difficulties for the whole group.

 **2. Study targets of the Topic**: Studying and proposing a rapid selection method for basic specifications of high-speed railway in the current conditions of no high-speed railway available in Vietnam.

 **3. Objects:** Basic specifications of high-speed railway lines and selection methods.

 **4. Scope of study**: Determine basic geometric specifications of high-speed railway lines to ensure their transportation capacity.

 **5. Methods of study**: Systematic analysis on factors affecting the selection of basic specifications and use of statistical probability theory ; expert method optimal for decison making to define basic specification groups rationally. Comparing with groups used in feasibility study on high-speed railway in Vietnam

 **6. Scientific and practical significance of the Topic**

 - Contributing in clarifying the theotical bases on basic specifications of high-speed railways, their impacts on the economy, society, environment and technical requirements of high-speed railway operation.

 - Rapidly selecting the most rational basic specifications of high-speed railways in the current conditions of no high-speed railway available in Vietnam and then considering the construction policy and preparing a feasibility study task for the project of constructing a high-speed railway line in Vietnam. **7. Structure of the thesis:**

Preface: Stating the reasons for studying the selection of basic specifications

Chapter 1. Overview on basic specifications selection of high-speed railway lines

Chapter 2: Methods of multi-criteria analysis and selection of basic specifications of high-speed railway lines.

Chapter 3: Selection of basic specifications of Ha Noi-Vinh high-speed railway line

Conclusion: Stating conclusions of research results and recommendations for further research directions

**CHAPTER 1. Overview of choosing on basic specifications selection of high-speed railway lines**

**1.1. Basic specifications of high-speed railway lines**

**1.1.1. Introduction about basic specifications of high-speed railway lines in countries**

**1.1.2. In Vietnam**

 22TCN362-07 Industry Standards only states:

 - Designed speed: Vmax ≤ 350 km/h; Horizontal curve radius under normal condition: Rmin ≥ 5000m; Difficult condition: allowed speed-based adjustment; Maximum longitudinal gradient under normal condition: Imax ≤ 25‰; Difficult condition: Imax ≤ 30‰; Roadbed size; Distance between 2 line hearts: D ≤ 5 m.

**1.1.3. Basic specifications of high-speed railway lines**

 *1.* *Designed speed (Vtk):* 200km/h - 250 km/h; 250km/h -300km/h and 300km/h - 350 km/h speed ranges.

 *2. No. of main lines (n)*: It is necessary to design a 2-way double line because high-speed railwa has high operation density, long distance between running trains, high possibility of transport adjustment; therefore, n ≥ 2.

 *3. Minimum distance between line hearts (D):* the shortest distance between departure line heart and arrival line heart in track section. It is specified by designed speed:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Designed speed (km/h) | 200 | 250 | 300 | 350 |
| Dmin (m) | 4.4 | 4.6 | 4.8 | 5.0 |

 *4. Minimum radius of circular curve (Rmin)*: This is one of basic specifications of high-speed railway lines. It is concerned with train operation method, designed speed, adaptability of passengers and train operation stability.

 *5. Maximum gradient (12-25%o):* The maximum gradient of main line in track section depends on train technologies and topographic conditions and traction audit of trains running at over maximum gradient.

Railways for passenger trains with mild wagons, high engine capacity, good traction force and brake force are appropriate for operating trains on steep terrain.

   *6. Length of departure and arrival lines in the station is over 480m*

 In the studies of Germany, France and Japan, the length of departure and arrival lines is not only appropriate for train length but also ensures safety. A train usually has 16 wagons at maximum. In this case, the length of train is rounded at 420m, reserved length for stoppage is 30 m on each side, the stoppage length of departure and arrival lines is 480m.

**1.2. Necessity to selecting appropriate specifications of high-speed railway lines**

- Each basic specification has a value range limited by the lower and upper bounds defined by the regulations, technical standards or the experimental research results of high-speed railway lines.

 - The most appropriate value of specification must be in the defined range and must satisfy the objectives of exploitation capacity, socio-economic and environment efficiency of the railway line at the highest level.

**1.3. Selection of basic specifications of high-speed railway lines**

1.3.1. Selection method of separate basic specifications

 By finding out factors affecting each basic specification and then setting value range for that specification and determining the most appropriate value by establishing quanlitative formula.

1.3.1.1. Select target speed. It depends on 5 main factors; namely the importance of railway line, relationship between speed and price, relationship between speed and energy consumption, the effect of speed on competitiveness with other transport means, the effect of speed on the environment.

1.3.1.2. Select the minimum circular curve radius (Rmin). The circular curve radius depends on factors: movement safety of train, economy and adaptability of passengers.

1.3.1.3. Select the maximum gradient of the main line.

1.3.1.4. Select the distance between two line hearts.

**1.3.2. Analysis and assessment of the traditional methods for selecting basic specification groups of railway lines.**

 Each basic specification group has a corresponding transport capacity diagram and economic efficiency of the railway line.

 The problem of selecting a set of basic specifications of railway lines according to traditional methods is solved provided that minimum arising costs and technical requirements are satisfied.

