Determining and Weighting the Sustainability Pillars: A Case Study in Petrochemical Industry

Elif Çirkin
Research Assistant of Production Management and Marketing Division
Faculty of Business Administration
Dokuz Eylül University,
Muş Alparslan University
Izmir, Turkey
elif.cirkin@deu.edu.tr

Aşkın Özdağoğlu
Associate Professor of Production Management and Marketing Division
Faculty of Business Administration
Dokuz Eylül University
Izmir, Turkey
askin.ozdagoglu@deu.edu.tr

Abstract

Natural resources have been diminishing, and even depleting as well as such issues as climate change, global warming, globalization, competitiveness, social concerns have been arising. Furthermore, increasing levels of industrialization, hence production ecosystems have been playing a vital role in the emergence of these environmental, financial, and social conditions. Therefore, blending sustainability pillars into manufacturing environments has been turning into more than a necessity when taking into today`s environmental, financial, and social conditions account. Within the scope of this study, it is aimed to determine and weigh social, economic, and environmental sustainability criteria to be considered in the selection of the Industry 4.0 technologies, which is a holistic production paradigm, in creating a sustainable production ecosystem. In line with the data obtained from the sample consisting of decision-makers being employed in the petrochemical industry, the main and sub-criteria of the sustainability dimensions are weighted with fuzzy DEMATEL (Decision Making Trial and Evaluation Laboratory), which is one of the multi-criteria decision-making methods. The results of the analysis are further employed in the selection of the Industry 4.0 alternative.

Keywords
Industry 4.0, Manufacturing, Sustainability, Sustainable Production Ecosystems, DEMATEL.

1. Introduction
The starting point of this study hinges upon such threats as intense globalization, competition, climate change, global warming, lack of resources, and even depletion. Accordingly, considering sustainability pillars while manufacturing is of great importance for today's business environments. Furthermore, creating potentials for sustainability with the integration of Industry 4.0 technologies and applications such as augmented reality, additive manufacturing, autonomous robots, cyber-physical systems, big data and analytics, internet of things, simulation, smart factory, cloud computing, system integration could open a new window in the literature. Hence, in this study, as a first step, the framework of sustainability pillars including social, environmental, and economic will be evaluated. To do so, first of all, with the help of a literature review the scope of the sustainability pillars will be handled. Next, with an application, the sustainability pillars will be attempted to reveal and weigh by considering their relationships with Industry 4.0 technologies and applications. In order to determine the sustainability criteria, the brainstorming technique and a focus group study will be benefitted. This brainstorming will be among personnel working in various departments in the petrochemical industry. After creating a mind map subject to this brainstorming, environmental, social, and economic sustainability criteria will be determined through a focus group study. For the analysis, the fuzzy-DEMATEL method (Decision-Making Trial and Evaluation Laboratory) will be used which is one of the multi-criteria decision-making

methods in order to sort and weigh the specified sustainability criteria. The study is prepared in such an order: first of all, the objectives of the study and next, the background information regarding sustainability dimensions will be demonstrated with the help of various views of the researchers. Thereafter, the preferred method, data collection process, discussions of the analysis, and finally the conclusion part of the study will be given.

1.1 Objectives

This study is planned to reveal and weigh the social, economic, and environmental sustainability criteria for a chosen industry. In order to find out these criteria and determine the weights of these criteria, thus performing the aim of the study multiple objectives have been proposed. The first objective is to gain information on creating sustainable social, economic, and environmental value through the use of Industry 4.0 technologies. Therefore, to achieve this firstly, a literature review has done, and then the main and sub-criteria of the sustainability framework were determined by brainstorming and a focus group study. Lastly, with the help of the fuzzy DEMATEL method specified main and sub-criteria were weighted for the petrochemical industry.

