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Use of data mining and neural network algorithms to optimize the implementation of value engineering in projects

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Abstract

The value methodology that is commonly known as "Value Engineering" is a systematic group problem-solving method that has been used for more than fifty years. In a brief review of its application process, consisting of three steps of pre-study, value study and post-study, it is inferred from its structure that various types of knowledge are created during the cycle of its implementation. Due to the different nature of the process of a value study and the resultant production of various types of knowledge with a different structure, we need to use strategies that help us to discover and extract a variety of knowledge. Data mining is one of the strongest knowledge management techniques that contributes to this matter. In other words, it is possible to create a system for discovering, extracting, storing and retrieving a variety of knowledge in value studies by using the concepts of data mining.
This research tries to find methods for discovery, extraction, storage and retrieval of all kinds of repeatable knowledge of value studies that are known as the outcomes of value studies with the data mining approach and using its concepts and one of the most powerful tools of this technique i.e. neural networks.

Keywords
Value Engineering, Data mining, Neural Networks, Feature and Decomposition

1. Introduction

More than half a century has passed from the first use of value methodology (including value study, value engineering, value management and value planning) to raise the value of projects and so far thousands of value studies have been done in the world. Because of the nature of this approach throughout any value study, information, innovative strategies and valuable knowledge- which are called the outcomes of a study in this article - are produced by a team of experts. Nevertheless, any new value study or planning, designing and implementing a new project is carried out without regard to the repeated outcomes of prior value studies and only the experiences and tacit knowledge of some of the team members present in the previous studies who participate in new project or value study can be used. Therefore, the problem-solving processes in value studies heavily depend on the experiences and attitudes of team members that can be influenced by various factors.

In this paper, it attempts to take steps to improve the value studies and develop the user domain by data mining concepts and the application of the neural networks. In this regard, first, the outcomes produced in a value study that can be used in the future for a variety of purposes are introduced by phase-to-phase analysis and value engineering steps. Then the uniqueness of the value study is discussed and solutions are provided to overcome the problem of using the outcomes of the study. Then a simple database is designed for classifying and categorizing the extracted

outcomes. In the final step, using artificial neural networks an intelligent method for database retrieval is described for future uses to provide the best results.
This paper looks at the principles and guidelines that maintain the efficiency and usefulness within it while improving the value engineering for future targets.
The data mining approach to value studies and the application of neural networks in the field of value engineering is addressed for the first time in the history of engineering and value methodology based on the conducted analyses.

2. Statement of the problem

Given the main purpose of the paper which is to create a system for the collection, storage, and optimal reuse of the outcome of previous value engineering studies for future use, the main issue of this study can be summarized as follows:
Definition of the problem: Solutions for using outcomes generated in previous value studies to use those results in future studies:
As mentioned in the definition of the problem, this research seeks discuss the related contents to prevent the threat of outcome loss and to improve future value studies.
Implementing a value study for any project or plan is not cost-effective; in fact, value studies are carried out for large-scale projects and plans with high costs to achieve the desired efficiency. A large project or plan consists of several minor projects, so when value studies are implemented for a large project, some subsets and minor projects are addressed automatically. The important thing is to extract tips and outcomes for those smaller subsets and projects from the mother projects (including the similar subsets) if one of the smaller subsets and projects wants to be designed and constructed elsewhere.

3. Time to apply value engineering

Whenever it comes to planning for a new product or project or an existing product or project requires some modifications, we should consider the use of value engineering. In other words, when a project does not follow the plan, or when one of the parameters or project objectives is not realized, a value engineering method is used to guide everything into the right direction. Ideally, value engineering should be implemented in the early stages of the project, where no commitment has been made. This makes it possible to use value engineering by recognizing the exact functions and expected performances of the product or project and with its maximum potential [1].
Figure 1 shows the graph of the relationship between time and cost and the occurrence of problems. As can be seen in this diagram, the beginning of the project or plan (where not much time has passed since the start of the project and high costs is not spent) it is best to avoid problems and eliminate them. With the advancement of the project, when it comes to the final stages before operation, the number of problems is increasing, and consequently, more expense should be spent to eliminate them.
After implementing the project any changes are subject to very high costs and problems. So according to Fig. 2 the best time to apply value engineering is the very beginning of the project.