**1.3.3. Analysis of the domestic studies related to the selection of basic specifications of high-speed railway lines**

 Vietnam has had only two feasibility studies of Korea so far: Hanoi – Vinh, Ho Chi Minh City - Nha Trang high-speed railway lines and a report of Japan: In Hanoi - Ho Chi Minh City, there are some studies on design methods in which basic specifications are determined.

 **1.3.4. The weaknesses in finding out basic specifications according to traditional methods**

 - Traditional methods only consider economic criteria but society and environment criteria and do not quantify their impact on high-speed railway lines.

 - It is required to design the railway line to calculate the volume and there are a lot of tasks related to design.

 - Calculation is time –consuming because a lot of information is required to calculate function Kdx, which is actually calculated by lots of steps.

 - The number of options taken into calculation and comparison is limited; thus not fully reflecting dependency between quantitative criteria and non-quantitative criteria.

 - Particularly in Vietnam, there are no studies on basic specifications of high-speed railway lines.

 **1.4. Targets of the thesis**

 - Analyzing and defining basic specifications of a railway line and formulating a model of the problem selecting basic specifications of high-speed railway lines; satisfying technical, socio-economic, environmental requirements with blur data.

 - Find out a method to quickly select a basic specification group of high-speed railway lines in consideration of both quantitative and non-quantitative criteria. The criteria are not in the same measurement unit; however, time and calculations are minimized to determine the preliminary plan before implementing the feasibility study on a high-speed railway line.

 - Application of the above theories to Hanoi – Vinh high-speed railway line.

**CHAPTER 2**

**APPLICATION OF MULTI-CRITERIA ANALYSIS METHOD IN SELECTING BASIC SPECIFICATIONS OF HIGH-SPEED RAILWAY LINES**

**2.1. Introduction of multi-criteria analysis method**

**2.1.1. Multi-criteria analysis**

 Multi-criteria analysis (MCA) method is analyzing a group of different criteria to produce a final result. The main applications of MCA are to assess the impact of a process.

 MCA is applied to the cases when there are multiple criteria with different importance levels needed selecting to meet the requirements simultaneously.

 The models or mathematical methods play a crucial role in the assessment process. They are tools to convert assessment criteria in order to make criteria “homogeneous” which can be compared with each other.

**2.1.3. Mathematical models in MCA**: Currently, there are six mathematical methods in MCA. To select the best and most appropriate solution to this problem, AHP or Cojunctive methods can be applied.

**2.1.3.1. AHP Method**

 \* Mathematical bases of AHP method:

 To solve blur multi-attribute decision-making problem in option selection, the decision makers must take aij ratios for each pair comparison based on the importance levels among criteria describing the attribute qj, j = 1,2, ..., m and Rij ratios for each pair comparison based on the relative values of each criterion qj corresponding to design options of A1, A2, ..., An according to each criterion describing the attributes.

 In making pair comparison between criteria qj, j = 1, 2 ..., m; we have matrix A (m x m):

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  | q1 | q2 | …. | qn |  |
|  |  | q1 | a11 | a12 | …. | a1m |
| A  | = | q2 | a21 | a22 | …. | a2m | (2-2) |
|  |  | …. |  |  | …. |  |  |
|  |  | qn | am1 | am2 | …. | amm |  |

 In which: aij is the relative importance of criterion qi in comparison with criterion qj (j = i and 1,2, ..., m). Aij values are taken from a set of scales, which are real numbers representing different levels of importance.

 Representing importance levels of qi and qj criteria as wi and wj, we have aij = wi/wj or:

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| A | = | a11 | a12 | …. | a1m | = | w1/w1 | w1/w2 | …. | w1/wm | (2-3) |
| a21 | a22 | …. | a2m | w2/w1 | w2/w2 | …. | w2/wm |
|  |  | …. |  |  |  | …. |  |
| am1 | am2 | …. | amm | wm/w1 | wm/w2 | …. | wm/wm |

w = (w1, w2, …, wj, …wm)

 Comparing relative pairs each criterion qj in terms of sizes corresponding to options A1, A2, ...., An, we have rikj is the relative value of criterion qj. The relative value of qj in Ai is qij in comparison with itself (i.e. qj); that of qj in Ak is qkj.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | qj | A1 | A2 | …. | An |  |
|  |  | A1 | r11j | r12j | …. | r1nj |
| Rj | = | A2 | r21j | r22j | …. | r2nj | (2-4) |
|  |  | …. |  |  |  |  |  |
|  |  | An | rn1j | rn2j | …. | rnnj |  |

rj= (r1j, r2j, …., rij, …., rnj)

 In the same way, we have rikj = rij/rkj where rij is the relative value of qij in Ai, rkj the relative value of qj in Ak. We have a matrix of relative values of criteria as follows:

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  | q1 | q2 | …. | qn |  |
|  |  | A1 | r11 | r12 | …. | r1m |
| R  | = | A2 | r21 | r22 | …. | r2m | (2-5) |
|  |  | …. |  |  | …. |  |  |
|  |  | An | rn1 | rn2 | …. | rnm |  |

According to Saaty’s particular vector, values in pair comparison are real numbers. Each pair comparison matrix shall be solved by defining particular vectors; thus importance levels and relative values of the criteria in each option will be real numbers.

