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INTRODUCING A MODEL FOR ROAD PRICING

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Abstract. In the present paper, a very condensed overview of the "Identification, Investigation, and Comparison of Road Pricing and Valuing Softwares" project is presented. This paper was defined and carried out as a research project and a guide to identify roads valuation and pricing models. This paper, roughly speaking, is a survey research on the literature and comparative analysis. To this end, a research including the 4 phases. With the exception of the first chapter which includes generalities and research methodology, the present study has embedded the above-mentioned issues in the following structure within three chapters. In Chapter 2 scientific and practical experiences of both Iran and other countries have been reviewed. Furthermore, the framework of the software utilized for the application and execution of road pricing models in other countries is presented. The main components of valuation models include database of road infrastructures (information about roads), amount of investment and road cost price, economical parameters regarding interest rate, rate of capital restoration, inflation rate and so on and so forth, road erosion calculation method, the method of engaging road maintenance and rehabilitations, the method of engaging renewed road investment and its development, and finally the method of depreciation calculation. All in all, the value of roads network which is considered as the major property of Ministry of Roads and Transportation should be obtained with respect to the current conditions. These issues have been dealt with in Chapter 2. In Chapter 3 road evaluating and pricing models are compared with each other. In this chapter, the comparison and benchmarking of the existing models and software are dealt with, and the best and the most appropriate model with regard to Iran's conditions is identified; then, the way it is performed is briefly explained. At the end of this chapter, the conclusions of the research are presented.

1 Introduction

Nowadays roads pricing has become one of the priorities in the agenda of transportation policies all over the world. Roads pricing has been also accepted and implemented by countries throughout the world as an appropriate process to return capital and costs of roads management and maintenance [1]. Road pricing is not a new concept. Roads and bridges tolls have been widespread in USA since the late 18th, i.e., from 1970. This era was contemporary to America's economic growth. Better transportation equaled better highways at that time. Local states and governments had limited financial resources which could not respond to transportation demands. Therefore, private highways which were financed by joint-stock companies were established, and their stocks were bargained in stock exchanges. Stockholders received their stocks interests from highway taxes and tolls [2]. This way, private roads and their toll systems continued until the mid of the 19th century and reached their heyday in those years. Rail development induced a tense competition between railroad and road which undermined the importance of road. As a result, most of the highways were given to the government or became semi-governmental. Since that time, i.e., from mid 19th century to mid 20th century, Americans have shown little tendency towards road pricing and have been opposed to it. In the early 60s, the traditional toll system was abolished and immediate payment system was replaced and used in the 60s, 70s, and 80s [3]. Among the most successful road pricing experiences one can refer to Hong Kong [4] and Singapore [5] since the mid 70s. In 1997, number of road construction projects financed by the income from road pricing increased up to 30% [6]. So far no systematic and comprehensive pricing has been carried out for roads network in Iran. The traditional toll system is only implemented in a few highways, and most of their income is devoted to constructing these highways. Generally speaking, during the last three decades in the majority of the countries all over the world a special attention has been paid to road pricing as a complementary resource for providing financial credits and resources of the transportation sector, a motive for the collaboration and interaction between private and government sectors, and managing demand and controlling roads network traffic. The objective of the present article is to examine road pricing and valuing models with the purpose of collecting income to construct and develop transportation substructures and to cover the cost of the constructed projects, identifying and examining the given software, and selecting the best model and software. To achieve this goal, it is necessary to have the current value of the country's roads. Therefore, as a core part of the study, country's road evaluation model is presented in order to estimate the current value of roads.

2 Statement of the Problem

Road pricing is a general term referring to the direct charging of drivers for their using roads or a specific part or path of the road networks at special times [7]. Examples of road pricing include its traditional and common

methods like toll booths in highways, and its modern methods like toll electronic systems in USA, Singapore, and Hong Kong. In the above-mentioned definition, the word "direct" was used to distinguish this method from indirect charging methods such as gas tax or other kinds of tax. One of the major components of the road pricing model is the way the current value of roads is calculated. Awareness of the current value of roads will remarkably help transportation planning and management, and roads construction, development, maintenance, and super structuring. It is noticeable that the attitude of this research towards the three issues of comprehensive asset management, valuation, and pricing is like the following hierarchical structure (figure 1):

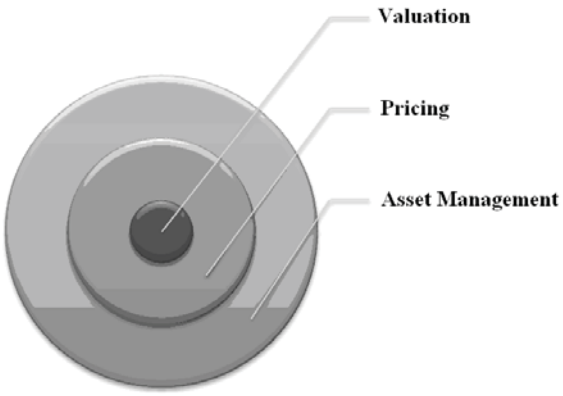

Figure 1. The hierarchical structure of comprehensive asset management, valuation, and Pricing

