mathematics

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Fuzzy Win-Win: A Novel Approach to Quantify Win-Win Using Fuzzy Logic

Ghada A. Altarawneh [1,†], Ahmad B. Hassanat [2,*,†], Ahmad S. Tarawneh [3,†] and David Carfì [4,†] and Abdullah Almuhaimeed [5,*,†]

[1] Department of Accounting, Mutah University, Karak 61710, Jordan; Ghadaa@mutah.edu.jo
[2] Department of Computer Science, Faculty of Information Technology, Mutah University, Karak 61710, Jordan
[3] Department of Algorithms and Their Applications, Eotvos Lorand University, 1053 Budapest, Hungary; ahmadtr@caesar.elte.hu
[4] Department of Mathematics, University of California Riverside, Riverside, CA 92521, USA; davidcarfi@ucr.edu
[5] The National Centre for Genomics and Bioinformatics, King Abdulaziz City for Science and Technology, Riyadh 11442, Saudi Arabia
* Correspondence: hasanat@mutah.edu.jo (A.B.H.); muhaimed@kacst.edu.sa (A.A.)
† These authors contributed equally to this work.

Abstract: The classic notion of a win–win situation has a key flaw in that it cannot always offer the parties equal amounts of winningsbecause each party believes they are winners. In reality, one party may win more than the other. This strategy is not limited to a single product or negotiation; it may be applied to a variety of situations in life. We present a novel way to measure the win–win situation in this paper. The proposed method employs fuzzy logic to create a mathematical model that aids negotiators in quantifying their winning percentages. The model is put to the test on real-life negotiation scenarios such as the Iraqi–Jordanian oil deal and iron ore negotiation (2005–2009), in addition to scenarios from the game of chess. The presented model has proven to be a useful tool in practice and can be easily generalized to be utilized in other domains as well.

Keywords: fuzzy logic; economics; win–win situation; win–win negotiations

MSC: 03B52; 94D05; 91A86

Citation: Altarawneh, G.A.; Hassanat, A.B.; Tarawneh, A.S.; Carfì, D.; Almuhaimeed, A. Fuzzy Win-Win: A Novel Approach to Quantify Win-Win Using Fuzzy Logic. *Mathematics* **2022**, *10*, 884. https://doi.org/10.3390/math10060884

Academic Editor: Ioannis G. Stratis

Received: 31 January 2022
Accepted: 7 March 2022
Published: 10 March 2022

1. Introduction

According to the Merriam Webster dictionary, the first known use of the phrase win–win goes back to the year 1962. As per the dictionary, the concept is defined as one that is "advantageous or satisfactory to all parties involved". In spite of the fact that some experts regard this concept as an oxymoron [1–4], it has attracted interest worldwide and is used on a daily basis by many people.Furthermore, it has piqued the interest of academics in relation to a wide range of topics and study disciplines, including economics [1,5], business [6,7], game theory [8,9], sustainability [10,11], biology [12,13], Policy [14,15], agriculture [16,17], health [18,19], education [20,21], social science [22,23], engineering [24,25], tourism [26,27], etc.

The phrase "win–win" made its first documented appearance in Singer's work [28], in which he characterized it as follows: "In zero-sum games, every win for one side is a loss for the other; there can be no such thing as a 'win–win' outcome. The non-zero-sum game, on the other hand, is not one of pure conflict, but a mixture of conflict and co-operation. An excellent example is the "prisoner's dilemma" noted in the previous chapter. Objectively, a win–win outcome was available, but the prisoners played as if it were not". Since then, the term has been defined several times based on the discipline of the study and the topic addressed; the following are examples of distinct definitions from various scholars:

- Covey defines win–win as "a frame of mind and heart that constantly seeks mutual benefit in business and personal transactions" [29].
- Nalis et al. define win–win solutions as "outcomes of interpersonal behavior that exceed the outcomes that each participant could achieve alone" [30].
- Fujita et al. define win–win as "ideas that might give both parties most of what they want" [31].
- Thompson and Gonzales regard a "win–win outcome to be one that is efficient—meaning that there is no other outcome parties could reach that at least one party would prefer without reducing the other party's utility" [32].
- Brooks defines win–win as "success in two or more of the outcomes measured (ecological, economic, social) and "tradeoffs" are defined as some combination of success, limited success, or failure" [33].
- Bottos, and Coleman define a win–win outcome in any negotiation as "the outcome that makes both parties feel as though they have benefited from the discussion" [34].
- Carbonara et al. concluded that win–win refers to the capacity to meet the diverse interests of the parties involved by assuring their profit demands while also fairly allocating risk among them [35].
- Ekermo defines win–win as "the theoretical possibility of finding mutually beneficial solutions for economy and environment" [36].
- Smith et al. define win–win as "the idea that one person's success is not achieved at the expense or exclusion of the success of others" [37].
- Engler defines win–win as "a fair distribution of the efforts of the collaboration and the results" [38]
- Moon and Dathe-Douglass defines win–win as "the only rational way for a leader to think" [39].
- Willing et al. define win–win as "the approach that seeks a mutually beneficial outcome, resulting in mutual cooperation and joint commitment in its implementation" [40].
- Blount defines win–win as "the warm blanket of delusion where your commission check and your company's profits curl up to die" [41].
- Dor defines win–win as "the art of winning while letting the other side think that they have won as well" [42].
- Recently, Zhang et al. defined win–win as "the realization of maximizing the interests of both sides, which is a harmonious development with mutual benefits" [43].

