APPLICATION OF AHP METHOD IN TRAFFIC PLANNING

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Abstract

Achieving competitiveness on the market ensures business continuity within terms of globalization. Consequently, competitiveness is determined by various factors which grading and evaluation require corresponding approach. The final result is a set of information used as basis for making the concrete decisions. Traffic of goods and services has a special importance in ensuring the concrete business, not just in logistic sense. Traffic planning and making decisions relevant to that area directly influence the business. Today there are different methodologies and techniques of planning in field of traffic. The choice of technology usually depends upon business management. Application of AHP method is one of the possibilities that can be used within mentioned circumstances. This paper analyses possibilities of applying AHP method in making decisions regarding planning and implementation of plans in traffic and ensuring the qualitative business logistics.

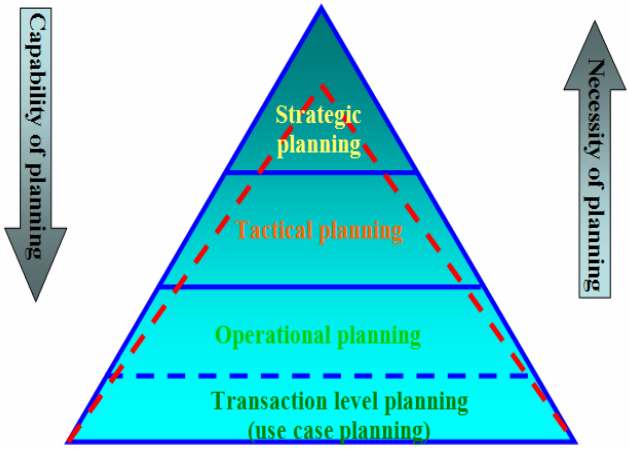
Keywords

Traffic, AHP, Decision making, Logistics, Competitiveness

I. Introduction

Planning is a process which starts with precise, clear definition and description of a desired outcome for planned acitivities, i.e. with defining a goal. A goal must be clearly defined and described. The realization of a defined goal is done through precisely defined arrangement of a series of activities which will enable one to achieve a defined goal. Each activitiy implies engaging certain resources. Human, physical and financial resources are engaged in particular planned activities with different dynamics. From that point of view, time needed to carry out planned activities and the overall plan represents the most important resource. Time management will be a criterion to decide how and when the plan will be realized. According to this criterion plans can be classified into strategic, tactical or operational ones (Pic 1).. A plan should also comprise a detailed list of circumstances and possible situations in which appropriate decision-making could be expected. Planning also includes optimization of utilization level of the above mentioned resources i.e. minimum cost with maximum efficiency in the shortest period of time. A plan must necessarily contain implementation strategy and a schedule of occasional controls and positions where certain potential modifications could be done without effecting the realization.

The above mentioned principles are applicable in general circumstances. In particular cases it is necessary to take into consideration some specific qualities in order to ensure efficiency and consistecy of a plan. Taking into consideration these specific qualities has also a preventive character, particularly in eliminating in a plan possible gaps and mistakes, dilemmas and vagueness, and it also gives the possibility for decision-making in a situation of a multiple choice.



Picture 1. Levels of Planing

A plan must have a purpose. In a specific business system, planning has management function. Therefore competent persons from the management level have to set a goal. The management level is responsible for the plan realization feasibility and the acceptability of a suggested plan.

Defining planned goals usually results in making them public, which can be considered as a starting point for plan realization. In a business environment a plan implies achieving implementation conditions of a business system. In the context of globalization two important goals could be found in literature lately: constant business importance and maximum competitiveness on the market.

Planning is therefore a consequence of changed circumstances in which business system exists. A specific plan must be based on detailed and comprehensive research and analysis of these circumstaneces.

Realization of a plan is a continuous process which starts with its completion and acceptance, which is preceded by a decion to accept the plan. Decision-making like planning, is a process, but the final outcome of that process is a decision which from the time aspect is a discreet event. On a time scale of the realization of a plan, decision-making is a process which is necessarily connected with check points and the assessment of the plan's feasibility level.