Therefore, to adapt road cost from users, it is necessary that road cost be calculated. It is clear that, however, to calculate road cost one should know the current value of the road. The current value of the road is a function of cost price of the road, road life, the current conditions of the road, cost record for different kinds of maintenance, economical parameters, etc. Nowadays all of these items are performed under a more comprehensive program called the comprehensive asset management of the transportation system. The logical principle of the comprehensive asset management of roads network holds that roads network is the most important property of Ministry of Roads and Transportation and, therefore, an accurate and comprehensive program should be designed to manage them. The main components of valuation models include database of road infrastructures (information about roads), amount of investment and road cost price, economical parameters regarding interest rate, rate of capital restoration, inflation rate and so on and so forth, road erosion calculation method, the method of engaging road maintenance and rehabilitations, the method of engaging renewed road investment and its development, and finally the method of depreciation calculation. All in all, the value of roads network which is considered as the major property of Ministry of Roads and Transportation should be obtained with respect to the current conditions.

3 Existing Models of Road Pricing and Valuing

3.1 Valuing

Calculating the value of road property is one of the important components of road management. Knowing roads network value helps us make logical decisions about network maintenance and improvement, and allocating financial credits to each of the sub-units. As mentioned before, one of the principal constituents of road pricing is knowing the current value of roads. Roads value changes due to changes in economic parameters such as inflation and interest rate, road ruining and erosion, renewed investments, and reconstruction after construction during the life of roads. Due to the significance of this issue, current policies regarding road maintenance, and allocating between 4% to 6% of road value to road maintenance models and methods of calculating current value of roads in Germany, Austria, and Canada were reviewed. In each of these models, roads value is calculated; then it is used to calculate vehicle charge amount (road pricing). What is being probed in most of the countries across the world is road valuing with the purpose of commercializing them as a public product to overcome the problem of providing financial resources for the transportation sector. A composite approach was used in Germany for the first time to calculate road costs. In the first step of this approach, the total cost of Germany's roads and highways for the different road substructures in 2000 (base year), 2003, 2005, and 2010, were estimated. In the second step, the total estimated costs were allocated to 6 different sets of vehicles (for pricing purposes) [8]. In Austria, road cost valuing and accounting was studied in 2000. Through comparing the costs related to the accounting of the total road cost, retrieval cost of the sub-structure cost (sub-structure costs are calculated only), and the retrieval costs of the total cost (including sub-structure and external costs) for different types of roads and transportation vehicles were calculated. Austria has taken into account environmental external costs and accident external costs for valuing and accounting road costs; it has also considered, for the first time, marginal (social) costs in cost accounting [9]. In 2006, Canada's Ministry of Transportation carried out a project named "Investigating the Total Cost of Transportation" collaborated with local transportation institutes. In this article,

roads were divided into different levels, and finally annual unitary costs (unitary cost per one kilometer road) were calculated for each subset. The total annual cost of the relevant is calculated by multiplying the number obtained for the unitary cost by the quantity obtained for the total substructure; the sum of theses quantities constitutes annual value of the road network [10]. The results of the accomplished studies in the field of roads network valuation and investigating other countries' experiences are as follows:

