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An integrated model using SWOT analysis and Hesitant fuzzy linguistic term set for evaluation occupational safety risks in life cycle of wind turbine

Aylin Adem[a,*], Ali Çolak[b], Metin Dağdeviren[a]

[a] Gazi University, Engineering Faculty, Industrial Engineering Department, Ankara, Turkey
[b] Soyut R&D, Ankara 06700, Turkey

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ABSTRACT

The production, operation, and transportation stages of wind turbines involve elements of risk with regard to occupational health and safety. In a previous study, a risk prioritization covering the whole product lifecycle of a wind-turbine was carried out for wind-turbine companies. In that study, the product lifecycle stages were examined using a fuzzy analytic hierarchy process. The two most risky stages were determined to be transportation and production. This study focuses on the risks that are inherent to the production stage of the wind-turbine lifecycle. The aim of this study is to propose a new occupational risk-scoring methodology for production stages of wind turbines and as well as for all sectors and processes. Firstly, a strengths–weaknesses–opportunities–threats (SWOT) analysis is conducted to determine the risks to the company and whether they are compatible with the risks determined by an EU agency. The risk score is then obtained by taking the opinions of three experts regarding the risks identified by the SWOT analysis. For risk assessment, a hesitant fuzzy linguistic approach is applied to the operation of wind-turbine production firm in Ankara, Turkey. A number of suggestions are proposed for the items of highest risk in the study. The related precautions are then introduced and implemented at the wind-turbine firm. After the firm has applied the recommendations for a certain period of time (approximately six months), the risk score is re-evaluated. The study ends by conducting comparative analyses for both cases.

1. Introduction

Wind is one of the most important renewable energy sources and is widely used throughout the world because it is cheaper, safer, and more eco-friendly than traditional energy systems (Adem et al., 2016).

The energy obtained by wind turbines utilizes the power of nature without harming the environment in an ecological sense, which is also known as green energy. Wind energy is seen as a natural solution to the world's energy problems, which are attracting the attention of more and more countries and causing increasingly serious issues around the world. The wind turbines' production stages used to produce this green energy have various risk factors with respect to occupational health and safety (OHS). The production, operation, and transportation stages of wind turbines pose a variety of risks. However, as the importance of OHS is increasingly understood, the measures to be taken by both the academic and the business community are examined together to prevent job losses. OHS issues are now taken into consideration by both companies and employees (Işık and Atasoylu, 2017). In the paper of Adem et al. (2016), a risk prioritization study was carried out for wind-turbine companies operating in Turkey, covering the whole product lifecycle of a wind turbine. In that study, the product lifecycle was examined using a fuzzy Analytic Hierarchy Process (AHP). The two most risky stages were determined to be transportation and production (Adem et al., 2016). The transportation phase is an external factor for manufacturing firms; thus, the risks that occur in the production stage of the wind-turbine lifecycle are considered in this study.

More generally, the aim of this study is to propose a new methodology for occupational risk scoring for all sectors and business lines, including manufacturing phase, across the whole companies. In a more specific sense, the aim of this study is to develop a risk-scoring system for a company operating in the field of wind-turbine production, to present solutions for the most risky stages, and to quantify the usefulness and sustainability of the solutions provided. At the same time, with this study, when experts hesitate between risk factors' importance degree, HFLTS, an approach by which experts can easily express their thoughts, is presented. To achieve the paper's goal, a Strengths–Weaknesses–Opportunities–Threats (SWOT)

* Corresponding author.
E-mail addresses: aylinadem@gazi.edu.tr (A. Adem), alicolak@soyut.com (A. Çolak), metindag@gazi.edu.tr (M. Dağdeviren).

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analysis was conducted to determine the risks to the company and whether they are compatible with the risks assessed by an EU agency (EU Risk Report, 2013). The reason for using SWOT analysis is to consider all aspects and clarify the risks associated with the production phase because SWOT analysis is a powerful tool that accurately represents the strengths and weaknesses of the firm, as well as its opportunities and threats (Babaesmailli et al., 2012). The second step of this study is to obtain risk scores by taking the opinions of three experts on the risks identified in the previous stage of the study. While receiving the expert opinions, we employed the Hesitant Fuzzy Linguistic Term Set (HFLTS) approach, a fairly novel method that has been applied in various fields (Yavuz et al., 2015; Shahzad, 2017; Tan, 2016; Onar et al., 2016; Oztaysi et al., 2016). The HFLTS approach has been used for risk evaluation because in this important area experts may hesitate when making decisions/evaluating risks. The accuracy of risk assessment results is vitally important to a firm, and the risk scoring of a firm's production department will help to determine the precise nature of the firm and the precise precautions to be taken. Following the scoring of risks, the firm reviews the most risky steps and apply the recommendations. Six months after the proposals were taken into consideration and implemented by the company, the same risk-scoring process was repeated by the same experts. The overall risk score of the company was observed to decrease. The difference of this study from other risk-scoring studies in the literature lies determination of the risks by SWOT analysis, and the first time that the HFLTS approach has been used for a risk-scoring study, also the application to a real-world problem.

