

IMPLEMENTATION OF ANALYTIC HIERARCHY PROCESS IN SOLVING TRANSPORT PROBLEMS

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ABSTRACT

This paper presents the analysis of the implementation of the Analytic Hierarchy Process (AHP) in solving problems in the area of transport. The transport sector is currently one of the most important sectors, and an efficient transport system requires continuous planning. Investments in transport infrastructure are projects that have specific characteristics. These projects have an extremely long lifetime (some thirty years), are not profit-oriented, are usually financed by the state of the local administration, and are primarily for social use. The decision-making process, which includes making decisions on investments, is extremely complex. The decision-maker has to envisage the future, and consequently make decisions in a modern and flexible manner. The methods used in the process of evaluating the investment projects in transport are numerous and usually distinguished by the optimization criteria. The projects can be evaluated through the prism of a single criterion or several criteria. The most common optimization criterion is the economic system; however, long-term and high-quality solutions require the introduction of other optimization criteria such as technological, technical, ecological and many others. Therefore, in such situations it is essential to implement multi-criteria decision methods which will eventually result in making the optimal decision. It will be determined in the paper to what extent the AHP method is implemented regarding transport problems and for which categories of transport problems.

Key words: multi-criteria decision-making; Analytic Hierarchy Process; transport; investments

1. Introduction

Traffic is like the bloodstream of every country, and therefore has deep effects on the economic and other activities within the country. The level of development of the transport system is correlated to the level of economic development and quality of the living conditions, and thus the entire economy of a country, region or area depends on transport. Therefore, it is vital to the interests of every community to continuously upgrade the level of quality of their transport system. Transport problems are not isolated and independent, and their solutions require an interdisciplinary approach. Project planning in transport can be characterized as a process of creative optimization using available resources. The analyses have shown that in practice (i.e. in pre-investment and investment studies) projects whose aim is financial efficiency most often rely on methods where a single criterion is used. One such method is the cost-benefit analysis, and it is used in the perspective of financial decision-making. The projects evaluated in this manner are acceptable if they have been positively assessed according to certain criteria of financial decision-making, i.e. expressed in monetary values. On the other hand, in scientific papers, analysis to select an optimal project use other criteria which are not based exclusively on the criteria of financial categories, monetary flows, etc. It is, namely, because of the complexity of the traffic system, that the approach of assessing a project with several criteria is important. The implementation of several criteria is used in assessing the projects using multi-criteria decision-making methods.

One of the most frequently applied methods to assess projects in the transport sector is the Analytic Hierarchy Process. It was developed by Thomas Saaty in the 1970s in order to solve the complex problems of decision making. It is one of the best known, most verified and most used decision making methods, i.e. method for multi-criteria analysis. Its basic advantage is reflected in the decision maker's ability to adjust the number of attributes. Attributes are criteria and alternatives about the decision being made simultaneously, and can be described both quantitatively and qualitatively. Therefore, the AHP method allows flexibility of the decision making process and helps the decision makers to set the priorities, and make the best decision while taking into consideration both qualitative and quantitative aspects of decisions. The implementation of the Analytic Hierarchy Process is significant in major investment projects that require substantial capital engagement, and have high social significance (e.g. transport infrastructure investment projects).

2. Objectives

Various methods are used for solving transport problems including both single- or multi-criteria ones. The objective of the paper is to determine to what extent the AHP method is used for decision-making in transport problems and for which categories of transport problems. The analysis of the papers in which the AHP method is implemented for solving the problems in the area of traffic primarily meant searching through single databases according to the key words in the title of the paper. However, numerous papers in which AHP has been implemented have AHP in their title. Therefore, it may be expected that the research results will deviate to a certain extent from the actual situation.