The importance of the notion of win–win is evident from its widespread applicability in almost all fields of study, providing feasible solutions for a vast array of challenges. Furthermore, a great number of scholars have praised the concept by giving it fancy titles based on its applications, referring to it, for instance, as the key [44], the solution [45], the optimal choice [46], the best model [47], the cornerstone [48], the ultimate goal [49], the only way [50], the final purpose [51], the logical force [52], the ideal way [53], the ideal solution [54], the objective [55], etc. Moreover, at the time of writing this paper, a search of Google Scholar for the word "win–win" returned 616,000 results, whereas the Google search engine returned 68,400,000. This is an indicator that the concept is widely used, both in academia and in general.

Scholars' differing opinions on win–win have resulted in a variety of explanations and definitions. Because of this difficulty, defining win–win as a rule of thumb is challenging. For example, Eshun et al. [56] defined a win–win situation in a public-private partnership as a situation in which both the private and public sectors are equally and actively involved in the formulation of optimal and equitable risk assessments and allocations. However, some scholars argue that negotiators with a fixed-pie bias consistently fail to attain optimal distributions because they do not seek out win–win solutions and are content with a merely acceptable compromise [57–59]. On the contrary, Nalis et al. argue that such views might be incorrect, implying that there is a feasible solution that people simply do not notice. As a result, it is crucial to figure out which personal qualities and circumstantial conditions make developing such solutions easier [30]. Similarly, Lute stated that understanding trends with various management styles is extremely beneficial in building and sustaining a win–win environment; thus the success of a win–win situation is attributed to personal behavior [60].

Because there are differing viewpoints, ambiguity, or at the very least misinterpretation of the notion of win–win, several researchers have worked to improve it. As an example, Fisher and Ury [61] presented a new form of win–win negotiation, referred to as "principled negotiation". They stated that effective negotiations promote collaboration toward a common objective. They defined a number of stages involved in conducting principled negotiation, including:

- Separating people from the problem;
- Focusing on interests, not positions;
- Inventing options for mutual gain; and
- Using objective criteria

The authors of [1] proposed goal-oriented balancing: happy–happy negotiations beyond win–win situations, suggesting that the term "win–win" is an oxymoron because it juxtaposes aspects that are incompatible (only winners are possible because winning, which implies that someone will lose). As a result, they proposed the term "happy–happy situation" to better explain the heart of a successful negotiating process, suggesting that both parties should be satisfied. According to [1], the concept of "happy–happy" offers a number of advantages, including:

- It is not an oxymoron; thus, it more accurately represents the desired situation.
- It is not a competitive metaphor because it emphasizes fulfilment instead of competitiveness.
- It is relational rather than transactional in nature.
- Because it depicts an emotion, it focuses on the process rather than an objective end.
- It signifies that the negotiating process is ongoing and does not come to an end in a specific circumstance.

Another interesting study conducted by Paul Gruenbacher [62] employed win–win solutions in software development. More specifically, he used a methodology called easy win–win. In this methodology, the author suggests the involvement of stockholders in the negotiations to maximize the level of satisfaction between the negotiators. In his methodology, the stockholders can be a part of processes such as brainstorming, which can be performed electronically and which enable them to share their ideas simultaneously. This approach helps to simplify their involvement, as well as enhancing interaction and communication with stockholders.

To the best of our knowledge, the only mathematical win–win model was proposed by Antonio Ruiz-Cortes and co-workers [63]. They suggested an improvement on the traditional win–win concept in the requirements engineeringstage of a given project. Their improvement was based on a mathematical representation of the requirements using set theory with constraints associated with each win condition in the requirement space. The improvement is applicable in product-oriented contexts and to projects involving many stockholders. The main benefit of their proposal is that it removes the conflicts before the negotiation starts in order to maximize the satisfaction for all the involved parties.

Research Gap, Motivation and Objective

Despite a plethora of research studies confirming the value of win–win implementation in a variety of academic fields (see Table 1), we came across findings that contradict each other, such as "the importance of teaching win–win" [64] and "the Myth of the win–win" [65]. There is thus a lack of agreement among scholars on the importance and definition of the win–win concept. Furthermore, in terms of win–win, all prior research and definitions have employed ambiguous or fuzzy terms such as outcomes, most, success, efficiency, utility, fairness, beneficial, maximizing, etc. Knowing that there is no universal or absolute measure of utility, fairness, success, etc. Therefore, we claim that the concept of win–win is ambiguous or at least fuzzy enough to produce such an inconsistency, since it has not been formally and accurately modelled, and this motivated us to provide an alternative concept. The objective and contribution of this paper were to develop a new win–win model based on fuzzy logic, which we refer to as fuzzy win–win. In a typical win–win situation, both parties believe they are winners; however, this is only partially accurate; in most circumstances, one side wins more, which is why we propose our fuzzy win–win model, which attempts to quantify the winning situation for each party.

Table 1. Some examples of win–win related publications.