1. Road valuation is considered the main component of road pricing. If the goal of road pricing is to cover road construction and maintenance costs, then the importance of this component is more highlighted. Therefore, it is necessary to identify all of the cost factors involved in road valuation, from the beginning of road construction to the present time, using a comprehensive model.
2. The dominant approach for calculating road valuation is to divide roads network into smaller factors, and to calculate the unitary value of each constituent. Thus, after determining the method of dividing the network into constituents and defining an appropriate hierarchy, one should embark on calculating the unitary values. Some steps have been taken to calculate the unitary value of some constituents; however, it is not the very thing which is appropriate for valuation. The reason lies in the fact that the constituents should be defined first; then, one can embark on calculating the unitary value of the constituents.
3. One of the major parts of the valuation system is a comprehensive database consisting of all the roads network constituents. Regardless of technical issues in designing the database, what matters is the division logic and the way the roads network are divided into the constituent components. Using a hierarchical approach which is compatible with the road management system of the country is of paramount significance. As one of the results of the present study, an approach has been devised for Iran based on an approach used in Canada.
4. Taking into account the existing complexities, the high number of the constituent components of the roads network, and the wide range of the network, it is absolutely impossible to calculate the current value using traditional approaches. Therefore, it seems quite necessary to use a comprehensive computer system to achieve this goal. The model that constitutes the main logic of the software is more important than the software itself. To make true decisions, it is vital to use a comprehensive model which takes into consideration all of the cost factors and the factors involved in the current value of the property such as erosion, depreciation, etc. developing such a model requires meticulous studies and carrying out a comprehensive project. In other words, it necessitates a research program.
5. As previously mentioned, the first step to calculate the current value of the roads is having a comprehensive database which has been designed based on an appropriate approach to divide roads network into the constituent components. Some of the major items of such a database are as follows:
    - The current features and statistics of the roads
    - The current features and statistics of the bridges
    - The current features and statistics of the tunnels
    - The average lifetime of the road infrastructures
    - Costs of the initial construction, maintenance, and rehabilitation of the infrastructure
    - The status of the road infrastructures regarding the amount of erosion
6. Most of the country's roads were constructed long time ago and it might not be possible to have access to the information about their construction, maintenance, and rehabilitation costs. This might not be true about the roads which have been constructed recently, but it remains more or less problematic regarding old roads. When there is no access to information about construction costs and other factors related to cost, one should estimate them. The HDM model (version 4) might be used as a reference model and for cost estimation due to the database it includes and the existing models and relations. It can also help to calculate the unitary costs of roads constituent components as well.

3.2 Road Pricing

Countries use different road pricing models. All in all user's charging methods fall into two categories: direct and indirect. Direct methods are performed by electronic systems. Indirect methods include charging the vehicle's owners. European countries use various tools for charging the users which is shown in Table 1. Overall, there are 5 basic models for road pricing and they depend on three basic variables: Infrastructure costs- different type of vehicles (horizontal equity) and costs of travel time. Combination of the mentioned variables make basic models of inter-city road pricing. These models are as follows:

country	Road user's charging tools
England	Fuel tax- vehicle tax (in production phase)
Sweden	Fuel tax- distance traveled tax- vehicle tax
Finland	Fuel tax- vehicle tax- tax for distance traveled by foreign vehicles
Germany	Fossil fuel tax- vehicle tax
France	Fuel tax- vehicle tax-tax based on no. of vehicle's axles –
Norway	Fuel tax- distance traveled tax- annual tax of vehicles- toll

Table 1. Road user's charging tools in some of the European countries

- **Distance-dependent AREA pricing (DAREA)**

This model determines the price/cost depending on the distance covered in a trip in a certain region expressed in kilometers. The calculated cost considers the minimum discrimination among different types of vehicles. Therefore, price/cost is proportionate to the kilometers covered, region, and vehicle type; it can also take into consideration other kinds of differences. The main variables, however, are the kilometers covered and region.

- **Distance-dependent NETwork pricing (NET)**

This model calculates the price or cost depending on the kilometers covered in a trip in a network of routes/roads and highways which are similar to each other regarding the transportation infrastructure hierarchy. The systemic arrangement of the networks taking tolls (tollbooths) might vary among opens, half-open and close types. In this model, the minimum difference of the vehicle type is considered.

- **CORdon pricing(COR)**

This model determines the price/cost for entering a predefined certain region, and vehicle type is also a criterion for pricing. Users, however, are not charged with further cost for passing within the region. As a sub-model of this model, the chargeable cost can be calculated in terms of arrival/departure time in/from the region or, in other words, time spent in the region.

- **PASsage pricing (PAS)**

This kind of pricing is used for certain places such as bridges, tunnels, or particular freeways. Cost/price differs depending on vehicle type. According to the executive and technical requirements of this pricing, it is very difficult to discriminate between passing a single place (like a bridge or a tunnel) and passing a continuous place (like a highway).

- **Driving PERMIT (PERM)**

In this model, special permissions are issued to drive in a particular region. Users have to undertake some costs to receive such permissions. Costs/prices are different depending on vehicle type. This model is also called Area Licensing which is frequently used in urban areas. “Tehran traffic limits” is one example.

4 Proposed road's pricing and valuation models for Iran

4.1 Valuation

According to the experiences of Germany, Austria, and Canada, and taking into consideration Iran’s conditions, a framework consisting of 4 major phases have been presented for road valuation. In phase 1, the database of the road network is identified. In the next phase, all the costs used for the construction of the roads are identified, and unitary costs of infrastructures will be obtained using this information. The way the unitary costs are calculated will be dealt with later. In phase 3, the status of the road network should be identified, and depreciation costs will be obtained. In this phase, based on different factors, the roughness of the road infrastructures will be estimated using relations which will be talked in the next phases. Then, road depreciation will be identified according to the calculated roughness.