3. Methodology

The areas of transport will be classified in which AHP is usually implemented, the category of papers will be determined in which AHP is usually used and the frequency of implementing AHP will be defined by reviewing the available literature, scientific papers, technical papers, diploma theses, doctoral dissertations and projects in the area of transport. Relevant databases will be analyzed. The scientific papers that primarily deal with the application of the AHP method have been analyzed by searching the journals of the leading publishers of academic papers (Elsevier, Taylor & Francis, Springer, Hrčak, etc.), selected scientific journals, selected conferences, doctoral dissertations, and diploma theses.

3.1 Analysis of the number of published papers in which Analytic Hierarchy Process has been implemented in solving the transport issues in academic journals of selected publishers

Journals from the available databases have been analyzed using the following publishers: ELSEVIER, Taylor & Francis, SPRINGER, Hrčak and Hrvatska znanstvena bibliografija (e. Croatian Scientific Bibliography). The databases have been searched using the selected key words: AHP & Analytic Hierarchy Process in the titles, key words and summaries. Only those papers in which the AHP method was implemented for solving traffic and transport problems have been selected. By searching the databases, the journals in which published papers that have been primarily oriented to solving transport problems using the Analytic Hierarchy Process were determined. According to ISI Web of Knowledge, relevant scientific journals from the category Transportation Science & Technology are as follows:

- *IEEE Transactions on Intelligent Transportation Systems*
- *Journal of Transportation Engineering-Asce*
- *Proceedings of The Institution of Civil Engineers-Transport*
- *Transportation Science*
- *IET Intelligent Transport Systems*
- *ITE Journal-Institute of Transportation Engineers*
- *Transportation Letters-the International Journal of Transportation Research*
- *International Journal of Automotive Technology*
- *Transportation Research Record*
- *Transportation Research Part A, B, C, D, E*
- *Proceedings of The Institution of Mechanical Engineers Part D, Part F*
- *Networks & Spatial Economics*
- *Transportation*
- *Promet-Traffic & Transportation*
- *Journal of Intelligent Transportation Systems*
- *Transportmetrica*
- *Transportation Planning and Technology*
- *Transport*
- *Journal of Advanced Transportation*

3.2 Analysis of published papers in which the Analytic Hierarchy Process has been implemented for solving transport issues in selected academic journals

Academic papers between 2009-2013 from three journals were analyzed to find articles in which the AHP method has been implemented for solving traffic problems. The selected journals were the *International Journal of the Analytic Hierarchy Process*

(ISSN: 1936-6744), *PROMET – Traffic & Transportation* (ISSN: 1848-4069), and *Transport* (1648-4142 (Print), 1648-3480 (Online)).

The *International Journal of the Analytic Hierarchy Process (IJAHP)* was selected because of its primary purpose of publishing articles about multi-criteria decision-making using the Analytic Hierarchy Process (AHP) and the Analytic Network Process (ANP). *IJAHP* has been continuously published since 2009. There have been 10 issues with a total of 45 papers published, out of which six can be identified as those dealing with the implementation of the AHP method for solving problems in the area of transport (Table 1).

Table 1
Selected papers dealing with the implementation of the AHP method for solving transport problems, published in the *IJAHP* from 2009 to 2013

Vol./No./Y. IJAHP	Authors	Title of the Paper
Vol. 2, No. 1 (2010)	Leila Paula Alves da Silva Nascimento, Mischel Carmen Neyra Belderrain	Purchase of a New Air Superiority Fighter Using the Analytic Network Hierarchy Process
Vol. 2, No. 2 (2010)	Sukulpat Khumpaisal, Mohd Noor Nazali, Zairul Musa Nisham, Andrew David Ross	An Application of the Analytic Network Process to Assess Risks in a Mega- Construction Project
Vol. 3, No. 2 (2011)	Eugene Kopytov, Vasilijs Demidovs, Natalia Petukhova	Application of the Analytic Hierarchy Process In Development of Train Schedule Information Systems
Vol. 4, No. 1 (2012)	Patrizia Lombardi, Silvia Giordano	Evaluating the European Smart Cities Visions of the Future
Vol. 4, No. 1 (2012)	Marta Bottero, Valentina Ferretti, Silvia Pomarico	Assessing the Sustainability of Alternative Transport Infrastructures
Vol. 4, No. 1 (2012)	Francesca Abastante, Marta Bottero, Isabella Maria Lami	Using the Analytic Network Process for Addressing a Transport Decision Problem