 Pair comparison matrix determining the importance level of the criteria A is a positive reciprocal matrix.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| A | = | a11 | a12 | …. | a1m | (2-6) |
| a21 | a22 | …. | a2m |
|  |  | …. |  |
| am1 | am2 | …. | amm |

With aij ≥ 0 & aij = 1/aij; ∀i, j (2-7)

aij= aik / ajk  (2-8)

aij  = wi / wj (2-9)

With aii = 1 that is always right. Multiplying A matrix with ,we have:

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Aw | = | w1/w1 | w1/w2 | …. | w1/wm | x | w1 | = | Mw | (2-10) |
| w2/w1 | w2/w2 | …. | w2/wm | w2 |
|  |  | …. |  | …. |
| wm/w1 | wm/w2 | …. | wm/wm | wm |

or (A – mI) w = 0 (2-11)

Thus, vector w = (w1, w2, ..., wm) is the particular vector of matrix A.

 Call A' as a matrix obtained from the assessment of the decision-makers, we can define vector w' corresponding to matrix A' by solving the following equation:

A'w' = λmax w' (2-12)

 λmax is the largest particular value of matrix A'. Vector w' is the particular vector corresponding to the maximum particular value (λmax) of matrix A'. The vectors rj = {r1j, r2j, …., rnj}, j = 1,m are also defined similarly to vector w.

 According to the matrix principle, the consistency in the assessments of the decision makers will be considered as warranty (i.e. Premise 1 is satisfied) when λmax = m. In contrast, when λmax ≠ m, the decision makers must review and revise their assessments for ensuring allowed consistency of pair comparison matrix. Saaty proposed a method of using the consistency ratio (CR) to assess consistency of estimates of pair comparison matrix as follows:

; (2-13)

;  (2-13)

 RI is the random (consistency) index determined from an optional matrix with elements randomly selected. By using simulation method, Saaty has identified a table of RI values for matrices with different sizes:

***Table 2-1. Table of values of RI***

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| S | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| RI | 0.00 | 0.00 | 0.58 | 0.90 | 1.12 | 1.24 | 1.32 | 1.41 | 1.45 | 1.49 |

 Through experiences, CR should be below 0.05 with 3 x 3 matrix; below 0.09 with 4x4 matrix and below 0.1 with larger matrices.

 For point scale applied to pair comparison, Saaty proposed the 1-9 point scale.

  The pair comparison in term of the relative value of criteria according to design solutions is also carried out under the above scale.

**2.1.4. Selection of participants in the multi-criteria assessment process**

2.1.4.1. Participants in the multi-criteria assessment and decision-making process

 The number and occupational structure of decision makers in MCA depends on the contents of the options and issues in making decisions.

**2.1.4.2. Leader of assessment process**

 The leader of the assessment process must meet the general requirements for decision makers. In addition, he/she also has good organization skills and management ability over procedures and assessment process of options.

**2.1.4.3. Analyst Group**

 Analyst group is responsible for setting up the mathematical models, proposing group decision –making methods, carrying out calculations and analyzing data to provide information for decision-makers. Analyst group is also in charge of collecting and processing data and coordinating activities in decision-making process.

**2.1.5. Decision-making methods in the MCA process**

 There are many decision-making methods such as voting, election, direct discussion, Nominal Group, Delphi, etc.

**2.2. Multi-criteria Evaluation Process**

The process consists of 5 following steps:

*Step 1*: Selecting participants in the process of Decision Making

*Step 2:* Identifying evaluation criteria and forming analysis tree – Rejecting unacceptable solutions

*Step 3:* Identifying the relative importance of criteria

*Step 4:* Identifying the value of criteria

*Step 5:* Identifying the best option.

**2.2.1. Selecting participants in the decision making process**

The selection of number and professional structure of decision makers needs carefully studying so as to minimize discussion time.

**2.2.2. Identifying evaluation criteria and forming analysis tree.**

**2.2.2.1. Identifying evaluation criteria and forming analysis diagram.**

This task is tough, complicated and important to select the best option.

During the analysis on technological, economic, social, environmental (standard) options, standards can be divided into many criteria.

In MCA, the analysis diagram is formulated by methods of group decision making. After the criteria analysis diagram has been completed, vectors of the criteria analysis for the options can be defined as follows:

 q = q1, q2, …..qj,…..qm (2-14)

Those criteria are correspondent to final elements of of each branch of the analysis diagram. The following step is to identify the criteria value for each option:

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Q | = | q11 | q12 | …. | q1j |  | q1m | (2-15) |
| q21 | q22 | …. | q2j |  | q2m |
| ….. | ….. | ….. | ….. | ….. | ….. |
| qi1 | qi2 | …. | qij | ….. | qim |
| ..... | ..... | ..... | ..... | ..... | ..... |
| qn1 | qn2 | ….. | qnj | …… | qnm |

The method of defining criteria qij depends on specific characteristics and conditions of analyized issues. Quantitative criteria can be identified by available traditional methods. Non-quantitative criteria can be defined by oral description or based on any scales through group decision making method or describing documents to provide to Decision Makers.

