

Conflict Resolution in the Era of Cognitive Multicriteria Decision Making: An AHP-Retributive Approach

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Abstract

The objective of this paper is to put forth the foundation for a different type of negotiator that reflects in a more realistic way the behaviour of human beings when making complex decisions, aligned with the cognitive process characteristic of the evolution of the species. The positive and the negative aspects of decisions reflect two components in the human brain: the nucleus accumbens and the amygdala. The first component deals with behaviour related to rewards or potential gains, and the other with behaviour related to risk aversion or potential losses. Negotiations require communication, learning, accommodation of positions, development of alternatives and modification of constraints. Negotiation support systems (NSS) are designed to help and advice negotiators; they are used to structure and analyze the problem, elicit preferences, and use them to construct a preference function, determine feasible and effective alternatives, visualize different aspects of the problem and the process, and facilitate communication and learning. The methodology used was a form of conflict resolution based on the Analytic Hierarchy Process (AHP) previously employed in a retributive conflict. In retributive negotiations, each party not only calculates the incremental benefits it gets, but also the costs to its opponent. It is with this setting in mind that we analyzed the Israeli-Palestinian conflict to show the viability of the approach and the type of inputs we need to study conflicts with this approach. The negotiation platform that we describe here help the actors to start and engage a negotiation from noncooperative parties. It can also be used in human-human negotiations to expedite reaching an agreement if one exists. However, we are not seeking automated negotiations. Advantages and risks of Artificial Intelligence (AI) contribution in NSS for cognitive and retributive conflict resolution based on AHP are also discussed.

Keywords: Negotiation, Conflict resolution, Retributive conflicts, Cognitive Multicriteria Decision Making, Analytic Hierarchy Process.

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1. Introduction

In the Spring of 2009, the first author was invited by our friend and mentor Tom Saaty to participate in a workshop/academic exercise involving two groups of people, five Israelis and five Palestinians. The main objective was to find out if an accord between the two groups could be reached that would lead to a solution of the Israeli-Palestinian conflict.

The methodology to be used was a form of conflict resolution based on the Analytic Hierarchy Process (AHP) previously used in a retributive conflict – the South Africa Apartheid problem (Saaty 1988). There are two types of conflict resolution (Saaty 2008): *Constructive*, in which each party attempts to maximize its gains; and *Retributive*, which requires consideration of both gains and losses to both parties. The former is considered the rational approach to conflict resolution, while the latter approach is applicable in long drawn-out conflicts which in the end aggravate and create almost ineradicable resentments. In retributive conflicts a party may be willing to give up much of its demands if misfortune can be brought to its opponent through some means, including justice as dispensed by the court systems.

Thus, in retributive negotiations, each party not only calculates the incremental benefits it gets, but also the costs to its opponent. The more of either, the greater the gain. Each party is concerned with maximizing its gains via its benefits and the costs to the opponent and by negotiating to increase this gain and decrease its own loss.

It is with this setting in mind that we analyzed the Israeli-Palestinian conflict. We will show some of those results later to show the viability of the approach from a cognitive perspective, and the type of inputs we need to study conflicts with this approach.

In the literature, people have tried to incorporate conflict resolution techniques using computers referred as agents. There are three basic modalities of conflict resolution (Yang et al. 2014): human-human, human-agent, and agent-agent conflict resolution. We are more interested in how to bring the agent into the conflict resolution loop to: (a) show how to start negotiations in noncooperative contexts, (b) facilitate the development of solutions, (c) explore and/or construct scenarios with the aid of event driven simulations, (d) deal with conflicts with partial information, i.e., some of the objectives, criteria and concessions for one of the parties are unknown, and (e) establish a continuous learning process for the system. (Yang et al. 2014) write that one of the main problems designing intelligent agents to serve as surrogates for human decision makers in negotiation is that there is always incomplete information. In agent-agent negotiations there is no need for social intelligence as with human-human negotiations. Human-agent negotiation will require that the agent takes into consideration the economic impact of decisions as well as the social, psychological, and affective consequences of the human (Shiv et al. 2005).

The cognitive orientation in conflict resolution seeks to incorporate the key element of the Knowledge Society into formal models (Moreno-Jimenez and Vargas 2018) – the human factor. It seeks to capture the behavior of the human mind when processing the relevant aspects in a

negotiation process. These include the following characteristics: (i) functional (consideration of gains and losses in the brain); (ii) cognitive (perception, attention, memory, learning, language, thought, intelligence); and (iii) affective (mood, emotions, personality, attitude, and motivation); and (iv) contextual (holistic vision of reality). Our cognitive orientation is aligned with the metacognitive attitude in the complex social problems and decision-making processes proposed for decision sciences by (Lins et al. 2021).

The proposed methodology focuses fundamentally on the incorporation of subjective, emotional, and intangible aspects using AHP, and on the continuous learning process that occurs in the resolution of retributive conflicts. Learning, understood as the capacity for a sustained change in the state of knowledge of an individual, group or organization, entails the transformation of the way of thinking (cognitive aspects – knowing), of the way of doing (psychomotor aspects – knowing to do) and of the way of feeling (affective aspects – wanting and being able to do), and the result of which is the appearance of a new and/or improved knowledge.

As (Dinnar et al. 2021) state, these lessons learned over time become the foundation of the individual “personal negotiation theory of practice.” By sharing these lessons learned with their colleagues, negotiators can become a learning team. Extending this process from the team level to the larger organizational level can help drive a culture of accountability and transparency. These ideas coincide with those proposed by the authors for dealing with the Era of Cognitive Multicriteria Decision Making. The two last steps for any scientific resolution process in the context of the Knowledge Society (Moreno-Jimenez and Vargas 2018) should be the extraction and diffusion of the knowledge derived from the resolution process, and the evaluation of its effectiveness (do the correct things). This accountability is the first step of the following resolution process and the essence of the continuous learning culture.

In general, humans engaged in online negotiations are mistrustful of the agent at the other end of the wire. Mistrust involves two dilemmas: honesty and trust. Honesty is deciding how much information to reveal to the other party and not being deceitful. Trust refers to how much of the information revealed is believed to be true.

Negotiations require communication, learning, accommodation of positions, development of alternatives and modification of constraints. Negotiation support systems (NSS) are designed to help and advice negotiators; they are used to structure and analyze the problem, elicit preferences, and use them to construct a preference function, determine feasible and effective alternatives, visualize different aspects of the problem and the process, and facilitate communication and learning.