2. Literature Review

The notion of sustainability has recently been heavily implemented in production environments. As a result, in order to avoid falling behind in the market, businesses are increasingly adopting ground-breaking and new trends that are compatible with their existing equipment and technology. As a result, it is expected that the introduction of Industry 4.0 and its supporting technologies would offer businesses the capacity to integrate, automate, and optimize their production cycle, resulting in increased sustainability potentials (Prakash et al. 2018; Nagasawa et al., 2017).

The sustainability and/or sustainable development is rooted in "the Brundtland report" (World Commission on Environment and Development, 1987). In the report, sustainable development is defined as "meeting the needs of the present without compromising the ability of future generations to meet their own needs". Based on the various views on sustainability, it is evident that sustainability covers the promise of societal, economic, and environmental evolution for a better future (Elkington, 1997). For the social pillar of sustainability Dyllick and Hockerts (2002: 134) describe socially sustainable companies as companies that "add value to the communities within which they operate by increasing the human capital of individual partners as well as furthering the societal capital of these communities. They manage social capital in such a way that stakeholders can understand its motivations and can broadly agree with the company's value system." In the context of this study, which is concerned with the convergence of social sustainability and Industry 4.0, it is suggested that brainpower is used instead of muscle power to perform monotonous and dangerous tasks in industrial workplaces, thanks to technologies such as autonomous robots, intelligent production infrastructures, intelligent factory systems, and advanced machine learning via human-machine interfaces. (Koca, 2018). As a result, if the aforementioned technologies are implemented at the factory level in various sectors such as production, transportation, and logistics, the scenario will generate a better, safer, and more secure working environment from the standpoint of social sustainability. This condition, however, leads to a battle of ideas. On the one hand, some scholars believe that blue-collar employees, in particular, will be rendered jobless and replaced by robots. On the other hand, Others believe that new job definitions will arise and that these new job definitions will provide new possibilities. These job definitions include robot engineering, industrial computer engineering, network development engineering, 3D printer engineering, big data expertise, data analyst, artificial intelligence, and machine learning experts (Prause, 2015; Cohen et al., 2019).

General views on the environmental dimension of sustainability refer to the practices that do not jeopardize the environmental resources for future generations. Environmental sustainability also focuses on the efficient use of energy recourses, reduction of greenhouse gas emissions, and minimization of the ecological footprint (Goel, 2010). In the context of this study, concerning the convergence of environmental sustainability with Industry 4.0, variables such as increased transparency and traceability in both demand and processes, intelligent process planning, and hence reduced energy and material usage are predicted. Furthermore, by utilizing smart factories, cloud computing, the internet of things, and system integration, immediate interventions for indicators such as greenhouse gas emissions, waste, environmental pollution, and excessive resource consumption can be effectively acted upon, managed, and controlled. (Valdez et al., 2015; Posada et al., 2015; Burritt and Christ, 2016).

As for economic sustainability, it is based on the management of financial capital such as stock and debt, tangible capital such as machinery and inventory, and intangible capital such as reputation, brand image, customer satisfaction, know-how, and organizational routines (Dyllick and Hockerts, 2002). For decades, technical advances in manufacturing have played and continue to play an important role in supporting economic growth and producing financial rewards. The sustainable factories of the future set the groundwork for industrial progress and economic and social well-being. Accordingly, new technologies that arose with Industry 4.0, such as simulation, simultaneous engineering, or rapid prototyping, may drastically reduce product time to market, and being the first provider in the market with a new product can offer organizations a competitive edge. Furthermore, Industry 4.0 technologies such as smart production can provide efficiency, flexibility, reliability, transparency, process traceability, optimization of quality problems and resource use, waste minimization, and early error detection, increasing a company's competitiveness and driving down costs. (de Man and Strandhagen, 2017).

3. Methods

Within this study, the fuzzy-DEMATEL (Decision Making Trial and Evaluation Laboratory) which is one of the Multi-Criteria Decision Making Methods was employed for criteria weighting. DEMATEL method was proposed between 1972 and 1976 in order to deal with the complex and interconnected problem group. With the use of a visualization structure model, this technique may improve comprehension of respondents' viewpoints on entangled components and criteria, as well as provide a suitable solution. (Gabus and Fontela, 1972, 1973). So, by examining and debating the structural model, it is possible to determine which components are more important for the overall system and which are not.