The international journal *PROMET-Traffic & Transportation* was selected as the national journal from the author's country that is primarily oriented to papers in the field of transport. This journal has been continually publishing scientific papers for as many as 26 years. The journal is published bimonthly, and up to now there have been 143 issues in which 1,065 papers have been published, out of which seven can be singled out with the primary topic of the implementation of the AHP method for solving transport problems. In the period from 2009 to 2013 there were 30 issues of this journal in which a total of 259 academic papers were published, out of which 4 can be singled out in which the AHP method was implemented for solving transport problems (see Table 2). Although we chose to analyze the period 2009-2013, it is important to mention that this journal published scientific papers with the implementation of the AHP method earlier (Bošnjak et al., 2005, Barić et al., 2007, Jugović et al., 2007).

Table 2

Selected papers in which the AHP method has been implemented for solving transport problems, published in *PROMET-Traffic & Transportation* from 2009 to 2013

Vol./No./Y. PROMET	Authors	Title of the Paper
Vol. 22, No. 3 (2010)	Deda Đelović, Dijana Medenica Mitrović	An Approach to the Selection of Optimal Transformation Strategy in Seaports
Vol. 23, No. 4 (2011)	Aleksandra Deluka-Tibljaš, Barbara Karleuša, Čedomir Benac	AHP Methodology Application in Garage- parking Facility Location Selection
Vol. 23, No. 5 (2011)	Fatemeh Haghghat	Application of a Multi-criteria Approach to Road Safety Evaluation in the Bushehr Province, Iran
Vol. 23, No. 6 (2011)	Andrija Vidović, Sanja Steiner, Igor Štimac	Development Potentials of Low Cost Aviation in the Republic of Croatia

Transport has been selected as an international journal primarily oriented towards papers in the area of transport. This journal has been published since 2002 and since then there have been 57 issues with a total of 606 scientific papers out of which 10 focused on the implementation of the AHP method to solve transportation problems. The period from 2009 to 2013 saw the publication of 20 issues of this journal with a total of 251 academic papers published, out of which 9 papers could be singled out which dealt with the implementation of the AHP method (see Table 3).

Table 3
Selected papers in which the AHP method was implemented to solve transport problems, published in *Transport* from 2009 to 2013

Vol./No./Y. Transport	Authors	Title of the Paper
Volume 24, Issue 2 (2009)	Lijana Maskeliūnaite, Henrikas Sivilevičius & Valentinas Podvezko	Research on the Quality of Passenger Transportation by Railway
Volume 25, Issue 2 (2010)	Nebojsa Bojovic, Branislav Boskovic, Milos Milenkovic & Aleksandar Sunjic	A Two-Level Approach to the Problem of Rail Freight Car Fleet Composition
Volume 25, Issue 4 (2010)	Henrikas Sivilevičius & Lijana Maskeliūnaite	The Criteria for Identifying the Quality of Passengers' Transportation by Railway and their Ranking Using AHP Method
Volume 25, Issue 4 (2010)	Zenonas Turskis & Edmundas Kazimieras Zavadskas	A New Fuzzy Additive Ratio Assessment Method (ARAS-F). Case Study: The Analysis of Fuzzy Multiple Criteria in Order to Select the Logistic Centers Location
Volume 26, Issue 1 (2011)	Henrikas Sivilevičius	Modelling the Interaction of Transport System Elements
Volume 27, Issue 3 (2012)	Szabolcs Duleba, Tsutomu Mishina & Yoshiaki Shimazaki	A Dynamic Analysis on Public Bus Transport's Supply Quality by Using AHP
Volume 28, Issue 4 (2013)	Jinbao Zhao & Wei Deng	Fuzzy Multiobjective Decision Support Model for Urban Rail Transit Projects in China
Volume 28, Issue 4 (2013)	Szabolcs Duleba, Yoshiaki Shimazaki & Tsutomu Mishina	An Analysis on the Connections of Factors in a Public Transport System by AHP-ISM
Volume 28, Issue 4 (2013)	Valentinas Podvezko & Henrikas Sivilevičius	The Use of AHP and Rank Correlation Methods for Determining the Significance of the Interaction between the Elements of a Transport System Having a Strong Influence on Traffic Safety

