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A MCDM MODEL PROPOSAL AND SOLUTION FOR EVALUATING AGILE METHODS USED IN SUPPLY CHAIN MANAGEMENT

TEDARİK ZİNCİRİ YÖNETİMİNDE KULLANILAN ÇEVİK YÖNTEMLERİN DEĞERLENDİRİLMESİNE YÖNELİK ÇKKV MODEL ÖNERİSİ VE ÇÖZÜMÜ

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Abstract

In the developing and changing world, the field of technology hosts many innovations. Supply chain management has also evolved in the light of technological developments and incorporated the concept of agility. Agile supply chain is the ability to respond quickly to the unexpected changes in demand and supply. As supply chains compete in a rapidly changing and growing market, the agility of the supply chain provides a significant competitive advantage to firms. An agile supply chain has the ability to respond flexibly and quickly to demands and problems. It benefits companies by adopting the right product, the right customer, the right transportation, and the right supply system. In this study, it was aimed to evaluate the agile methods used in the supply chain management processes, and for this purpose, a multi-criteria model consisting of 12 criteria and 9 alternatives was proposed. This proposed model was solved with two-stage multi-criteria solution techniques, and in the first stage of the solution, criterion weights were calculated with the SWARA method, while the evaluation and ranking of alternative agile methods were carried out with the WASPAS method. Thus, the most appropriate agile method methodology to be used in supply chain management was determined.

Keywords: Agile Management, Agile Supply Chain, Supply Chain Management, SWARA, WASPAS

Özet

Gelişen ve değişen dünyada teknoloji alanı birçok yeniliğe ev sahipliği yapmaktadır. Tedarik zinciri yönetimi de teknolojik gelişmeler ışığında evrim geçirmiş ve çeviklik kavramını bünyesine katmıştır. Çevik tedarik zinciri, talep ve arzdaki beklenmedik değişikliklere hızla yanıt verme yeteneğidir. Tedarik zincirleri hızla değişen ve büyüyen bir pazarda rekabet ederken, tedarik zincirinin çevikliği firmalara önemli bir rekabet avantajı sağlamaktadır. Çevik bir tedarik zinciri, taleplere ve sorunlara esnek ve hızlı bir şekilde yanıt verme yeteneğine sahiptir. Doğru ürünü, doğru müşteriyi, doğru nakliyeyi ve doğru tedarik sistemini benimseyerek firmalara fayda sağlar. Bu çalışmada tedarik zinciri yönetimi süreçlerinde kullanılan çevik yöntemlerin değerlendirilmesi amaçlanmış ve bu amaçla 12 kriter ve 9 alternatiften oluşan çok kriterli bir model önerilmiştir. Önerilen bu model iki aşamalı çok kriterli çözüm teknikleri ile çözülmüş ve çözümün ilk aşamasında SWARA yöntemi ile kriter ağırlıkları hesaplanırken alternatif çevik yöntemlerin değerlendirilmesi ve sıralaması WASPAS yöntemi ile gerçekleştirilmiştir. Çalışmada uygulama sonuçları sunulmuş, böylece tedarik zinciri yönetiminde kullanılacak en uygun çevik yöntem metodolojisi belirlenmiştir.

Anahtar Kelimeler: Çevik Yönetim, Çevik Tedarik Zinciri, Tedarik Zinciri Yönetimi, SWARA, WASPAS

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1. INTRODUCTION

It is very important for companies to be able to respond to the expectations of customers as a result of constantly changing conditions and increasing competition with the developing technology, and companies that cannot keep up with today's technological innovations disappear because they cannot adapt to the age. In order for companies to ensure their continuity, they need to adapt to technology, meet customer needs, and determine their production and logistics strategies in the light of this information.

