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R&D PROJECT SELECTION BY INTEGRATED GREY ANALYTIC NETWORK PROCESS AND GREY RELATIONAL ANALYSIS: AN IMPLEMENTATION FOR HOME APPLIANCES COMPANY

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ABSTRACT
For many firms, the key to improve competitiveness is their ability of research and development (R&D);therefore the R&D project selection is an essential decision process for them. In this study, we worked on R&D Project Selection issue and performed an implementation for a home appliances company. Wefirst discussed important criteria for R&D projects selection with R&D specialists in the company. Inorder to evaluate projects, many criteria, containing various sub-criteria were determined via extensiveliterature research. After reviewing multi criteria decision methods in order to handle theinterdependencies among the criteria and the sub-criteria, Analytic Network Process (ANP) was chosen.Due to being conformed to characteristics of R&D projects, the ANP model generated basing on greynumbers. Also, ANP was used to get the weight of criteria. The experts filled the pairwise comparisonmatrices, which were built up for defining the importance and influences of the criteria/sub-criteria inthe ANP model. According to these matrices, weights were determined. Then, determined alternativeprojects were ranked via Grey Relational Analysis (GRA) method. The model was applied on a real liferefrigerator projects in a home appliances company.

Keywords: *R&D Project Selection, Grey Analytic Network Process, Grey Relational Analysis.*

GRİ ANALİTİK AĞ SÜRECİ VE GRİ İLİŞKİSEL ANALİZ İLE ENTEGRE EDİLMİŞ AR-GE PROJELERİNİN SEÇİMİ: EV ALETLERİ ŞİRKETİNDE BİR UYGULAMA

ÖZET
Araştırma ve geliştirme yeteneği bir çok şirketin rekabet etme gücünü arttıracak önemli bir faktördür. Bu nedenle Ar-Ge projelerinin seçimi şirketler için temel karar sürecidir. Bu çalışmada, Ar-Ge projeleri seçimi üzerine çalışılmış ve bir ev aletleri şirketinde konuyla ilgili bir uygulama yapılmıştır. İlk olarakAr-Ge uzmanlarıyla birlikte Ar-Ge projeleri seçiminde önemli olan kriterler üzerine çalışılmıştır. Projeleri değerlendirmek için birçok kriter ve bunlara bağlı alt kriterler geniş bir literatür araştırmasıyla belirlenmiştir. Birçok çok kriterli karar verme metodu incelendikten sonra, kriterler ve kriterler arası bağlılığı ele almak amacıyla ANP metodu kullanılmıştır. Bu çalışmada Ar-Ge projelerinin karakteriyle uyumlu olması nedeniyle gri sayılara dayalı ANP modeli oluşturulmuş ve kriter ağırlıklarının belirlenmesi için kullanılmıştır. ANP modelinde kriterlerin ve alt kriterlerin birbirlerine olan etkileri ve önem derecelerinin belirlenmesi için ikili karşılaştırma matrisleri oluşturulmuş ve uzmanlar tarafından değerlendirilmiştir. Oluşturulan bu matrislere göre ağırlıklar belirlenip, tanımlanan alternatif projelerGri İlişkisel Analiz (GİA) metodu kullanılarak sıralanmıştır. Uygulama olarak da bir ev aletleri şirketindeki gerçek buzdolabı Ar-Ge projelerinde bu modele başvurulmuştur.

Anahtar Kelimeler: *Ar-Ge Projelerinin Seçimi, Gri Analitik Ağ Süreci, Gri İlişkisel Analiz.*

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1. INTRODUCTION

R&D project management is one of the most difficult areas in projects management. In today's world, precondition of surviving of a company in highly competitive environment is conducting Research and Development (R&D) projects. Developed countries generally encourage the R&D activities of private sector and government to improve the overall competitive power of the country.