Figure 1 shows the share of the published papers in which the Analytic Hierarchy Process was implemented to solve transport problems in the total number of published papers in the *IJAHP*, *PROMET-Traffic&Transportation* and *Transport* in the last five years.

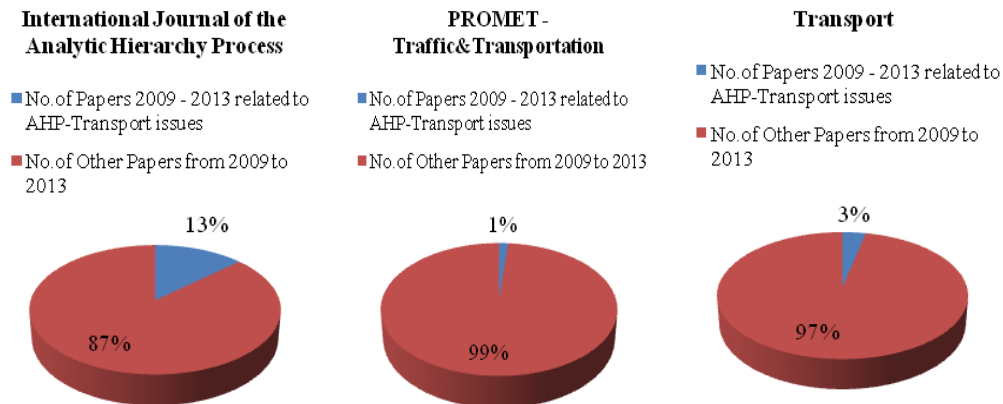


Figure 1. Share of papers in which the Analytic Hierarchy Process has been implemented for solving transport problems in *IJAHP*, *PROMET – Traffic & Transportation* and *Transport*

Figure 2 shows the comparison of the three selected journals regarding the total number of the published papers in the last five years and the number of the published papers in which the Analytic Hierarchy Process was implemented. During the period 2009–2013, a larger number of papers related to AHP-transport issues were published in *Transport* (9 papers) than in *IJAHP* (6 papers) and *PROMET – Traffic & Transportation* (4 papers).

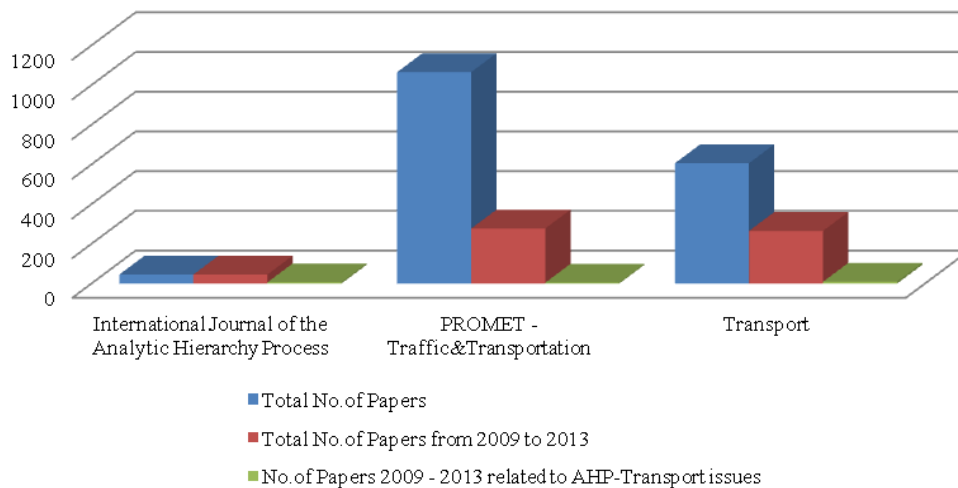


Figure 2. Comparison of the total number of published papers and papers in which the Analytic Hierarchy Process has been implemented