The objective of this paper is to put forth the foundation for a different type of negotiator that reflects in a more realistic way the behaviour of human beings when making complex decisions, aligned with the cognitive process characteristic of the evolution of the species. The positive and the negative aspects of decisions reflect two components in the human brain: the nucleus accumbens (Volman et al. 2013) and the amygdala (LeDoux 2007). The former relates to positive

behaviour in response to rewards (e.g., eat food, have sex, take drugs), and the latter relates to emotion and behaviour and it is best known for the role it plays in the processing of fear. Thus, we could say that one component deals with behaviour related to rewards or potential gains, and the other with behaviour related to risk aversion or potential losses.

The negotiation platform that we are describing here help the actors to start and engage a negotiation for noncooperative parties. It can also be used in human-human negotiations to expedite reaching an agreement if one exists. We are not seeking automated negotiations. However, if the parties are not talking to each other, or experts are not available, we would like to use natural language understanding from Artificial Intelligence (AI) to abstract information about the objectives, criteria, and concessions of the parties from available information, e.g., digital media, books, news and so on. This information will then be used to abstract priorities to compute gain/loss ratios that will help us think about possible solutions to the problem (Vargas 2016).

AI tools, among other machine learning, text and data mining, opinions and sentimental analysis, affective computing, and natural language understanding, effectively contribute to the learning process that occurs in any conflict resolution process, hence their incorporation into NSS is an urgent need. These tools transversally contribute to improving individual and collective skills. AI uses objective contextualization to facilitate negotiators' post action reports. The subjective contextualization of this information corresponds to the knowledge that should be shared and learned.

2. The Negotiation Platform

Conflict resolution methodologies have gone through a transformation over the past decades since

(a) The economist Kenneth Boulding of the University of Michigan along with the mathematician-biologist Anatol Rapoport, the social psychologist Herbert Kelman and the sociologist Robert Cooley Angell created the *Journal of Conflict Resolution* in 1957, and the Center for Research in Conflict Resolution in 1959;

(b) Johan Galtung, the founder of Peace Research, created a unit within the Institute of Social Research at the University of Oslo in 1960, that later became the International Peace Research Institute Oslo, and he started the *Journal of Peace Research* in 1964; and

(c) John Burton developed a new way of studying conflicts based on problem-solving methodologies such as game theory and organizational behavior. This constituted a paradigm shift in thinking about behavior and conflict in general. The book by (Ramsbotham et al. 2011) has a comprehensive summary of the developments of conflict resolution. It provides an in-depth exposition of the conflict resolution tradition encompassing the “subjectivist” controlled communication and problem-solving approach, the “objectivist” rational negotiation/mediation approach, and the “structuralist” social justice approach.

In 1981 the book “*Getting to YES*” (Fisher and Ury 1981, Fisher et al. 1991) introduced the concept of principled negotiation in which the participants are problem solvers. The approach is based on

four principles: (1) Separate the people from the problem, (2) Focus on interests instead of positions, (3) Invent options for mutual gain, and (4) Insist on using objective criteria. However, this approach does not measure the gains and losses of the parties for different options, and hence the parties may not be able to perceive how fair the proposed solution is.

Principled negotiation looks for fair and equitable solutions to conflicts rather than finding solutions in an environment in which each party considers the other party an adversary. To find fair and equitable solutions we need to use measurement to determine which options are: (1) best for both parties, and (2) as close as possible to each other in the value provided and perceived by the parties.

The scientific literature includes some negotiation support systems (NSS) or electronic negotiation systems (eNS) such as Inspire (Kersten and Noronha 1999), Negoisst (Schoop et al. 2003), SmartSettle (Thiessen and Soberg 2003) or eNego (Wachowicz and Roszkowska 2020), but none of the existing negotiation platforms deals with retributive conflicts.

Most of the current NSS incorporate some cognitive aspects (perception - judgments - memory - databases - learning - knowledge base - intelligence - problem solving), but they do not incorporate others such as attention, language, speech, thought or prioritization and measurement of intangibles. Hopefully, the new developments in AI will solve some these difficulties. Our platform already addresses prioritization and measurement of intangibles.

Let us assume that two parties are negotiating, and that they are willing to share information with the intention of starting the negotiating process and acquiring a better understanding of the wishes and needs of the other party. What the parties will share are their demands from the other party but not the priorities. Each party controls the benefits they receive from concessions from the other party and the costs from giving concessions. In addition, each party has perceptions about: (a) the benefits the other party gets from its concessions, and (b) the costs the other party incurs from its concessions. This information is not uncertain since each party retains it and it is not shared with the other party. Thus, only the concessions sought are known to both.

In a retributive conflict we need to find out what each party is willing to trade to arrive at an acceptable solution. Sometimes it is difficult to have a party disclose what is willing to give away or trade. In that case, it is best to ask each party separately what they want the other party to give them – concessions. In some environments, for example, in the Israeli-Palestinian conflict, the use of the word “concession” is not acceptable. According to the Palestinians, they have conceded too much already. They refer to them as tradeoffs. Some of those concessions may appear inadmissible to a party, but just because a party wants them, it does not mean that they will be part of the stable solution. It is just part of the negotiation process.

The next step is to find out the benefits a party receives from the concessions by the other party, and the costs of its own concessions. However, because of the retributive nature of the conflict we also need to find out the perceived benefits from its concessions and the perceived costs of the other party concessions.