In recent years, while customers are looking for quality and easy availability features in the product and/or service they buy, they also want manufacturers to establish a structure that can produce quick solutions to their problems, and minimize waiting times. For this reason, the profitability and continuity of companies depends on looking at the results and taking quick action according to these results, taking into account the other companies with which they are in competition, being sensitive to the needs and feedback of the customers. It will become more important in time for companies to focus on customer needs and to adapt to unforeseen events in the sector over time, and it will be possible for companies to respond quickly to these requirements by being agile in all processes. Today, it has become important for companies to have an agile understanding in order to ensure continuos success, and this understanding has begun to influence all sectors.

In this study, it is aimed to determine the necessary criteria for a company's supply chain management (SCM) to be agile, and to reach the optimal one among the agile methods with a multi-criteria decision-making approach. For this purpose, a multi-criteria decision-making (MCDM) model consisting of 12 criteria and 9 alternatives has been proposed, and this proposed model has been solved by sequentially used SWARA and WASPAS MCDM techniques. In this direction, general information about the study is given in the introduction part of the study. In the second part, information about SCM is given; its purpose and advantages are explained. In the third chapter, the concept of agile management and agile practices in SCM are mentioned. In the fourth chapter, a multi-criteria model is proposed for the evaluation of agile techniques used in SCM and the solution of this proposed model is realized. In the fifth and last chapter, an evaluation is made in the light of the solutions obtained, and the results and suggestions are given.

2. SUPPLY CHAIN MANAGEMENT

The supply chain can be defined as a network of physical and technological tools, processes, and methods, including the functions of procuring the raw material, transforming this supplied raw material into intermediate products or end-products, distributing these value-added products to customers, manufacturers, and distributors. SCM, on the other hand, is the planning and optimization of all processes from the producer to the consumer, down to the last detail. The main purpose is to bring together more than one activity in the SCM and to ensure that it works as a single system and increases customer satisfaction through customer feedback. Thus, the final product is delivered to the consumer at the right time, at the right place, and at the optimum cost.

SCM, which has a great importance for ensuring/maintaining the efficiency of companies and ensuring customer satisfaction, can direct the information and material flow that emerges because it has a command of all processes (Soltanmohammadi et al., 2021).

The main objectives of SCM are to standardize production, to ensure material and information flow, to keep stock costs and losses at the lowest level, to protect the quality of the product and to reduce product faults, to find reliable suppliers and to manage processes with the lowest management expense. In order to achieve these goals, companies need to improve and increase the flow of information between suppliers and customers. High-quality information flow ensures that the performance of companies will become high-quality.

By adopting SCM, competitive advantage is achieved; quality control requirement and supply related problems are minimized, and faster and more flexible operation is achieved (Moktadir et al., 2021). In addition, with the help of the technologies used in SCM, all the processes become easier; the uncertainties that may arise for the customer are minimized and eliminated, and human errors are largely eliminated with automation systems. As a result of a successful collaboration with SCM, each company gains advantages in terms of cost, quality, speed, and reliability.

3. AGILE MANAGEMENT

The concept of agile management is a different perspective on projects and products and includes cyclical processes (Marnada et al., 2022). These processes trigger each other and interact with each other. This interaction requires flexibility and continuity.

While classical project management focuses on the whole, the agile approach focuses on the parts. The risks that will arise when focusing on the whole are reduced by focusing on the parts. Self-managed teams do all these processes, and these teams produce high-quality solutions that meet the ever-changing needs, with minimum cost and in a timely manner, with sufficient formality, in a highly collaborative manner. While producing solutions, the teams pay attention to include the customer in the process.

This principle, which first emerged in the software world, has been started to use over time in other sectors with the development of technology. The principles of agile management are customer satisfaction, adapting to change, fast results, working together with business partners and the team, trust and freedom in the team, face-to-face communication, result-oriented, fast transactions, attention, simplicity, self-organizing team, and regular self-control (Loiro et al., 2019).

3.1 Agile Supply Chain

Agile supply chain is the ability to respond quickly to the unexpected changes in demand and supply. The agility of the supply chain, which grows and becomes more complex with each passing day, provides an important competitive advantage in the rapidly changing market (Ciccullo et al., 2018; Shashi et al., 2020).