**2.2.2.2. Forming options and rejecting unacceptable options.**

Unacceptable options are those with at least one unacceptable criterion as breaching codes, standards or current State regulations or failing to meet the prerequisite requirements for the problem, etc.

**2.2.3. Identifying the relative importance of criteria**

If the analysis diagram has over two levels, the relative importance of criteria respecting to the common target is identified according to the following principles:

Identifying the relative importance respecting to the common target for all criteria of analysis diagram according to the top-to-bottom order, in which the importance of criterion in the foot of diagram is equivalent to 1. In other words, representing the foot of analysis diagram as the first level; the calculation for criteria will be from the second to the final level respectively.

The relative importance of criteria respecting to principal criterion is identified by generalizing subjective evaluations of decision makers through comparing each pair of criteria.

Criteria at level y are those saperated from level (y-1). In Figure 2-4, criteria q(y-1), … q(y-j)… q(y-s)… at level y are separated from principal criterion.

q(y – 1) – k)) at level (y-1). Thus, the relative importance of criteria q(y-j) respecting to the common targets, noted as w(y-j), is defined in accordance with the formula:

W(y-j) = w\*(y – j) x w ((y-1)-k); ∀j = 1- s (2-16)

In which: w(y-j) is the relative importance of criterion q(y-j) respecting to the principal criterion q((y-1)-k); w((y-1)-k) is the relative importance of criterion q((y-1)-k) respecting to common target. Because the calculation is conducted under the top-to-bottom order i.e. from the second level to the last level, w((y-1) – k) is definitely identified in the previous calculation step. w\*(y-1) is identified by comparing pair of criteria respecting to the principal criterion q((y-1)-k)) based on the 9-point scale of Satty as follows:

Representing aij as the relative importance of criterion q(y-i) compared to the criterion q(y-j) respecting to the principal criterion q((y-1)-k), aij will be valued as:

 \* 1 if the two criteria are considered as equally important,

 \* 3 if criterion q(y-i) is considered to be relatively more important than q(y-j),

 \* 5 if criterion q(y-i) is considered to be very more important than q(y-j),

 \*7 if criterion q(y-i) is considered to be extremely more important than q(y-j),

 \* 9 if criterion q(y-i) is considered to be absolutely more important than q(y-j),

 \* Values 2,4,6 and 8 are intermediate between the upper and lower values respectively.

Pair of criteria are only compared respecting to principal criterion regardless of other criteria. Thus, we have the pair comparing matrix, Ak, as a square matrix valued s x s :

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | q((y – 1) – 1) | q(y – 1) | q(y – 2) | …. | q(y – s) | (2-17) |
|  |  | q(y – 1) | a11 | a12 | …. | a1s |
| Ak | = | q(y – 2) | a21 | a22 | …. | a2s |
|  |  | ……. | ….. | ….. | ….. | ….. |
|  |  | q(y – s) | as1 | as2 | …. | ass |

 As shown above, particular vector corresponding to the highest particular value of the standardized matrix A , noted as w\*, is the vector indicating the relative importance of the criteria q(y-j); j=1-s respecting to their principal criterion:

w\* = w\* (y – 1), w\* (y – 2), …. w\* (y – j), ….. w\* (y – s) (2-18)

Because Pair of criteria are only compared respecting to principal criterion regardless of other criteria, it is neccessary to check and deal with the consistency of estimates within the matrix A through identifying the Consistency Rate as shown above.

**2.2.4. Identifying the relative value of criteria**

**2.2.4.1. Identifying the relative value of quantitative criteria**

Relative value of quantitative criteria is easy to define valuefor each option by normalizing their absolute value. Respecting number of quantitative criteria as b, vetor showing the relative criteria for methods can be easy to define for options as follows:

rj  = r1j, r2j, …., rij,…. Rnj , j = 1 – b : (2-19)

**2.2.4.2. Identifying the relative value of non-quantitative criteria**

Relative value of quantitative criteriavalue will be identified by pair comparison for all options according to each criterion:

Representing number of non-quantitative criteria as f, we have the matrix of pair comparison Rj, j = 1 – f:

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | qj | A1 | A2 | …. | An |  |
|  |  | A1 | r11j | r12j | …. | r1nj |
| Rj | = | A2 | r21j | r22j | …. | r2nj | (2-20) |
|  |  | …. |  |  |  |  |  |
|  |  | An | rn1j | rn2j | …. | rnnj |  |

Rj, is the matrix comparing solution pairs according to each non-quantitative criterion qj, j = 1 – f. The element rikj is the relative value of criterion qj corresponding to solution Ai (as qij) compared to the criterion itself corresponding to the solution Ak (is qkj). Pair comparison is conducted by group of decision markers and the number rikj is also defined as group decision making method based on 9-point scale.

Finally, we can define and normalize values of particular vectors corresponding to the highest particular value of the matrices Rj; j = 1 – f. These are particular vetors rj showing the relative value of non-qualitatve criteria rj  = r1j, r2j, …., rij,…. Rnj , j = 1 – f. Also, the consistency of estimates in the matrices Rj must be checked and dealt with by defining the Consitency Rate.