Thus, we proceed as follows:

1. Let A and B be the two parties. Each party identifies a set of concessions (or tradeoffs) that it would like to receive from the other party. Let $T(A)$ be the tradeoffs that Part B wants from Part A. Similar for $T(B)$.
2. Each party determines the criteria (costs and benefits) that they will use when evaluating the concessions. Let C_A and C_B be the costs of the tradeoffs for each party. Similar for the benefits (B_A and B_B).
3. Each tradeoff that a party gives away yields for that party a set of costs (not necessarily monetary) and a perceived set of benefits for the party receiving it.
4. Each tradeoff that a party receives generates a set of benefits and a perceived set of costs for the party giving it away.
5. Each party, using the AHP with relative measurements (eigenvector as the prioritization procedure, distributive mode as normalization technique, and AIJ – aggregation of individual judgments - as aggregation method), prioritizes its own benefits and costs, and the perceived benefits and perceived costs of the other party, by constructing four different hierarchies. Let $w_A(C_A | T_A)$ and $w_B(C_B | T_B)$ be the relative costs of the tradeoffs for each party; let $w_A(PB_B | T_A)$ and $w_B(PB_A | T_B)$ be a party's relative perceived benefits of the other party from its own concessions. For example, $w_A(PB_B | T_A)$ represents A's relative perceived benefits of B from A's concessions. Let $w_A(B_A | T_B)$ and $w_B(B_B | T_A)$ be the relative benefits of a party from the concessions of the other party; and let $w_B(PC_A | T_A)$ and $w_A(PC_B | T_B)$ a party's relative perceived costs of the other party from its own concessions
6. The tradeoffs are evaluated using the AHP absolute measurement according to the benefits, costs, perceived benefits, and perceived costs. Finally, every pair of tradeoffs (T_A, T_B) is evaluated with gain-loss ratios for each party (see Figure 1). These ratios are not symmetric. The gain-loss ratios are formed as follows:

$$\text{A's ratios: } R_A(T_A, T_B) = \frac{\left[\frac{w_A(B_A | T_B)}{w_A(C_A | T_A)} \right]}{\left[\frac{w_A(PB_B | T_A)}{w_A(PC_B | T_B)} \right]} = \frac{w_A(B_A | T_B) * w_A(PC_B | T_B)}{w_A(C_A | T_A) * w_A(PB_B | T_A)}, \quad (1a)$$

$$\text{B's ratios: } R_B(T_A, T_B) = \frac{\left[\frac{w_B(B_B | T_A)}{w_B(C_B | T_B)} \right]}{\left[\frac{w_B(PB_A | T_B)}{w_B(PC_A | T_A)} \right]} = \frac{w_B(B_B | T_A) * w_B(PC_A | T_A)}{w_B(C_B | T_B) * w_B(PB_A | T_B)} \quad (1b)$$

In Figure 1 we illustrate how the ratios are formed. For example, the gain to Party A from a concession is the product of the benefits and the perceived costs to Party B. The loss to Party A from its own concession is given by the product of the costs and the perceived benefits to Party B. The same process is used to compute the gain-to-loss ratio for Party B. This way of computing gains and losses agrees with the interpretation that (Kahneman and Tversky 1979) give to the preferences of decision makers when faced with gains and losses.

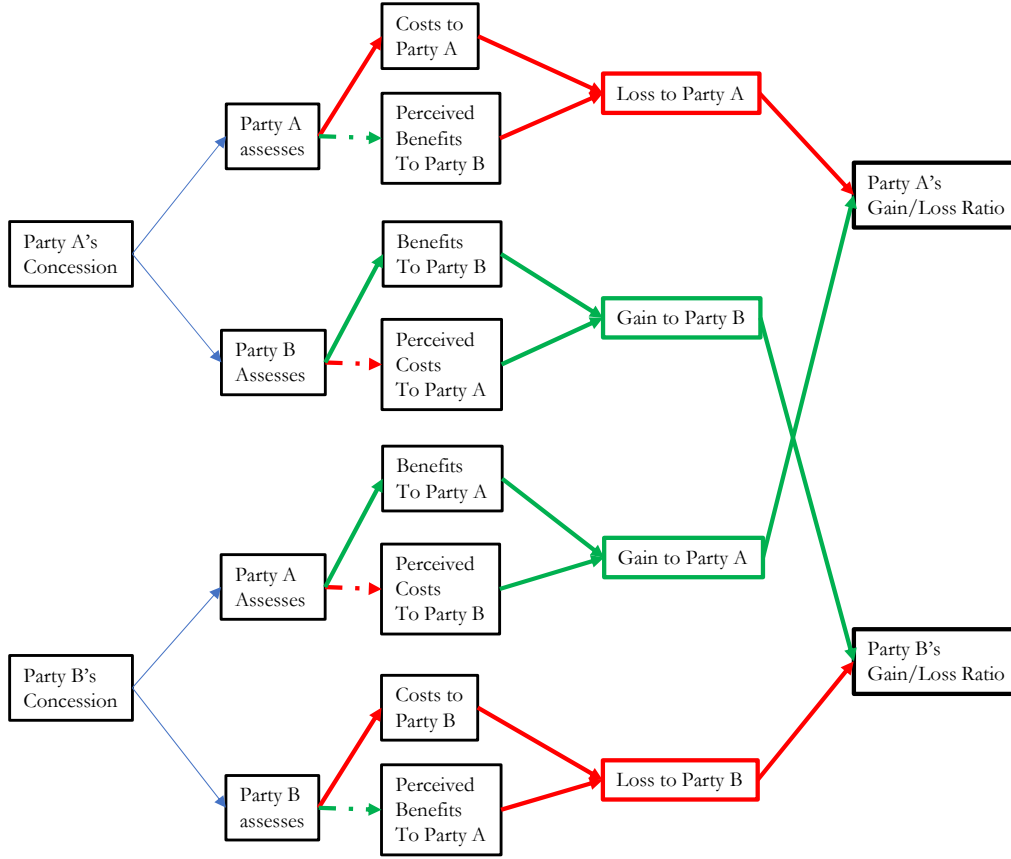


Figure 1. Gain to Loss Ratios for parties' concessions

These ratios show that there is no need to directly compare gains and losses to account for their influence as in Prospect Theory (Kahneman and Tversky 1979).

7. The tradeoffs or concessions of the parties are paired to decide which pairs are acceptable. Acceptable tradeoffs means that both parties benefit from the tradeoff and that they receive more than they lose from the tradeoff they give away. Acceptability of a pair of tradeoffs is implemented using the gain-loss ratio. Gain-loss ratios are not symmetric for the parties. This is not a zero-sum game. The problem consists of finding pairs of concessions $(i, j) \in T_A \times T_B$ such that:

- (1) $R_A(i, j) \geq 1$ and $R_B(i, j) \geq 1$;

- (2) They are as close as possible, i.e., $\left| \frac{R_A(i, j) - R_B(i, j)}{R_A(i, j)} \right| < \varepsilon$; and

- (3) The smallest gain of each party is as large as possible, i.e., maximize the minimum gain of each party.

