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Full Length Research Paper

Comparative study of environmental impact assessment methods along with a new dynamic system-based method

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Environmental Impacts Assessment has been developed as a critically substantial approach to determine, predict and interpret the ecological impact on the environment, public hygiene and healthy ecosystems. This study aims to introduce and systematically investigate the environmental issues during important decision-making stages. Meanwhile, impacts of development on the environmental components will be also analyzed. This research studies various methods of predicting the environmental changes and determining the impacts through both qualitative and quantitative methods. Qualitative approaches rely fully upon the expert's decisions, while quantitative ones are entirely based on mathematical methods where the relations between the elements are expressed through variables and parameters. Then both approaches required be comparing and contrasting. Among these methods, expertise method, check list, matrix, overlaying maps and networks are crucially considerable. These methods, based on the static variables, mostly describe the relations which are constant over time. The most important objective of this study is providing a dynamic model of the environmental assessment based on dynamic variables. Such a model can define changeable relations. Therefore, to present a new model based on system dynamics, the environmental components and changes due to the project have been considered as a set of interrelated elements and variables. There are some variables as input element whose interrelations and mutual effects are considered as a process which leads to the output of the system. This research investigates the existing dynamism among the components affecting the environmental assessment. Static and single function systems cannot make real simulation. Thus, this research benefits from dynamic systems that can display multifunctional structures, model nonlinear and time delays, as a means of Environmental Impacts Assessment.

Key words: Simulation, dynamic system, dynamic variables, input elements, output elements, environmental component and environmental impact.

INTRODUCTION

Focusing on the origin of the methods used to study the complicated economic, engineering, management and social problems, it can be clearly shown that each method is looking for a special outlook to the problems (Wiseman, 2006; Roudgarmi et al., 2008a). Among these methods, Environment Impact Assessment (EIA) plays an important role in the process of planning, decision-making and project implementation (Khordagui, 2002; Nouri et al., 2008). Considering the sustainable development, EIA is essentially considered as a planning tool of a project. People ask for comparing different alternatives for every kind of project and plan (Höpner and Lattemann 2002).

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Table 1. Comparison of assessment methods.

Relative use	Shortcomings	Features	Data analysis	Variable kind used	Method
Expanded	Non-systematic non-comparative	Impact identification	Special expertise method	qualitative	Ad hoc
Optional	Lack of ability in intensive impact identification-obvious impact identify-cation-lack of ability in inspection of the secondary impacts-need to differ-rent maps-high expense-lack of cri-teria and determined for assessment	Power of the distinction impacts-determining of impact importance-des-cription of impacts-high analysis-ability of the contrastive impact iden-tification	Based on the environ-ment maps	Qualitative and based on the place	Map overlaying
Expanded	Just effect inspection	Impact identification	Inspection of the effective parameters	Qualitative	Checklist
Expanded	Low-data analysis-lack of certainty-lack of consideration to the compara-tive impacts	Simple criterion- possi-bility of the comparing the decisions-being cheap-flexibility	Simple description of the project impacts	Quantitative	Matrices
Average	Lack of the criterion to determine the impact in comparison with another impact-complexity-high expense-need to the long time	Impact identification-showing cause and effect relationship-high analysis	Based on the descrip-tion of cause and effect impact	Quantitative analyzing	Networks

Each alternative involves economical cost (Abdel-Jawad and Al-Tabtabaei 1999) and benefits. Meanwhile, the correct perception of the nature of proposal and use of the similar results of project are of great importance. Some different methods used for determining key impacts, including checklists, matrices; overlaying maps and networks are among the group decision-making based on the stable variables and application (just based on the expert's opinion). The main objective of this study is achieving the dynamic model for the environment assessment based on dynamic variables.

The simulation model can be used as a tool for determining and predicting the impacts on the basis of the dynamic system (Roudgarmi et al., 2008b; Kennish, 1997). The structure of the cause and effect of variables and complicated issues focusing on feedback process are solely considered throughout this model. Since, the model is based on the relationships between the elements and dynamism, determining the relationship among the dynamic model elements is of great importance.