Decision-making, like planning, involves defining goals that want to be achieved with this decision. In a business system and its environment both through plans and decisions, the desired circumstaces are tried to be achieved.

Decision-making, unlike planning is a situation when a person who makes a decision, is in a position where he must choose between two or more alternative possibilities. Potential multiple possibilities of achieving desired goals require setting criteria. They must characterize certain alternative and show clearly what makes it different from other alternatives. In this case an alternative is characterised in terms of quality and quantity. If in decision-making more criteria is used, they do not have to be equally important. Therefore criteria are assigned a level of weight and severity. In that way we determine their importance. It is common for a decision-maker, a person who is an expert in a given field, to decide about the level of weight. There are various methods and techniques of decision-making, simple and more complex ones. Analytic hierarchy process (further in the text AHP) according to the classification is a method for multicriteria decision-making.[1] The concept of AHP, as well as some other theories have been developed by Thomas Saaty, American matematician from the University of Pittsburgh [2]. The author of AHP Thomas L. Saaty called this method a process, and not a method probably becauseof the process character of its elements.

II. AHP – analytic hierarchy process

II.1. Approach

A hierarchy represents a system of organizing and ranging phenomena, people, things, ideas, etc. Each element of the system, except the highest one, is subordinate to another element in the system. Hierarchical diagrams are therefore most commonly shaped as pyramids, because of the fact that at the top of the structure there is only one element, even though in practice it does not have to be the case.

Human structures are most commonly organized as hierarchies, where we use this system to share responsibilities, carry out management and rationalize communication. As for «things» included in hierarchical structures, we can take as an example a diagram of any system where at one level we can determine periphery and base and the top at the other level.

In the world of ideas, we use hierarchy to ensure clearer notion of complex reality: we structure the real world, system and environment in constituent parts. In that way, going through a process, we gain complete understanding about the complex reality that we study. We repeat the procedure by separating elements into smaller parts. We continue this division down to the basic level where we can unmistakably comprehend a part of the system as an independent whole. When observing elementary part, we temporarily ignore the rest of the system. During that process we try to comprehend the complexity of a system we study, i.e. a system within which we make certain decisions.

II.1.1. What is analytic hierarchy process (AHP)?

Analytic hierarchy process (AHP) is a methodological approach which implies structuring criteria of multiple options into a system hierarchy, including relative values of all critera, comparing alternatives for each particular criterion and defining average importance of alternatives.

In that way a basis is created to make appropriate decisions. AHP is a structured technique which is used with complex decision-making. The goal is to single out and offer one out of several possible decisions. While doing so one does not insist on exclusively «correct» decision, but one chooses one which through this method proves to be the most adequate or the most useful one for the user. AHP method offers meaningful and rational framework for structuring problems, presentation and quatification of elelents that make a problem. Techniques of putting together these elements and techniques of evaluating alternative solutions enable directing towards a final solution.

Since the method of AHP decision-making can be combined with various methods of development planning applicable in every situation, when a decision should be made choosing between alternative solutions, this approach is used in solving various different situations where the goal is to make decisions in areas like government administration, economy, health, education etc.[3]

II.1.2. How users see AHP?

The users of AHP first decompose /break down a problem into a hierarchical structure or easily undestood sub-problems, each of which could be observed separately. Elements of such a structure can be put into relationship with different aspects of solution to a problem whether they are tangible i.e. more or less obvious, carefully measured or roughly estimated, understood a bit better or worse – which means that it is useful everything that can be used in given circumstances.

After the initial structure has been set up, the task of an analyst is to start systematic assessment of elements comparing them with one another in pairs. In the process of comparison specific data which are linked to particular elements can be used or an estimate about relative importance and value of elements can be done. The key assumption of this method is human power and ability of judgement against exact information.

Further on, AHP expresses these comparisons in numeric values which can be easily processed and compared in the context of a bigger picture of the observed problem. Numeric value or certain priority is derived from each element in the hierarchy, enabling various and very often unmeasurable elements to be compared in a rational and consistent way. This

approach makes AHP different from all other techniques of decision-making.