Companies that want to maintain their existence in competitive environment must continually change and develop their products, services and production processes. This is only possible through R&D activities and innovation. R&D activities generally involve scientific and technological uncertainties. Innovations are also unpredictable, and thus involve large uncertainties. Corporate R&D management, supporting the maximal use of new innovations and technologies, always tries to keep the company up with the pace of technological development. R&D projects are tools for the company's management to outpace competitors and obtain new information about promising technologies and methods. With such new information, companies aim to defend and build sustainable competitive advantages [1].

2. R&D PROJECT SELECTION

Around the world advanced high-tech companies are investing R&D projects. R&D projects must be compatible with the company's vision and mission. Such projects should provide benefits for stakeholders, link with the company's expertise and have clear objectives in place along with built-in appropriate evaluation resources and have prospects of sustaining itself. The most challenging tasks areto choose the right projects in order to survive in the competitive environment. The projects that will lead to success should have a positive cost/benefit, provide the organization to improve the chance of success, have futuristic scope and strategic fit on stakeholder involvement [2].

The selection of R&D project is a complex decision-making problem encountered by most industrial firms. R&D project selection requires consideration of uncertain and/or subjective multiple criteria. The selecting and determining relative importance of criteria will differ according to the goals and objectives of the sponsoring organization and the nature of the R&D activity itself [3].

A wide range of criteria and sub-criteria such as strategic fit, capacity, technical success, funding, risks, considerations, opportunity costs, manpower, etc., are used for decision process [2]. Obviously, wrong decisions in project selection have two negative consequences: (1) resources are spent on unsuitable projects and, (2) the organization loses the benefits it could have gained if these resources had been spent on more suitable projects [4]-[5]. Therefore, most companies apply the scientific selection methods that are generally multi criteria decision methods for R&D projects.

An extensive literature review is carried out on the subject of R&D Project selection and evaluationcriteria. R&D project selection criteria available in the literature are categorized into five factors; technical, marketing, financial, environmental and organizational factors. In this study, 12 sub-criteria,which are evaluated by the decision committee, are classified into these five factors. The sub-criteria that are grouped are shown in Figure 1.

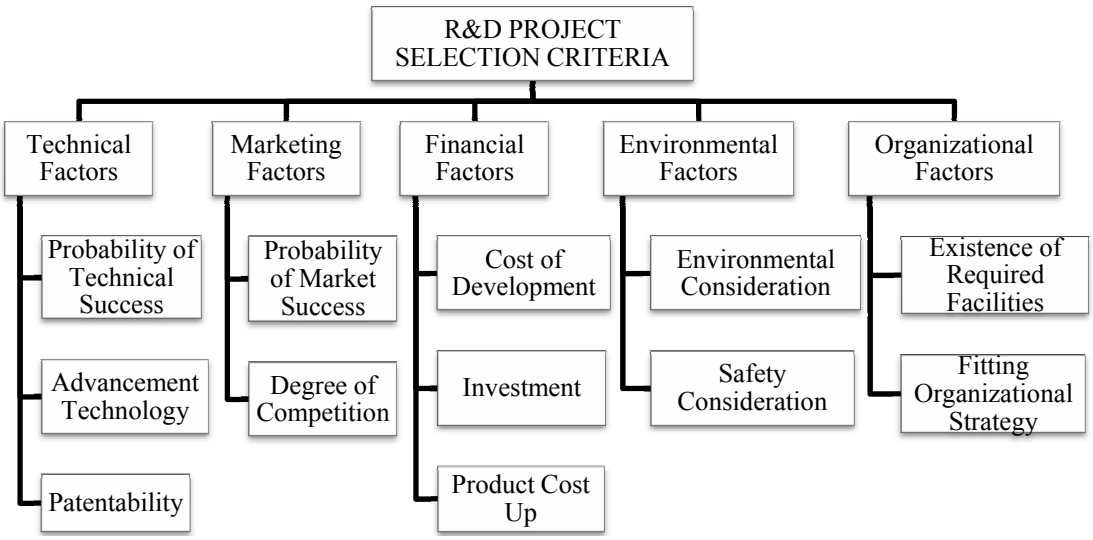

Figure 1. Project selection criteria.