This is accomplished by solving a MaxMin problem given by:

$$\begin{aligned} & \underset{(i,j) \in T_A \times T_B}{\text{Max}} \quad \underset{\substack{x_{ij} = 0,1 \\ R_A(i,j) \geq 1 \\ R_B(i,j) \geq 1 \\ \left| \frac{R_A(i,j) - R_B(i,j)}{R_A(i,j)} \right| < \varepsilon}}{\text{Min}} \quad \{R_A(i, j)x_{ij}, R_B(i, j)x_{ij}\} \end{aligned} \quad (2)$$

The result of this model is a set of pairs of concessions that are at most within ε percent of each other.

8. The acceptable paired concessions are used to develop principles on which the parties must agree to solve the conflict. This is explained in more detail in the next section dedicated to a case study.
9. Acceptable pairs of tradeoffs are identified with the additional condition that the gainloss ratio of a pair of concessions is as close as possible to each other for the parties (i.e., within a small percentage of each other) yielding the desired balanced agreement. Incidentally, the idea of fairness has been applied in conflict resolution as, for example by (Brams and Taylor 1996) and illustrated in their well-known book, and by (Klamer 2010).
10. The facilitator should extract and share the knowledge about the results (decision), the process and the people, derived from the resolution of the problem. The evaluation of the effectiveness of the resolution process (accountability) is the last step of this process and the first one of the continuous learning processes followed in the cognitive orientation.

The use of AHP as methodological support of the proposed cognitive and retributive conflict resolution (CRCR-AHP) approach, is because of its: (1) intuitive and realistic character in scientific decision making; (2) ability to integrate through hierarchies and clustering the large and the small; (3) capability of combining tangible and intangible aspects of problems by means of absolute pairwise comparisons that yield relative ratio scales of priorities; (4) flexibility to consider dependencies between levels in a hierarchy with the extension of the AHP known as ANP (Analytic Network Process); (5) power in group decision making by allowing decision makers the construction of group welfare functions that do not violate Arrow's conditions; and (7) strength in negotiations and learning /cognition (discussion, extraction and dissemination of knowledge) (Moreno-Jimenez and Vargas 2018).

3. Case Study

From 2009-2014 small groups of distinguished Israeli and Palestinian advisors met under the auspices of conflict resolution researchers from the University of Pittsburgh. The Israeli and Palestinian advisors have participated in their personal capacities, rather than on behalf of their respective governments. Participants, however, have briefed key members of their respective Middle East Peace negotiating teams on the nature of the project and on its practical application by the two governments.

Following the steps described above we obtained the Israelis and the Palestinians' concessions (Tables 1 and 2. respectively); the costs and perceived benefits (Table 3), the benefits and perceived costs (Table 4).

The concessions are provided by the opposing party. They are what a party would like to obtain from the other. In addition, each party developed their own set of benefits, costs, perceived benefits, and perceived costs. Their priorities were provided by each group using the AHP.

Table 1. Israelis' Concessions

Israelis' Concessions	Description
I1	Abandon the Idea of Jewish State
I2	Accept Palestinian full control of the borders of the Palestinian State and its outlets
I3	Accept the historical responsibility for the Palestinian refugee problem
I4	Accept the Palestinian refugee rights to return
I5	Accept to abide by the status quo in the holy places in Jerusalem
I6	Accept to abolish law of return
I7	Accept to respect the integrity of the West Bank and Gaza by allowing free and safe passage between the two areas.
I8	Accept East Jerusalem as the capital of the Palestinian State
I9	Accept Two-State Solution on the borders of the 4th of June 1967
I10	Allow all parties to have equal access to and control of religious sites and holy places
I11	Allow the sharing of all natural resources between Palestinians and Israelis
I12	Comply with all applicable UN Resolutions
I13	Evacuate settlers of Jewish settlements on land claimed by the Palestinians with or without compensation
I14	Release all political prisoners including those who are Israeli citizens
I15	Share Jerusalem as two capitals of two states
I16	Solve the Palestinian refugee problem in a just and agreed upon manner
I17	Stop incitement by the religious and national education and religious leaders in Israel against Muslims and Arabs

Table 2. Palestinians' Concessions

Palestinians' Concessions	Description
P1	Accept mutually agreed upon land swap
P2	Accept settlers under Palestinian sovereignty as residents
P3	Accept the temporary presence of multinational military monitoring system in Jordan Valley
P4	Accept Two-State solution
P5	Accept a Two-State solution which includes a non-contiguous state
P6	Acknowledge Israel's existence as a Jewish State
P7	Acknowledge Israel's existence as an independent State
P8	Agree to compromise to the demand of the right of return
P9	Agreeing with Palestinian demilitarized state
P10	Preserve the status quo in the Holy places of Jerusalem
P11	Allow Israel to use Palestinian airspace
P12	Declare against Iranian nuclear development
P13	Denounce & reign in violence
P14	Denounce Iranian pursuit of nuclear arms and support Israelis effort to remove the threat
P15	Lobby Arab states to allow both Israelis and Palestinians to have the right to return to their land of origin
P16	Make compromises on the status of Jerusalem
P17	Palestinians must guarantee that any agreement reached with Israel will be accepted and supported by the majority of the Palestinian people, both in Gaza and the West Bank
P18	Refrain and work against any anti-Israel sentiments in Palestinian schools
P19	Seek assistance for a legitimate settlement of refugees
P20	Sharing of natural resources
P21	Work cooperatively and in active engagement w/ Israel