In this paper, we selected papers from three journals; however, we analyzed several other journals which published articles discussing AHP, for example *Transportation* (Gercek et al., 2004), *The Baltic Journal of Road and Bridge Engineering* (Aghdaie et al., 2012), *Automation in Construction* (Lin et al., 2008), *Journal of Business Economics and Management* (Podvezko et al., 2009), *Tehnički vjesnik – Technical Gazette* (Rouyendegh

et al., 2012), *Journal of Transportation Engineering* (Sun et al., 2011), *Transportation Research Part D: Transport and Environment* (Vreeker et al., 2002), etc.

3.3 Analysis of the published papers at the International Symposium on the Analytic Hierarchy Process (ISAHP) in which the Analytic Hierarchy Process has been used for solving transport issues

The International Symposium on the Analytic Hierarchy Process (ISAHP) for Decision Making is a conference on multi-criteria decision analysis, particularly the Analytic Hierarchy Process (AHP) and its extension, the Analytic Network Process (ANP), both developed by Thomas L. Saaty. The symposium brings together researchers, teachers, students and users of AHP/ANP to share their research and experiences in decision making. Table 4 presents the selected papers from ISAHP conferences (2009 to 2013) in which the Analytic Hierarchy Process has been primarily implemented to solve transport issues. In four previous ISAHP conferences before 2009 (2001, 2003, 2005 and 2007) some authors published papers focusing on the implementation of AHP method for solving transport issues (Anagnostopoulos et al., 2001, Ding et al., 2001, Anagnostopoulos et al., 2003, Galvão Jr., 2003, Gerdstri et al., 2005, Ko, 2005, Piantanakulchai, 2005, Jung et. al., 2007).

Table 4
Selected papers focusing on the implementation of the AHP method for solving transport issues, published at ISAHP from 2009 to 2013

ISAHP	Authors	Title of the Paper
ISAHP 2009	Denise Lindstrom Bandeira, João Luiz Becker, Amanda Kruse Rocha	Applying AHP to the Prioritization of Maritime Booking Confirmation
	Thomas Michael Lintner	The Aerospace Performance Factor: Utilization of the Analytic Hierarchy Process to Develop a Balanced Performance and Safety Indicator of the National Airspace System for the Federal Aviation Administration
	Berna Ulutas, Burak Ulutas	An Analytic Network Process Combined Data Envelopment Analysis Methodology to Evaluate the Performance of Airports in Turkey
ISAHP 2011	Pablo Aragonás-Beltrén, J.P. Pastor-Ferrando, J. Montesinos-Valera	Selection of Rail Improvement Projects Using the Analytic Network Process (ANP)
	Elio Padoano, Fabio Lamanna, Giovanni Longo, Giorgio Medeossi, Stefano Strami	The AHP Approach for Railway Project Appraisal: Proposal for a Specific Problem Structure
	Isabella M. Lami, Francesca Abastante, Marta Bottero	Using the Analytic Network Process (ANP) for Ranking the Critical issues of a Transport Decision Problem: The Italian Section of the Corridor 24
	Marta Bottero, Valentina Ferretti, Silvia Pomarico	An Application of the Analytic Network Process for Assessing the Sustainability of Different Transport Infrastructures
	Waclaw Przybylo, Józef Moryl	Choice of the Best Public Transportation System for the City of Cracow and Cracow District
	Eugene Kopytov, Vasilijs Demidovs, Natalia Petukhova	Choice of the Model of Presenting Temporal Data in the System of the Train Traffic Schedule
ISAHP 2013	Giuseppe Bruno, Emilio Esposito, Andrea Genovese	A Hybrid AHP/FST Model for Regional Aircraft Evaluation
	Christian Tabi Amponsah	An Integrated Approach for Prioritizing Projects for Implementation Using AHP
	Richard Cimler	Analytic Hierarchy Process and Agent-Based Simulation for Traffic Modeling
	Mohd Uzair Mohd Rosli	Car's Dashboard Improvement Design Concepts through Integration of AHP and TRIZ
	Insannul Kamil, Buang Alias, Abdul Hakim Mohammed, Nilda Tri Putri, Cresti Kalani	Design of Performance Evaluation Tools for Drainage of Roads System in Developing Country (Case Study: Drainage System for City Roads in Padang Indonesia)