Also, these systems proceed to the inspection of the complex problem considering the feedback process. The logical base is that the feedback structure is sensitive to the changes occurred during the time. To achieve a dynamic model, some measures have been taken.

Among these substantial measures are identifying the existing dynamism amongst the components of an environmental system, predicting environmental system behavior, providing the possibility to make decisions, identifying various scenarios (proposed solutions in a simulated environment) and using experts' opinions in fuzzy situations. In the above field, there have been few sources and practically, it is only possible to study the available sources in separate fields (Haugwitz, 2005; Skoglund and Dejmek 2007; Tiller, 2001).

Comparative study of the environment assessment methods

Nowadays, in Iran, the main objective of environment assessment is achieving sustainable development within economic plans along with preservation and prevention of renewable and non-renewable resources (Nouri et al., 2009; Andreasen et al., 2001). The most important ones are special expertise method, overlaying maps, checklists, matrices and net-works as shown in Table 1.

Since EIA future events are collated, it should have enough ability to predict the predictable events. The environment assessment methods use qualitative phases for probability of the event occurrence. Lack of certainty factor demands the result to be presented qualitatively.

In comparing the environment assessment methods, following items can be pointed out:

i) Dependence on expert's opinions: It means that the final results do not depend on the data analysis process, but will directly be asked from the experts. It seems that experts can be useful in information presentation.

ii) Lack of certainty.

iii) Lack of consideration of the comparative impacts of

components (in the construction or operation of the project).
iv) Lack of unity.
v) Lack of consideration of the comparative impacts of the components result from the changes happened in the environment.
vi) Lack of possibility of benefiting from aggregative opinions of experts.

In fact, there is no unity possibility and relationship of much information and pure data of these methods-lack of certainty in these methods does not mean that it is not possible to predict the future events and get to the result (Buckley, 2000). The assessment methods do not care about the comparative impacts and relationships among components (cause and effect).

Also, time limitation is ignored. Comparing the methods and identification of the shortcomings, the goal is to cover the shortcomings by presenting the relative modern method for system dynamics and the environment assessment, because dynamic systems can identify the dynamism of the effective components of the environment assessment. Also, they are able to show multifunctional structures and model the feedback and time delays.

MATERIALS AND METHODS

Application of dynamic systems in EIA

Dynamic models have the ability to use structural and behavioral methods to solve complex problems at the same time (Cornforth, 1999). The components are used as the elements and sub-systems of the model during modeling process. Dynamic simulation model is a strong tool for predicting the connected behaviors of different systems in answering the stimulus signals in a period of time. Using dynamic model, identified elements and their relationship would be clear (Dale and Bayeler 2001). Considered model provides the possibility to run many tests on the system, while different assumptions and different policies will be accomplished and their behavior will be inspected.
Following objectives will be achieved in EIA using a dynamic system:

1. Possibility of the environment assessment of the proposed project in dynamic time.
2. Identifying the dynamism among the available components in an environment system.
3. Possibility of the predicting and decision-making in an environmental system according to the different views by dynamic model.

Dynamic model tends to inspect the complex problems focusing on the feedback process. Therefore, feedback structures are sensitive to the changes happened during the time (Kurtz et al., 2001).

As a result, dynamic behavior is due to system's structure. Different stages of defining dynamic modeling process are as below:

i) Describing and identifying the problem, conceptualization, formulation, simulation and assessment of the model, documentation, policy analysis and finally application of the model.
ii) Identifying the model depends on definition of the problem and its elements. This stage, actually, is the spiritual verbal description of the symbols of problem. This process should be presented dynamically and according to the variables.

Conceptualization, in fact, is the abstraction of the world phenomenal meanings for the model which is fulfilled in the framework of the variables. In presenting the identified model's goals, policy, political viewpoints in modeling, consideration of the simulation model, type determining, operation degree and accomplishment are among the most important components.

The goals scope and desirable accomplishment can be considered as a tool for testing the former policies. The system territory guarantees system structure parts which are necessary to produce system behavior. The system border should be vast enough to include cause-effect relationships and information. This phenomenon is very important for the system behavior. The system territory should include political powers (factors related to the policy test) and available variables (such as costs). Therefore, policies of the real system can be assessed (Stave, 2002).