Agile supply chain consists of four main criteria such as market sensitivity (uses technology based on predicting customer's future orders), process integration (requires all stakeholders in the chain to act as a whole), network integration (requires strong communication and complete information flow among stakeholders), virtual network (with the developing technology, the data flow in the chain is facilitated and constantly observed).

The differences between the agile supply chain and the classical supply chain are shown in Table 1.

Table 1: Comparison of agile and classical supply chain (Taş, 2022).

Feature	Agile Supply Chain	Classical Supply Chain
Market demand	Variable	Predictable
Product lifecycle	Short	Long
Costs	Marketing costs	Physical costs
Collaborations	Short-term and variable	Stationary and long-term
Profit rate	High	Low
Product types	Trending products	Raw Materials
Product variety	High	Low
Guidance of customers in the market	Accessibility	Price
Logistics planning	Quick answers	Fixed period
Key assessment criterion	Customer satisfaction	Cost and efficiency
Estimation mechanism	Based on consultation	Algorithmic
Structure of processes	Increased automation	Standardization
Information	Necessary	Expected

4. MULTI-CRITERIA MODEL PROPOSAL AND SOLUTION FOR EVALUATING AGILE METHODS USED IN SUPPLY CHAIN MANAGEMENT

In today's developing and changing world, the field of technology hosts many innovations. Companies investing in technology gain competitive advantages by being positively affected by these technological developments.

SCM has evolved in the light of technological developments and incorporated the concept of agility. An agile supply chain has the ability to respond flexibly and quickly to demands and problems. Agile supply chain benefits companies by adopting the right product, the right customer, the right transportation, and the right supply system.

In this study, the agile methodologies used in SCM were evaluated according to the proposed MCDM model, and SWARA and WASPAS methods were used in this evaluation. With these evaluations, it is aimed to determine the most appropriate agile methodology to be used in SCM in the light of the proposed model.

4.1 Proposed Research Model with Its Criteria and Alternatives

The ability of companies to respond quickly to customer needs depends on the agility of the processes they contain. Today, companies have come a long way in agility. Companies that apply agility in their processes have added the value to themselves by gaining effectiveness in business life.

In this study, agile methods that can be used for a company's supply chain to be agile were evaluated with the MCDM approach. The MCDM model established within the scope of the study consists of 12 criteria and 9 alternative agile methods. The criteria and alternatives that make up the model are explained as follows, respectively:

Research criteria:

- C_1 *Reliability*: The data to be obtained with the agile method to be used should be precise and reliable, and the method should produce similar results under certain conditions.
- C_2 *Cost*: The agile method to be used should have cost advantage.
- C_3 *Time*: The agile method to be used should be effective in supplying all kinds of goods or services on time and ensuring the continuity of production, which is very important for SCM.
- C_4 *Flexibility*: The agile method to be used should be flexible enough to adapt to the changes that may occur in the process.
- C_5 *Usability*: It is preferred that the agile method to be used is user-friendly and has reusability feature.
- C_6 *Quality*: It is expected that the agile method to be used will be able to meet the demands and expectations accurately and in the best way.
- C_7 *Testability*: It is expected that the agile method to be used will be testable, that the written codes, established network models and more can be tested.
- C_8 *Technical competence*: The agile method to be used should have the necessary technical skills to perform supply chain processes.
- C_9 *Risk Oriented*: With the agile method to be used, it is aimed to examine the existing or potential risks and to reduce these risks to the minimum level by.
- C_{10} *Cooperation*: A collaborative approach is important for the interaction of individuals in agile teams to be productive.
- C_{11} *Continuous improvement*: The agile method to be used should be in accordance with the continuous improvement strategy and practices.
- C_{12} *Open communication*: Open communication with all stakeholders is very important for any problems or improvement suggestions that may occur.