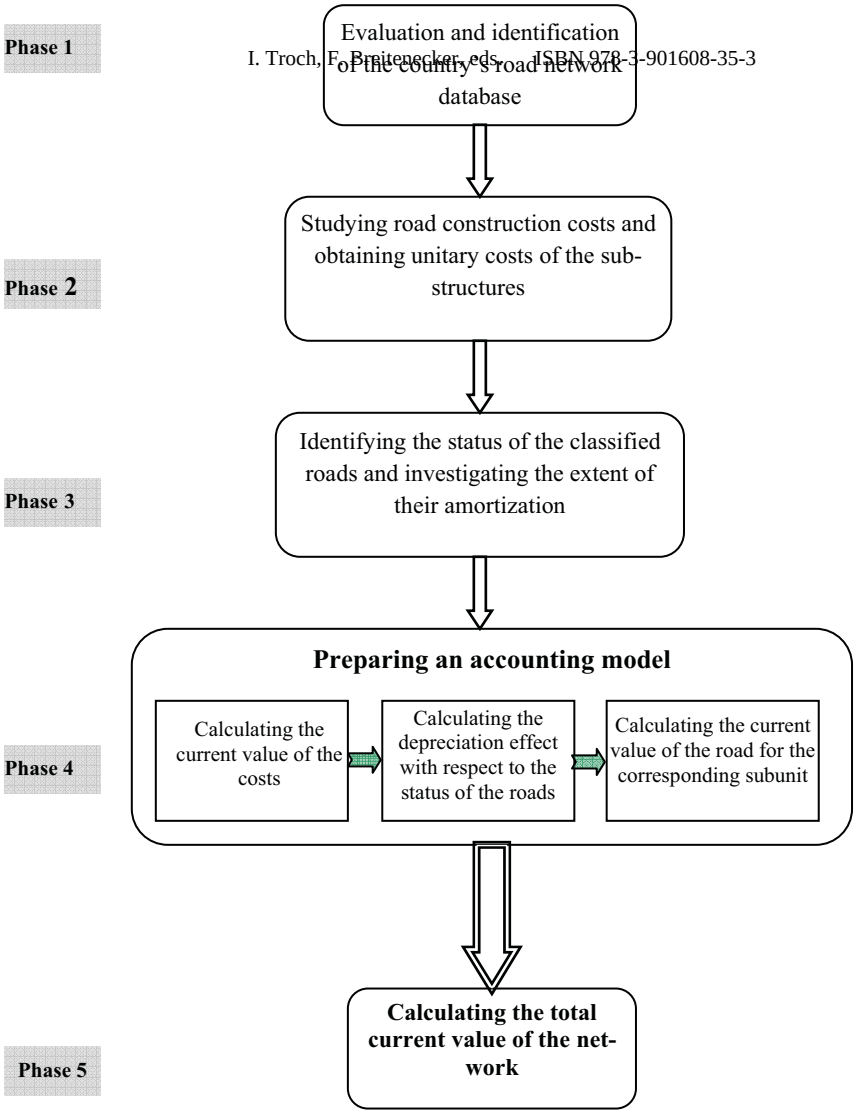

Figure 2. Basic phases of calculating the current value of the road network property

In phase 4, an accounting model will be presented the purpose of which is to calculate the current value of the costs of the infrastructures. In the final phase, the total current value of the road network will be calculated by aggregating the current value of different infrastructures. The accounting phases shown in figure 2 constitute the basic phases of calculating the current value of the road network property. In this article roads are divided into different levels, and unitary cost (unitary costs per kilometer) are calculated for each subset. Since the calculated value is valid when there is no depreciation, the current status of the infrastructure should be considered; the real value (the current value) of the structure should be calculated by getting involved the depreciation. The current value of the road network property will be calculated by aggregating the current value of all the infrastructures. Therefore, to estimate the network current value roads are divided into small units, and the unitary cost will be calculated for each unit. The total sum of the value of these units constitutes the road network final value estimation (in terms of quality and unitary cost). Since the number of these value units (costs) are abundant, in the event that the value of some of these small units are not estimated, one can still trust the value estimation and the total costs to an acceptable level.

- **The hierarchical structure to divide (separate) road networks**

Various classifications could be presented for the country's road network. In this paper,the following hierarchical structure has been used. This classification includes 5 different levels each of which being divided into different categorizations (figure 3):

i. Ministry of Roads and Transportation
ii. Roads and Transportation Organizations in the provinces (including 30 provinces)
iii. Roads and Transportation Organizations in cities (including cities in each province)
iv. Roads in terms of function: highway, major and minor roads
v. Different infrastructures of road: bridges, tunnels, and road (including all units such as embankment, asphalt, watercourse, transportation safety equipments, etc.)