In order to eliminate the vagueness and provide consistency, a fuzzy set theory put forward by Zadeh (1965) was employed. Based on the research done, it is evident that the fuzzy DEMATEL method has been used in different fields including green and sustainable supply chain management, emergency management, and purchasing for effective decision-making processes (Lin, 2013; Lin et al., 2018; Govindan et al., 2015; Zhou et al., 2011; Chen Yi et al., 2007). The stages of this method are as follows:

1. Experts` opinions are transformed into fuzzy numbers.
2. An initial direct-relation matrix is generated.
3. Expert opinions are blended in to form a single fuzzy initial direct relationship matrix.
4. The normalized fuzzy direct relationship matrix is prepared.
5. The row and column totals in the fuzzy sum relationship matrix are obtained.
6. By taking the sums and differences of the values in the fuzzy sum relationship matrix the degree of influence and influence for each criterion is determined.
7. The defuzzification process is performed by taking the average of the values that make up the triangular fuzzy number.
8. Unnormalized criterion weights are found with the help of these defuzzified values.
9. Finally, the weight values are normalized. After the normalization process, the sum of the weight values of the criteria is equal to 1 (Wu and Lee, 2007; Altan and Aydın, 2015).

After following, these steps weights of the criteria can be determined and the largest value among these values represents the most important criterion to be considered in the decision-making problem.

4. Data Collection

In this study, the expert sampling method which is one of the purposive sampling procedures has been applied. The reason why this sampling method has been applied is lying behind the idea of when looking into new topics of research, expert sampling is considered to be a useful technique to provide solid results or when there is currently a lack of observational evidence (Etikan et al., 2016). Therefore, the sample of this study constitutes experts from a blend of various departments spanning from research and development, production, and supply chain management functioning in the petrochemical industry. The reason why the petrochemical industry was used in this study is that the petrochemical industry can be regarded as one of the most polluting industries with its carbon footprint ratios and the selected firm gives specific importance to sustainability issues and waste management. With the help of the brainstorming and focus group techniques, the sustainability criteria were determined and shown in Table 2 below.

Table 1. Main and Sub-Criteria for Sustainability

Main Criteria	**Sub-Criteria**
Social Sustainability	Workplace Safety Improvement in working standards and conditions The emergence of new job definitions Demand for a qualified workforce Increase in social welfare
Economic Sustainability	Increase in profitability cost reductions Productivity in production Flexibility in production Quality control and assurance Delivery and lead time reductions Transparency and monitoring in production Process optimization Standardization in production
Environmental Sustainability	Increasing the use of renewable energy resources Environmental pollution prevention, management and control Increasing recovery, recycling and reusing rates Reducing greenhouse gas emissions Ensuring efficiency in resource and energy use Developing green innovative strategies

Based on the table, experts working in the petrochemical industry defined social sustainability sub-criteria as workplace safety, improvement in working standards and conditions, the emergence of new job definitions, demand for a qualified workforce, and increase in social welfare. For the economic sustainability sub-criteria, experts decided on an increase in profitability, cost reductions, productivity in production, flexibility in production, quality control and assurance, delivery and lead time reductions, transparency and monitoring in production, process optimization, and standardization in production. Lastly, for the sub-criteria of environmental sustainability increasing the use of renewable energy resources, environmental pollution prevention, management and control, increasing recovery, recycling and reusing rates, reducing greenhouse gas emissions, ensuring efficiency in resource and energy use, and developing green innovative strategies were determined by the experts.

After gathering the main and sub-criteria based on the brainstorming as well as focus group study outputs, the weighting process with the fuzzy DEMATEL method was applied and the results are given within the results and discussion part.