The share of papers in which the AHP method has been implemented to solve transport issues is presented in Figure 3. In all ISAHP conferences (2001-2013) a total of 610 papers were published, of which 22 were related to transport issues. During the analyzed period 2009-2013, 346 papers were published of which 14 related to transport issues. The highest number of total papers at a single conference was at ISAHP 2011 (162 papers), and this was also the conference with the highest number of papers related to AHP-transport issues (6 papers).

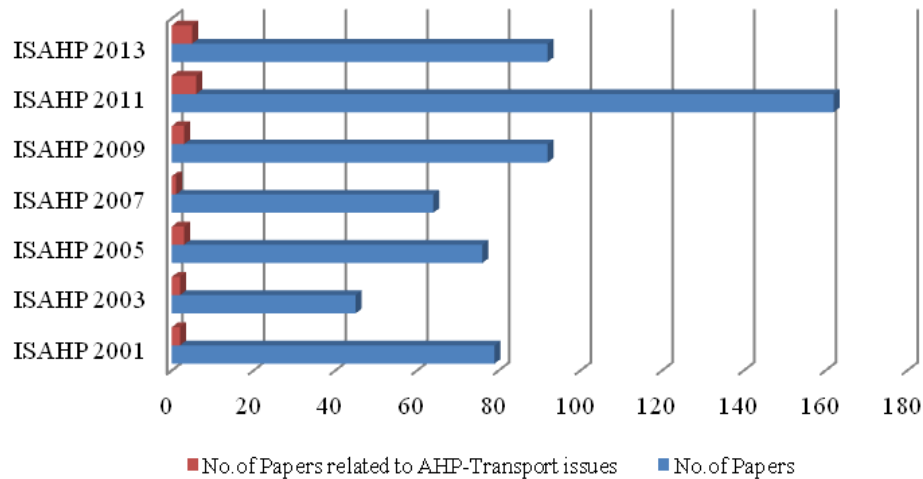


Figure 3. Share of papers in which the AHP method has been implemented, published at all ISAHP Conferences

According to data about the topic of the papers in Table 4, the share of papers has been determined with regard to the transport branch (Figure 4). Figure 4 shows that the Analytic Hierarchy Process is most used in solving road traffic problems (27%), followed by rail (18%) and air transport (14%). Also, the implementation of the AHP method is important in the selection of the priorities in the realization of the traffic projects (18%) and the selection of the terminal locations (9%). The Analytic Hierarchy Process was also used in the papers for the selection of the best public transport system (5%), selection of the sustainable transport infrastructure (5%) and the maritime traffic problem (4%).