Table 3. Costs and Perceived Benefits

Israeli Costs from its Concessions	Priorities	Palestinian Costs from its Concessions	Priorities
End of claims and end of conflict	0.2093	Accommodation and rehabilitation of Palestinian refugees not allowed to return to Israel	0.1192
Integrity and unity of Israeli society post agreement	0.0659	Conflict between Palestinian diaspora and the internal leadership	0.0948
Legitimization of the State of Israel	0.0778	Dislocation and fragmentation of Palestinian social fabric	0.0392
Maintain the Jewish majority of Israel alongside with the Arab minority	0.2249	Giving up the claim over historic Palestine occupied in 1948 and known later as the State of Israel	0.2055
Make Israel more attractive to Jewish diaspora and Israelis citizens	0.0322	Loss of military capability to defend the State of Palestine	0.0575
Peace, economy and stability in region	0.086	Loss of property rights	0.0395
Security	0.1831	Partial loss/depletion of natural resources by sharing them with Israel	0.1257
Stop being occupiers	0.0477	Restrictions on national sovereignty by accepting demilitarization and multinational monitoring	0.1013
Strengthening the alliance with the United States	0.0457	Territorial loss as a result of unfair land swap	0.2173
Weakening the radical forces in the Middle East headed by Iran	0.0274		
Israeli Perception of Palestinian Benefits from Israeli Concessions	Priorities	Palestinian Perception of Israeli Benefits from Palestinian Concessions	Priorities
Control of the Muslim holy places	0.0853	Acknowledgement of Israeli control over the Wailing Wall and the Jewish Quarter in the Old City of Jerusalem	0.1626
East Jerusalem as the capital of Palestine	0.1361	Economic relations and new markets including tourism with neighboring Arab and Islamic countries	0.0999
Economic stability and prosperity	0.0219	End of claims by the Palestinians	0.2556
Evacuation of the settlers in the settlements	0.0661	Gaining legitimacy of the Palestinian and Arab and Muslim world	0.1111
Freedom, dignity and feeling of equality	0.1449	Integration in the Middle East with normal relations with its neighbors and Arab World	0.0658
Independent state	0.2145	Obtaining security by acceptance and recognition of the Palestinians and Arab and Muslim world	0.108
International recognition & permanent borders	0.0368	Obtaining territorial gains	0.1184
Maximization of the area (land)	0.0816	Reduction of military expenditures enabling national development	0.0239
Solve the refugees problem	0.2128	Regional cooperation against external threats	0.0333
		Sharing the Palestinians with their own natural resources	0.0215

Table 4. Benefits and Perceived Costs

Israeli Benefits from Palestinian Concessions	Priorities	Palestinian Benefits from Israeli Concessions	Priorities
End of claims	0.2216	East Jerusalem as the capital of the State of Palestine	0.1654
Integrity and unity of Israeli society post agreement	0.0753	Evacuation of the Israeli settlements	0.0415
Legitimization of the State of Israel	0.0654	Having full control over air space, maritime, borders and outlets	0.1086
Maintain the Jewish majority of Israel alongside with the Arab min	0.1899	International guarantees and assurances to protect Palestine State security and integrity	0.0403
Make Israel more attractive to Jewish diaspora and Israelis citizens	0.0397	Permanent borders	0.2095
Peace, prosperity and stability in region	0.0959	Release of political prisoners including those who are Israeli citizens	0.0186
Security	0.1636	Resolution of the refugee problem	0.0654
Stop being occupiers	0.0529	Respect the integrity of West Bank and Gaza	0.0571
Strengthening the alliance with the United States	0.0477	Share of water and other resources	0.0181
Weakening the radical forces in the Middle East headed by Iran	0.0479	Shared control of Jerusalem and holy places	0.0613
		Sovereign Palestinian State	0.2054
		Stop incitement and raging hatred	0.0087
Israeli Perception of Palestinian Costs from Palestinian Conc	Priorities	Palestinian Perception of Israeli Costs from Israeli Concessions	Priorities
Giving up on the Idea of a Greater Palestine	0.088	Changing of Zionist narrative	0.4541
Loss of 'victim' status	0.0288	Property restitution and compensation	0.0689
Loss of International financial support	0.0252	Rehabilitating evacuated settlers from the Palestinian territories	0.2047
Loss of land (67 Border) /swap	0.15	Settlements evacuation	0.2723
Partial control of East Jerusalem as the capital of Palestine	0.1735		
Partial control of the Muslim holy places	0.128		
Partial solution refuge problem	0.3101		
Remainder of part of the Settlement Community	0.0964		

The priorities in Tables 3 and 4 are obtained using the AHP from group judgments (AIJ - aggregation of individual judgments) and represent the relative importance a party gives to an issue.

Note that the columns of Tables 3 and 4 are calculated using relative measurements and add to one. The benefits, costs, perceived benefits, and perceived costs are used to evaluate the worth of each concession from each party's perspective. This evaluation uses absolute measurement. Thus, concessions are not compared in pairs with respect to benefits, costs, perceived benefits, and perceived costs. An example of an absolute scale used is given in Table 5. Different criteria could have different scales. We only show the scale in Table 5 to simplify the exposition. Each concession was evaluated according to each benefit, cost, perceived benefit, and perceived cost using a scale like the one shown in Table 5.

Table 5. Absolute Measurement Scale for the Tradeoffs with respect to the Criteria

Excellent	1.00
Very High	0.90
High	0.75
Medium	0.50
Low	0.25
Very Low	0.10
Negligible	0.01

The result of that evaluation is given in Table 6. The priorities in that table are normalized with the ideal mode, i.e., each priority, for example for costs, was divided by the largest value. In Table 6, for Israelis' concessions, the costliest concession from the Israelis' perspective is #1 – Abandon the Idea of a Jewish State. According to the Palestinians, the Israeli concession which provided them with the most benefits is #8 – Accept to withdraw from East Jerusalem.

Because all the scales are relative, they are dimensionless, so it is not meaningful to add them. Instead, Israelis' total loss from concessions (Column 4 in Table 6) are obtained by multiplying the Israelis' costs (column 2) by the Israelis' perception of Palestinians' benefits (column 3). Likewise, the Palestinians' total gain (column 7) is obtained by multiplying the Palestinians' benefits (column 5) by the Palestinians' perception of Israelis' costs (column 6). This process is repeated for the Palestinians' concessions.

For example, the total loss of the Israelis from Concession 2, i.e., 0.4922, is obtained as the product of the cost to the party (0.6445) and the perceived benefit to the other party (0.7637). Similarly, the total gain by the Palestinians from Israeli's Concession 2, i.e., 0.9613, is obtained as the product of the benefit to the party (0.9894) and the perceived cost to the other party (0.9717).

Now it is possible to compute the gain/loss ratios for the two parties (Tables 7 and 8).