Research alternatives:

- A_1 *SCRUM*: The SCRUM method, which is used in the management of complex processes, breaks the whole project into process pieces and relies on repetition while managing the processes. It also helps to achieve the goal with regular feedback and plans. Communication between the team members is very important in the method that uses a flexible structure for needs.

- A_2 *XP Programming*: The focus of the method in which communication is very important is on the customer and customer requirements. In this method, the customer's requirements are learned in detail before the project to be carried out and to be acted accordingly. Because the project progresses will increase the cost when the changes to be needed according to customer expectations.

- A_3 Kanban: With the Kanban methodology, which is a visual methodology applied to manage the work in a process while it is in progress, the ongoing workflow is visualized, constraints are made clear for the whole team, and continuous improvement is encouraged.

- A_4 *Lean Software*: The method, whose basic principle is to eliminate all kinds of wasted resources, aims to remove all processes or all efforts that are meaningless for the customer from the workflow.

- A_5 *Feature Driven Development (FDD)*: The method focuses on development with short

iterations to help the development team become more adaptive and responsive to customer needs. The method performs the new update step by step, rather than making an all-encompassing update in the system.

- *A_6 Dynamic System Development Method (DSDM)*: The method that helps determine the process model and team roles consists of agile management philosophies such as iterative delivery, effective communication, collaboration, and focusing on continuous improvement.
- *A_7 Adaptive Software Development (ASD)*: Since the method used to build complex software and systems has a complex structure, it is based on self-organized human association in its infrastructure.
- *A_8 Microsoft Solution Framework (MSF)*: The method is an adaptive approach that provides high-quality results while successfully delivering technology solutions faster, with fewer people and with less risk.
- *A_9 Rational Unified Process (RUP)*: The method is based on a step-by-step iterative development model.

The proposed research model is seen in Figure 1.

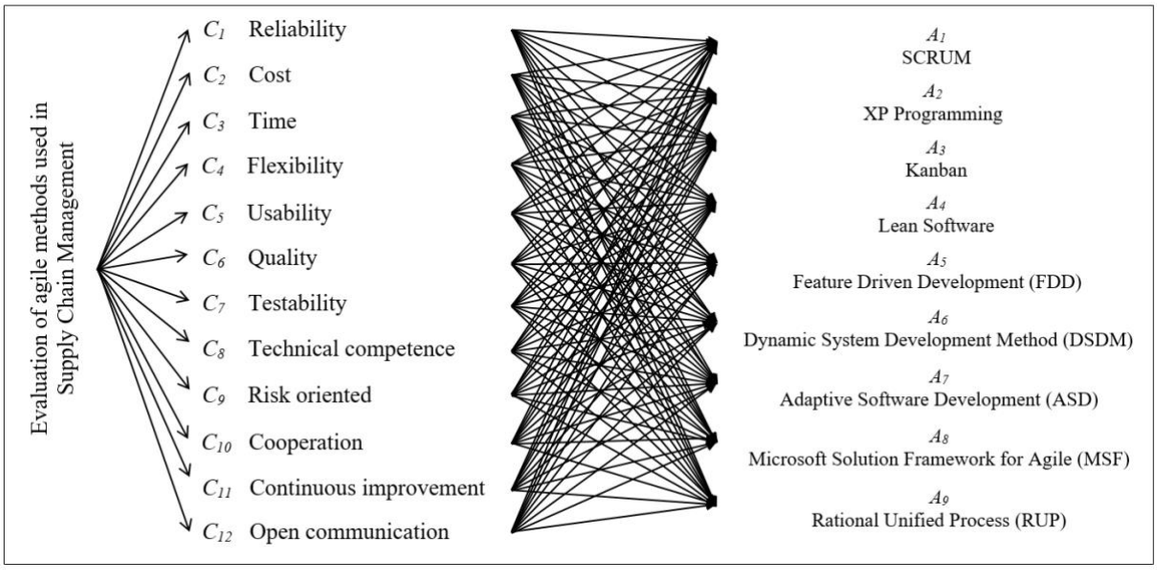

Figure 1: Proposed research model in MCDM structure.