Although there are many studies on occupational risk assessment in the literature, it is very hard to find a study that specifically focuses on wind turbines. At the same time, it is very difficult to find studies that use fuzzy logic and HFLTS when considering general risk assessment. One study that combines fuzzy logic and occupational risk assessment is that of Mure et al. (2006). A few studies have been used in conjunction with risk assessment and fuzzy logic related to the construction sector (Amiri et al., 2017; Shi et al., 2008; Parmooze et al., 2014). Hajakbari and Bidgoli (2014) proposed a new risk-scoring system to assess the risks of occupational accidents. The authors used data mining techniques to achieve their goals. Examples of risk assessment and SWOT analysis approaches include the work of Kokangül et al. (2017), who proposed a new risk assessment approach combining AHP with the Fine–Kinney method, and Kheirkhah et al. (2009), who studied fuzzy SWOT analysis to develop strategies for reducing the risk of hazardous materials transportation in Iran. Ozcan and Turan (2009) proposed a risk assessment method for marine casualties in the Strait of Istanbul. In their study, SWOT was used together with AHP. Working examples have been given in different areas where the HFLTS approach is used (Tan, 2016; Onar et al., 2016; Oztaysi et al., 2016). The HFLTS approach has been successfully implemented in the field of multi-criteria group decision making by Yavuz et al. (2015), who used both HFLTS and AHP to solve the problem of choosing the vehicle fuel type to be used in home care services.

Most of the studies on risk assessment in the literature are, generally, weighting risk factors with multi-criteria decision-making methods, and then prioritize measures that will be taken(Gül et al., 2017; Ahmadi et al., 2017).

In a more general sense, there are studies that use the fuzzy logic with risk assessment methods, ie, modelling uncertainties in decision environment using fuzzy logic approach (Li et al., 2017; Pinto, 2014; Camastra et al., 2015; Azadeh, et al. 2014).

Jiang et al. (2017) proposed a new approach with integrated into FMEA (Failure mode and Effect Analysis) and fuzzy logic. They considered determining risk priority number with fuzzy logic to achieve more accurate results. Ji et al. (2015) proposed an integrated fuzzy entropy-weight multiple criteria decision-making method and applied to risk assessment of hydropower stations in the Xiangxi River. There are many studies in the literature that find RPNs in FMEA (Mandal and Maiti, 2014; Yazdi et al., 2017; Petrovic et al., 2014;) with the fuzzy logic approach and then MCDM methods to prioritize risks (Ozdemir et al., 2017; Liu et al., 2014; Kumar et al., 2018; Silva et al., 2014).

After examining the relevant literature, no examples of HFLTS applied to risk scoring were found. We, therefore, decided to use this approach, which offers the opportunity to make assessments that are closer to the human mind than other options, in the risk-scoring study.

This paper is organized as follows. Section 2 introduces the HFLTS and SWOT analysis methods used in the study, before Section 3 explains the real-life applications. Finally, in section 4, the results are explained and some ideas for future work are discussed.

2. Materials and methods

In this study, SWOT analysis was carried out to clarify the risks related to a wind-turbine firm and to help the firm define itself. The SWOT analysis clearly demonstrates the risks involved in the production process of the firm. Subsequently, experts in the field assessed these risks using the HFLTS approach. This section explains these two methods.

2.1. SWOT analysis

SWOT analysis is a very successful tool for understanding what a firm is doing in terms of the features being analysed (Babaesmailli et al., 2012). The overall objective of SWOT analysis is to identify the strengths, weaknesses, opportunities, and threats to a business or organization on the subject of interest, and to identify the conditions of the company according to these characteristics. In most studies, SWOT analysis focuses on how the opportunities will be assessed and how to eliminate the threats after the company's situation is revealed. In other words, SWOT analysis is generally the first stage of a large-scale study. SWOT analysis is often used to examine financial issues, such as firms' market and brand values, and competitive aspects. However, recent studies have also shown that SWOT analysis can analyse features in quite different areas, such as OHS (Jansen, 2005). Readers who wish to learn more about SWOT analysis are referred to Jackson et al. (2003) and Helms and Nixon (2010).

2.2. Hesitant fuzzy linguistic term set

HFLTS is a novel issue in fuzzy logic (Herrera et al., 2011). Rodriguez et al. (2012) were the first researchers to use these sets of fuzzy terms for decision making. Since then, HFLTS has repeatedly been applied in decision making itself (Fahmi et al., 2016; Liao et al., 2015; Wei et al., 2015).

The HFLTS approach simplifies the decision-making process when it may be difficult to express an opinion (Gou et al., 2017). In other words, HFLTS makes it easier for the decision-maker convey their perspective into the decision-making process.

In this study, the HFLTS approach is employed to elicit expert opinions in the risk assessment phase. Three experts whose have at least five years' experience in this area were asked to assess the risks identified by the SWOT analysis. Risk assessments were taken using the linguistic expressions of the experts.

Since the assessment was made by more than one expert, the evaluations of these experts are needed to show with a single value. In the following stage, the experts' evaluations were combined using the widely used arithmetic mean method (Yavuz et al., 2015).

The HFLTS approach has the following stages:

Step 1: Define the semantics and syntax of the used linguistic term set S. S has the following components:

In fact, what is needed in step 1 is to determine the semantics and sets (words) that the experts will use when evaluating risk factors.