3. MULTI CRITERIA DECISION MAKING METHODS

In this study, multi criteria decision-making methods are used on selecting of R&D projects. These methods can provide solutions to increasing complex management problems. Here, the background information about the used multi criteria decision methods is provided. Firstly, Grey System approach is explained. Then, Grey Analytic Network Process (GANP) method and finally Grey Relational Analysis (GRA) method are described.

3.1. Grey System Theory

Grey theory, which was proposed by Chinese scholar Professor Deng Julong [6], is one of the new mathematical theories born out of the concept of the grey set. It is an effective method used to solve uncertainty problems with discrete data and incomplete information [7]. The concept of the Grey System, in its theory and successful application, is now well known in China [8]. The major advantage of grey theory is that it can handle both incomplete information and unclear problems very precisely. It serves as an analysis tool especially in cases where there is insufficient data [9].

3.2. Grey Analytıc Network Process (GANP)

GANP method is applied for weighting of criteria using ANP and grey system theory based on Saaty'sANP model. The ANP is coupling of two parts. The first consists of a control hierarchy or network ofcriteria and sub-criteria that control the interactions. The second is a network of influences among theelements and clusters. The network varies from criterion to criterion and a different super matrix oflimiting influence is computed for each control criterion. Finally, each of these super matrices is weightedby the priority of its control criterion and the results are synthesized through addition for all the controlcriteria [10].

Pairwise Comparison and Local Weights Estimation: The ANP is based on deriving ratio scalemeasurements founded on pairwise comparisons to derive ratio scale priorities for the distribution ofinfluence among the elements and clusters of the network [11]. In the study, grey numbers were applied.The parameters G1 and G1, denote the smallest possible value and the largest possible value that describea fuzzy event. Grey number scale that used in this study is given in Table 1.

Table 1. Linguistic scales for difficulty and ımportance [12].

Linguistic Scale For Importance	Grey Number Scale	Grey Number Reciprocal Scale
Just equal (E)	(1, 1)	(1, 1)
Equally important (EI)	(1/2, 3/2)	(2/3, 2)
Weakly more important (WMI)	(1, 2)	(1/2 ,1)
Strongly more important (SMI)	(3/2, 5/2)	(2/5, 2/3)
Very strongly more important (VSMI)	(2, 3)	(1/3, 1/2)
Absolutely more important (AMI)	(5/2, 7/2)	(2/7, 2/5)

Pairwise comparison matrices are formed by the decision committee by using the grey number scale.

Super Matrix Formation and Analysis: According to the ANP approach, we need to define interdependencies among factors and clusters. This is also possible with super matrix formation. The relative weights are aggregated into a super matrix based upon influence from one cluster to another, or from one factor to another within a cluster itself. The super matrix formation incorporates four elements:(1) relationships to the final objective; (2) comparisons among factors and clusters; (3) comparisons ofalternative relationships with respect to the factors; and (4) an identity matrix for all alternatives (unlessthe alternatives influence each other) [13].

Calculate The Global Weight: Finally, to yield thecumulative influence of each element on every other element with which it interacts, the super matrix is raised to limiting Powers [14]. Before taking the limitof the matrix, it must first be reduced to a column stochastic matrix (i.e. weighted super matrix), each ofwhose column sums to unity. Then via normalization, the normalized weight vectors can be found in therelevant rows of the normalized limit super matrix. In this way, global weights for all elements will beachieved.

3.3. Grey Relatıonal Analysıs

GRA method is applied for ranking of alternative projects. GRA is a new analysis method, which hasbeen proposed in the Grey system theory and it is founded by Professor Deng Julong from Huazhong University of Science and Technology, People's Republic of China [15].