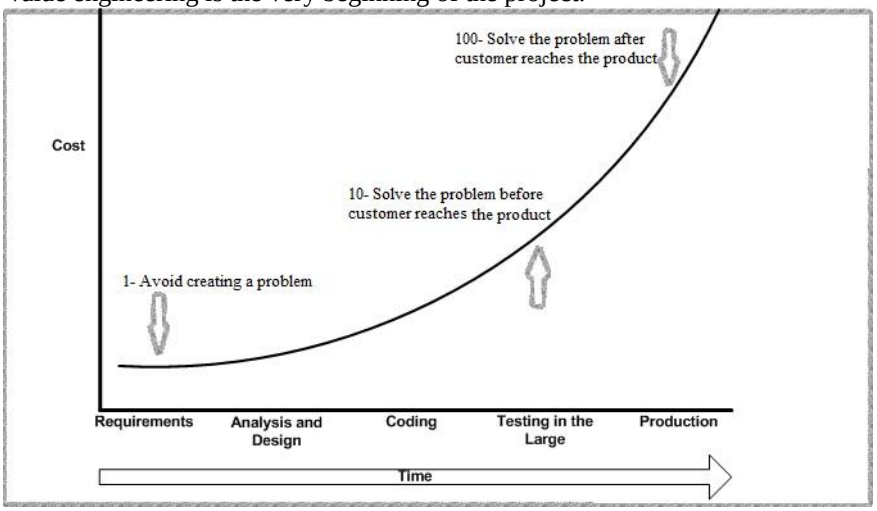

Fig 1. The relationship between time and cost in problem solving

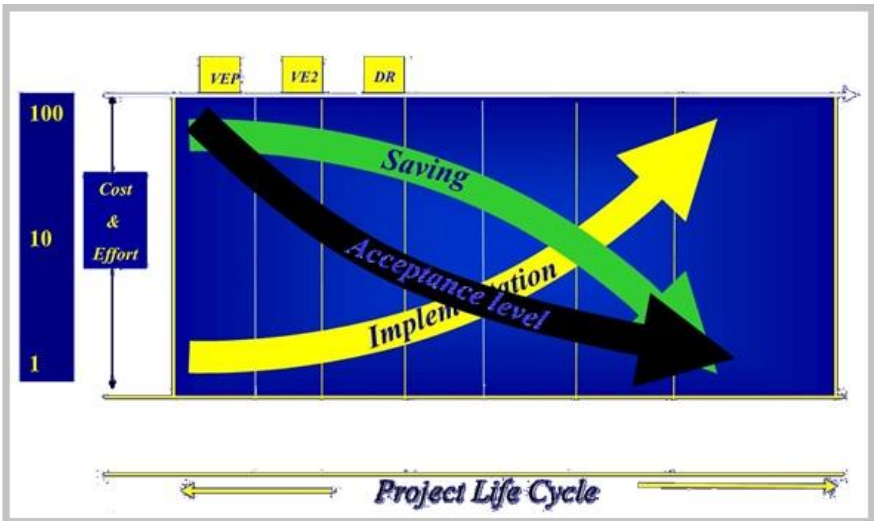

Fig2. Relationship between cost of VE and Project Life Cycle

In the early years of the project life, (at the time of planning and analysis), the cost of conducting studies is very low and the savings resulting from the use of engineering value is very high. As the project progressively moves forward, the cost of studies is increased and the potential for savings is reduced. According to the figure 2 in the construction phase of the project, as shown in the figure 2, the cost of applying changes to the studies suddenly increases and the cost-saving potential of the engineering value decreases significantly [2].

4. Value engineering job plan

The job plan is a systematic process and it is a framework for all the necessary activities of value study. Adherence to a specific plan leads to the most possible valuable results.