**2.2.4.3.** Collecting experts’ opinions to compare and define the criteria value.

Decision Makers shall send applications for experts’ opinions.

**2.2.4.4.** Dealing with data collected from experts

Includes:

- Rejecting specific data by calculating the variance and the standard deviation of the criteria (probability theory).

- Forming priority matrix, calculating consistency rate.

**2.2.5. Identifying the best option**

**2.2.5.1.** Identifying the relative value for criteria of options

Gathering all vectors rj identified in the Item 2.2.4, we have the matrix for relative value of all criteria of the analyzed option.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  |  | r11 | r12 | …. | r1m |  |
| R  | = | r21 | r22 | …. | r2m | (2-21) |
|  |  |  |  | …. |  |  |
|  |  | rn1 | rn2 | …. | rnm |  |

**2.3. Characteristics and applications of multi-criteria analysis**

**2.3.1. Characteristics of multic-criteria analysis:**

* *Advantages:* take full use of avalaible information; only use one unique criterion for selection and comparision (generalized criterion); Many criteria can be offered in comparison, making the comparison more generalized and reflecting the comprehensive connotation of the option, especially blur criteria (unclear criteria).; Method of marking by experts can be applied for non-quantitative criteria.
* *Disadvantages:* It biases to the subjective opinion due to consulting expert’s opinion for marking the importance of criteria; it will collapse the key criteria if so many criteria are offered in comparison.

**2.4. Applying MCA in selecting Basic Specifications of High Speed Railway**

**2.4.1. Bases for proposing to apply multi-criteria analysis method to select basic specifications of high speed railways:**

Suitable method needs studying to overcome shortcomings of traditional methods and satisfy conditions in Vietnam.

By studying national and international data, it can seen that: MCA is now the most optimum method to make the decision on selecting an issue which depends on inconsistent factors on measurement unit and is not quantified specifically, as this method can solve disadavantages of traditional methods. Non-quantitative criteria (society, environment) will be presented nto qualitatitve criteria, then analyzed generally through a general criterion and finally, by concurring these criteria and canceling measurement unit, evaluated the importance level (according to expert’s method), then synthevalued into a criterion by the weighted average according to the analyzed importance level.MCA’s advantages are putting many criteria into comparision, supporting the generity of comparision and reflecting all aspects of the issue which needs selecting

With the above advantages, MCA has been applied in many socio-economic fields, including construction. However, *there has been no study proposing the its application in selecting Basic Specifications of the High-Speed Railway in Vietnam.*

Therefore, the proposal to apply MCA (known as the optimum method for decision making) to select the combination of Basic Specifications of High-Speed Railway to best fit technical, economic, environment and social criteria is the most proper and ensures the reliability.

**2.4.2. MCA stepsfor selecting Basic Specifications of High-Speed Railway.**

**2.4.2.1. Developing problem and forming analysis diagram**

Basing on the principles, steps of MCA method are implemented to solve the above problem. Analysis criteria include:

- Standard group includes: Technical – technological, economic, social, environment and blur data criteria.

- Criteria group includes:

*\* Group of technical and technological criteria comprises detailed criteria as*: traction, locomotive technology, operating form, targeted speed, energy consumption, transport energy, terrain, geology, hydrology.

*\* Group of economic criteria includes:* Construction cost, exploitation cost and transportation revenue.

*\* Group of social criteria includes:* Occupied land, passager’s satisfaction, development chances for areas along railway lines, impacts on national security and defense.

*\* Group of environmental criteria includes:* Environmental pollution, impacts on historical relics and beauty spots.

*\* Group of blur data criteria includes:* Unit price, geology, hydrology, construction technology (unidentified criteria due to non-performance of detail survey and design).

\* Bases for identifying comparing criteria:

- Regulations of Investment Law, Building Code, Environment Law and other relevant legal regulations in investment, manufacture and business activities.

- Processes, specifications in the construction and exploration of High-Speed Railway.

- Traditional methods from the calculation, comparision of design options in construction in general and in railway in particular to comparision oftechnical-technological, economic, social, environmental criteria and construction sites in relation to geological, hydrological factors.

- Principles of Analytic Hierarchy Process (AHP) in MCA.

Among Basic Specifications, velocity parameter is both necessary Basic Specification and factor affecting on other parameters. This parameter is settled by establishing the speed spectrum. The analysis diagram for selecting Basic Specifications of High-Speed Railway lines can be offered as follows:

Option n

Option 3

Option 2

Option 1

Hydrogeology

Construction technology

Unit price

Preservation of historical relics, culture, ecology

Environmental pollution

Railway lines’ location

Development of areas along railway lines

Impacts on nation security and defense

Occuppied Land

Competitiveness with other vehicles

Passengers’ adaptability

Transportation cost

Exploitation cost

Construction cost

Traction when two trains meet each other

Terrain

Traction

Organizational method for train operation

Technology of train

Bluriness data

Environment

Society

Economy

Technology - technique

**Select basic specification of High-Speed Railway**

(Vmax, Imax, Dmin, Rmin, n, Lsd)

***Figure 2-6. MCA Model for selecting Basic Specifications of high-speed railway lines.***

**2.4.2.2. Selection of experts participating in decision-making process**

The construction of one high-speed railway line is a work of national level, which significantly impacts on economic-social development, security and defense. Therefore, the number and professional structure of selected experts to participate in the evaluation process must be ensured.