The presentation process should begin and finish by the system perception. Figure 1 shows 7 levels of modeling and their direction paths (Stereman, 2000).
In fact, the nature of modeling is in the manner that each change affects the process of the guideline accomplishment and goals opportunity. This impact shall be identified in a dynamic environment. In other word, the model will test these guidelines by performing the needed guidelines in a virtual place aiming at goals opportunity. At last, it identifies the suitable guideline.

RESULTS AND DISCUSSION

Indicating the impacts using a mathematical model

In this model, there is one relation between both components shown as a transformation function. This function indicates the mutual impacts of the components. Transformation function, in fact, is an index that shows the extent of mutual impact between two components. For example, to identify the impact of component I on component j, it is required to consider both components I and J. The type of impact of I on j is a function of the following three elements:

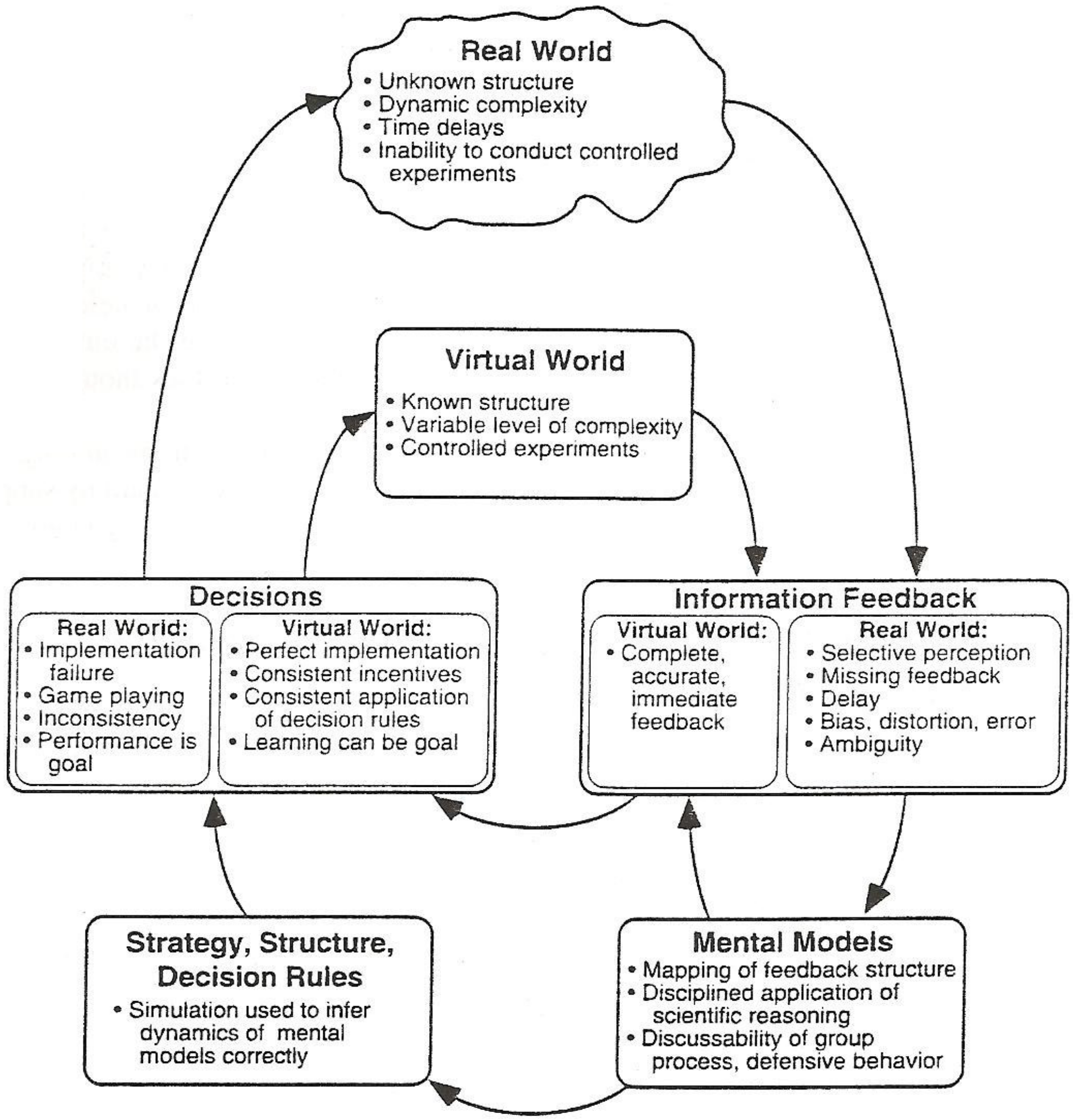

Figure 1. Dynamic modeling levels (Stereman, 2000).

i) The extent of affection on other components.
ii) The duration of the effect (time constant).
iii) The time delay.

To analyze a system three elements must be taking into consideration:

i) Delay in system answer: Time required for the system to respond to an input signal (Figure 2) (Stereman, 2000).