Table 6. Evaluation of Concessions

Israelis' Concessions	Israelis' Costs	Israelis' _Perception_of_Palestinians' _Benefits	Israelis' Total Loss	Palestinians' Benefits	Palestinians' _Perception_of_Israelis_ Costs	Palestinians' Total Gain
I1	1	1	1	0.883	0.9683	1
I2	0.6445	0.7637	0.4922	0.989	0.9717	0.9613
I3	0.9051	0.2705	0.2449	0.957	0.7835	0.7501
I4	0.9470	0.8253	0.7815	0.883	0.9515	0.8401
I5	0.1961	0.5405	0.1060	0.798	0.7583	0.6050
I6	0.8824	0.4280	0.3777	0.543	0.7410	0.4020
I7	0.1984	0.5149	0.1022	0.979	0.9054	0.8861
I8	0.8299	0.8068	0.6695	1.000	0.9692	0.9692
I9	0.0545	0.8205	0.0447	0.979	0.9080	0.8887
I10	0.1006	0.5323	0.0536	0.809	0.5459	0.4414
I11	0.1120	0.2853	0.0320	0.670	0.5260	0.3525
I12	0.8596	0.9571	0.8228	0.979	0.9075	0.8882
I13	0.3593	0.8915	0.3203	0.926	1	0.9255
I14	0.5178	0.4781	0.2476	0.755	0.6508	0.4916
I15	0.1633	0.6027	0.0984	0.851	0.7334	0.6242
I16	0.1806	0.7329	0.1323	0.883	0.9174	0.8101
I17	0.0741	0.1110	0.0082	0.415	0.4991	0.2071

Palestinians' Concessions	Palestinians' Costs	Palestinians' _Perception_of_Israelis' _Benefits	Palestinians' Total Loss	Israelis' Benefits	Israelis' _Perception_of_Palestinians' _Costs	Israelis' Total Gain
P1	0.9349	0.2000	0.1870	0.9233	0.6353	0.5866
P2	0.8877	0.2000	0.1775	0.2333	0.4743	0.1107
P3	0.8101	0.2000	0.1620	0.7033	0.1106	0.0778
P4	0.8518	0.8947	0.7621	0.9944	0.1660	0.1651
P5	0.8438	0.2000	0.1688	0.7543	0.3011	0.2271
P6	0.9035	0.9345	0.8443	0.8741	1	0.8741
P7	0.8635	0.2000	0.1727	0.8055	0.6196	0.4991
P8	0.9298	0.9573	0.8901	1	0.8557	0.8557
P9	0.8718	0.2000	0.1744	0.5968	0.1353	0.0807
P10	0.7691	0.2331	0.1792	0.7031	0.3355	0.2358
P11	0.8957	0.2000	0.1791	0.6592	0.1096	0.0723
P12	0.5522	0.2000	0.1104	0.3968	0.0348	0.0138
P13	0.6878	0.2000	0.1376	0.6153	0.1119	0.0689
P14	0.5098	0.2000	0.1020	0.4967	0.0443	0.0220
P15	0.8119	0.2000	0.1624	0.2009	0.3663	0.0736
P16	1	1	1	0.9251	0.6221	0.5755
P17	0.5796	0.2000	0.1159	0.8541	0.5253	0.4487
P18	0.7352	0.2000	0.1470	0.7583	0.1871	0.1419
P19	0.8621	0.3910	0.3371	0.9572	0.8724	0.8350
P20	0.8158	0.2000	0.1632	0.4069	0.0544	0.0221
P21	0.2000	0.2000	0.0400	0.7613	0.1858	0.1414

Table 7. Israelis' Ratios for pairs of concessions

Israelis' Ratios	Accept mutually agreed upon land swap	Accept settlers under Palestinian sovereignty as residents	Accept the temporary presence of multinational military monitoring system in Jordan Valley	Accept Two-State Solution	Acceptance a Two-State solution which includes a Non-Contiguous State	Acknowledge Israel's Existence as a Jewish State	Acknowledge Israel's Existence as an Independent State	Agree to Compromise to the Demand of the Right of Return	Agreeing with Palestinian demilitarized state	Preserve the Status Quo in the Holy places of Jerusalem	Allow Israel to use Palestinian airspace	Declare Against Iranian Nuclear Development	Denounce & Reign in Violence	Denounce Iranian pursuit of nuclear arms and support Israeli effort to remove the threat	Lobby Arab States to Allow both Israelis and Palestinians to Have the Right to Return to their land of origin	Make Compromise on the Status of Jerusalem	Palestinians must guarantee that any agreement reached with Israel will be accepted and supported by the majority of the Palestinian people both in Gaza and the West Bank	Refrain and work against any anti-Israel sentiments in Palestinian schools	Seek Assistance for a Legitimate Settlement of Refugees	Sharing of Natural Resources	Work Cooperatively and in active engagement w/ Israel
Abandon the Idea of Jewish State	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Accept Palestinian full control of the borders of the Palestinian State and its outlets	1.192	0.000	0.000	0.000	0.000	1.776	1.014	1.739	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.169	0.000	0.000	1.697	0.000	0.000
Accept the historical responsibility for the Palestinian refugee problem	2.395	0.000	0.000	0.000	0.000	3.570	2.038	3.494	0.000	0.000	0.000	0.000	0.000	0.000	0.000	2.350	1.832	0.000	3.410	0.000	0.000
Accept the Palestinian refugee rights to return	0.000	0.000	0.000	0.000	0.000	1.118	0.000	1.095	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.068	0.000	0.000
Accept to abide by the status quo in the holy places in Jerusalem	5.533	1.044	0.000	1.557	2.143	8.246	4.708	8.072	0.000	2.225	0.000	0.000	0.000	0.000	0.000	5.429	4.233	1.338	7.877	0.000	1.334
Accept to abolish law of return	1.553	0.000	0.000	0.000	0.000	2.314	1.321	2.266	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.524	1.188	0.000	2.211	0.000	0.000
Accept to respect the integrity of the West Bank and Gaza by allowing free and safe passage between the two areas.	5.742	1.083	0.000	1.616	2.224	8.557	4.886	8.377	0.000	2.309	0.000	0.000	0.000	0.000	0.000	5.634	4.392	1.389	8.175	0.000	1.385
Accept East Jerusalem as the capital of the Palestinian State	0.000	0.000	0.000	0.000	0.000	1.306	0.000	1.278	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.247	0.000	0.000
Accept Two-State Solution on the borders of the 4th of June 1967	13.108	2.473	1.738	3.689	5.076	19.534	11.153	19.123	1.804	5.270	1.615	0.000	1.539	0.000	1.645	12.860	10.027	3.170	18.660	0.000	3.161
Allow all parties to have equal access to and control of religious sites and holy places	10.953	2.066	1.453	3.083	4.242	16.323	9.320	15.980	1.508	4.404	1.350	0.000	1.286	0.000	1.375	10.747	8.379	2.649	15.593	0.000	2.641
Allow the sharing of all natural resources between Palestinians and Israelis	18.354	3.463	2.434	5.166	7.108	27.352	15.617	26.776	2.526	7.380	2.262	0.000	2.155	0.000	2.303	18.008	14.040	4.439	26.129	0.000	4.426
Comply with all applicable UN Resolutions	0.000	0.000	0.000	0.000	0.000	1.062	0.000	1.040	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.015	0.000	0.000
Evacuate settlers of Jewish settlements on land claimed by the Palestinians with or without compensation	1.831	0.000	0.000	0.000	0.000	2.729	1.558	2.672	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.797	1.401	0.000	2.607	0.000	0.000
Release all political prisoners including those who are Israeli citizens	2.369	0.000	0.000	0.000	0.000	3.531	2.016	3.457	0.000	0.000	0.000	0.000	0.000	0.000	0.000	2.325	1.812	0.000	3.373	0.000	0.000
Share Jerusalem as two capitals of two states	5.959	1.124	0.000	1.677	2.308	8.881	5.071	8.694	0.000	2.396	0.000	0.000	0.000	0.000	0.000	5.847	4.559	1.441	8.484	0.000	1.437
Solve the Palestinian refugee problem in a just and agreed upon manner	4.432	0.000	0.000	1.247	1.716	6.605	3.771	6.466	0.000	1.782	0.000	0.000	0.000	0.000	0.000	4.349	3.390	1.072	6.310	0.000	1.069
Stop incitement by the religious and national education and religious leaders in Israel against Muslims and Arabs	71.312	13.453	9.458	20.070	27.616	106.275	60.678	104.036	9.816	28.674	8.787	1.679	8.374	2.674	8.949	69.967	54.551	17.249	101.521	2.692	17.196