Publication Year	Reference	Research Field	Publication Year	Reference	Research Field
1962	[28]	Policy	2014	[66]	Sustainability
1995	[8]	Game Theory	2015	[10]	Sustainability
1995	[14]	Policy	2015	[27]	Tourism
1998	[6]	business	2016	[9]	Game Theory
1998	[21]	Education	2016	[17]	Agriculture
2000	[67]	Social science	2017	[1]	Economics
2000	[62]	Engineering	2017	[68]	Game Theory
2001	[69]	business	2017	[22]	Social Science
2002	[61]	Public Relations	2018	[70]	Game Theory
2002	[63]	Engineering	2018	[15]	Policy
2004	[13]	Biology	2018	[18]	Health
2005	[23]	Social science	2019	[5]	Economics
2006	[25]	Engineering	2019	[71]	Policy
2007	[72]	business	2020	[16]	Agriculture
2008	[73]	Education	2021	[74]	Game Theory
2009	[12]	Biology	2021	[19]	Health
2010	[75]	business	2021	[76]	Health
2012	[77]	Biology	2021	[78]	Education
2012	[20]	Education	2021	[24]	Engineering
2014	[79]	Game Theory	2021	[80]	Engineering
2014	[11]	Sustainability	2021	[26]	Tourism

2. The Proposed Fuzzy Win–Win Model

Almost all the models proposed in the literature have attempted to ensure satisfaction between different parties. However, no model has answered the question of how much each party benefits from the deal or the negotiations. The fuzzy win–win approach is based on the well-known fuzzy logic technique, and we propose here to determine the winning proportion of each negotiator. Fuzzy logic was first proposed by Lotfi Aliasker Zadeh in 1965 [81], and since then it has been used in fields as diverse as economics, statistics, finance, management, engineering, etc. [82–99].

Fuzzy logic uses membership functions to determine the percentage of the win for each party. To simplify the illustration of the proposed model, we consider two parties in the negotiation. The first one is the seller and the second one is the buyer. Let us assume that both are negotiating on selling/buying of a product, with the following parameters:

- The product's initial cost price (CP).
- The negotiation results in selling the product at price P, which is the selling price at which the deal is consummated.
- The seller's wanted price, or simply the seller price (SP)—normally this price is the fair market price of the product measured at the same time of the negotiated deal.

Typically, $SP > CP$ therefore, and according to the win–win concept, if $P > CP$ then the seller is consider a winner. At the same time, if $P < SP$ then the buyer is considered a winner. However, if $P > CP \wedge P < SP$, then both parties are considered winners regardless of P. This is exactly the dilemma of the win–win scenario, as the seller and buyer do not win the same amount. One of them might win more, and therefore benefit more from the deal. The previous aspects of the proposed fuzzy win–win model can be quantitatively expressed using membership functions in order to quantify the quantity; or, to be more specific, the percentage of the win for each party as follows:

$$Seller(P) = \begin{cases} 0\% & P < CP \\ 100\% & P > SP \\ \frac{P-CP}{SP-CP}\% & otherwise \end{cases} \tag{1}$$

where $Seller(P)$ is a function of P, which outputs the percentage of winning of the seller, and

$$Buyer(P) = \begin{cases} 100\% & P < CP \\ 0\% & P > SP \\ \frac{SP-P}{SP-CP}\% & otherwise \end{cases} \tag{2}$$

where $Buyer(P)$ is a function of P, which outputs the percentage of winning of the buyer.

Obviously, the fuzzy win–win model has two membership functions. One is dedicated to the seller, and the other is dedicated to the buyer. These functions can determine the winning percentage for each party. Figure 1 shows a simple deal in which the seller function is presented as a blue dotted function, whereas the buyer function is depicted in dotted red.

Figure 1. Illustration of the membership function using a simple deal example. In this deal, the cost price of the product is 10 and the seller price is 60 regardless of the currency.

According to the previous Equations (1) and (2) and the curves in Figure 1, we can calculate the percentage of winning for each party. For example, the buyer is considered 100% winning if they can secure a deal with $P \leq CP$. However, this rate decreases as P increases, until it reaches 0% if the buyer paid SP or more, because if the buyer wants to sell what he just bought he will most likely receive only what he paid, without any profit. On the other hand, the seller's winning percentage is considered zero if they secure a deal with $P \leq CP$, because they have only received the cost price or less, with no profit gained from the deal. However, this rate increases as P increases, until it reaches 100% if the seller receives his wanted price of SP or more.

It is worth mentioning that the curves in Figure 1 show three distinct areas that describe three different situations, namely:

1. Lose-win situation, starting from $P = 0$ until $P = CP$.
2. Fuzzy win–win situation, starting from $P = CP$ until $P = SP$, the so-called zone of possible agreement (ZOPA).
3. Win-lose situation, starting from $P = SP$ until $P = infinity$.

However, in this work we focus on the fuzzy win–win situation, because the goal of this paper is to quantify the win–win situation alone.

The inverse functions of Equations (1) and (2) are also important for our model, because by using them, we can obtain P given the percentage of winning of any party, and this can be formulated as follows

$$P_s = \begin{cases} CP & SWP = 0\% \\ SP & SWP = 100\% \\ SWP * (SP - CP) + CP & otherwise \end{cases} \quad (3)$$

where P_s is the price that the seller should secure the deal with, if they want to achieve a specific seller winning percentage (SWP) out of the deal, and

$$P_b = \begin{cases} CP & BWP = 100\% \\ SP & BWP = 0\% \\ SP - BWP * (SP - CP) & otherwise \end{cases} \quad (4)$$

where P_b is the price that the buyer should secure the deal with, if they want to achieve a specific buyer winning percentage (BWP) out of the deal. Figure 2 depicts the curves of the inverse functions of the fuzzy win–win model.