ii) To establish a barrier or a lake, cutting is an effecting factor for the atmosphere. Time delay means that how long does it take to effect on the atmosphere quality after cutting?
iii) Does it effect without delay after operation start or does it take a definite time to show effect?
1. The extent of responding to system: The reaction of the system to the input signal. This can act as a reinforcement, reduction or neutral element (Figure 3) (Stereman, 2000). Utilization of barrier or a lake can be considered as an effecting environmental parameter. Effecting factor in pro-fiting phase is the lake watering and the tourism can be included in influenced factors. The effecting frequency means the intensive impact on the tourism rate.
2. The duration of effect: Required time for the input signal impact to be started in the system and make development? When the time elapses, the developments resulting from the signal actions die down (Figure 4) (Stereman, 2000).
3. Exploitation of a barrier or lake can affect environmenttal parameters, while among these parameters, watering and hydrology are considered as effecting factor and influenced factor, respectively.

The effecting frequency means that lake watering

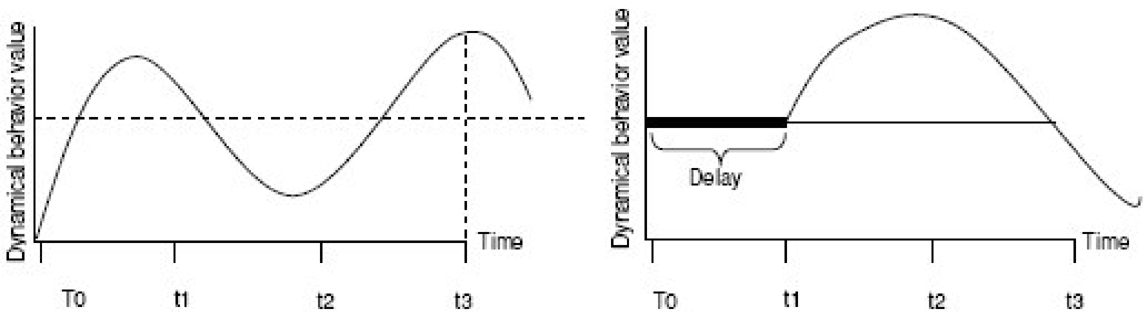

Figure 2. Delay in system's answer (Stereman, 2000).

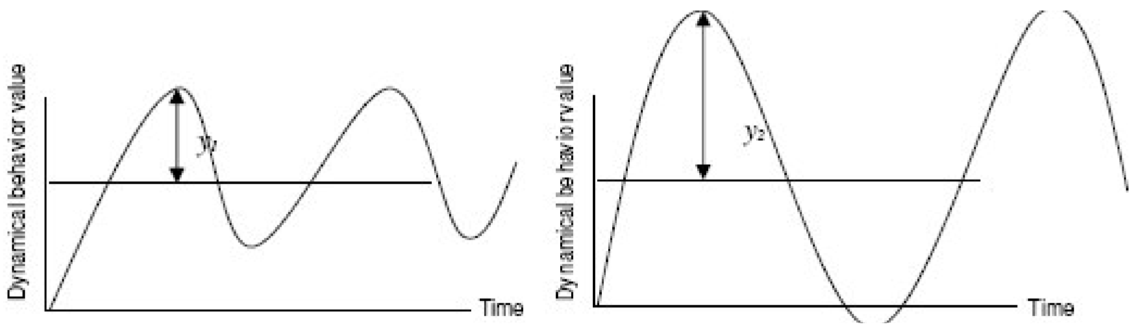

Figure 3. The extent of responding to system (Stereman, 2000).