Various methods have been proposed for conducting value-engineering studies in various sources the most comprehensive of which is a three-step methodology (presented by the Society of American Value Engineering (SAVE)) as follows:

1. Pre study: The preliminary activities of value engineering a project is carried out in six areas including: collection and definition of the needs and demands of the employer/user, collection of complete information from the project, determination of evaluation criteria, determination of the scope of studies, construction of the necessary models and determining team composition.

   The above activities are carried out by an initial team. The composition of this team for the rest of the studies is determined by the information obtained from the project and the scope of work as well as the clarification of the study lines at the end of this phase.
2. Value Study (Workshop): A value study is performed following the initial stages of the value methodology in 6 phases of information, function analysis, creativity, evaluation, development and presentation.
3. Post study: The purpose of the post-study activities is to ensure the implementation of the changes. Certain changes to the proposed project may take place after the study stage where the task of experts of the value engineering team or other experts approved by the management is to prepare and provide a complete executive plan based on the changes.

The leader of the methodology team follows up on the progress of implementation and the designer has an executive responsibility. Each selected option must be designed independently and the required contractual changes must be identified and approved before the execution. In addition, it is suggested that the financial sectors perform the required evaluations from all the benefits of project value studies for management certification and approval.

Post-study step: This step involves the preparation and completion of the final report and the formulation of future programs. This step usually takes 3 to 4 weeks [3].

5. Data mining

Data mining is the extraction of knowledge from data and this is possible through discovery of patterns in data related to the past behavior of processes. Data mining tools predict future behaviors and trends and allow organizations to make more informed decisions. In fact, data mining tools provide responses to questions that required a long time to be answered [4].
Simultaneous data mining utilizes several disciplines such as database technology, artificial intelligence, machine learning, neural networks, statistics, pattern recognition, knowledge-based systems, knowledge acquisition, information retrieval, high-performance computing, and data visualization. Although the algorithms discussed above have existed at least at university level, but data mining in business has been discussed in recent years. Since 1990, the set of factors has been developed at once which did not exist at the same time before. This has led to the emergence of data mining algorithms in business areas. Some of these factors include:

- ✓ Mass and continuous production of data
- ✓ Data warehouse
- ✓ Increased computational power
- ✓ Increased competition
- ✓ The emergence of commercial data mining software products [5]

6. The outcomes (knowledge) generated in each of the three stages of value engineering

6.1. First stage (pre-study)

Some of the pre-study activities are as follows:

- Specifying the needs and desires of the employer, users and project customers
- Identification and collection of project information
- Developing a cost model
- Providing study planning and the need for support staff and... [6]

This information is limited to the scope of the project being studied and is less generalizable. Therefore, in the preliminary stage, there is no new knowledge (because it already exists) or in other words this information and knowledge is specific to the specific conditions of each project.

6.2. Second stage (value or workshop study)

At this stage i.e. the workshop study, the value study is the most sensitive and important part of each study. Society of American Value Engineering International (SAVE) has proposed six phases as a job plan for value study [6].

1. Information Phase: The main objective of this phase is to complete the information collected in the pre-study phase. This phase identifies the components of the project and defines the sub-systems of each project which is the basis for the next phase i.e. the function analysis phase. This identification and diagnosis of components as well as sub-systems and sub-components of each component can be considered as one of the important information created in the value study.
2. Function analysis phase: If we consider creativity and teamwork as the soul of value engineering, the function analysis is its heart. In fact, this functional approach in value methodology distinguishes it from other improvement methods and techniques [6].

The purpose of the function analysis is to analyze and develop the areas that value study is more effective on them; the following cases are the study team actions in this phase:

- ✓ Identifying and determining the functions of each project or process
- ✓ Classifying functions into two primary and secondary general categories
- ✓ Designing a functional model
- ✓ Mapping a Function Analysis System Technique (FAST)
- ✓ Cost allocation and / or other measurable measures and counting for each function

- ✓ Comparing the cost of functions to determine the best improvement approach
- ✓ Choosing the right application for analysis

Functions can be considered as one of the most important information and outcomes of each study. Functions are defined according to the following goals and usually are defined as two different types including:

A) Definition of the function from the consumer's perspective
B) Function analysis based on components or specifications [6]

In the standard form the definitions functions, components, and main features of the project are written in the macro level and then their components are specified and defined for those components, features or functions or the functions are discussed for the main project (function from the consumer's perspective) [7].