GRA is used to determine the relationship between two series of data in a grey system. Its structure hasuncertainty, therefore it handles the problems consisted of discrete data and partial information [16]. It operates the grey relational grade to determine the relational degree of factors. Grey relation analysis is also an effective means of analyzing the relationship between sequences with less data and can analyze many factors that can overcome the disadvantages of statistical method [17]. GRA is based on geometrical mathematics, which compliance with the principles of normality, symmetry, entirety, and proximity. GRA is suitable for solving complicated interrelationships between multiple factors and variables. There are 3 main steps in GRA [15]. The first step is data pre-processing, the second step is locating the grey relational coefficient and the final step is calculating of grey relational grade.

4. IMPLEMENTATION

We have performed an implementation about R&D project selection issue for an R&D system development department in a home appliances company. Various projects on refrigerator production processes are considered for ranking. Some of these projects have already been actualized and some of them have not been actualized. Objective of this study is to rank the projects according to priority and to see whether the right projects have been actualized or not.Firstly, we have analyzed the R&D project selection criteria that are used in literature with two R&D specialists and then we determined the convenient ones. Secondly, the ANP model formed by the criteria and sub-criteria determined in the first step. Criteria have been evaluated by two decision makers via linguistic variables that can be expressed in grey number. Then, a degree of grey possibility is proposed to calculate the weights. Thirdly, alternative projects have been evaluated by decision makers in the same way with GANP method's weighting. Finally the GRA model formed and alternative projects have been ranked. A detailed implementation steps are given below.

4.1. Data Gatherıng And Usıng The Ganp Technique

Firstly, main factors are evaluated by using pairwise comparison matrices (assumed that there is nodependence among the factors). The decision committee has formed pairwise comparison matrices byusing the scale given in Table 1. Linguistic scale is placed in the relevant cell against the grey numberwhile evaluating. Then this scale will be transformed into whitened value by the whitening membershipfunction and local weights are calculated using GANP method formulation.

Pairwise comparison matrix for the main factors is filled and the local weights for the main factors arecalculated as shown in Table 2.

Table 2. Local weights and pairwise comparison matrix of main factors.

MAIN FACTORS	Technical	Marketing	Financial	Environmental	Organizational	Local Weight
Technical	(1, 1)	(2/5, 2/3)	(1/3, 1/2)	(3/2, 5/2)	(2/3, 2)	**0,16**
Marketing	(3/2, 5/2)	(1, 1)	(2/5, 2/3)	(2, 3)	(3/2, 5/2)	**0,24**
Financial	(2, 3)	(3/2, 5/2)	(1, 1)	(5/2, 7/2)	(2, 3)	**0,35**
Environmental	(2/5, 2/3)	(2/5, 2/3)	(1/3, 1/2)	(1, 1)	(2/5, 2/3)	**0,1**
Organizational	(1/2, 3/2)	(2/5, 2/3)	(1/3, 1/2)	(3/2, 5/2)	(1, 1)	**0,15**

Sub-factors are also evaluated and weighted in the same way with main factors. Pairwise comparisonmatrix for sub-factors of technical factors is filled and the local weights for their sub-factors are calculated in Table 3. Sub-factors of other main factors are also evaluated and weighted in the same way.

Table 3. Local weights and pairwise comparison matrix of sub-factors of technical factor.

TECHNICAL FACTORS	Probability of technical success	Advancement technology	Patentability	Local Weights
Probability of technical success	(1, 1)	(2, 3)	(3/2, 5/2)	**0,511**
Advancement technology	(1/3, 1/2)	(1, 1)	(2/5, 2/3)	**0,182**
Patentability	(2/5, 2/3)	(3/2, 5/2)	(1, 1)	**0,307**

Afterwards, interdependent weights of the main factors are calculated and the dependencies among themain factors are considered. Dependence among the factors is determined by analyzing the impact of each factor on every other factor using pairwise comparisons. Same linguistic variable scale is used again. Allthe grey evaluation matrices are produced in the same manner. Then this scale will be transformed

intowhitened value by the whitening membership function and local weights are calculated using GANP method formulation.