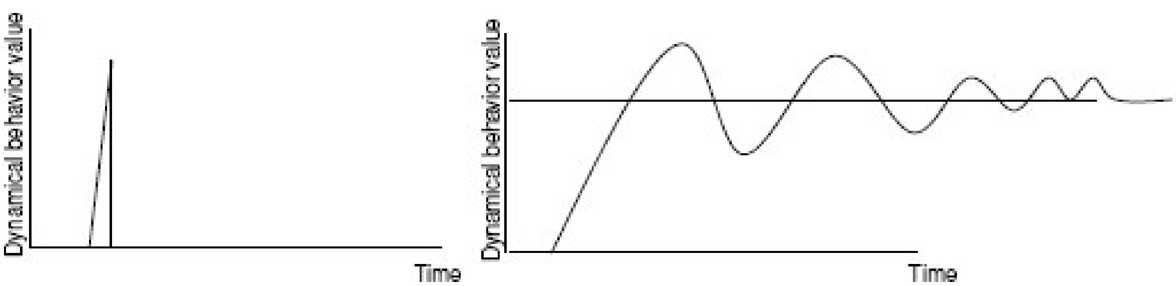

Figure 4. The duration of effect (Stereman, 2000).

effects just the river hydrology in a period of time or lake watering is not based on period of time, but continues in a long time. In fact, if there is transformation function such as G (S) to explain the relation between components I and j, function G (S) shall be a function of the above-mentioned indices. Therefore, transformation function between both components has turned into a Laplace general form in standard function format of first and second degree. They appear as relation 1 and 2, respectively (Figure 5).

$$G(s) = \frac{k}{\tau\delta+1} \qquad \text{relation 1}$$

$$G(s) = \frac{y(s)}{u(s)} \qquad \text{relation 2}$$

Where, K = Extent of affecting, T = Duration / time of effect (time is constant in normal situation), N = affecting vibration frequency (in vibration), S = Laplace variable. Figure 5 shows the output of the transformation function for both cases (Ogata, 1997).

Where the impact of component I on component j is not oscillating, b = V0, then a shows the duration of effect (T). For the other values except V0, a shows the vibration death factor (ξ). In fact, the model is capable of determining the relations between the components.