Table 8. Palestinians' Ratios for pairs of concessions

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Palestinians' Ratios	Accept mutually agreed upon land swap	Accept settlers under Palestinian sovereignty as residents	Accept the temporary presence of multinational military monitoring system in Jordan Valley	Accept Two-State Solution	Acceptance a Two-State solution which includes a Non-Contiguous State	Acknowledge Israel's Existence as a Jewish State	Acknowledge Israel's Existence as an Independent State	Agree to Compromise to the Demand of the Right of Return	Agreeing with Palestinian demilitarized state	Preserve the Status Quo in the Holy places of Jerusalem	Allow Israel to use Palestinian airspace	Declare Against Iranian Nuclear Development	Denounce & Reign in Violence	Denounce Iranian pursuit of nuclear arms and support Israelis effort to remove the threat	Lobby Arab States to Allow both Israelis and Palestinians to Have the Right to Return to their land of origin	Make Compromise on the Status of Jerusalem	Palestinians must guarantee that any agreement reached with Israel will be accepted and supported by the majority of the Palestinian people both in Gaza and the West Bank	Refrain and work against any anti-Israel sentiments in Palestinian schools	Seek Assistance for a Legitimate Settlement of Refugees	Sharing of Natural Resources	Work Cooperatively and in active engagement w/ Israel
Abandon the Idea of Jewish State	4.573	4.816	5.277	1.122	5.066	1.013	4.951	0.000	4.904	4.770	4.773	7.742	6.216	8.385	5.266	0.000	7.376	5.815	2.537	5.240	21.376
Accept Palestinian full control of the borders of the Palestinian State and its outlets	5.141	5.415	5.933	1.261	5.696	1.139	5.566	1.080	5.513	5.363	5.366	8.704	6.988	9.428	5.920	0.000	8.293	6.538	2.852	5.892	24.033
Accept the historical responsibility for the Palestinian refugee problem	4.012	4.225	4.630	0.000	4.445	0.000	4.344	0.000	4.302	4.185	4.187	6.792	5.453	7.357	4.620	0.000	6.471	5.102	2.226	4.597	18.754
Accept the Palestinian refugee rights to return	4.493	4.732	5.185	1.102	4.978	0.000	4.865	0.000	4.818	4.687	4.690	7.607	6.107	8.239	5.174	0.000	7.247	5.714	2.493	5.149	21.003
Accept to abide by the status quo in the holy places in Jerusalem	3.236	3.408	3.735	0.000	3.585	0.000	3.503	0.000	3.470	3.375	3.377	5.478	4.398	5.934	3.726	0.000	5.220	4.115	1.795	3.708	15.126
Accept to abolish law of return	2.150	2.264	2.481	0.000	2.382	0.000	2.328	0.000	2.306	2.243	2.244	3.640	2.922	3.943	2.476	0.000	3.468	2.734	1.193	2.464	10.050
Accept to respect the integrity of the West Bank and Gaza by allowing free and safe passage between the two areas.	4.739	4.991	5.469	1.163	5.251	1.050	5.131	0.000	5.082	4.944	4.946	8.023	6.442	8.690	5.457	0.000	7.644	6.027	2.629	5.431	22.153
Accept East Jerusalem as the capital of the Palestinian State	5.183	5.459	5.982	1.272	5.743	1.148	5.612	1.089	5.558	5.407	5.410	8.775	7.045	9.505	5.969	0.000	8.361	6.591	2.875	5.940	24.229
Accept Two-State Solution on the borders of the 4th of June 1967	4.753	5.005	5.485	1.166	5.266	1.053	5.146	0.000	5.097	4.958	4.961	8.046	6.460	8.715	5.473	0.000	7.666	6.044	2.637	5.446	22.217
Allow all parties to have equal access to and control of religious sites and holy places	2.361	2.486	2.724	0.000	2.615	0.000	2.556	0.000	2.532	2.463	2.464	3.997	3.209	4.329	2.718	0.000	3.808	3.002	1.310	2.705	11.035
Allow the sharing of all natural resources between Palestinians and Israelis	1.885	1.986	2.176	0.000	2.089	0.000	2.041	0.000	2.022	1.967	1.968	3.192	2.563	3.457	2.171	0.000	3.041	2.398	1.046	2.161	8.813
Comply with all applicable UN Resolutions	4.750	5.003	5.482	1.165	5.263	1.052	5.143	0.000	5.094	4.955	4.958	8.042	6.457	8.711	5.470	0.000	7.662	6.041	2.635	5.444	22.205
Evacuate settlers of Jewish settlements on land claimed by the Palestinians with or without compensation	4.950	5.213	5.713	1.214	5.484	1.096	5.359	1.040	5.308	5.163	5.166	8.380	6.728	9.077	5.700	0.000	7.984	6.295	2.746	5.672	23.138
Release all political prisoners including those who are Israeli citizens	2.629	2.769	3.034	0.000	2.913	0.000	2.847	0.000	2.819	2.743	2.744	4.451	3.574	4.821	3.027	0.000	4.241	3.343	1.458	3.013	12.290
Share Jerusalem as two capitals of two states	3.338	3.516	3.853	0.000	3.698	0.000	3.614	0.000	3.580	3.482	3.484	5.652	4.537	6.121	3.844	0.000	5.385	4.245	1.852	3.825	15.604
Solve the Palestinian refugee problem in a just and agreed upon manner	4.332	4.563	5.000	1.063	4.800	0.000	4.691	0.000	4.646	4.519	4.522	7.335	5.889	7.944	4.989	0.000	6.988	5.509	2.403	4.965	20.252
Stop incitement by the religious and national education and religious leaders in Israel against Muslims and Arabs	1.107	1.166	1.278	0.000	1.227	0.000	1.199	0.000	1.187	1.155	1.156	1.875	1.505	2.031	1.275	0.000	1.786	1.408	0.000	1.269	5.176