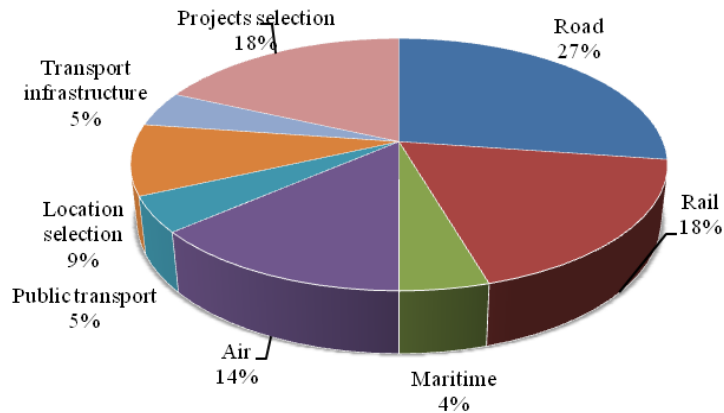


Figure 4. Share of the papers in which AHP method has been implemented with regard to the transport branch and purpose

3.4 Analysis of students' papers at the University of Zagreb, Faculty of Traffic and Transport Sciences implementing the Analytic Hierarchy Process for solving transportation issues

At the University of Zagreb, Faculty of Transport and Traffic Sciences undergraduate, graduate, specialist and doctoral study programmes are performed. The students' papers have been analyzed including diploma thesis, master thesis and doctoral dissertations, in which primarily the AHP method was used to solve the transport problems from all transport branches (road, rail, air, urban, telecommunications, maritime). The selected academic papers are presented in Table 5.

Table 5

Overview of students' papers (diploma thesis, master thesis, doctoral dissertation) dealing with the implementation of AHP method in solving transportation issues

Paper category/Year	Author	Title of the Paper
Doctoral dissertation (2013)	Grgurević, I.	Determination of Starting Locations of Carpooling Trips in the Cities
Doctoral dissertation (2013)	Petrović, M	Planning of Locations of Intermodal Passenger Terminals in Urban-Suburban Rail Transportation
Doctoral dissertation (2010)	Barić, D.	Model of Planning Traffic and Technological Projects in Railways Development
Doctoral dissertation (2010)	Vidović, A.	Model of Low-Tariff Aircraft Operations in Croatia
Master thesis (2010)	Ćosić, P.	Segmentation of Users of Telecommunication Services by Means of Multi-Criteria Decision-Making

Paper category/Year	Author	Title of the Paper
Diploma thesis (2013)	Ćorluka, I.	Selection of the Optimal Version of The Project of Reconstructing the Intersection of Bistrička Street and Trakošćanska Street in the City of Zagreb by Applying Analytic Hierarchy Process
Diploma thesis (2013)	Divić, K.	Assessment of Possible Solutions of Reconstructing the Intersection of State Road 60 and County Road 6157 by Applying AHP Method
Diploma thesis (2013)	Glasnović, M.	Selection of Optimal Version of the Project in Reconstructing the Intersection of Križni Put Street and Blaža Jurišića Avenue in Zagreb using Multi-Criteria Decision-Making
Diploma thesis (2013)	Karoglan, A.	Assessment of Possible Solutions of Reconstructing the Intersection of Kaštelanska Street and Exit from Jadranska Magistrala in the City of Solin by Applying AHP Method
Diploma thesis (2013)	Kljajić, M.	Assessment of Possible Solutions of Reconstructing the Intersection of the Streets Petra Svačića - Josipa Rimca - Hanibala Lucića in Slavonski Brod by Applying Multi-Criteria Analysis
Diploma thesis (2012)	Babić, S.	Analysis of Assessment Methods of Road Traffic Projects
Diploma thesis (2012)	Jurić, I.	Assessment of Versions in Solving the Reconstruction of the Intersection of Čavićeva Street and Borongajska Street in the City of Zagreb by Implementing Analytic Hierarchy Process
Diploma thesis (2012)	Mikić, V.	Implementation of AHP Method in Assessing the Variant Solutions in Reconstructing the Intersection of Dubrovačka Street – Industry Road in the City of Požega
Diploma thesis (2011)	Bareša, I.	Assessment of Traffic and Technological Projects of the City of Velika Gorica and Proposal for Design Priority
Diploma thesis (2011)	Kostić, I.	Multi-Criteria Decision-Making in Selection of Optimal Project of Intersection Reconstruction
Diploma thesis (2011)	Sirovec, S.	Assessment of Traffic and Technological Projects of the City of Krapina and Proposal of Design Priorities
Diploma thesis (2011)	Jozić, V.	Selection of Mobility Control Measures in the Cities Using Multi-Criteria Analysis
Diploma thesis (2010)	Radoš, I.	Multi-Criteria Analysis of Possible Scenarios of the Zagreb Airport Development