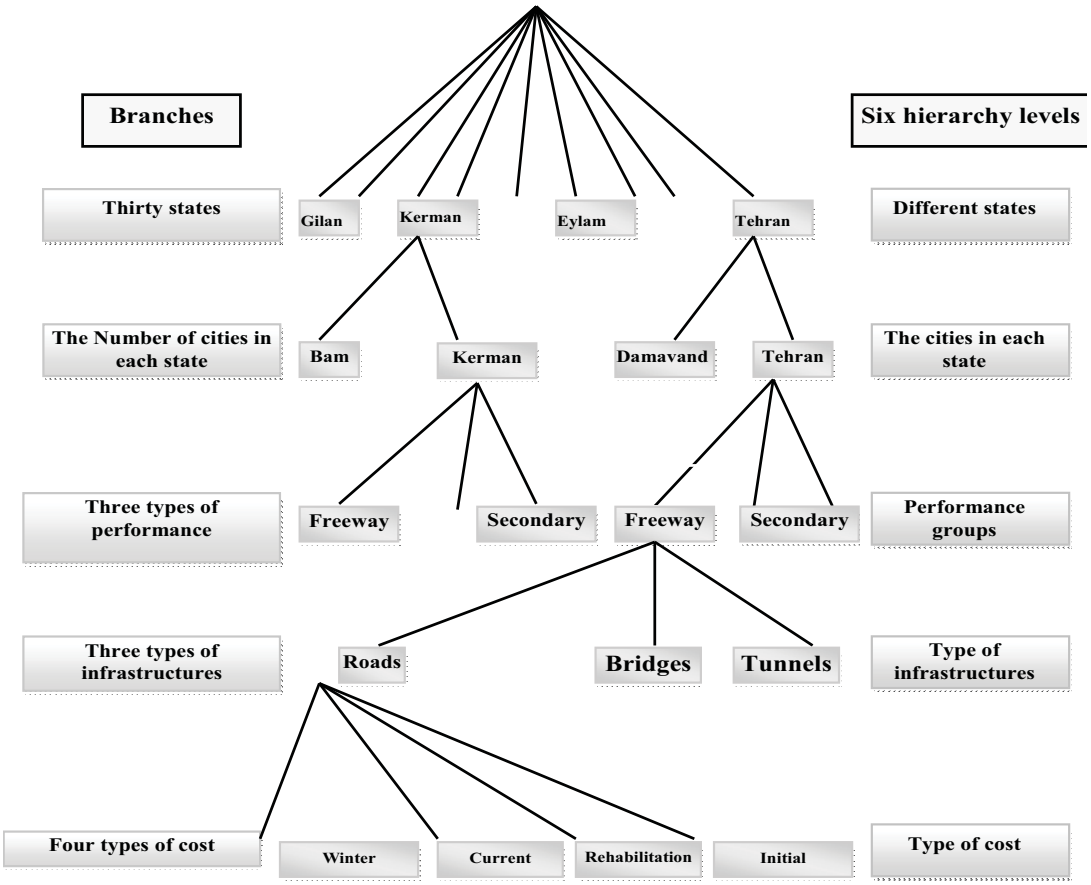

Figure 3. Classification of the Iran's road network based on the 5-phase hierarchy

Cost types: initial costs of construction, maintenance and rehabilitation, maintenance)

The above classification was done due to the fact that each region and city has its own specific properties from the climatic and geographical points of view, and this affects the performance/function, erosion, and depreciation of road. collecting data in terms of province or city as well as managing the data and other related operations would be more convenient. Figure 3 shows the different levels for Iran's road network. The mentioned names are used to drive the point home and do not include all of the provinces and cities. Figure 4 shows a model that demonstrates the different phases of obtaining the total current value of the road network.

4.2 Road Pricing in Iran

In order to evaluate and identify the best road pricing model for the intercity roads it is necessary to evaluate the existing models (models presented in section 3) form various dimensions. There are various options for each of these dimensions and, thus, different components should be taken into account for this purpose. Nonetheless, other countries' experiences indicate that only some of the scenarios can be implemented; therefore, attempt should be made to evaluate and examine the feasible options. Figure 5 shows the overall stages of identifying the best pricing model.