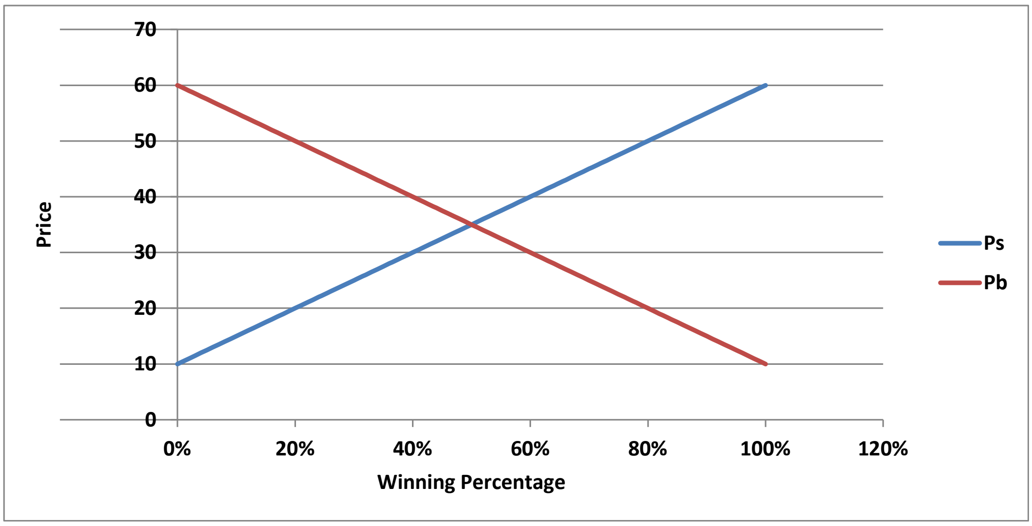

Figure 2. Illustration of the fuzzy win–win inverse functions (Equations (3) and (4)) based on the same example used in Figure 1, where $CP = 10$ and $SP = 60$ regardless of the currency.

As can be seen from Figure 2, the domain of both functions P_s and P_b is defined for all real values in the range of $[0, 1]$; hence, both functions can take any winning percentage from 0% to 100%. Furthermore, the range of both functions is defined for all real values in the range of $[CP, SP]$; in our example these values are 10 and 60, respectively. Therefore, both functions can suggest a specific price given a winning percentage. Figure 3 presents a schematic diagram of the proposed approach.

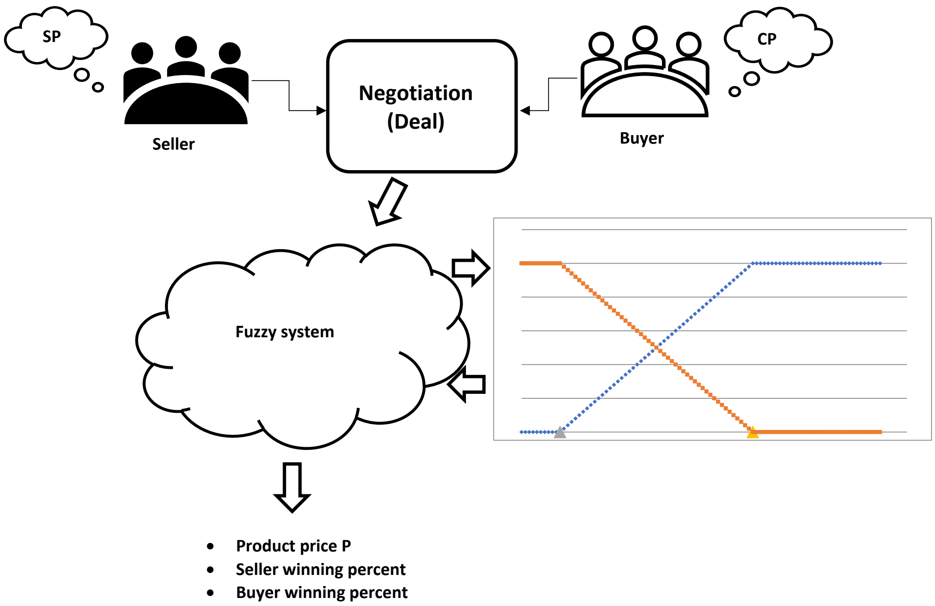

Figure 3. Schematic diagram of the fuzzy win–win approach.

3. Results and Discussion

In order to apply the proposed fuzzy win–win system to the solution of a specific problem, we used a toy example for an imaginary simple deal, and two real-world cases, namely, the current Iraqi–Jordanian oil deal, and the international iron ore negotiations (2005–2009).

3.1. Toy Example

Assume that the CEOs of two corporations, company $C1$ and company $C2$, are negotiating the purchase of some of the latter's shares. The current price of the share is $33. However, this is expected for some reason to double soon. How we can use the fuzzy win–win model to help any CEO in this negotiation? According to the normal win–win concept, both of the CEOs will be happy and winners if they secure a deal with any price in the range of [$33, $66]. However, the proposed Fuzzy win–win model is more precise, and can answer two types of questions for each party:

(Q1) If the share is sold for P, what is the winning percentage for each of $C1$ and $C2$?
(Q2) If the CEO of $C2$ wants to achieve a specific winning percentage out of this deal, at what price should $C2$ sell its shares?

Similarly, if the CEO of $C1$ wants to achieve a specific winning percentage out of this deal, at what price should $C1$ buy the shares of $C2$?

By applying the proposed fuzzy win–win model (Equations (1)–(4)) to the data of our toy example, we get Table 2.