This model has tested the solutions required to realize

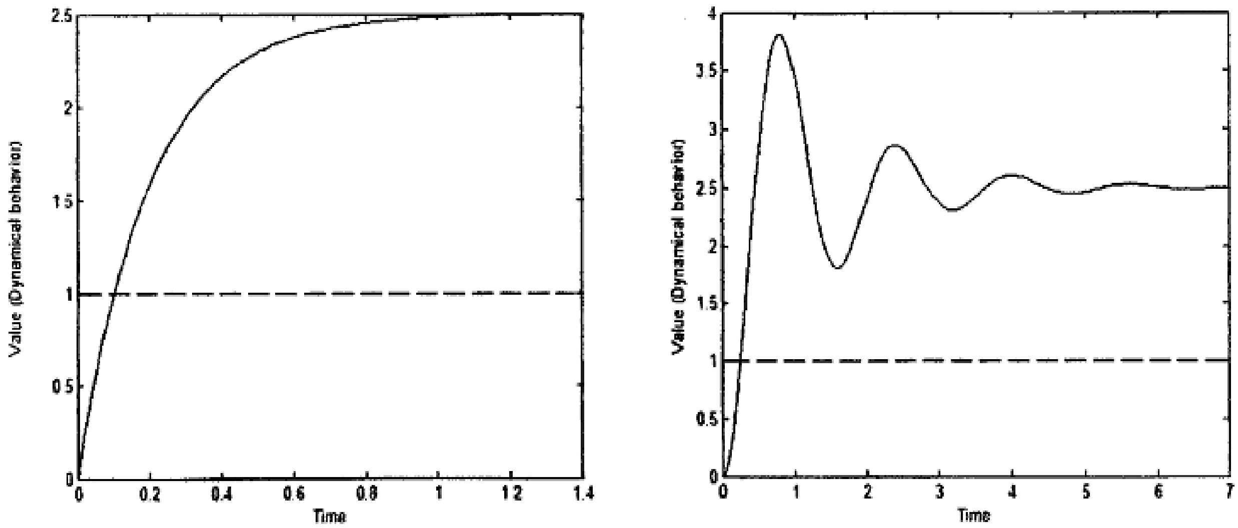

Figure 5. Output of transformation function in first degree and second degree condition vibration (Ogata, 1997).

the necessary goals as simulations and finally proposes the suitable solution. To identify the components, such methods as Delphi method, nominal group technique, analysis methods and other valid methods are required to be applied. For instant, during the construction of man-made lake in western Tehran (Chitgar lake), related activities lead to destructive environmental consequences. Among the resulted consequences, excavation can damage soil and flora. Such impact does not have chronologically frequency and is not vibrating / oscillating.

After all calculations are done, the system should be simulated based on the internal components of the system and their relations. The components can be divided into three categories:

1. Input components which include controllable variables.
2. Output variables which show the goal of the system and are considered as decision.
3. Medium components which have interaction with input and output components and play a role in implementing the simulated model.

After modeling of system, the different strategies should be tested and deciding-making should be done based on simulation model results. For this purpose, following stages should be carried out sequentially. At first, the conceptual model and the construction and exploitation phase's activities should be identified and then implemented as this model show exclusive cause-effect relationships among the selected important elements of the system.

The different processes of a system can be described as below: Water of the river and deviation of the water which reduce the water of the river, planting, growth and picking, production, grazing and local plants analysis and birth and death of the fauna. The production growth is a function of the watering rate. The water deviation rate, planting and picking month are determined by farmers.

The local planting production is a function of the water of the river which falls in a habitat. Grazing the plant depends on the plants rate and number of the Fauna. Both birth and death depend on the number of the Fauna. In addition, death depends on availability of gross. This qualitative description can be quantitative using some information like river water. For example, the system behavior would be assessed during 3 years which can be available to show the reality of quantitative model. Figure 6 shows the conceptual model of the water deviation for watering the product on the dynamism of the Fauna under the danger of the extinction in a habitat.

Also comparing these methods with modern tools like dynamic model for environment assessment impact, it can be concluded that using dynamic model for the environment assessment impact will be made possible (Lee, 2006; Conley and Rusu 2005). Also, it will be possible to identify the dynamism among the components in an environmental system and predict the component behavior (Elgar et al., 2001).

Using the dynamic model, the suggested guidelines related to the environment impact assessment can be implemented in a simulated environment and finally the best strategy and decision will be selected (Holman et al., 2003; Ruessink et al., 2001). It is evident that using this method, it is possible to attain a model that behaves based on the real world and inspect the different decisions and politics in the dynamic behavior of each system (Anderson, 2005).

If there are no applicable solutions in each subcategory, there will be two statuses for each solution-perform or not perform (1.0). Different combinations will be performed in the model and the results will be drawn in the form of curves. These carves show the changes of the

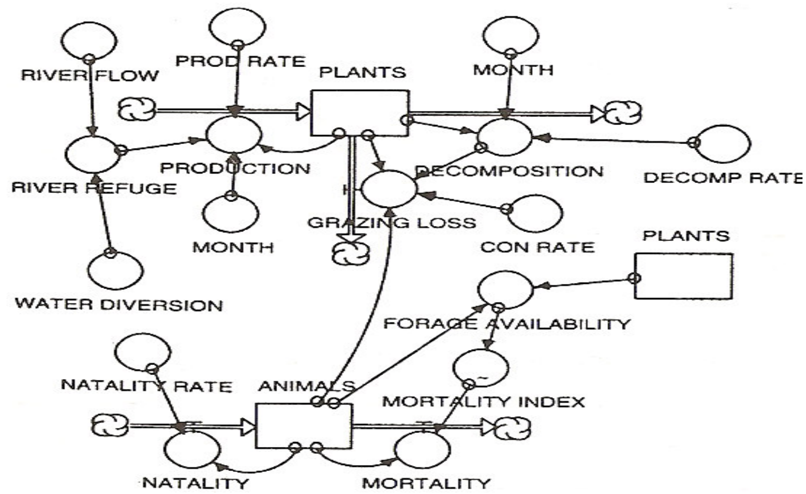

Figure 6. Impacts of conceptual model and water deviation on the dynamism of the Fauna population.