3. Creativity phase: In this phase, the goal is to generate multiple ideas to operate each of the selected functions at the end of the function analysis phase. This phase is referred to as the spirit of value engineering because it has a decisive role in obtaining effective and efficient results from value methodology [8].
4. Evaluation phase: During the evaluation phase, ideas generated in the previous phase are analyzed and ideas are selected for further development. In fact, the goal of this phase is to evaluate the proposed ideas, eliminate inappropriate ideas and select the best options.
5. Development phase: The goal of the development phase is to provide the best option for improving the value of the ideas selected in the previous phase. The best options are obtained by the selection and combination of the best solutions in the evaluation phase [8].
6. Presentation phase: The purpose of the presentation phase is to present the results of the value study by the group and to ensure the clients including the project designer, the project stakeholders, and other executive directors about conducting the description of the study services and agree on the operational of the recommendations provided by the value team. This will be done by physical and oral presentation of the results and providing a written report. Reports do not necessarily have the same structure, but the following 18-clause list is commonly used [8].

6.3. Third stage (post study)

The goal of this stage (sometimes also referred to as the implementation stage) is to implement the recommendations that are approved in the studies recommending value engineering and are taken into account in the scheduling of the final design. The employer usually follows the implementation of the selected scenario and the summary of the goals of the report. Therefore, no outcome can be imagined at this stage.

7. Eliminating the uniqueness of the value study of each project through the decomposition of value studies

Before addressing the retrieval and effective use of the results and outcomes of each study, first it is necessary to the limitations of the uniqueness of the value study of each project (in other words, there is a view that each project is unique, and, in the end, its value study is unique). In fact, the main goal is to look at a value study from a perspective to access its outcomes in the best and fastest way in future. If this limitation is resolved, it is possible to benefit from the many advantages and disadvantages of the outcomes of each study and use those outcomes to make them more useful and, consequently, to improve and develop the value study.

In the previous section, all steps of a value-based study are analyzed and the outcomes that can be found at each stage and phase are mentioned. The summarized outcomes are as follows:

- Information on the components and features of the project for value study;
- Information on function analysis phase and functions defined for the whole project, components and project features;
- Screened ideas of creativity phase at the end of the evaluation phase along with the advantages and disadvantages of each of them;
- Recommendations extracted from ideas within the evaluation phase;
- Top scenarios and options that are presented in the development phase.

The main source of all outcomes is the subject of the project and its main components and features as well as the sub outcomes of the main components because the function analysis phase and the other stages of the value study are implemented for each of them.
If value studies are divided into different components, it is possible to overcome the uniqueness of the value study of projects. Although each project has its own specific features and constraints, its main components are recurring components that are commonly used in other projects. Therefore, using a subsystem view to any complex system in addition to fully understand the features of that project, it is possible to overcome the unique constraints of the project to a large extent.

8. Investigating the relationship between outcomes and value study decomposition

There is a chain relationship between the outcomes of a value study and the method of decomposing value studies into components and features, and the value study decomposition not only does not disrupt the expected outcomes of the value study but it makes it possible to relate the outcomes of the value study described in the previous sections to the components and features identified by the value study decomposition and categorized those outcomes. This results in a very good organization of the outcomes of each value study based on decomposition.