5. Results and Discussion

In order to attain experts' views on the specified main and sub-criteria, a questionnaire form was designed and the outputs of this questionnaire form were passed onto the Excel sheet in which the formula for the fuzzy DEMATEL method was prepared. In the table below three experts' opinions regarding the comparison of sustainability dimensions were included based on the numbers ranging from 1 to 5 representing equal importance, slightly important, important, very important, and absolutely more important respectively.

Table 2. Evaluation of the Main Criteria

Expert 1	**Social Sustainability**	**Economic Sustainability**	**Environmental Sustainability**
Social Sustainability	0	3	4
Economic Sustainability	5	0	5
Environmental Sustainability	1	2	0

Expert 2	**Social Sustainability**	**Economic Sustainability**	**Environmental Sustainability**
Social Sustainability	0	4	3
Economic Sustainability	3	0	2
Environmental Sustainability	2	3	0
Expert 3	**Social Sustainability**	**Economic Sustainability**	**Environmental Sustainability**
Social Sustainability	0	2	4
Economic Sustainability	2	0	3
Environmental Sustainability	4	2	0

In the next step, these numbers were converted into fuzzy numbers by using the corresponding linguistic expressions into triangular fuzzy numbers of Wu and Lee (2007) and the table below was gathered.

Table 3. Converting the Main Criteria to Fuzzy Numbers

Expert 1	**Social Sustainability**			**Economic Sustainability**			**Environmental Sustainability**		
	l	**m**	**u**	**l**	**m**	**u**	**l**	**m**	**u**
Social Sustainability	0.00	0.00	0.00	0.25	0.50	0.75	0.50	0.75	1.00
Economic Sustainability	0.75	1.00	1.00	0.00	0.00	0.00	0.75	1.00	1.00
Environmental Sustainability	0.00	0.00	0.25	0.00	0.25	0.50	0.00	0.00	0.00

* The same calculations are also done with Expert 2 and Expert 3.

Thereafter, the single fuzzy initial direct relationship matrix is formed as in the table below by taking the average of each cell of the matrices created in Table 3, which was obtained based on the data received from three expert decision-makers.

Table 4. The Single Fuzzy Initial Direct Relationship Matrix

Expert 1, 2, 3	**Social Sustainability**			**Economic Sustainability**			**Environmental Sustainability**		
	l	**m**	**u**	**l**	**m**	**u**	**l**	**m**	**u**
Social Sustainability	0.000	0.000	0.000	0.250	0.500	0.750	0.416	0.666	0.916
Economic Sustainability	0.333	0.583	0.750	0.000	0.000	0.000	0.333	0.583	0.750
Environmental Sustainability	0.166	0.333	0.583	0.083	0.333	0.583	0.000	0.000	0.000

Later, the normalized fuzzy direct relationship matrix is prepared by dividing the total u value into the fuzzy initial direct relationship matrix. The table below demonstrates the normalized fuzzy direct relationship matrix.

Table 5. The Normalized Fuzzy Direct Relationship Matrix

Expert 1, 2, 3	**Social Sustainability**			**Economic Sustainability**			**Environmental Sustainability**		
	l	**m**	**u**	**l**	**m**	**u**	**l**	**m**	**u**
Social Sustainability	0.00	0.00	0.00	0.15	0.300	0.45	0.25	0.40	0.55
Economic Sustainability	0.20	0.350	0.45	0.00	0.00	0.00	0.20	0.35	0.45
Environmental Sustainability	0.10	0.20	0.35	0.050	0.20	0.35	0.00	0.00	0.00

Next, the total relationship matrix and/or the fuzzy sum relationship matrix is calculated. First of all, l, m, u matrices are generated then by extracting the unit matrix and taking the reverse l (l-X)^(-1), m (I-X)^(-1), u (I-X)^(-1) matrices are calculated to later use in the fuzzy sum relationship matrix. The table below gives the fuzzy sum relationship matrix.