target model within the period of implementation. Thus, implementation of each combination makes some changes in the target model. The model which provides the most access to the goal will be selected as the combination of suitable solutions.

Modeling (simulating) of environmental impacts assessment (For a man-made lake project)

To attain the mentioned goals, there should be some steps repetitively: In Figure 7, the steps of environment impact assessment of man-made lake are shown by the dynamic model. At first, the proposal project (man-made lake construction) operation and construction phase's activities are identified, then they would explain existing environment condition.

To show the comparative impacts among the components, the functions among the components would be identified by the mathematical modeling-finally, after description of the problem and system comprehension, model formulating and behavior analysis, assessment, designing and policy analysis would be accomplished. For example, for the assessment of the man-made lake construction impact by a dynamic model, at first, the related activities to the construction phase such as cut and fill, purifying the operation environment, road establishment and development should be identified.

Then, the influenced environment components, including physico-chemical, economical and social environment would be determined. Also, to determine the relationships among the components, expert's opinion should be used and it helps to identify the relationships in the modeling among the components. For example, cut and fill can affect quality of water.

After that, the transfer function of these impacts would be recognized in the environment impact assessment. The identified components would be categorized in 3 groups. The first group is the controllable variables for decision-making which are among the input components. The second one is the uncontrollable variables. The third one is the output components, which indicate the system goal. There are same controllable variables such as road construction and cutting in the related activities to the construction of man-made lake.

Also, there are some uncontrollable components in the environment such as district and the environment plants. At last, after finalizing the system modeling, different strategies should be tested in the model. In the impacts assessment process of the mentioned project, different decisions are considered: lake construction and non-construction strategies which can be tested in the model and be decided based on the simulation results. At last, related different forms of the selected guideline in the model would be accomplished and results are shown by some curves.

Conclusion

Based on the recognition of the most important methods for the environment assessment and the inspection of advantages and disadvantages, also comparing these methods with modern tools like dynamic model for environment assessment impact, it can be concluded that using dynamic model for the environment assessment impact will be made possible. Also, it will be possible to identify the dynamism among the components in an environmental system and predict the component behavior.

Using the dynamic model, the suggested guidelines related to the environment impact assessment can be implemented in a simulated environment and finally the best strategy and decision will be selected, It is evident that using this method, it is possible to attain a model that