In the last phase numeric priorities are derived from the observed and established alternatives. Since these numbers represent relative probability of an alternative in achieving a goal for which a decision is being made, they can be used as a guideline for future actions.

II.1.3. Application of AHP, where and how?

Although this method can be used in individual processes of decision-making, it is most useful in situations where teams of experts cooperate in solving complex problems, especially those which involve a high level of risk, and are based on human judgement and perception, with far-reaching effects.

It is important to stress also unique advanateges of AHP method when, for example, decisive elements for making decisions are difficult to compare and to quatify or in the circumstanes where there are communication problems between members of a team as a consequence of different profiles of experts, differences in terminology, points of view etc.

Potential environments where AHP can be used are numerous and they represent a source of a high number of very different results in the area of planning, transport, setting priorities and choosing the right alternative. Many of these environments are not widely known because of their specific quality. To a large extent here we talk about situations concerning big business settings and making strategic and long-term decisions accompanied by certain discretion or safety limitations.

Here are some examples how AHP which have been made public and have been dealt with in literature, are used (http://en.wikipedia.org/wiki/Analytic_Hierarchy_Process, septembar 2008):

• Deciding how best to reduce the impact of global climate change (Fondazione Eni Enrico Mattei)

• Quantifying the overall quality of software systems (Microsoft Corporation)

• Selecting university faculty (Bloomsburg University of Pennsylvania)

• Deciding where to locate offshore manufacturing plants (University of Cambridge)

• Assessing risk in operating cross-country petroleum pipelines (American Society of Civil Engineers)

• Deciding how best to manage U.S. watersheds (U.S. Department of Agriculture)

AHP is sometimes used when designing highly specialized procedures for specific situations, for example when evaluating building structures according to their historic importance. In the USA this method is included in the project of monitoring the condition of federal freeways, which are superrvised by video cameras. Engineers used AHP method to determine optimal area which the project should cover, and at the same time to account for budget for investors.

Even though one may get impression we are talking about methodology which does not imply specific academic education, AHP is nevertheless a subject of study at some of the most renowned universities.

AHP is considered an important subject in technical schools as well as in schools of economics. APH was, for example, presented to some Chinese experts some twenty years ago, who accepted its implementation, among other things because of the fact that its methods very highly compatible with traditional Chinese systems of decision-making. In China more than 900 different papers have been presented on the subject.[6-15] There is also a monthly scientific review dedicated exclusively to this topic.

This is where majority of papers related to the problems of planning and organising transport comes from. University of Zagreb has a softwrae Expert Choice and the university scientists have published several papers using this method. [5]

II.2. Basic tenets of AHP

A group of axioms which in detail define a problem in a system and its evnironment represent basic tenets of AHP [2].

It is based on the well-defined mathematical structure of consistent matrices and their associated right-eigenvector's (non zero vector) ability to generate true or approximate weights[2]. The AHP methodology compares criteria or alternatives with respect to a criterion, in a natural, pairwise mode. AHP uses a fundamental scale of absolute numbers that has been proven in practice and validated by physical and decision problem experiments. The fundamental scale has been shown to be a scale that captures individual preferences with respect to quantitative and qualitative attributes just as well or better than other scales [2]. It converts individual preferences into ratio scale weights that can be combined into a linear additive weight w(a) for each alternative a. The resultant w(a) can be used to compare and rank the alternatives and, hence, assist the decision maker in making a choice. Given that the three basic steps are reasonable descriptors of how an individual comes naturally to resolving a multicriteria decision problem, then the AHP can be considered to be both a descriptive and prescriptive model of decision making. The best way to represent AHP method is to describe basic AHP functions, axioms and basic AHP principles.