4.2 Solution of the Problem

In the solution of the proposed MCDM model, SWARA and WASPAS, which are among the MCDM solution methods, were used. In the first stage of the solution, the criteria weights were found by the SWARA method, while in the second stage of the solution, alternative agile methods were evaluated with the WASPAS method. Opinions were taken from three experts with high sectoral experience in order to make evaluations during the solution phase.

4.2.1 SWARA method

SWARA method was developed by Keršulienė, Zavadskas, and Turskis in 2010 and has been used to determine the criterion weights of many problems until today. The process steps of the method, which is simple, suitable for working with experts, and very easy to use, are as follows (Prajapati et al., 2019):

Step 1: The criteria are simply ranked by the decision makers in descending order of importance. Then, each decision maker assigns the p_j^k value between 0 and 1 to each criterion in accordance with the first sorting (*j = 1, …,n; k = 1, …l*).

Step 2: If more than one decision maker evaluates the criteria, the geometric mean of the p_j^k values created by each decision maker is taken with the help of Equation 1, and the $\bar{p}_j$ value is formed.

$$\bar{p}_j = \frac{\sum_{k=1}^{l} p_j^k}{l} \quad (1)$$

Sorting of criteria according to decision makers and calculated $\bar{p}_j$ values are seen in Table 2.

Table 2: Sorting of the criteria and calculated $\bar{p}_j$ values of criteria.

Criteria		*Decision Makers*						$\bar{p}_j$
		DM₁	*DM₂*	*DM₃*	*DM₁*	*DM₂*	*DM₃*	
C₁	Reliability	6	7	7	0.75	0.60	0.60	0.650
C₂	Cost	1	2	1	1.00	0.95	1.00	0.983
C₃	Time	2	1	3	0.95	1.00	0.90	0.950
C₄	Flexibility	3	4	4	0.90	0.80	0.85	0.850
C₅	Usability	5	8	6	0.80	0.50	0.70	0.667
C₆	Quality	4	3	2	0.85	0.90	0.95	0.900
C₇	Testability	7	9	8	0.70	0.45	0.50	0.550
C₈	Technical competence	8	5	5	0.65	0.75	0.80	0.733
C₉	Risk oriented	9	6	9	0.60	0.65	0.45	0.567
C₁₀	Cooperation	12	11	12	0.20	0.20	0.10	0.167
C₁₁	Continuous improvement	10	10	11	0.40	0.40	0.30	0.367
C₁₂	Open communication	11	12	10	0.30	0.05	0.35	0.233

Step 3: The criteria are ordered from the largest to the smallest according to their $\bar{p}_j$ values, and the relative importance (s_j) of each criterion is obtained by subtracting in each other the $\bar{p}_j$ values of successive criteria.

Step 4: The coefficient value (c_j) is calculated with the help of Equation 2. For the criterion with the largest s_j value, $c_j = 1$.

$$c_j = s_j + 1 \quad (2)$$

Step 5: Adjusted weights (s_j') are calculated with the help of Equation 3. For the criterion in the first row $s_j' = 1$.

$$s_j' = \frac{s_{j-1}'}{c_j} \quad (3)$$

Step 6: Importance weights (w_j) are calculated with the help of Equation 4.

$$w_j = \frac{s_j'}{\sum_{j=1}^{n} s_j'} \quad (4)$$

Calculated $\bar{p}_j$, s_j, c_j, s_j', and w_j values of criteria are seen in Table 3.

Table 3: $\bar{p}_j$, s_j, c_j, s'_j and w_j values of criteria.