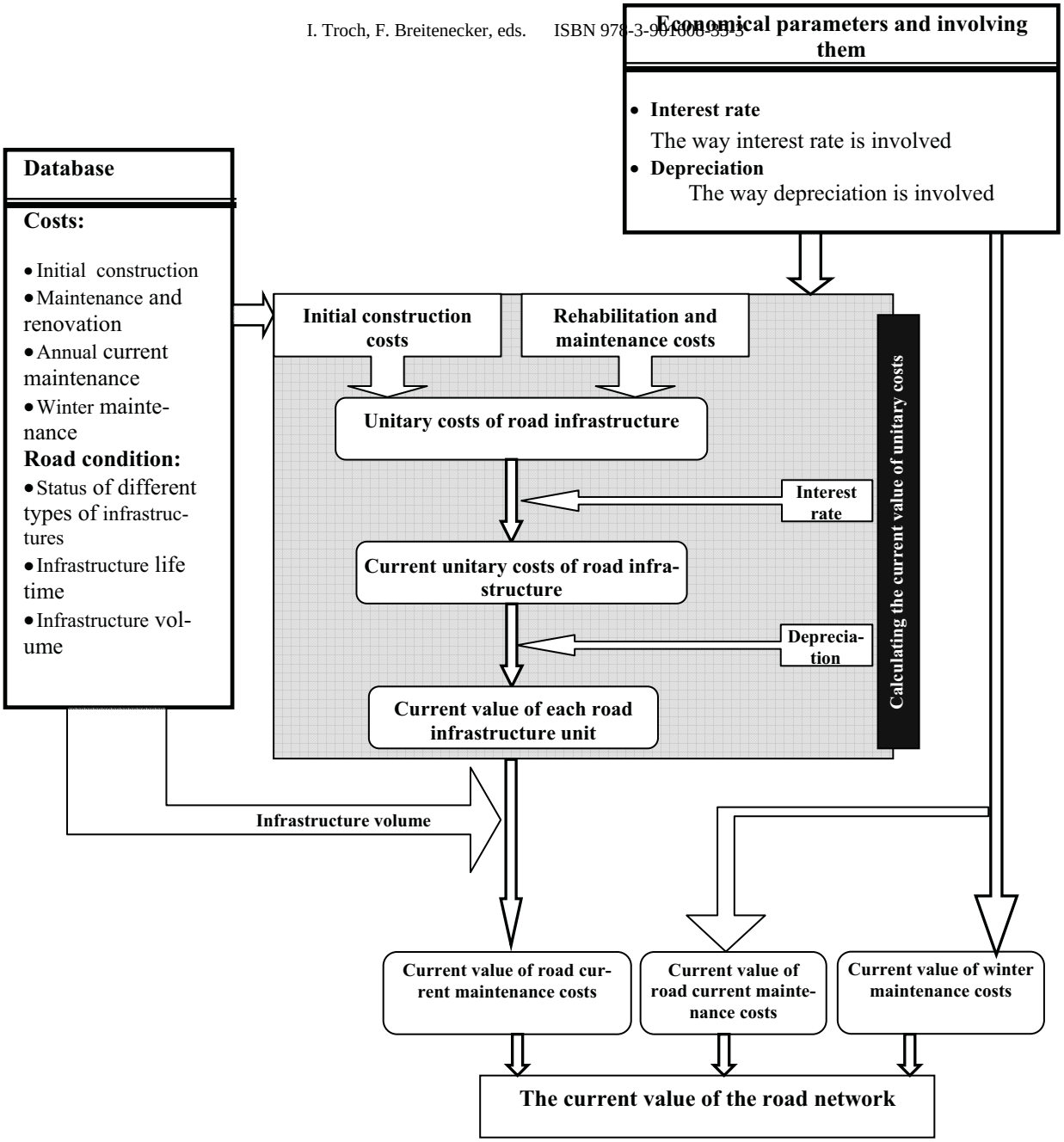

Figure 4. Framework of the road valuation model including different phases of accessing the total current value of the road network

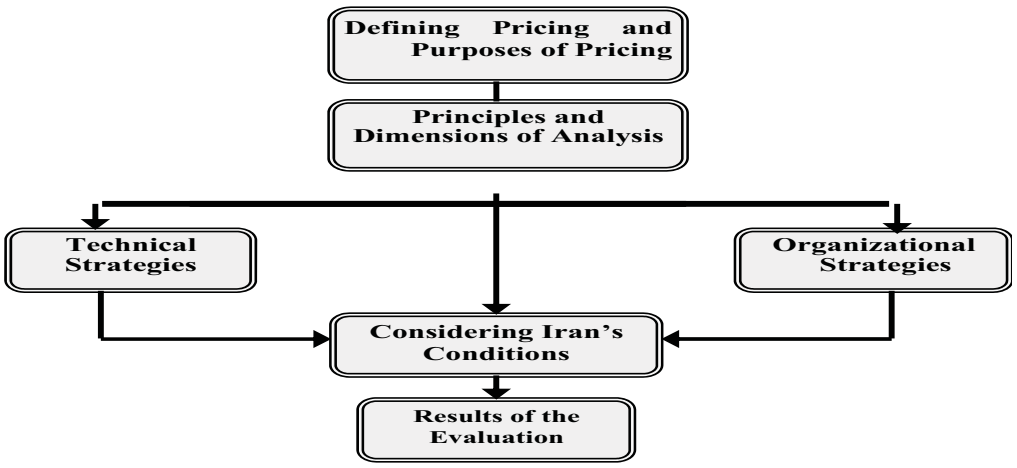

Figure 5. The Overall Stages of Identifying and Evaluating the Best Pricing Model