II.2.1. AHP functions

According to [2] AHP functions are:

Structuring complexity – decomposition. The aim is to structure a problem into smaller «sub-problems» and in that way to make it easier to work with in the process. Constructing such a

structure starts from the top down to bottom, from more general towards more detailed and specific observations of the problem. At the beginning, the problem is not structured while more detailed division into sub-models is done in the subsequent iterations.

These modules will become separate hierarchical modules inside the whole. Following the hierarchy from the top to the bottom, with AHP goals are gradually singled out, semantic branching and defining modules is done. Criteria are set – testing parameters and evaluating alternatives – measuring the level of success of a certain solution according to a given criterion. The hierarchy does not have to be complete, i.e. one element does not have to be a criterion for all subordinate elements. Each branch is divided into appropriate rational level for working out details. At the end of this phase, the iteration process transforms non-structural problem into a hierarchy defined by criteria, which can then be easily manipulated in vertical and horizontal directions. Increasing the number of criteri, their importance decreases and they become equal which eventually is solved by assigning values to each criterion.

It is important for a criterion to meet the requirements for independence of alternatives and to meet expectations including all important alternatives and criteria.

Measuring on a ratio scale – Assessment. Using hierarchy allows a high level of concentration when judging separately each quality, independently of other qualities, which is important in order to make the right decision.

Assigning relative values to each criterion is based on the importance of the module content to which the criterion belongs. The sum total of all criteria that belong to modules directly defines the value of the «parent module» (super-module) i.e. it assumes the value of 100% or 1. The global importance acquires an average value of the sum of all relative importance of the given criteria. If we, for example, compare alternatives with the goal of purchasing land and construcing a building, we can say that for an investor location will have priority over price or the price over the time needed to finish construction work. Next activity is evaluating or assessing all alternative solutions and thier mutual comparison. The matrix of these desired solutions is estimated and the so-called coefficient of consistency is added to it where value 1 means that all the desired solutions internally for this module are consistent. On the other hand, there can be internal inconsistency when we say that X is more desirable than Y, and Y is more desirable solution than Z, and Z is more desirable than X and then this coefficient will acquire lower value.

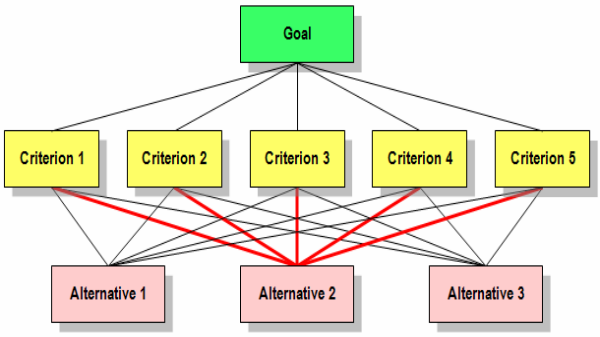
According to many, the quality of this step of AHP process represents key importance supporting the opinion that AHP is theoretically well organized. According to AHP assessment is done in the way that a relative assessment is assigned to the most specific decisions within hierarchy, then to a wider context and so on up to the top where the total assessment is calculated.

Synthesizing - Because complex, crucial decision situations often involve too many dimensions for humans to synthesize intuitively, we need a way to synthesize over many dimensions.

II.2.2. Principles of AHP

Three basic principles of AHP and certain axiom tenets are linked with the above mentioned functions as follows [2]:

Decomposition The principle of decomposition presupposes structuring of a complex problem into hierarchical modules or clusters down to the level of elementary sub-module.(Pic. 2)



Pic 2. Hierachical threshold levels

The principle of comparative judgements This principle implies comparisom of pairs of all elements in a certain hierarchy taking into consideration superior hierarchy.

Comparing pairs is necessary because local priority of elements must be defined, taking into consideration their superior element.

The principle of hierarchic composition or synthesis is applied to multiply the local priorities of the elements in a cluster by the 'global' priority of the parent element, producing global priorities throughout the hierarchy and then adding the global priorities for the lowest level elements.

II.2.3. Axioms of AHP

Each theory is based on axioms, some basic and implied facts which make it applicable. AHP is based on three relatively simple axioms.