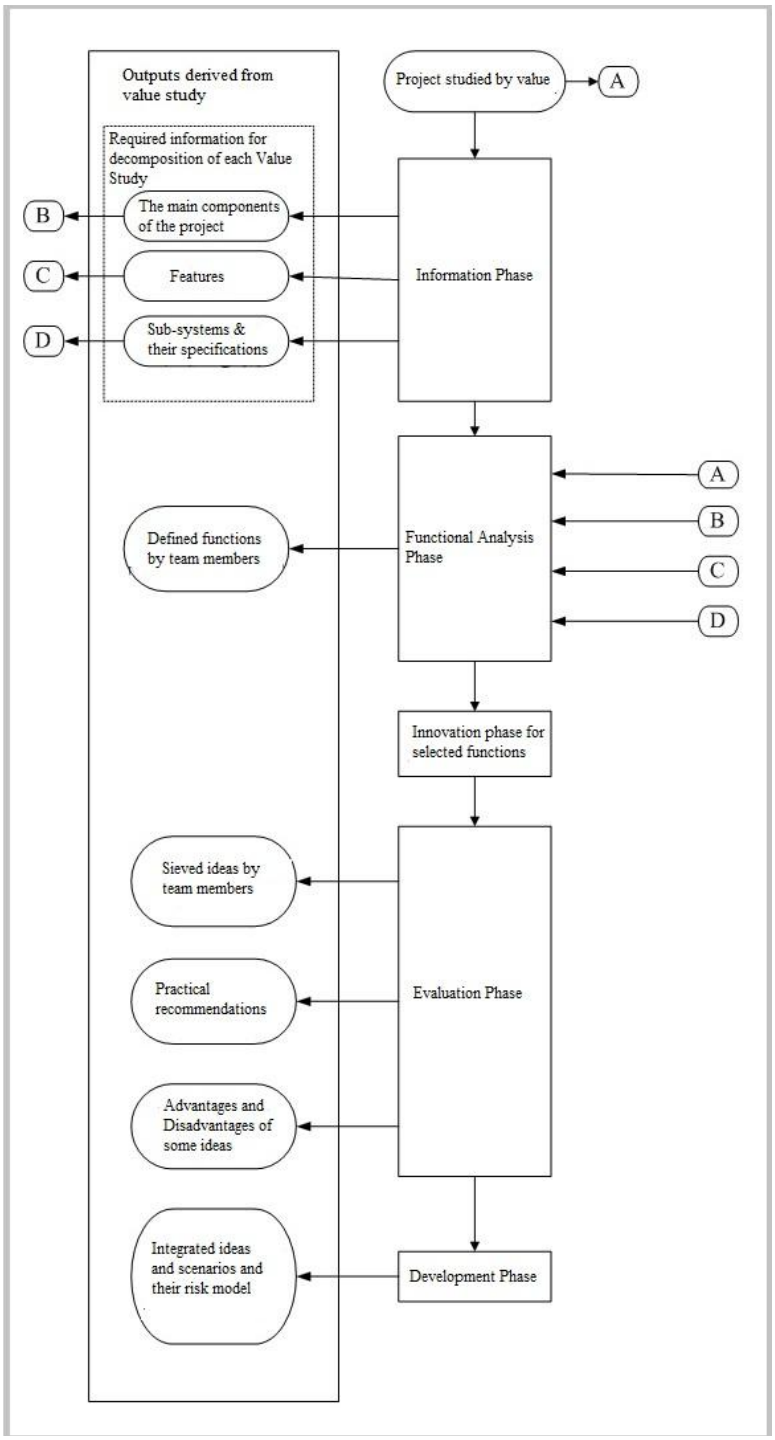

Fig3. Output production process using the method of decomposition of studies

9. Defining the neural network

Different researchers and experts working in the field of neural network have presented various definitions of the neural network. Common points are mentioned in all of these definitions which are in fact the components of the neural network which include processor units, connections, and functions that affect input signals. Some of these definitions are presented below:

Hykin (1999) defines the neural network as follows [10]:

In general, a neural network is a machine that tries to model a method through which the human brain performs a particular task. Neural networks are parallel processors that are made up of simple processor units and are willing to store empirical data and make them available for future use. Thus, artificial neural networks are similar to brain in to two ways:

1. The required information by the network will be obtained through a learning process
2. An estimate of the strength of neuronal connections weights is used to store information in the form of synaptic weights.

Fausette also defines the artificial neural network as follows [11]:
An artificial neural network is an information processing system that has specific functional features that are shared with biological neural networks. Artificial neural networks are a generalization of mathematical models of human perception biological neural network based on which the following hypotheses are included:

1. Information processing occurs in simple processor elements called neurons;
2. The signals are transmitted through the connections;
3. Each connection has its own weight multiplied by the transmitted signals
4. Each neuron transmits its net input (total input weight signals) through an activity function.