**2.4.2.3. Analysis of assessment criteria**

**a. Analysis of factors affecting the determination of basic specifications Vmax, I max, Rmin, Dmin, n, Lsd).**

**a.1. Factors affecting target speed:** The importance of geographical location of the line; Impact of power consumption on speed; Impact of competitiveness on the target speed; Impact of noise (environment) on target speed; Impact of construction costs on target speed

**a.2. Factors affecting the number of roads on the main line:** a large amount of passengers results in a large number of roads; a large number of roads leads to the high transport cotrolability so as not to affect the route. Normally, number of roads in high-speed railway is 2.

**a.3. Factors affecting to the distance of two line heartsline hearts:** For lines with electric poles and sign posts in the middle, the distance must be increased (0.41m); the distance of two line hearts depends on the width of train body (B) and wagon functions (pressure wave, tightness of wagon windows ...). The value of pressure wave depends on the speed of the train at the adjacent line.

 This relationship represented by the formula: D= Y+ (B1+B2)/2. The greater the distance of the two line heart hearts is, the higher the cost of construction is.

 **a.4. Analysis on factors affecting minimum curve radius**

*- Safety criterion affects minimum curve radium. This criterion is assessed through:*

+ Derailment coefficient in the locomotive: Q/P<0.8 and in wagons Q/P<1.0

+ Load reduction leading to derailment: ∆P/P<0.6

+ Wagon turnover: D= Pđ/ Pst< 0.8

 + Horizontal stability of the line Q < L

*- Adaptability criterion of the passengers affects the minimum radius.*

**a.5. Analysis on factors affecting the maximum gradient of the line Imax**

*- Speed and traction factors*

*- Topographical factor:* Topography is the major factor affecting the maximum gradient.

**a.6. Analysis on factors affecting the used length of departure line: Length of train and safety line**

 **Comment**: Two over the six above parameters are minimum radius, and used length of departure and arrival lines with its calculation formula through the target speed. And number of the main lines n as mentioned above is fixed at n = 2.

Thus the problem is finally to find 3 parameters including target velocity, maximum gradient and distance of the two line heart hearts D.

**b. Analysis on criteria**

**b.1. Analysis on technical - technological criteria**

Includes 6 criteria: Train operation technology,train operation organization, power consumption, traction, topography, pressure wave when two trains meet each other. These criteria should be defined to ensure: high-speed operation; large volume of transport; the maintenance methods to maintain reliability.

**b.2. Analysis on economic criteria:**

**- Construction cost**: Construction cost will be certainly increased if the gradient is small and the target speed increases.

**- The cost of locomotive and wagon procurement:** The cost of buying electric dynamic locomotives to pull passenger trains is cheaper than that of decentralized dynamic trains

The higher gradient leads to the larger running cycle, thus increasing number of trains in comparison to smaller gradient.

**- The cost of exploitation:** The larger gradient is limited, the greater the cost of exploitation is.

**- Transport revenue:** Depends the competitiveness of the route and target speed.

**b.3. Analysis on social criteria**

**- Occupied land area:** large land occupied leads to high construction cost and large volume of layout clearance.

**b.4. Analysis on environmental criteria:** Noise and cultural-historic landmarks, beauty spots and natural reserves

**b.5. Analysis on criteria of blur data:**

Among the factors determining the specifications of high-speed railway line, alignment planning contains many blur data, including: geological and hydrological criteria; construction technology; unit price and environment:

**2.4.2.4. Forming options and determining the relative importance of criteria.**

**a. Forming combination option, basic specifications of high-speed railway**

As stated in Chapter I, each value of one combined specification would results in an Ai option (Vi, imax, Rmin, Dmin, n, Lsd).

- Conducting the analysis to reject unacceptable options in which one of the basic specifications fails to meet the numbers specified in Industry Standard 22TCN-361-07 [1]

- Forming options combining basic specifications of high-speed railway: Basing on characteristics of one high-speed railway line to develop regulations, plans and policies of administration agencies in terms of objectives and scope to determine preliminary values of each basic specification, then in turn combining each value of one basic specification and the values of other parameters correspondingly to offer different options into assessment.

**b. Collecting and summarizing experts’ opinions**

- Providing full documents of the options and information relating to the works, comparative transcript of criteria pairs with the other instructions and necessary explanations. Experts send their opinion cards for summarizing calculation black points.

- Testing the consistency of the criteria by inputting the survey data (After rough handling by eliminating the errors under probability theory) into “Expert choice” software to get the relative importance of each criterion expressed in numbers and CR consistency ratio.

If the value CR does not meet the requirements CR (CR ≥ 0.1), i.e not meeting the consistency, consultation must be recarried out through discussion and exchange to narrow the discrepancies in experts’ opinions.