Table 2 shows discrete data; that is, the share price in the table has been increased by one for illustrative purposes. The fuzzy win–win model, on the other hand, is continuous by nature, as inherited from fuzzy logic. If we employ the model's equations, we can obtain real values. We can answer any of the above questions for $C1$ or $C2$ in either case. For example, if a deal was made on $40, the SWP for $C2$ is 21%, and the BWP for $C1$ is 79%. Both percentages are complements of each other; this is because the equations used are linear, and these functions and curves are subject to altering and tuning by the users of the system. On the other hand, if CEO of $C2$ came to the negotiations with 40% SWP in mind, they need to sell their shares at $46.2. If taken literally, the win–win concept could be equivalent to the fuzzy win–win model when both parties achieve 50% winning percentages. For this toy example, the share needs to be sold for $49.5. It is worth noting that fuzzy win–win is not designed for predicting winning/losing situations; rather it is based on current information and given data. If we assumed that the price was doubled, then this would be a fact for the fuzzy win–win model, regardless of its truth/falsehood, since the model is based only on the given data.

Table 2. A toy example illustrating the calculation of wining percentages produced using the proposed method.

Share Price	C2-SWP	C1-BWP	P_s	P_b
33	0%	100%	33	33
35	6%	94%	35	35
37	12%	88%	37	37
39	18%	82%	39	39
41	24%	76%	41	41
43	30%	70%	43	43
45	36%	64%	45	45
47	42%	58%	47	47
49	48%	52%	49	49
51	55%	45%	51	51
53	61%	39%	53	53
55	67%	33%	55	55
57	73%	27%	57	57
59	79%	21%	59	59
61	85%	15%	61	61
63	91%	9%	63	63
65	97%	3%	65	65

3.2. Real-World Case 1: Current Iraqi–Jordanian Oil Deal

In case number one, we look at the oil deal struck between the governments of Iraq and Jordan between September 2019 and November 2020 [100]. The Jordanian government agreed to buy a barrel of oil crude for USD16 less than the Brent price. The barrel's production cost was USD 12.57. Table 3 shows the price information and the fuzzy win–win calculations.

By applying our equations, we can obtain the seller's win percentage (SWP) for Iraq, and the buyer's win percentage (BWP) for Jordan. These percentages show how many times and at which prices each country achieved greater winning percentages. As can be clearly seen in Table 3, the deal was almost fair; however, there were more winning percentages for the Jordanian side. Jordan won more in 28 cases, whereas Iraq won 27 times. The average of the winning percentages was 45% and 55% for Iraq and Jordan, respectively. The win percentages were perfectly equal in five cases, according to the data in the table. In three cases out of 50, Jordan achieved a 100% win percentage. Figure 4 shows the winning percentage curves for Iraq and Jordan.

Table 3. Information about the oil deal between Iraq and Jordan, with the winning percentages calculated using the proposed method.

Date	Production Cost	Brent International Price	Jordan Buying Price	Iraq SWP	Jordan BWP	Iraq Wins More	Jordan Wins More
December 30	10.57	68.44	52.44	72%	28%	✓	
January 6	10.57	68.91	52.91	73%	27%	✓	
January 13	10.57	64.2	48.2	70%	30%	✓	
January 21	10.57	64.59	48.59	70%	30%	✓	
January 27	10.57	59.32	43.32	67%	33%	✓	
February 3	10.57	54.45	38.45	64%	36%	✓	
February 10	10.57	53.27	37.27	63%	37%	✓	
February 18	10.57	57.75	41.75	66%	34%	✓	
February 24	10.57	56.3	40.3	65%	35%	✓	
March 2	10.57	51.9	35.9	61%	39%	✓	
March 6	10.57	45.27	29.27	54%	46%	✓	
March 10	10.57	37.22	21.22	40%	60%		✓
March 16	10.57	30.05	14.05	18%	82%		✓
March 24	10.57	27.15	11.15	3%	97%		✓
March 30	10.57	22.76	6.76	0%	100%		✓
April 7	10.57	31.87	15.87	25%	75%		✓
April 14	10.57	29.6	13.6	16%	84%		✓
April 20	10.57	25.57	9.57	0%	100%		✓
April 28	10.57	20.46	4.46	0%	100%		✓
May 4	10.57	27.2	11.2	4%	96%		✓
May 11	10.57	29.63	13.63	16%	84%		✓
May 18	10.57	34.81	18.81	34%	66%		✓
May 26	10.57	35.53	19.53	36%	64%		✓
Jun 1	10.57	38.32	22.32	42%	58%		✓
Jun 8	10.57	40.8	24.8	47%	53%		✓
Jun 15	10.57	39.72	23.72	45%	55%		✓
Jun 22	10.57	43.08	27.08	51%	49%	✓	
Jun 29	10.57	41.71	25.71	49%	51%		✓
July 6	10.57	43.1	27.1	51%	49%	✓	
July 13	10.57	42.72	26.72	50%	50%	✓	✓
July 20	10.57	43.28	27.28	51%	49%	✓	
July 27	10.57	43.41	27.41	51%	49%	✓	
August 3	10.57	44.15	28.15	52%	48%	✓	
August 10	10.57	44.99	28.99	54%	46%	✓	
August 17	10.57	45.37	29.37	54%	46%	✓	
August 24	10.57	45.13	29.13	54%	46%	✓	
August 31	10.57	42.61	26.61	50%	50%	✓	✓
September 8	10.57	39.78	23.78	45%	55%		✓
September 14	10.57	39.61	23.61	45%	55%		✓
September 21	10.57	41.44	25.44	48%	52%		✓
September 28	10.57	42.43	26.43	50%	50%	✓	✓
October 5	10.57	41.29	25.29	48%	52%		✓
October 12	10.57	41.72	25.72	49%	51%		✓
October 19	10.57	42.62	26.62	50%	50%	✓	✓
October 26	10.57	40.46	24.46	46%	54%		✓
November 2	10.57	38.97	22.97	44%	56%		✓
November 9	10.57	42.4	26.4	50%	50%	✓	✓
November 16	10.57	43.62	27.62	52%	48%	✓	
November 23	10.57	46.06	30.06	55%	45%	✓	
November 30	10.57	47.59	31.59	57%	43%	✓	
Avg				45%	55%	27	28