A neural network is distinguished from other networks by its three distinct features:

1. A pattern based on which connections formed between neurons. This pattern is called structural connection pattern.
2. Determining the weight method called learning algorithm or training algorithm.
3. Its activity function [12].

10. Advantages of Artificial Neural Networks

1) Nonlinearity: a synthetic neuron can be linear or nonlinear. A neural network consisting of nonlinear neuron connection is nonlinear. This feature is one of the important features of the neural network.
2) Input-Output Mapping: this feature is also referred to as learning capability. A typical example of network learning is the learning with teacher or supervised learning. In this process, the weights of the neural network connections are improved. Accordingly, the network learns relationship between input and output non-parametrically.
3) Evidential response: In the classification of the patterns, a neural network can be constructed in such a way that not only provides information about the particular selected pattern but also is responsive in relation to the confidence in the choice made. This confidence is used in rejecting vague patterns.
4) Parallel processing: When a neural network is implemented in the form of hardware, cells that are aligned at the same level can respond to its levels simultaneously. This feature increases processing speed. In fact, in such a system, the overall task of processing between smaller processors is distributed independently.
5) Processing of contextual information: information is provided by the structure and activity status of a neural network. The learning material of a network is hidden in synaptic weights. There is no one-to-one relationship between inputs and weights. It can be said that each weight belongs to all inputs, but it does not belong to any of them individually. Therefore, each neuron in the network is heavily influenced by the total activity of the neurons in the network space. As a result, contextual information is processed by a neural network.
6) Faster provision of the response (learning): this feature will appear after network training. Neural networks are trained by examples and provide the response based on their generalizability as quickly as possible in comparison with traditional methods.
7) Fault tolerance: In a neural network, each cell operates independently, and the overall network behavior is the outcome of local behaviors of multiple cells. This feature hides local faults from the final output. This means that the network performance is constantly improved in a variety of conditions and is therefore robust against faults.

8) Generalization: after network training the network is able to encounter an untrained entry and provide an appropriate output. This outcome is achieved based on the generalization mechanism which is the same as interpolation process.
9) Robustness: the main advantage of using the neural network in each of the above problems is the extraordinary ability of the neural network to learn as well as the stability of the neural network against the negligible input disturbances. For example, if normal methods are used to diagnose the a man's handwriting, they may have a false diagnosis due to the slight hand shake while an appropriately trained neural network will achieve a valid while even in such discrepancies. This feature increases the robustness (fault tolerance) in the system [13].

11. Network Learning

Among all the important features the learning capability is of great importance which is discussed in this section. As learning systems, the neural networks have the ability to learn from the past, experience and the environment and improve their behavior during each learning process. Improvement in learning over time should be measured based on a criterion. The improvement criterion models the learner system's target. The learning rule here is the process by which the weight matrix and bias vectors of the neural network are set. The goal of the learning rule is to train the neural network to perform certain tasks, in other words, the neural networks become more aware of the environment, the conditions and the purpose of their task after each repetition of the learning algorithm. The type of learning is also determined by the process by which the network parameters are set.
But when a neural network changes and improves its behavior in a shared way, not independently as discussed for a single neuron, each neuron changes its corresponding weight vectors in accordance with its own learning rule. In this case the data source environment of each neuron is not constant but changes by altering the weight of other neurons. Neural network learning has many different types that are discussed below [14]:

10.1. Supervised learning:

In this method the answer to be achieved in training stage is specified for the network. With the presentation of the data, the results or responses related to them are also presented to the network and the network compares its output with the results in each replication and approximates its predictions to these results by changing weights; in other words, in this method the answer is defined for the network [14]

11.2. Unsupervised learning:

In unstructured learning or self-organized learning, the neural network parameters are only set by the system response. In other words, the input vectors form the only received information from the environment by the network. Compared to supervised learning, no optimum response vector is applied to the network. As discussed in the previous section, the neural network does not receive any examples of the function to be learnt. The competitive learning rule that is not included in this discussion is a kind of unsupervised learning. The unsupervised learning is too slow for networks with a large number of neurons and in this case a combination of supervised and unsupervised learning is suggested [14].