The first axiom, *the reciprocal axiom*, requires that, if PC(EA,EB) is a paired comparison of elements A and B with respect to their parent, element C, representing how many times more the element A possesses a property than does element B, then PC(EB,EA) = 1/PC(EA,EB).

The second, or *homogeneity axiom*, states that the elements being compared should not differ by too much, else there will tend to be larger errors in judgment. When constructing a hierarchy of objectives, one should attempt to arrange elements

in clusters so that they do not differ by more than an order of magnitude in any cluster.

The fundamental scale for pairwise comparisons		
Intensity of importance	Definition	Explanation
1	Equal importance	Two elements contribute equally to the objective
2	Equally to moderately	*
3	Moderate importance	Experience and judgment slightly favour one element over another
4	Moderately to strongly	*
5	Strong importance	Experience and judgment strongly favour one element over another
6	Strongly to very strongly	*
7	Very strong importance	One element is favoured very strongly over another; its dominance is demonstrated in practice
8	Very strongly to extremely	*
9	Extreme importance	The evidence favouring one element over another is of the highest possible order of affirmation
Intensities of 2, 4, 6, and 8 can be used to express intermediate values. Intensities 1.1, 1.2, 1.3 (at sublayer level) can be used for elements that are very close in importance.		

Table The AHP verbal scale ranges 1 to 9 (Saaty scale)[4]

The third axiom *states that judgments* about, or the priorities of, the elements in a hierarchy do not depend on lower level elements. This axiom is required for the principle of hierarchic composition to apply.

A *fourth axiom*, introduced later by Saaty, says that individuals who have reasons for their beliefs should make sure that their ideas are adequately represented for the outcome to match these expectations. While this axiom might sound a bit vague, it is important because the generality of AHP makes it possible to apply AHP in a variety of ways and adherence to this axiom prevents applying AHP in inappropriate ways.

II. 3. Advantages, disadvantages and criticism of AHP

AHP helps comprise subjective and objective measurements offering useful mechanism for checking their consistency and alternatives which members of the team suggest. In that way they reduce differences which make decision-making difficult.

AHP also helps minimize the most frequent mistakes in the process of decision-making like lack of focus, mistakes in the segment of planning, monitoring all participants etc.

Special advantage is relative simplicity of use, specially because of use software packages available on the market.

There are several companies in the world that develop software solutions as support to AHP process of decision-making.

Some of them are: Expert Choice and Team Expert Choice 2000 (http://www.expertchoice.com), HIPRE 3+ i HIPRE 3+ Group (http://www.hipre.hut.fi) software which supports methods of AHP and SMART, Logical Decision (http://www.logicaldecisions.com) packages available as demo versions linked with software, meant for groups, and Web-HIPRE Global Decision Support (http://www.hipre.hut.fi/) web version of HIPRE 3+ software and good quality eLearning material.

In spite of the success of AHP method in practice and a large number of scientific papers, AHP method has been criticized. Some of the objections are nonexistence of theoretical basis for constructing hierarchies. This leads to various models that describe identical situation which can produce completely different final solutions. AHP assessment is also criticized because it is considered unreliable and based on the user subjective notion, because of deviation from individual values – assessment of individual elements and composite collective values. AHP is criticized for the lack of foothold in the basic statistics theory.

III. AHP and transport planning

In order to present uses of AHP method in planning and organizing transport, we shall start with some basic tenets important for this paper:

- AHP is a method which does not depend on the type of problem. This means that it can be equally applied in planning any type of transport: road, rail, air or maritime-river, respectively, if we look at the means of transport or postal services, telecommunication or the transport of goods and services if we observe business function of system.
- AHP can be equally applied in situations with different problem complexity and organization size. In other words it can be applied in medium-sized companies like for example in a freight forwarding firm as well as in a state railway company. In all situations it is possible to separate a problem into: a goal, criteria and alternatives.
- AHP as a multiple criteria method of decision-making implies participation of a team of experts, starting with specialists in a specific field to specialists in computer application, if there is any need for them. AHP can be combined

with Fagan inspection when the proposal of the problem decomposition/division is completed.