Table 6. The Fuzzy Sum Relationship Matrix

	Social Sustainability			Economic Sustainability			Environmental Sustainability		
	l	m	u	l	m	u	l	m	u
Social Sustainability	0.065	0.336	1.905	0.174	0.545	2.215	0.301	0.725	2.594
Economic Sustainability	0.236	0.603	2.094	0.048	0.321	1.784	0.268	0.704	2.405
Environmental Sustainability	0.118	0.387	1.750	0.069	0.373	1.750	0.043	0.285	1.750

After having created the fuzzy sum relationship matrix**,** the row and column totals in the fuzzy sum relationship matrix are calculated to obtain $\tilde{R}_i$ and $\tilde{C}_i$ values as well as the $\tilde{R}_i + \tilde{C}_i$ and $\tilde{R}_i - \tilde{C}_i$ values and given in the table below.

Table 7. Row and Column Values

$\tilde{R}_i$			$\tilde{C}_i$			$\tilde{R}_i + \tilde{C}_i$			$\tilde{R}_i - \tilde{C}_i$		
l	m	u	l	m	u	l	m	u	l	m	u
0.541	1.607	6.715	0.420	1.327	5.750	0.961	2.935	12.465	-5.208	0.280	6.295
0.554	1.629	6.284	0.293	1.241	5.750	0.848	2.870	12.034	-5.195	0.387	5.990
0.231	1.047	5.250	0.613	1.715	6.750	0.845	2.762	12.000	-6.518	-0.668	4.636

Lastly, the defuzzification process is performed by taking the average of the values that make up the triangular fuzzy number. Unnormalized criterion weights are found with the help of these defuzzified values. The table below shows the values of defuzzified and unnormalized weights.

Table 8. Defuzzied Values and Unnormalized Weights

Defuzzied Values		Unnormalized Weights
5.454044	**0.455574**	5.473038
5.251159	**0.394436**	5.265952
5.202849	**-0.850010**	5.271826

With the defuzzied values, a causal diagram for the petrochemical sector is created and given in the figure below.

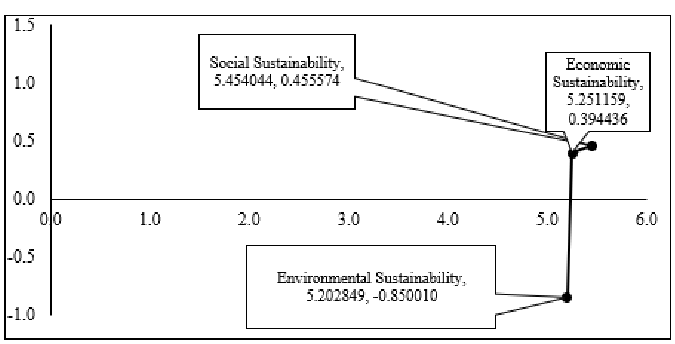

Figure 1. The Causal Diagram for Petrochemical Sector

According to the causal diagram of the petrochemical industry, it can be said that the environmental sustainability criterion is affected (an effect group) whereas economic and social sustainability criteria are affecting (a cause group) and the most influencing criterion is social sustainability according to the data gathered from the experts' views.

The same logic, as well as the formulations of fuzzy DEMATEL, are applied and the same steps are taken for determining the weights and relationships of sub-criteria. The weights of the sub-criteria are given in the table below in which weights clarify the weights of each criterion when considering their interrelationships among each other.

Table 9. Weights of the Sub-Criteria for Petrochemical Industry

Sub-Criteria	**Weights**
Workplace Safety	0.0609
Improvement in Working Standards and Conditions	0.0755
The Emergence of New Job Definitions	0.0618
Demand for a Qualified Workforce	0.0710
Increase in Social Welfare	0.0727
Increase in Profitability	0.0349
Cost Reductions	0.0317
Productivity in Production	0.0344
Flexibility in Production	0.0315
Quality Control and Assurance	0.0319
Delivery and Lead Time Reductions	0.0315
Transparency and Monitoring in Production	0.0354
Process Optimization	0.0310
Standardization in Production	0.0336
Increase in Profitability	0.0331
Increasing the Use of Renewable Energy Resources	0.0533
Environmental Pollution Prevention, Management and Control	0.0556
Increasing Recovery, Recycling and Reusing Rates	0.0537
Reducing Greenhouse Gas Emissions	0.0544
Ensuring Efficiency in Resource and Energy Use	0.0560
Developing green innovative strategies	0.0562