	$\bar{p}_j$	s_j	c_j	s'_j	w_j		$\bar{p}_j$	s_j	c_j	s'_j	w_j
C_2	0.983	-	1.000	1.000	0.1130	C_1	0.650	0.017	1.017	0.725	0.0819
C_3	0.950	0.033	1.033	0.968	0.1094	C_9	0.567	0.083	1.083	0.670	0.0756
C_6	0.900	0.050	1.050	0.922	0.1042	C_7	0.550	0.017	1.017	0.658	0.0744
C_4	0.850	0.050	1.050	0.878	0.0992	C_{11}	0.367	0.183	1.183	0.556	0.0629
C_8	0.733	0.117	1.117	0.786	0.0888	C_{12}	0.233	0.134	1.134	0.491	0.0554
C_5	0.667	0.066	1.066	0.737	0.0833	C_{10}	0.167	0.066	1.066	0.460	0.0520

As seen in Table 3, cost is the most important criterion with a weight of 11.3% in determining the appropriate agile method for the supply chain according to the proposed model. While this criterion was followed by time and quality criteria, respectively, cooperation was determined as the least important criterion with a weight of 5.2%.

4.2.2 WASPAS method

In the WASPAS method, which combines the results of two different models, the Weighted Sum and the Weighted Product Model, the alternatives are ranked according to the value of the combined optimality criterion. The method proposed by Chakraborty and Zavadskas in 2014 does not require extra sensitivity analysis due to its nature. The steps of the method are as follows (Prajapati et al., 2019):

Step 1: The MCDM model is established by determining the alternatives ($A_{i(i=1,\dots m)}$) and criteria ($C_{j(j=1,\dots n)}$).

Step 2: With one of MCDM methods, the importance weights of the criteria are calculated. In this study, SWARA method was used for this step.

Step 3: Using the (1-5) scale, the initial decision matrix is created according to the evaluations of the decision makers. Table 4 shows the initial decision matrix for this study.

Table 4: Initial decision matrix.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}
	max	*min*	*min*	*max*	*max*	*max*	*max*	*max*	*max*	*max*	*max*	*max*
w_j	0.082	0.113	0.109	0.099	0.083	0.104	0.074	0.089	0.076	0.052	0.063	0.055
A_1	4	1	4	4	4	4	5	3	5	5	5	5
A_2	4	2	3	5	3	5	5	5	2	4	5	5
A_3	5	3	5	5	5	4	5	4	3	4	5	4
A_4	3	2	5	4	3	5	3	4	5	5	4	5
A_5	3	3	3	3	3	4	2	2	2	4	3	4
A_6	4	3	1	4	4	4	3	3	3	5	4	5
A_7	4	3	4	4	3	3	3	3	5	5	5	4
A_8	5	2	5	5	4	5	3	4	5	3	5	5
A_9	4	2	2	5	4	2	5	5	3	2	4	4

Step 4: The initial decision matrix is normalized according to the characteristics of the criteria. Equation 5 is used for benefit-based criteria that should be maximized, and Equation 6 is used for cost-based criteria that should be minimized.

$$\overline{x_{ij}} = \frac{x_{ij}}{max_i x_{ij}} \quad (5)$$

$$\overline{x_{ij}} = \frac{min_i x_{ij}}{x_{ij}} \quad (6)$$

The created normalized decision matrix is shown in Table 5.

Table 5: Normalized decision matrix.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}
w_j	0.082	0.113	0.109	0.099	0.083	0.104	0.074	0.089	0.076	0.052	0.063	0.055
A_1	0.80	1.00	0.25	0.80	0.80	0.80	1.00	0.60	1.00	1.00	1.00	1.00
A_2	0.80	0.50	0.33	1.00	0.60	1.00	1.00	1.00	0.40	0.80	1.00	1.00
A_3	1.00	0.33	0.20	1.00	1.00	0.80	1.00	0.80	0.60	0.80	1.00	0.80
A_4	0.60	0.50	0.20	0.80	0.60	1.00	0.60	0.80	1.00	1.00	0.80	1.00
A_5	0.60	0.33	0.33	0.60	0.60	0.80	0.40	0.40	0.40	0.80	0.60	0.80
A_6	0.80	0.33	1.00	0.80	0.80	0.80	0.60	0.60	0.60	1.00	0.80	1.00
A_7	0.80	0.33	0.25	0.80	0.60	0.60	0.60	0.60	1.00	1.00	1.00	0.80
A_8	1.00	0.50	0.20	1.00	0.80	1.00	0.60	0.80	1.00	0.60	1.00	1.00
A_9	0.80	0.50	0.50	1.00	0.80	0.40	1.00	1.00	0.60	0.40	0.80	0.80