- AHP method can be applied at any point of the plan realization when it is necessary to make a decision. The final goal set by the plan and strategy of a plan maker depends on the nature and the level of difficulty of this decision.
- AHP can be carried out in two ways: relatively and absolutely. In the situation of relative judgement, alternatives are compared pairwise to reach the priority criterion. With absolute judgement we do not do that. In both cases we have to be careful not to deviate from the desired goal. Absolute judgement is usually used where there are lots of alternatives.

IV. Practical carrying out of the AHP method

To use AHP in practice means to apply principles of AHP method and realize AHP functionalities in a specific case, for example in planning public city transport network.

For graphic representation of hierarchical structure the most appropriate is a tree structure. A simple form of this structure includes the goal of a plan and project at the highest level i.e. at the top of the tree. Criteria are subordinate to the goal. They are at the following level. Alternatives are at the lowest level. Each alternative is linked to the superior level and connected with criteria.

If there is some specific plan, the picture is more complex. The level in the middle, the level of criteria can be/must be divided into layers. In that way the hierarchy of sub-criteria is created. When such hierarchy of criteria is set up, priorities are defined for each node separately. This activity is somewhat complex, and the participants have many options on the road to completing it. According to [3] Analytic Hierarchy Process (AHP) can be divided into nine phases:

I. *Beginning*. Defining a problem and collecting necessary information. Identification markets and users , user needs and requirements, service operation etc.. If there are alternatives in the choice of projects, the most appropriate one is decided for. At this level already simple assessment of the project with AHP method can be applied. Methodologically this is a moment to kick off the project.

II. *List alternatives importance of criteria*. In this phase a certain alternative is chosen out of a group of identifiable possibilities. The result of this phase is a list of all alternatives. The decision maker should examine the scores to ensure that they are sensible and should be adequately aware of the issues so as to defend the scores. If there are n alternatives, then $n(n - 1)/2$ pairwise comparisons are needed. Clearly, for expedient application of AHP, the alternatives must be limited to a reasonable number.

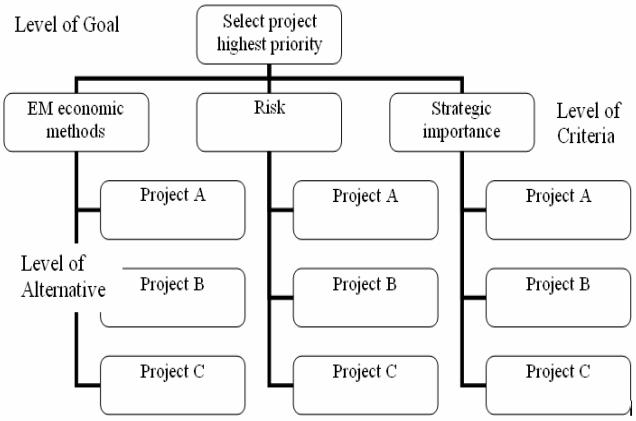
III.1. *Define threshold levels.* The threshold levels are defined; these are the minimum requirements which an alternative has to fulfill. (pic 3.)

III.2. *Determine acceptable alternatives.* All alternatives listed in step 1 are reviewed with respect to the threshold levels. Alternatives which do not meet these requirements are dismissed. Phases III.1. and III.2. can be carried out simultaneously.

IV. *Define criteria*. This phase assumes the completion of phase II. and III.. The project team or management structures define criteria that will be used when judging alternatives. [2vz] Suggest three methods to select criteria, a pro/con analysis of the alternatives, using 'off-the-shelf' norms, and the critical success factors technique.

V. *Develop decision hierarchy.* This phase follows phase IV. The team develops a decision hierarchy. This hierarchy consists of at least three levels, a goal, criteria and alternatives. These elements are represented in a tree structure. The hierarchy represents the structure of the decision problem.