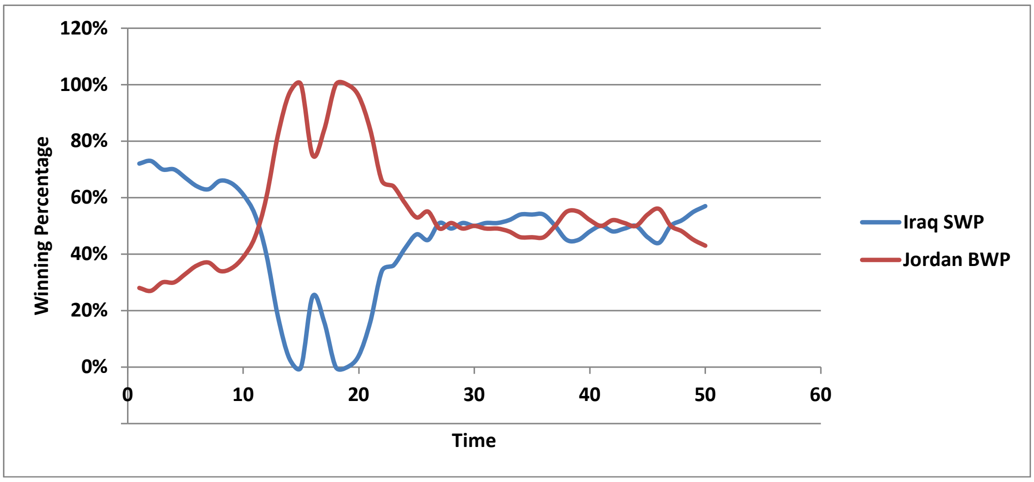

Figure 4. Winning percentage curves for Jordan and Iraq in the oil deal. The graph displays the winning rates as a function of time (data records).

3.3. Real-World Case 2: International Iron Ore Negotiations (2005–2009)

This section discusses the negotiations on iron ore that took place between the major mining companies (sellers), including Companhia Vale do Rio Doce (known as both CVRD and Vale), located in Brazil; Rio Tinto Group, located in Australia; and the Anglo-Australian firm BHP Billiton (BHP), also located in Australia. The example covers the negotiations in the years between 2005 and 2009. The buyers were the big steel companies located in countries from Asia, Europe, and North America [101].

In 2005, the first offer announced by BHP was a 50% price increase; Vale, one of the largest iron ore producers, announced that it had received an offer with a 90% price rise on the older market price. After negotiations, Nippon (one of the largest iron ore buyers) and Vale eventually agreed on a 71.5% increase a month later.

In 2006, mining firms proposed a 10% to 20% price increase and Vale proposed a 24% increase. After arduous negotiations, Vale and ThyssenKrupp announced that they had agreed on a 19% price increase.

In 2007, mining firms proposed a 5% to 10% price increase, and Baosteel and Vale announced that they had agreed on a 9.5% price increase.

In 2008, Vale asked for a 70 percent price increase, and Nippon and Posco announced an agreement with Vale, calling for a two-tiered price increase of 65% in the price of southern ore, and a 71% increase in the price of northern ore. Here we have two deals—one was secured with higher increase than what the seller asked for, and one with a lower increase that what the seller asked for.

In 2009, as a result of the global financial crisis, the spot price of iron ore began to decline, and it soon fell below the agreed-upon negotiation price. Therefore, some of the buyers refused to import iron ore, breaching their contracts. As a response, the major buyers of the ore proposed reduced prices; for example, Baosteel proposed a 45% decrease of the price. Nippon and Rio Tinto reached an agreement with price decreases of 33%, and 44% for two types of ore.

Before applying the proposed fuzzy win–win model on these deals, we need to define its parameters as follows:

- 2005 negotiations: $CP = 50\%$ price increase, SP = 90% price increase, and P = 71.5% price increase.
- 2006 negotiations: $CP = 10\%$ price increase, SP = 24% price increase, and P = 19% price increase.
- 2007 negotiations: $CP = 5\%$ price increase, SP = 10% price increase, and P = 9.5% price increase.
- 2008 negotiations: $CP = 10\%$ price increase (as we assumed that the buyers' negotiator came with a 10% increase in mind, like that of the previous year), $SP = 70\%$ price

increase, and $P = 65\%$ price increase. For the other type of the ore; $P = 71\%$ price increase.

- 2009 negotiations: $CP = 0\%$ price decrease (as we assumed that the seller's negotiator came with a 0% decrease in mind, as they used to increase the price of the ore in the previous years), $SP = 45\%$ price decrease, and $P = 33\%$ price decrease, and $P = 44\%$ price decrease of the other type of ore.