**2.4.2.5. Calculating and determining the best option by calculating the weight R of each option**

Solving matrix R set from the results of calculated relative value of each pair of comparative criteria by “Expert choice” software, we have the values R1, R2, …. Ri corresponding to the combination options A1, A2, … Ai.

The option with the highest value of R is the best.

**2.5. Conclusion of Chapter 2:** Researching multi-criteria analysis methods and the current applications. On scientific basis, using the algorithms in MCA method to determine the appropriateness, proposing applications to solve the problem of selecting basic specifications groups of high-speed railway route with concrete steps from formulating problem, defining standards and criteria; analyzing relationships, impacts among the criteria, forming analysis diagram, collecting opinions, comparing and taking into calculation to define the best basic specifications to design and construct one high-speed railway line in Vietnam.

**CHAPTER 3: THE SELECTION OF BASIC SPEFICIATIONS OF HANOI-VINH HIGH-SPEED RAILWAY LINE**

**3.1. Introduction the present railway:** Basic specifications of the present railway are: Ip= 120/00, Vmax = 100 km/h, Rmin =180 (m), size 1000(mm) with Diesel locomotive traction, single-track line.

***Table 3-1. Forecast on the demand for passenger transportat in Hanoi-Vinh line*** *(passengers/day)*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Year  | 2020 | 2025 | 2035 | 2045 | 2050 |
| Passengers  | 46,405 | 72,894 | 125,152 | 175,781 | 226,315 |

**3.2. Identifying problem and forming analysis diagram of input data**

**3.2.1. Forming problem:** Find the basic specifications such as design velocity (Vmax), max gradient (Imax), minimum distance between the two line heart hearts (Dmin), the minimum curve radius (Rmin), number of lines (n) and the used length of departure line (Lsd) satisfying the conditions of technology, economy, environment, society and blur data.

**3.2.2. The criteria analysis diagram and calculation diagram**

**Select basic specification of High-Speed Railway**

(Vmax, Imax, Dmin, Rmin, n, Lsd)

Technique - Technology

Economy

Society

Environment

Blur data

Technology of train

Organizational method for train operation

Traction

Terrain

Traction when two trains meet each other

Construction cost

Exploitation cost

Transportation cost

Passengers’ adaptability

Competitiveness with other vehicles

Occupied land

Impacts on national security and defense

Development of areas along railway lines

Railway lines’ location

Environmental pollution

Preservation of historical relics, culture, ecology

Unit price

Construction technology

Hydrogeology

Option 1

Option 2

Option 3

Option n

***Figure 3-1. Analysis diagram of criteria***

Summarizing experts’ opinions

Using Expret Choice software in calculation for the above options

Processing experts’ data (variance and standard deviation of the criteria)

Defining weights in each criteria

Calculate weights for 20 criteria to mark points for each gradient option corresponding to 04 target speeds by VBA and summarizing the results

Decision-making for options based on the highest point values

Defining common weights for criteria

Forming 4 target speed options, each makes 04 gradient options (4x4=16 options)

Priorities Level Matrix of 05 standards

Priority level standardization of 05 standards (Check for consistency)

Priorities Level Matrix of gradient options under each criterion

Matrix standardization to make points to each gradient option (Check consistency)

Compared with the research results of international organizations

Take Priorities Level Matrix of each criterion on each standard

Priority level standardization of each criterion on each standard (Check consistency)

***Figure 3-2.Diagram of calculation steps in selecting the best basic specifications***

**3.2.3. The initial data for analysis:** Indicating the alignments of high-speed railway line crossing Ha Nam, Nam Dinh, Ninh Binh, Thanh Hoa, Nghe An; on some sections through Ha Nam, Nam Dinh Ninh Binh on the left of the old line, the terrain is relatively flat; Ninh Binh - Thanh Hoa - Vinh section goes the right of the old line, the line crossed intermingle mountains and hills. The line diagram is as follows:

***Figure 3-3. The entire alignment.***



**3.3. The selection of experts:** The thesis proposes the experts of the Ministry of Transportation, University of Communications and Transport, Transport Engineering Design Inc., some localities the line passes through.

**3.4. Analysis on assessment criteria for marking comparative points of criteria**

**3.4.1.Analysis for basic specifications selection**

- Target speed Vmax: Compare some speeds such as 200, 250, 300, 350 km/h.

- Number of main lines: According to the passenger transport demand forecast: Due to the large transport, the time must be compatitive in order to reduce the load on highway so double lines, n = 2 would be needed.

- The distance between the two line hearts: With the advantages of Shecanshen train, the distance between the two line hearts are selected to ensure that the technology ofShecanshen is also applied.

- Rmin minimum curve radius: calculated after selecting velocity ensure ensuring safety conditions and the adaptability of passengers.

- Imax maximum gradient of main line: In passenger trains, the lines run through some hilly areas so Imax should be selected at 12%o, 15%o, 20%o, 25%o for proper comparison.

- The length of receiving and departure lines: Lsd corresponding to a longest passenger train with 16 wagons

**3.4.2. Analysis on criteria**

With Hanoi - Vinh route, noted specific data for analysis and comparison include:

- Technical-technological criteria group: double-track lines, electric traction, topography including hills and plains.