VII.1. *Compare criteria pairwise* (important of criteria) AHP determines the relative importance of each criterion. This is done by means of the same process which was used in the previous step to derive the relative priorities of the alternatives. The Team or decision maker compares all criteria pairwise. The manager indicates which criterion is more important, and to what extent.



Pic 3. . The decision hierarchy levels for the project

VI. *Compare alternatives pairwise* (Relative priorities of projects). For each criterion, the decision maker evaluates all alternatives pairwise. For each criterion, every possible combination of two alternatives is judged in this way.(table 2). The other criteria or characteristics of an alternative should not be considered in making the pairwise comparisons with respect to one particular criterion. Team can make numerical or verbal judgements. It is assumed that the prevoius phase V. is completed.

Criteria *n*	Project A	Project B	Project C
Project A	1	2	8
Project B	1/2	1	6
Project C	1/8	1/6	1

Total	13/8	19/6	15

Table 2. The full judgement matrix (example)

Criteria *n*	Project A	Project B	Project C
Project A	8/13	12/19	8/15
Project B	4/13	6/19	6/15
Project C	1/13	1/19	1/15
Total	1	1	1

Table 3. The normalised pairwise comparison matrix

VII.2. *Calculate overall priorities of alternatives.* The overall priorities are determined by means of a linear additive function, in which the relative priorities for an alternative are multiplied by the importance of the corresponding criteria and summed over all criteria. The AHP analysis shows which project has the highest priority. Phases VII.1 and VII.2. are carried out simultaneously, and it is assumed that phase VI. is completed.

Criteria *n*	Project A	Project B	Project C	Row Average
Project A	(8/13	+ 12/19	+ 8/15) / 3	0.593
Project B	(4/13	+ 6/19	+ 6/15) / 3	0.341
Project C	(1/13	+ 1/19	+ 1/15) / 3	0.066
Total				1

Table 4. The relative priorities for the criteria *n*

VIII. *Sensitivity analysis.* Sensitivity analysis is the most important moment in the AHP process. Before the Team or Management chooses the plan with the highest overall priority, a sensitivity analysis can show the robustness of the overall priority rating. Sensitivity analysis shows to what extent the overall priorities are sensitive to changes in the importance of criteria. The more stable the ranking of the alternatives, the more confident the manager will be in the proposed choice. This phase assumes that all the previous phases have been completed.

IX.*Final activities*. Preparation of a proposal: the plan or project with the highest level of priority. Preparation of the project for the realization.

V. Conclusion

Planning business activities is of vital importance for realizing business goals completely, on time, while meeting the required standards of quality at the same time.

Decision-making is an activitiy which should adequaltely be incorporated in the process of realization of the accepted plan.

Planning and organization in a business system which deals with transport and/or logistics because of specific demands of the business processes could be a very demanding job. The above mentioned activities by complexity are proportionally dependent on the size and structure of the business system, but their seriousness and importance are constant.

Which and what methods of planning and decision-making will be applied in a specific situation depends on particular case and circumstances in which that business system functions. In the context of business globalization, a business system must constantly update its business functions in order to maintain importance and position on the market. In such circumstances, a well coordinated team of experts that will have some common, but also some supplementary competence should assume the task of planning and decision-making. The choice and application of some of the developed and accepted methods of decision-making in transport, AHP included, will depend on, among other things, on these competences. Developed computer applications which apply some of these methods are available on the market today at very reasonable price. Their use assumes that some member(s) of the team has been adequately trained. Computer application today does not necessarily require information scientist as was the case in the past, because new generations of experts have adequate competences in applying ICT in the field they have specialized in.

Considering these needs, it is important today to prepare in the best possible way future experts who will work in the field of organizing traffic and logistical functions of a business system. Incorporating these methods into school curricula through practical application in specific or hypothetical cases with the use of available computer packages such as Mathematica, Expert Choice or, HIPRE 3+, becomes an imperative. AHP method can also be used as a powerful means in simulations and preparation of alternative models of business system, especially when functioning of a business system in a specific environment needs to be tested.

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