After applying the proposed fuzzy win–win model, we get the data presented in Table 4 and Figure 5.

Table 4. Fuzzy win–win results of the international iron ore negotiations (2005–2009).

Year	*CP*	*SP*	*P*	*SWP*	*BWP*	Sellers Win More	Buyers Win More
2005	50%	90%	71.5%	54%	46%	✓	
2006	10%	24%	19.0%	64%	36%	✓	
2007	5%	10%	9.5%	90%	10%	✓	
2008 Southern ore	10%	70%	65.0%	92%	8%	✓	
2008 Northern ore	10%	70%	71.0%	100%	0%	✓	
2009 Southern ore	0%	45%	33.0%	27%	73%		✓
2009 Northern ore	0%	45%	44.0%	2%	98%		✓
Average	12%	51%	45%	61%	39%	5	2

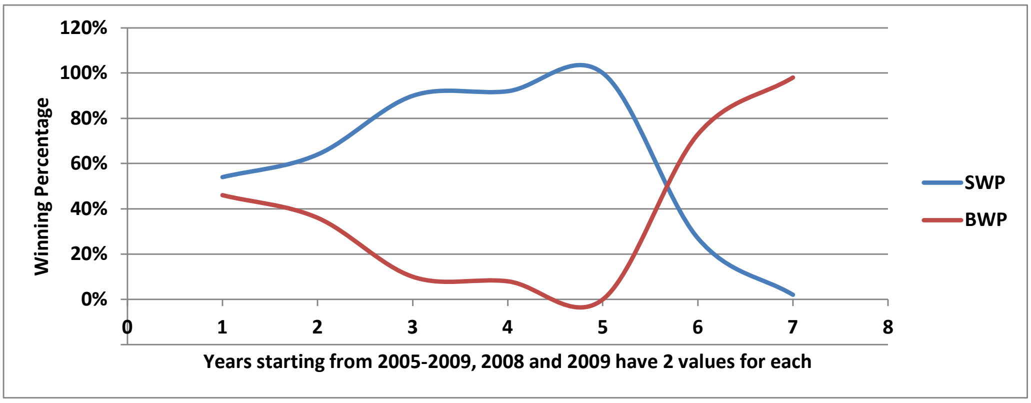

Figure 5. Sellers' and buyers' winning percentages in the ore negotiations.

As can be seen from Table 4, the sellers won the negotiations five times on a row, from 2005–2008. In 2009 the buyers' winning percentages were 27% and 2% for southern ore and northern ore, respectively. The average winning percentage for the sellers was 61%, whereas it was 39% for the buyers, for these 5 years. The sellers benefited more from the first five deals because there was a great demand for the ore during the period (2005–2008). However after the global financial crisis of 2007–2008, the buyers began winning more according to the proposed fuzzy logic win–win model.

3.4. Game Theory

The proposed fuzzy win–win model can be utilized in game theory to quantify a large number of scenarios, or more precisely, in any case where the classic win–win concept is applied [8,9,68,70,74,79]. For example, in a chess game, fuzzy win–win can be used to quantify the amount of winning when a novice player loses against a grandmaster after a large number of moves. Indeed, losing at chess to a grandmaster can be considered a winning situation for a novice payer, particularly after playing a good and long game, as it can be considered good practice and a learning experience.

Before we can apply the proposed fuzzy win–win approach to the previous novice–grandmaster scenario, we must first define the minimum and maximum number of moves that both players must make. Perhaps the average number of moves in chess is the best number we can choose, which is equal to 38 moves according to [102], and let us assume that the maximum number of moves is double that number. These numbers can be changed depending on the end user's preferences and the definition of a win–win situation, as well as the players' rankings.

Having said that, according to the fuzzy win–win model, a novice player will start winning after 38 moves, and if he/she loses the game with less than 38 moves, he/she will be considered a 100 percent winner if he/she plays more than 76 moves, whereas a grandmaster will be considered a 100 percent winner if he/she wins the game playing less than 38 moves, and a loser if he/she wins playing more than 76 moves. The fuzzy area is located between 38 and 76 moves for both players. Figure 6 depicts the fuzzy win–win model for such a scenario.

As can be seen in Figure 6, the fuzzy win–win model can answer questions such as:

- (Q1) If the Game ended with 50 moves, what is the fuzzy win–win situation for each of the players? The model response: The novice's win–win percentage is 32%, whereas the grandmaster's win–win percentage is 68%.
- (Q2) If the novice player wants to achieve a 60% winning percentage out of his/her game, in what number of moves should he/she lose the game? The model response: the novice's number of moves is 61.
- (Q3) If the grandmaster wants to achieve 60% wining out of his/her game, in what number of moves should he/she win the game? The model response: the grandmaster's number of moves is 53.