- Economic criteria group: construction of a new routes and some new stations such as Phu Ly, Ninh Binh, Thanh Hoa, etc.

- Environmental criteria group: Route goes through some concentrated urban areas, natural reserves such as Hoa Lu, Ba Trieu Temple, Lam Son, Ngoc Trao, Chung Mountain, Vuc Mau.

- Social criteria group: Because the route runs through densely populated areas and high traffic density so the assessment and comparison of the layout clearance volume, occupied land more favorable than other transport means are important.

- Blur criteria of data: Factors determining basic specifications of Hanoi-Vinh newly high-speed railway line contain many blur data such as: Geology and Hydrology (due to no detailed surveydetails), the unit norms and construction technology of high-speed railways.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| No. | Max gradient (0/00) | Speed (km/h) | Radius (Rmin) | Distance of two line heartline hearts (m) | Length of receiving and departure line  |
| 1 | 12 | 200 | 2200 | 4.2 |  480 |
| 2 | 15 |
| 3 | 20 |
| 4 | 25 |
| 5 | 12 | 250 | 3500 | 4.6 |
| 6 | 15 |
| 7 | 20 |
| 8 | 25 |
| 9 | 12 | 300 | 5000 | 4.8 |
| 10 | 15 |
| 11 | 20 |
| 12 | 25 |
| 13 | 12 | 350 | 6600 | 5.0 |
| 14 | 15 |
| 15 | 20 |
| 16 | 25 |

**3.5.5.2. Option selection decision-making:** From the general table of the results calculated by Expert Choice software (0.288), the 9th option has the highest weight R, i.e. the best option. So the decision on selecting a basic specification combination is the most reasonable:

- 300 Km/h target speed: The maximum gradient 12 (‰), the distance of the two line hearts 4.8m, minimum curve radius 5000m, 2 main lines, the length of receiving departure line 480m.

**3.5.6. Comparison with the researched results of international organizations**

- KOIKA’s research proposed Hanoi - Vinh route to run only passenger trains with the speed of 200km/h with consideration to raise to 300km/h in the future.

- JICA’s research proposed Hanoi-Vinh route to run commodities and passenger trains with the speed of 200km/h h.

 **\* Conclusion of Chapter 3**

- Calculation results of this thesis are basically consistent with the findings of international organizations in case only passenger trains are applied.

- The selected option with the most reasonable basic specifications: Vmax = 300km/h; Imax = 12‰; D = 4.8m; Rmin = 5000m; n = 2 and Lsd = 480m.

To meet transport demand, in the immediate period, this route can be exploited with target speed below 300km/h (200 km/h, 250km/h) or after this period, the target speed can be increased over 300km/h, but the above basic specifications must be immediately invested to ensure the effectiveness. The investment is phased only for adjusting investment level in train operating technology (locomotive, wagon) and the train control and operation system.

**CONCLUSIONS AND RECOMMENDATIONS**

1. **New contributions of the thesis:**

- The thesis has developed analytical models for evaluating, selecting combinations of basic specifications in high-speed railway construction based on multiple-criteria analysis theory.

- Based on technical standards and technical instructions, the thesis has selected 06 basic specification domains of the high-speed railway line.

- The thesis has used MCA based on processing the experts’ opinions to calculate common weight R of the options with the different values of basic specifications, thence selecting reasonable criteria based on option with the weight Rmax.

- The thesis has applied the above theories to survey Hanoi-Vinh route and offered 6 basic specifications of the high-speed railway line for Hanoi-Vinh passenger trains: Target speed V= 300km/h; longitudinal gradient Imax = 12 ‰; distance of the line hearts D = 4.8m; minimum curve radius Rmin = 5000m; Number of main lines n = 2; Length of receiving and departure lines Lsd = 480m.

- The thesis has offered a fast look-up method of the basic specifications of the high-speed railway lines without conditions survey, has formed detailed options as a basis for study and investment preparation for projects

- The thesis is a good reference for study and teaching of high-speed railway not avaible in Vietnam.

**2. Conclusion:**

In the context Vietnam has not had high-speed railway, no conditions of resources and time for survey, no detailed calculations of factors for consideration, decision and selection of the investment plans in the high-speed railway in general and Hanoi-Vinh section in particular, the research and the proposal on fast selection method of the reasonable basic specifications of the route play important role both theoretically and practically.

The research results of this thesis have been preliminarily identified combined with geometric elements of Hanoi - Vinh railway route in case new route would be constructed only for passenger trains.

The above results will contribute to the basis for proposing to competent authorities to plan investment strategy and will be used to formulate feasibility study task for the construction of Hanoi – Vinh high-speed-railway line.

**3. Recommendations for further researches:**

To meet the requirements of economic- social development and ensuring security - defense, the study in investment and construction of high-speed railway in Vietnam is necessary, in which Hanoi - Vinh route needs studying for investment and construction as soon as possible. I recommend to select the basic specifications as in the above research results to perform feasibility study for the construction of Hanoi – Vinh the high-speed railway line.