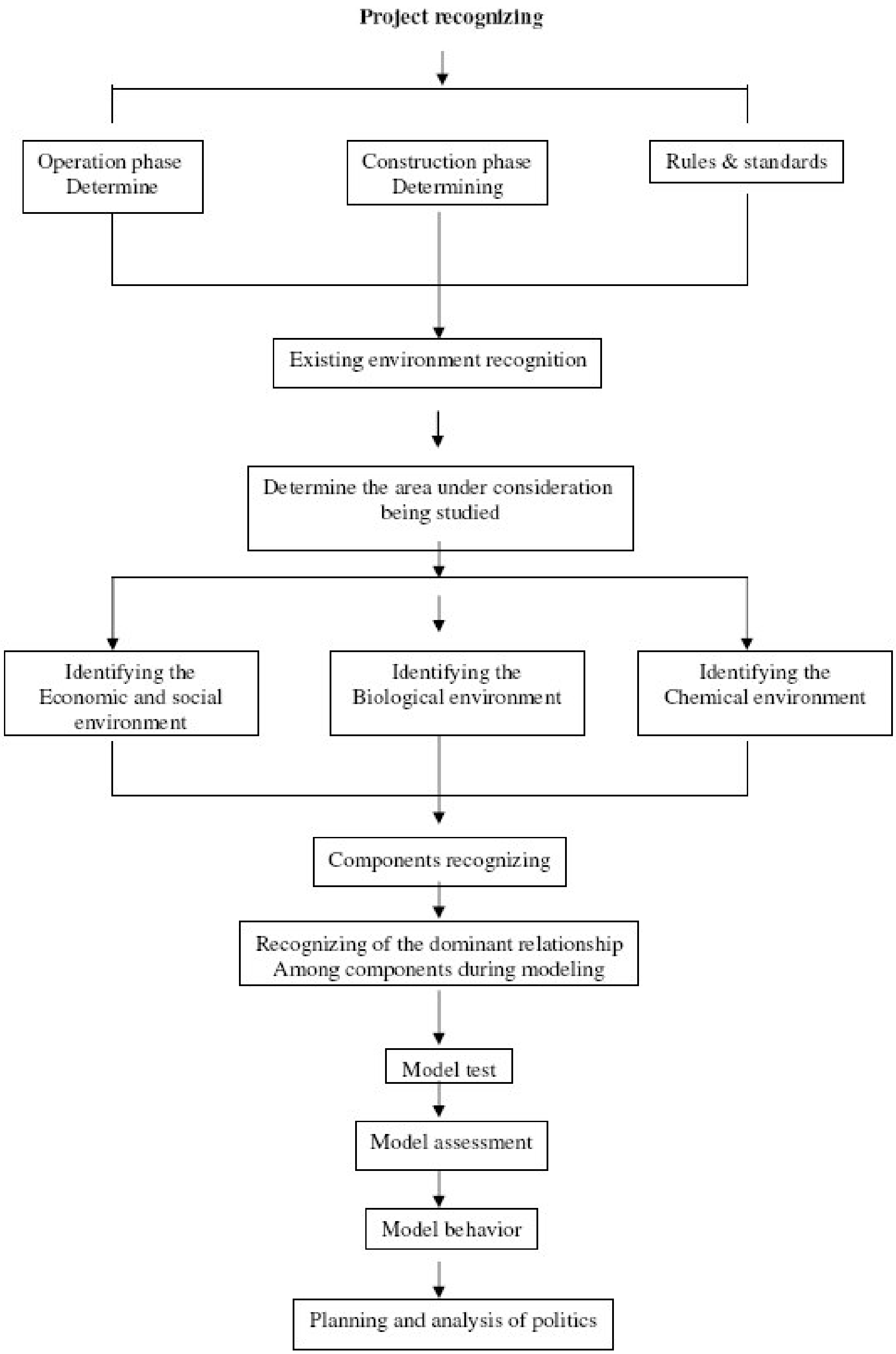

Figure 7. Assessment algorithm of the environment impact using the dynamic model.

behaves based on the real world and inspect the different decisions and politics in the dynamic behavior of each system.

In this research, a model for the environment impact assessment based on the dynamic behavior among the internal and external components with the problem solving approach is presented in which the relationships among the model components shall be determined using the experts' opinions. In fact, the presented model is able to recognize the relationships among components. It is also able to show variables behavior during each component changes. It also shows the influence on the components during the time and changes. Therefore, it can provide a criterion for the environmental experts to identify the best impact in the environment and be much more successful in the environment assessment.

Generally speaking, advantages of this model compared to the other methods can be described as follow:

1. In the dynamic model, effects can be specified for a time period, so it is useful to analyze phenomena, effects of which are known during a period of time.
2. In the previously introduced models, relations between effective elements of the system have been removed, so a cause and effect system is not considered between the elements. This is why such effects can cause many changes. In the presented dynamic model, these relations have been considered using a cause and effect relation between elements.
3. In most of classic models, the analysis of cases and scenarios is not possible after collecting viewpoints of experts, while the model which has been presented in this article gathers experiences of experts in a model. So, analyzing the scenarios and related sensitivities will be made possible.
4. In the previously introduced models, both those which are based on mathematics and those which act based on the AHP pattern, the model can not be used through changing variables and elements, so data will be related to a specific field and hence it can not be extended to other similar projects.

Thus, the presented dynamic model offers a general framework for other similar projects and it is only needed to localize special conditions. Therefore, flexibility and extendibility are among features of the presented model.

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