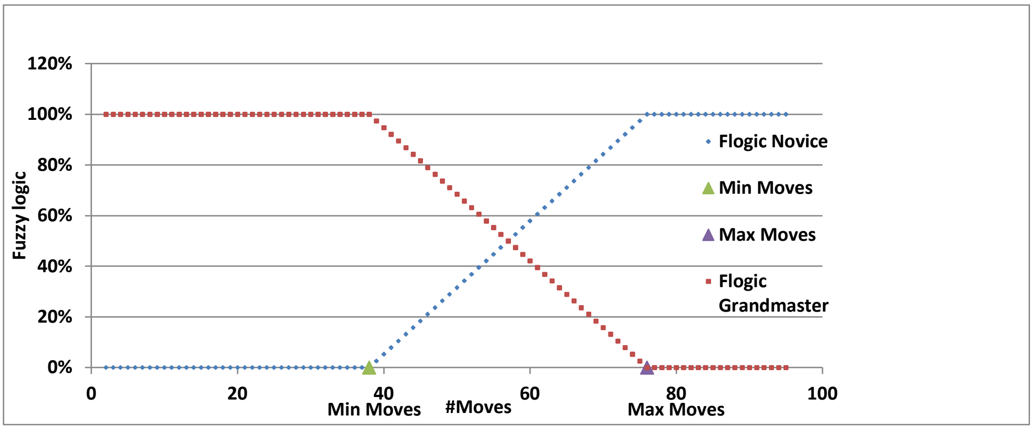

Figure 6. Fuzzy win–win model for novice–grandmaster chess scenario.

Solving chess puzzles is another area where the proposed Fuzzy win–win approach can be put to good use. For example, a 100 percent winning situation could be defined as solving a puzzle by making all of the optimal/correct moves, and the winning percentage would drop to zero if the player made no optimal/correct moves. This could be useful when assessing a ranking of players of chess puzzles. If a Chess puzzle is partially solved, the player's rank should be reduced by a fraction of points rather than by an arbitrarily large number of points.

We have studied the implementation of the proposed fuzzy win–win model in several research areas, ranging from business, economics, and politics to game theory, as a result of the prior discussion. However, the proposed approach's applications are not restricted to these sectors. It can be utilized in any circumstance where the traditional win–win concept applies.

3.5. Conceptual Comparison to the Traditional Win–Win Approach

It is important to compare the proposed fuzzy win–win model to the traditional win–win concept. However, because applying the proposed approach to win–win situations found in the literature is beyond the scope of this paper, we will instead compare the results of applying the proposed fuzzy win–win to the aforementioned real-world cases and comparing them to the traditional win–win approach. The comparative results are shown in Table 5.

Table 5. Comparison results of the fuzzy win–win model to the traditional win–win approach.

Case	Fuzzy Win–Win Result	Traditional Win–Win Result
Iraqi–Jordanian current oil deal	Iraq is 45% winner Jordan is 55% winner	Both sides are winners
International Iron Ore Negotiations (2005–2008)	Sellers are 61% winners Buyers are 39% winners	Both sides are winners
International Iron Ore Negotiations (2009)	Sellers are 14.5% winners, Buyers are 85.5% winners	Both sides are winners
Chess Grandmaster wins against a novice after 50 moves	Grandmaster is 68% winner Novice is 32% winner	Both sides are winners
Chess Grandmaster wins against a novice after 75 moves	Grandmaster is 3% winner Novice is 97% winner	Both sides are winners

As shown in Table 5, the traditional win–win model assumes that both parties are winners in all cases; however, this is only partially accurate; in all cases, one party wins more or less, which is the significant advantage of our proposed fuzzy win–win model, which quantifies the winning situation for each party, as can be seen in Table 5.

4. Conclusions

In this work, we have proposed a new mathematical fuzzy logic-based model that helps in quantifying win–win situations. The model is based on an artificial intelligence knowledge representation approach called fuzzy logic. The main advantage of the proposed fuzzy win–win model is that it can determine the win percentages for each party, and inversely, it can provide the value to negotiate for, given a winning percentage.

The model has been tested on experimental real-life negotiation cases, in which there were sellers and buyers negotiating on a product or service, with each of them wanting to achieve the highest winning percentage. The findings suggest that the proposed fuzzy win–win model can assist negotiators in obtaining the best feasible deal by providing quantified winning percentages for each party, something the traditional win–win approach cannot provide. Furthermore, the proposed fuzzy win–win approach has been shown to be effective in game theory for win–win situations, and two scenarios in the game of chess have been explored to demonstrate the potential of the proposed fuzzy win–win approach.

In its current form, the fuzzy win–win model can be applied to any negotiation-like circumstance where both sides share the same benefit type (x-axis), such as money, enrichment rates, water amount, energy, and so on. It cannot, however, provide answers for parties with opposing viewpoints on benefits, such as factory owners and the environment, in which the first party prioritizes money and the second party or representative prioritizes the amount of gas emitted. This is the major limitation of the proposed model. However, in order to handle such problems, a modified form of the fuzzy win–win model can be utilized, which consists of independent curves/functions for each party. In our future work, we will address such enhancements, among others, in relation to the fuzzy win–win–win model.

Author Contributions: Conceptualization, A.B.H.; methodology, A.B.H., G.A.A., A.S.T., D.C. and A.A.; software, A.B.H. and A.S.T.; validation, A.A.; formal analysis, A.B.H., G.A.A., A.S.T., D.C. and A.A.; investigation, A.B.H., G.A.A., A.S.T., D.C. and A.A.; resources, A.A.; data curation, G.A.A., A.S.T. and D.C.; writing—original draft preparation, A.B.H., G.A.A., A.S.T. and D.C.; writing—review and editing, A.A.; visualization, A.S.T.; supervision, A.B.H.; project administration, A.B.H. and A.A. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data related to the oil deal struck between the governments of Iraq and Jordan between September 2019 and November 2020 can be found at [100]. The data related to the international iron ore negotiations (2005–2009) can be found at [101].

Acknowledgments: We thank the anonymous reviewers whose comments/suggestions helped improve and clarify this manuscript.

Conflicts of Interest: The authors declare no conflict of interest.

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