Based on the data gathered from the experts working in the petrochemical industry implies that improvement in the working standards and conditions, increasing competitiveness, and developing green innovative strategies precede the other criteria and workplace safety, transparency and monitoring in production, and increasing the use of renewable energy fall behind the remaining criteria. Furthermore, improvement in the working standards and conditions, as well as an increase in social welfare, are the most important criteria whereas the transparency and monitoring in production flexibility in production and delivery and lead time reductions are the least important ones.

6. Conclusion

The creation of a sustainable industrial value with increasing the effectiveness of social, environmental, and economic sustainability dimensions has been occupying the agenda of today's business environments more than ever with the spreading of Industry 4.0 technologies. According to the results of the fuzzy DEMATEL used for weighting the main and sub-criteria, it was implied that the most critical sustainability dimension was social and improvement in the working standards and conditions and increase in social welfare were the most important criteria though the transparency and monitoring in production, flexibility in production, and delivery and lead time reductions are the least important ones for the decision-makers working in the petrochemical industry. These results show that overall, social and environmental sustainability were given the most importance under the umbrella of sustainability. This is a confounding however a favorable situation as generally businesses focus heavily on economic aspects. Since this study used a purposive sampling procedure, the focus was only on experts in the field, which may have resulted in a failure to capture the insights and experiences of other sectors. For future research suggestions, other sectors such as logistics, automotive, and food industries would enhance the breadth and scope of the existing results.

References

Altan, Ş., and Karaş Aydin, E. Bulanık DEMATEL ve Bulanık TOPSIS Yöntemleri ile Üçüncü Parti Lojistik Firma Seçimi için Bütünleşik bir Model Yaklaşımı. *Suleyman Demirel University Journal of Faculty of Economics & Administrative Sciences*, 20(3), 2015.

Brundtland, G.H. The United Nations World Commission on Environment and Development: Our Common Future, Oxford, UK, 1987.

Burritt, R., and Christ, K. Industry 4.0 and environmental accounting: a new revolution?. *Asian Journal of Sustainability and Social Responsibility*, *1*(1), 23., 2016.

Chen-Yi, H., Ke-Ting, C., and Gwo-Hshiung, T., FMCDM with Fuzzy DEMATEL Approach for Customers' Choice Behavior Model. *International Journal of Fuzzy Systems*, *9*(4), 2007.

Cohen, Y., Naseraldin, H., Chaudhuri, A., and Pilati, F., Assembly systems in Industry 4.0 era: a road map to understand Assembly 4.0. *The International Journal of Advanced Manufacturing Technology*, *105*(9), 4037-4054, 2019.

de Man, J. C., and Strandhagen, J. O., An Industry 4.0 research agenda for sustainable business models. *Procedia Cirp*, *63*, 721-726, 2017.

Dyllick, T., and Hockerts, K., Beyond the business case for corporate sustainability. *Business strategy and the environment*, *11*(2), 130-141, 2002.

Elkington, J., The triple bottom line. Environmental management: Readings and cases, 2, 1997.

Etikan, I., Musa, S. A., and Alkassim, R. S., Comparison of convenience sampling and purposive sampling. *American journal of theoretical and applied statistics,* 5(1), 1-4, 2016.

Gabus, A., and Fontela, E., World problems, an invitation to further thought within the framework of DEMATEL. Battelle Geneva Research Center, Geneva, Switzerland, 1-8, 1972.

Gabus, A., and Fontela, E., Perceptions of the world problematique: Communication procedure, communicating with those bearing collective responsibility. (DEMATEL report no. 1). Switzerland Geneva: Battelle Geneva Research Centre, 1973.