Source: *Croatian Scientific Bibliography (CROSB)*, <http://bib.irb.hr/>

Figure 5 indicates an increase of academic papers about the use of the AHP method for solving transport issues, especially in diploma theses, reflecting the growing popularity of the AHP method among students.

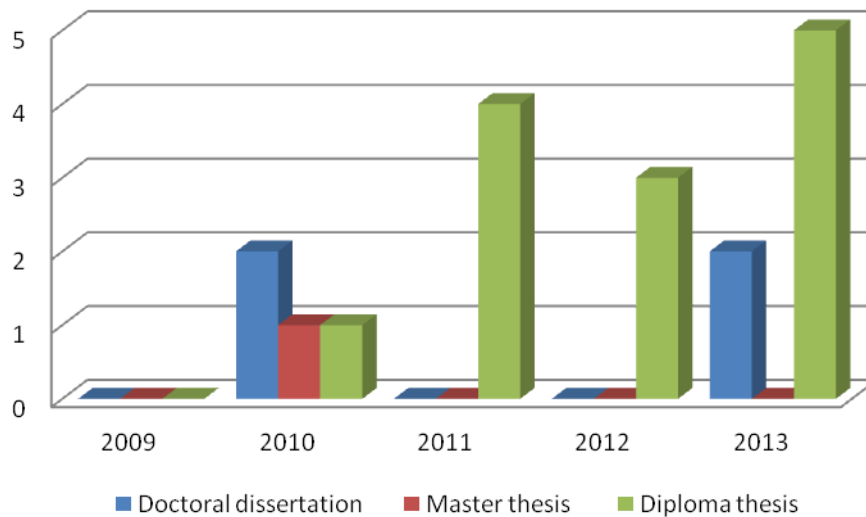


Figure 5. Share of the academic theses in which AHP method has been implemented with regard to the transport issues

4. Discussion and conclusions

Based on the previous research it may be concluded that the implementation of AHP in solving problems in the area of transport is extremely high. The analysis of relevant databases has shown that the AHP method has been implemented in scientific papers, scientific projects, diploma theses and doctoral dissertations.

Although the cost-benefit analysis is currently the only method implemented in practice, the number of scientific papers based on the AHP method is an indicator for the justification of implementing this method in practice as well, i.e. in pre-investment and investment studies.

The methods used in the process of assessing transport and technological projects, including making investment decisions, are numerous and usually differ regarding criteria of optimization. The projects can be assessed through the prism of a single criterion, but also based on several criteria. The usual optimization criterion is the economic characteristic. However, for the purpose of long-term and higher quality solutions it is necessary to introduce several criteria of optimization. Apart from the economic criteria, the technological, technical, environmental and numerous other criteria are significant. This is where the AHP method plays a very important role.

By analyzing the literature it can be concluded that there are numerous papers in which the AHP method has been implemented in order to solve transport problems. All of the transport branches have been represented including road, rail, air, maritime, telecommunications, and postal traffic. Within the context of AHP method implementation in order to solve transport problems, it may be concluded that the AHP method is usually implemented for the selection of the optimal road or rail route, selection of the optimal transport means, establishing priorities in project realization,

selection of the optimal telecommunication operator, selection of the airline, urban traffic management, determining of locations of terminals, definition of schedules, selection of the optimal traffic infrastructure, determining of road and rail corridors, etc. Generally, these issues can be divided into the following three groups: transport planning, transport infrastructure and transport management.

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