Step 5: For all alternatives as the total relative importance value, while $Q_i{}^{(1)}$ is calculated with the help of Equation 7 according to the Weighted Sum Model, $Q_i{}^{(2)}$ is calculated with the help of Equation 8 according to the Weighted Product Model.

$$Q_i{}^{(1)} = \sum_{j=1}^{n} \overline{x_{ij}}\, w_j \quad (7)$$

$$Q_i{}^{(2)} = \prod_{j=1}^{n} \left(\overline{x_{ij}}\right)^{w_j} \quad (8)$$

Step 6: The Combined Optimality Value (Q_i) for the alternatives is calculated with the help of Equation 9. $\lambda \in [0,1]$ which is the combined optimality coefficient was accepted as 0.5 for this study.

$$Q_i = \lambda Q_i{}^{(1)} + (1-\lambda) Q_i{}^{(2)} \quad (9)$$

Step 7: Alternatives are ranked according to their Q_i values; the alternative with the largest Q_i value is the best solution.

In Table 6, calculated $Q_i^{(1)}, Q_i^{(2)}$, Q_i values and the ranking of alternatives are shown.

Table 6: $Q_i^{(1)}, Q_i^{(2)}$, Q_i values and the ranking of alternatives.

Alternatives	$Q_i^{(1)}$	$Q_i^{(2)}$	Q_i	*Ranking*
A_1 SCRUM	0.8081	0.7568	0.7824	1
A_2 XP Programming	0.7642	0.7118	0.7380	2
A_3 Kanban	0.7461	0.6668	0.7064	5
A_4 Lean Software	0.7095	0.6493	0.6794	7
A_5 Feature Driven Development (FDD)	0.5346	0.5081	0.5214	9
A_6 Dynamic System Development Method (DSDM)	0.7419	0.7101	0.7260	4
A_7 Adaptive Software Development (ASD)	0.6547	0.6025	0.6286	8
A_8 Microsoft Solution Framework for Agile (MSF)	0.7705	0.7001	0.7353	3
A_9 Rational Unified Process (RUP)	0.7074	0.6711	0.6893	6

According to the values in Table 6, the alternatives are listed as $A_1 > A_2 > A_8 > A_6 > A_3 > A_9 > A_4 > A_7 > A_5$. Accordingly, with a Q_i value of 0.7824, SCRUM is the most appropriate agile method to be used in SCM for the MCDM model proposed in this study. XP Programming follows this method with a Q_i value of 0.7380.

5. CONCLUSION AND RECOMMENDATIONS

Supply chain consists of suppliers, manufacturers, wholesalers, retailers, customers, consumers, distributor elements, and warehouses. The uninterrupted communication among these elements is very important for the supplier, the company, and the customer. In addition, in agile methodologies where communication is very important, agility includes elements such as responsiveness, flexibility, open communication between the team, and examining the existing problem at the piece level.

In this study, agile methodologies that can be used rather than traditional methods in SCM are evaluated. In this evaluation, the proposed MCDM model was analyzed by using the SWARA and WASPAS methods, considering the dimensions such as the reliability, cost, time, flexibility, usability, testability, technical competence, risk-oriented, continuous improvement, and open communication.

After all evaluations, SCRUM was found the most suitable agile methodology for SCM according to proposed model. In future researches, the proposed model can be expanded with new criteria, or the solution techniques can be changed.

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