According to figure 5, evaluation of the transportation models is initially founded on the purposes, and then the principles and dimensions of the analysis are dealt with. Analysis principles include the basic form of the model, technical strategy, organizational strategy, and pricing principles. Analysis principles constitute SWOT analysis framework. The results have been achieved for Iran by comparing the mentioned models (in chapter 3), doing an analysis similar to the SWOT analysis, considering Iran's conditions, and taking into account the weaknesses, strong points, opportunities, and risks of each option. Initially, it is necessary to notify some points about the NET, DAREA, and PERM models regarding decision making and strategic perspective. Regarding pricing models ranking, the DAREA model has been identified as the most advanced and lucrative model so far. The NET model is ranked second regarding application and enjoys a relatively high level of technology. The PERM model, which is the simpler and the most elementary model in terms of technological facilities, is ranked third. So much is certain that these models develop and road pricing system can be promoted to each other. In Singapore, for example, road pricing was performed using manual systems at the very beginning, and now they are using the DAREA model. In Swiss also there was an abrupt shift from manual systems to the systems based on the DAREA model, and it has proved very successful. A country's plan for using road pricing systems is based on one of the following modes in figure 6 (introduction or promotion paths) depending on its current situation. As shown in figure 6, considering Iran's current status (absence of road pricing), there are three options for road pricing for the policymakers of the transportation industry to choose from which are: 1.Remaining in the present situation 2.Settling the pricing system based on the NET model 3.Settling the pricing system based on the DAREA model

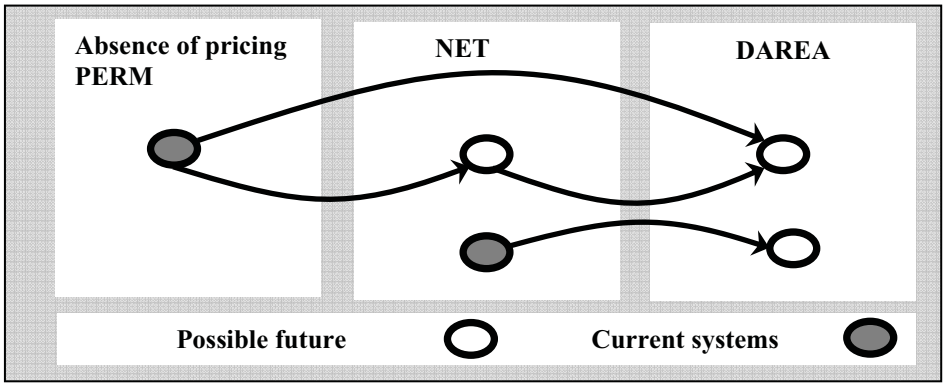

Figure 6. The possible developmental path for the pricing systems based on absence of pricing, and the PERM, NET, and DAREA models

The consequences of the first option are obvious; it is a long time that this situation exists in the country and, the current status of the transportation infrastructures are good indicators of the consequences of this option.According to the SWOT (strength, weakness, opportunities, threats) analysis, one can make use of the merits of the second option using the NET model. Having an appropriate level of technology, the NET model has a good operational efficiency. Furthermore, the initial costs for settling the pricing system based on the NET model is not that much costly. It is possible to promote, step by step, the NET model to the DAREA one for future developments without devoting high costs. The third option indicates that pricing systems should be directly settled based on the DAREA model. According to the SWOT analysis, and considering the facts that the initial costs of this model are relatively high and that the technology used in this model is very advanced, this option is considered a leap which is very risky. In figure 7, the decision tree has been presented to select the required model for road pricing from the perspective of two definitely basic pivots of financial needs for construction and roads network density. It has been devised based on the SOWT analysis of different models. According to figure 7 and the current conditions of the country, the hachured part shows the pricing path that Iran is confronted with. Regarding the current needs of constructing and developing transportation infrastructures and the limitation of financial resources to accomplish this aim the NET model is suggested for this purpose.

Furthermore, due to the low density[1] of roads network the DAREA model cannot be used.

[1] . By road density, we mean the roads (amount of road) existing per square kilometer (in terms of the country's area.) The amount of this index is lower than half of Turkey's. Turkey is very similar to Iran regarding economy and population.