Goel, P., Triple bottom line reporting: An analytical approach for corporate sustainability. *Journal of Finance, Accounting, and Management, 1*(1), 27-42, 2010.

Govindan, K., Sarkis, J., Jabbour, C. J. C., Zhu, Q., and Geng, Y., Eco-efficiency based green supply chain management: Current status and opportunities. *European Journal of Operational Research*, *233*(2), 293-298, 2014.

Koca, K. C., Industry 4.0: Chances and threats from the point of Turkey. Sosyoekonomi Journal, 26 (36), 2018.

Lin, K. P., Tseng, M. L., and Pai, P. F., Sustainable supply chain management using approximate fuzzy DEMATEL method. *Resources, Conservation and Recycling*, *128*, 134-142, 2018.

Lin, R. J., Using fuzzy DEMATEL to evaluate the green supply chain management practices. *Journal of Cleaner Production*, *40*, 32-39, 2013.

Nagasawa, T., Pillay, C., Beier, G., Fritzsche, K., Pougel, F., Takama, T., and Bobashev, I., Accelerating Clean Energy through Industry 4.0: Manufacturing the Next Revolution. *A Report of the United Nations Industrial Development Organization*, 2017.

Posada, J., Toro, C., Barandiaran, I., Oyarzun, D., Stricker, D., De Amicis, R. et al., Visual computing as a key enabling technology for industrie 4.0 and industrial internet. *Computer Graphics and Applications*, IEEE, 35(2), 26-40, 2015.

Prakash, K. S., Nancharaih, T., and Rao, V. S., Additive manufacturing techniques in manufacturing-an overview. *Materials Today: Proceedings*, *5*(2), 3873-3882, 2018.

Prause, G., Sustainable business models and structures for Industry 4.0. *Journal of Security & Sustainability Issues*, *5*(2), 2015.

Valdez, A. C., Brauner, P., Schaar, A. K., Holzinger, A., and Zieflea, M., Reducing Complexity with simplicity-Usability Methods for Industry 4.0. *Proceedings 19th Triennial Congress of the IEA. Melbourne, Australia, RWTH Publications*, 9-14, 2015.

Wu, W. W., and Lee, Y. T., Developing global managers' competencies using the fuzzy DEMATEL method. *Expert systems with applications*, 32(2), 499-507, 2015.

Zadeh, L. A., Fuzzy sets. In *Fuzzy sets, fuzzy logic, and fuzzy systems: selected papers by Lotfi A Zadeh* (pp. 394-432), 1996.

Zhou, Q., Huang, W., and Zhang, Y., Identifying critical success factors in emergency management using a fuzzy DEMATEL method. *Safety science*, *49*(2), 243-252, 2011.

Biographies

Elif Çirkin, a Research Assistant at Dokuz Eylul University, Faculty of Business, Department of Business Administration, Division of Production Management and Marketing. In 2012, she graduated from Gaziantep University with a bachelor's degree in Industrial Engineering. After that, she gained MSc. in Manufacturing Management with distinction from the University of Hertfordshire in 2015 and PhD degree in Business Administration from Dokuz Eylul University in 2021. Her research interests are Supply Chain Management, Lean Manufacturing, Logistics Management, Sustainability, and Industry 4.0.

Aşkın Özdağoğlu, an Associate Professor at Dokuz Eylul University, Faculty of Business, Department of Business Administration, Division of Production Management and Marketing. In 1999, he graduated from Dokuz Eylul University Faculty of Economics and Administrative Sciences, Department of Business Administration. He gained MSc. in Production Management in 2003 and PhD degree in 2008. Askin Ozdagoglu is still working as Associate Professor at Dokuz Eylul University Faculty of Business, Division of Production Management and Marketing. He is also the member of Systems Thinking Society in Turkey and Production Researches Society in Turkey. His research interests are multi-criteria decision making, fuzzy logic, and system dynamics.