After pairwise comparisons for technical factors are completed, the resulting relative importance weight sare presented in Table 4.

Table 4. The inner dependence matrix of the factors with respect to ‘‘Technical Factors”.

TECHNICAL FACTORS	Marketing	Financial	Environmental	Organizational	Relative Importance Weight
Marketing	(1, 1)	(2/3, 2)	(1, 2)	(3/2, 5/2)	0,32
Financial	(1/2, 3/2)	(1, 1)	(1, 2)	(3/2, 5/2)	0,3
Environmental	(1/2, 1)	(1/2, 1)	(1, 1)	(1, 2)	0,22
Organizational	(2/5, 2/3)	(2/5, 2/3)	(1/2, 1)	(1, 1)	0,16

Same operations are generated for the sub-factors of each main factor and inner dependence relative importance weights are obtained. Finally, to compute the interdependent weights of the factors, these inner dependence matrices are multiplied with the local weights of the factors. The result of the GANP, Table 5 is obtained.

Table 5. Computed weights.

Main Criteria (Factors)	Factors Local Weights	Sub-Criteria (Sub-Factors)	Local Weights
Technical Factors	0,19	Probability of technical success	0,511
		Advancement technology	0,182
		Patentability	0,307
Marketing Factors	0,2	Probability of market success	0,414
		Degree of competition	0,586
Financial factors	0,28	Cost of development	0,203
		Investment	0,353
		Product Cost Up	0,444
Environmental Factors	0,17	Environmental considerations	0,253
		Safety considerations	0,747
Organizational Factors	0,16	Existence of required facilities	0,29
		Fitting organizational strategy	0,71

4.2. Application of The Gra Technique

The weighting of project selection criteria are obtained by GANP. Then, according to criteria, alternative projects are evaluated by two decision makers as using the grey number scale. Linguistic values are transformed into grey numbers and these grey numbers are transformed into whitened value by the whitening membership function. The data that are formed by whitened value are studied for the purpose of applying GRA steps.

Then referential series are determined according to original data series. After that, in GRA objective model, data are normalized in the range between zero and one based on referential series. Subsequently, absolute data table is obtained and the grey relational coefficient is calculated from the normalized data to express the relationship between the referential series and original data series. At the end, the aggregated grey relational grade vector is obtained by multiplying the resulting grey relational coefficient matrix by the weights of criteria that are shown in Table 5.

Table 6. Grey relational grades for alternatives.

Alternatives	Average	RANK
Project A	0,728	1
Project B	0,572	4
Project C	0,711	2
Project D	0,579	3

As illustrated in Table 6, the four alternative projects, that is Project A, Project B, Project C and Project Dare ranked 1, 4, 2 and 3 respectively. When the results are compared with the common previous opinions,high-ranked alternatives are overlapped with the most expected project alternatives. However, previouslyunconsidered criteria decreased the importance level of two projects. Considering the results of this study,the company has chosen two projects to actualize instead of three projects.

5. CONCLUSION

The R&D project selection is a difficult multi-criteria decision making process to handle. The most crucial features of this process are complexity and especially uncertainty. As a novel approach for solution, GANP and GRA based on grey number, have been utilized to determine the best project to actualize. These methods have been used together at first time for R&D project selection issue. The proposed model constituted from two parts. The first part applies ANP based on grey number to determine the weights of the criteria. And the second part applies GRA to rank the alternative projects. The refrigerator projects are convenient to demonstrate the effectiveness of the proposed methodology for selecting the best project. The method provides an objective and effective decision model for selecting the most appropriate project to develop. The analytical results of this approach show that it can help to deal with complex decision making processes and provide acceptable and reasonable results for administrators and decision makers. Furthermore, this approach may be used for other group of projects that considered in department of R&D system development in the home appliances company.

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