12. Neural network training method for database

The application and training of the neural network is based on considering the defined values of the features for the samples in the main branch as the input and the number of each sample as the outcome. Then the network is trained.
Regarding the classification of functions into two main and secondary parts in this phase, it should be noted that this categorization varies with respect to each project and its conditions and this classification cannot be considered as created information.
Functions are defined according to the following targets and usually are defined as two different types:

A) Definition of the function from the perspective of the consumer
B) Function analysis based on components or features [15]

The point here is the definition of functions based on each component, subcomponent and features. In the workshop, after reviewing the team members' information the main components of the project or product are determined from a macro level perspective.
In some cases, the division into components is based on the various functions of the project (from the consumer's perspective) or the classification is done according to the physical volume of the hardware of the project and other

possible situations. This breaking is performed more easily using the WBS[1] and the breaking structure found in the project planning and control units [4]. In fact, in the standard form of defining the functions as stated in Fig.3, the features and components are written in the macro level and then the components are defined and the functions are defined for those components or features or they are defined for the main project (function from the consumer's point of view) [16].

13. Designing a simple database and the necessity of using neural networks in it

Now a database is established by dividing a value study into the component and feature project (i.e. a project from a consumer perspective) that can store the outcomes and it is possible to provide these outcomes with a simple search on each part. In other words, using the decomposition of value studies into the components, features and project itself (from a consumer perspective) and identifying the outcomes associated with each of them in value studies, it is possible to create simple databases the main parts of which are those obtained from decomposition. Also whenever a new section with its outcomes is obtained by value studies it is possible to quickly transfer it to the database as an essential part to be used in the future.

The database is defined as the main branch for designing. Each main branch has a main title. These titles are defined in two ways one is the title of a project which is subject to value engineering and the other is subject to value study by the main components and features provided that they are not already included in the main branches.

Of course, it should be noted that for any ground of value engineering projects a relevant database should be defined in the same field. The drawback and problem with using this simple database is to use a common search for the outcome of value studies. When searching for a new project, if the number of samples in a header is high; first, the study of all those cases is time-consuming and secondly choosing the sample similar to the new item is difficult and confusing. Accordingly, it is not possible to choose a similar case regardless of some conditions. So in addition to the work conducted so far to improve and develop the value engineering, it is required to look for a solution that can search the database intelligently and automatically and estimate and provide the best option through the similarity and overlap with the new project.

After various studies of various types of tools, neural networks were selected for intelligent usage and estimation of the created databases. The key to choose it is in minimizing the need for changes to the database structure as well as eliminating the need for changes to processes within the system.

All the materials presented about the job plan and outcomes of a value engineering study, decomposition of a value study, storable data in a typical database and the use of the neural network in the database are summarized in Fig.3.