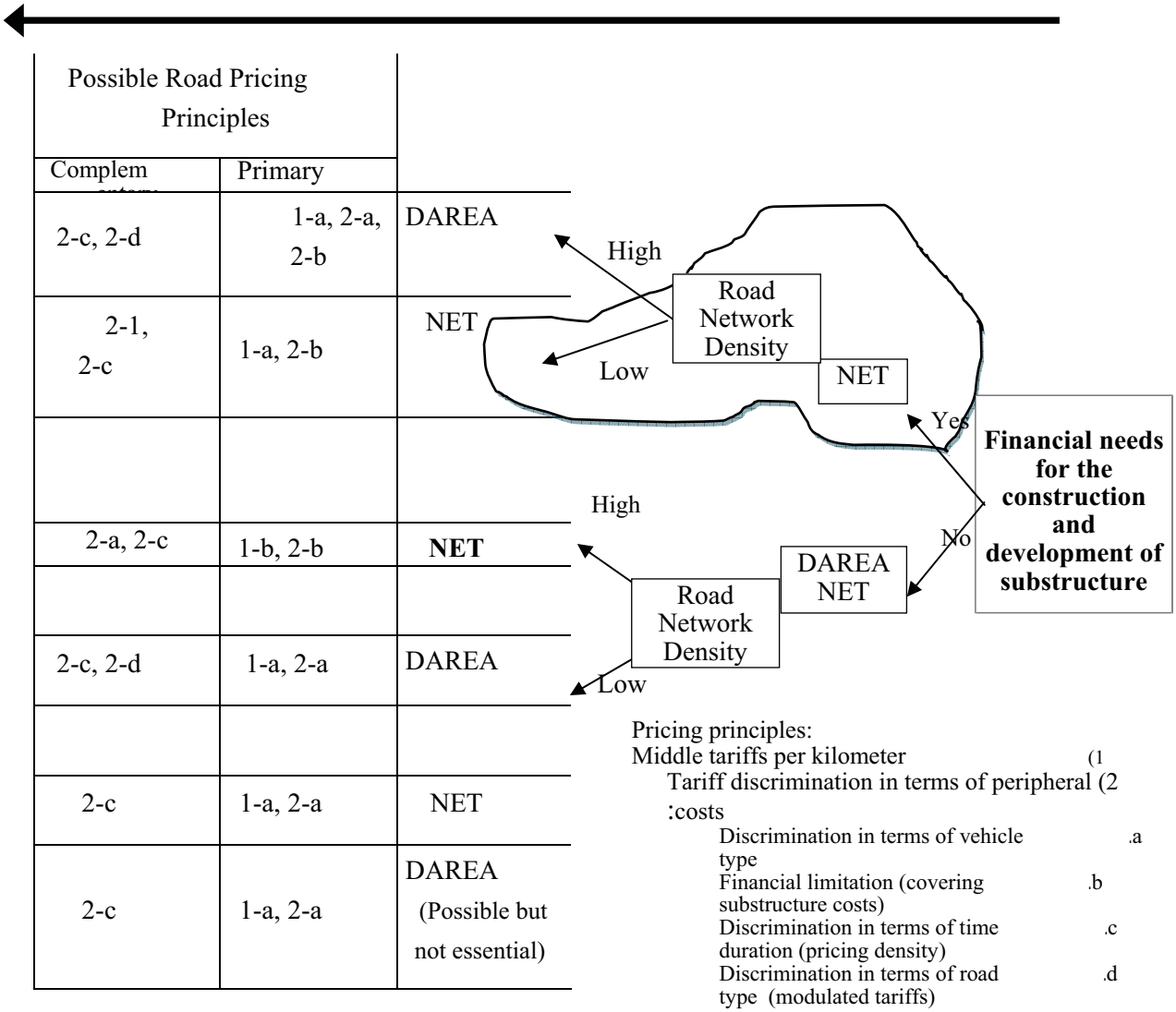

Figure 7. The decision tree to select the required model for road pricing from the perspective of two definitely basic pivots of financial needs for construction and roads network density

5 Conclusion

In this paper identification and investigation of existing road pricing models and comparison of road's evaluating models is presented. There are several models for roads pricing and evaluation. Regarding basic research, one model for calculation of roads network evaluation is proposed also, with SWOT analysis among five prevalent road pricing models in the world, the best and appropriate model regarding Iran's conditions is selected which is NET (Distance- depending network pricing). Regarding basic research and necessary explorations to evaluate the country's roads, it should be noted that making such an endeavor feasible requires a research program which includes several varied projects. Some of the suggested research topics confronting road pricing in Iran are as follows:

1. Economical evaluation of road pricing and examining its effects on the transportation sector and national economy

2.Examining the amount of acceptability of road pricing by senior management and society and finding some ways and solutions for improvement

3.Designing and compiling the technical structure of pricing and its basic form

4.Designing and compiling the implementation and organizational structure of pricing in Iran

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