[1] Work Breakdown Structure

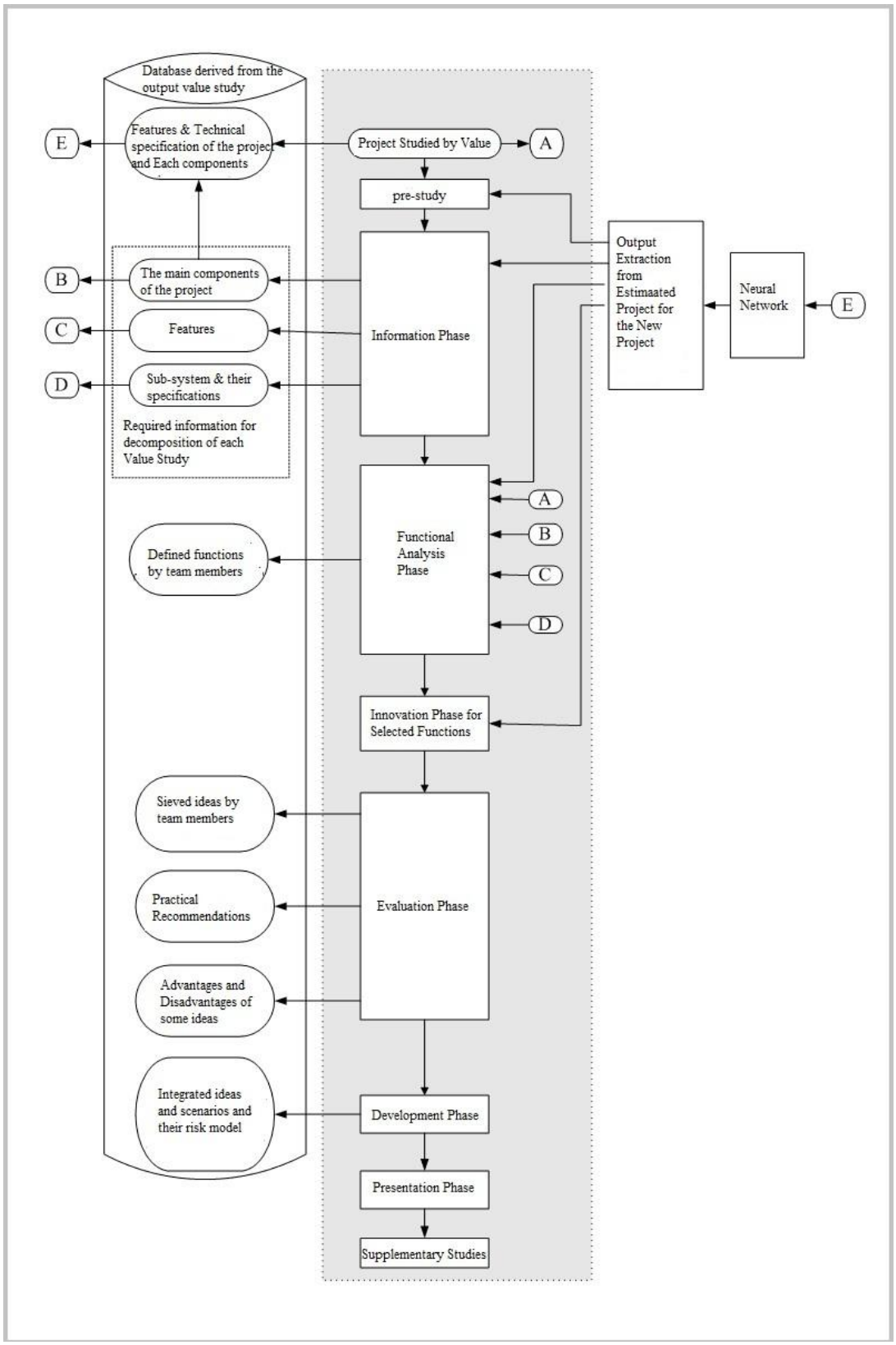

Fig4. The process of value engineering using a graphical neural network

14. Conclusions

We attempt to design and use a systematic model for the management of value studies' knowledge using data mining concepts. Using this systematic and purposeful model can remove the value studies from their traditional state and increase their efficiency either in terms of raising the value of each project or in terms of creating the ability to extract, record and retrieve the experts' experience, skills and opinions as the team member of any value study. Accordingly, some effective results are as follows:

- ✓ The most important result is meeting the main research problem i.e. "the lack of strategies to use the generated outcomes in previous value studies to use them in future applications".
- ✓ Contributing to implement value studies and increasing their efficiency: Using the results of this paper it is possible to overcome the difficulties and limitations mentioned above by using the outcomes of previous value studies that have a connection and overlap with the new project. Accordingly, in each of the mentioned phases the information and necessary elements of that phase are provided as a primary feed for the team members leading the effective use of time in a value study.
- ✓ The transformation of tacit knowledge of experts and elites in multidisciplinary team (that provide this tacit and experimental knowledge in different phases of a value study) into applied and objective knowledge.
- ✓ Expansion and development of value engineering for smaller projects where best specialists are absent it is possible to use their respective views and experiences.
- ✓ Creating an intelligent system for organizations and ministries where the employers have large projects as well as the design consultant firms so that they can estimate the prior value studies that are relevant to their project based on the designed database.

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