The entries in Tables 7 and 8 with zero values correspond to tradeoffs in which one of the parties or both parties do not gain in the transaction. The reason why the concessions are evaluated using multiplication and ratios as shown in formulas (1a) and (1b) is because all the measurements are in relative ratio scales which do not have units. If perceptions were not included, then formulas 1a and 1b reduce to the classical case of benefit to cost ratios. Ratios are appropriate because there were no measurement scales with agreed upon units.

The result of model (2) is a set of pairs of concessions which were at most within 20 percent of each other (Table 9). Note that the total value of the trades are within 5 percent of each other.

Table 9. Paired concessions

# Israeli Concessions	Trade Value	% Separation	# Palestinian Concessions	Trade Value
12 Comply with all applicable un resolutions	1.062	1%	6 Acknowledge Israel's existence as a Jewish state	1.058
9 Accept two-state solution on the borders of the 4th of June 1967	5.076	5%	5 Acceptance of a two-state solution which includes a non-contiguous state	5.289
7 Accept to respect the integrity of the West Bank and Gaza by allowing free and safe passage between the two areas.	4.885	5%	7 Acknowledge Israel's existence as an independent state	5.159
16 Solve the Palestinian refugee problem in a just and agreed upon manner	4.432	5%	1 Accept mutually agreed upon land swap	4.359
13 Evacuate settlers of Jewish settlements on land claimed by the Palestinians with or without compensation	2.607	10%	19 Seek assistance for a legitimate settlement of refugees	2.763
11 Allow the sharing of all natural resources between Palestinians and Israelis	2.303	10%	15 Lobby Arab states to allow both Israelis and Palestinians to have the right to return to their land of origin	2.168
15 Share Jerusalem as two capitals of two states	4.559	20%	17 Palestinians must guarantee that any agreement reached with Israel will be accepted and supported by the majority of the Palestinian people both in Gaza and the West Bank	5.361
10 Allow all parties to have equal access to and control of religious sites and holy places	2.649	20%	18 Refrain and work against any anti-Israel sentiments in Palestinian schools	2.991
17 Stop incitement by the religious and national education and religious leaders in Israel against Muslims and Arabs	1.679	20%	12 Declare against Iranian nuclear development	1.868
8 Accept east Jerusalem as the capital of the Palestinian state	1.278	20%	8 Agree to compromise to the demand of the right of return	1.089
Total	30.53		Total	32.105

Figure 2 shows that the matched concessions yield a balanced result.

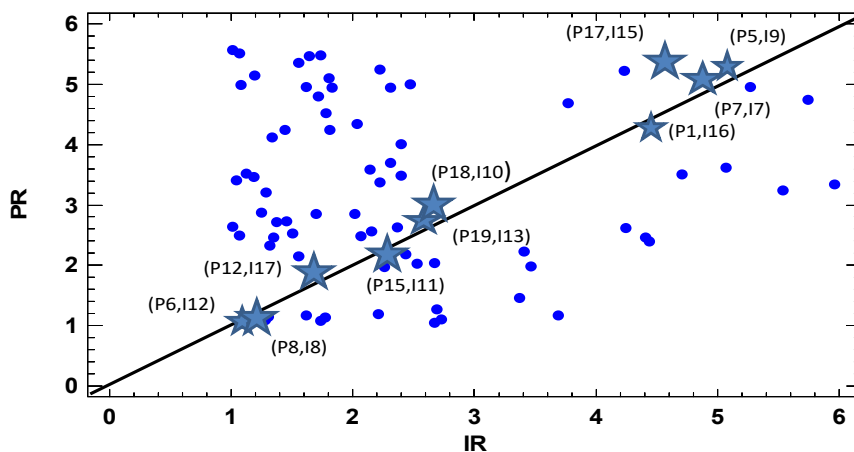


Figure 2. A Balanced Agreement

Note that concessions were paired, rather than matching sets of multiple concessions from each side. This allows the parties to develop the principles shown in Table 10. For example, Principle 1: A Two-State solution on the borders of the 4th of June 1967, with mutually agreed upon land swaps, was developed by combining I9 (“A Two-State Solution on the borders of the 4th of June 1967, with mutually agreed upon land swaps”), P1 (“Accept mutually agreed land swap”), and P5 (“Acceptance of a two-state solution which includes a non-contiguous state”). It did not matter that P1 was not paired with I9, what was important was that it was part of the final set of concessions to consider.

This matching was subsequently written as the Pittsburgh Declaration of Principles (Table 11).

Table 10. Pittsburgh Declaration of Principles

Pittsburgh Declaration of Principles – August 2011	
	Concessions used to develop the principle
1. A Two-State Solution on the borders of the 4th of June 1967, with mutually agreed upon land swaps.	I9, P1 & P5
2. Israel must respect the integrity of the West Bank and Gaza by allowing free and safe passage between the two areas, and the Palestinian State must guarantee that any agreement reached with Israel will be accepted and supported by the majority of the Palestinian people both in Gaza and the West Bank.	I7 & P17
3. East Jerusalem is the capital of the Palestinian State. The parties will maintain the status quo of the holy places in Jerusalem.	I8, I15 & P10
4. Acknowledge Israel's existence as a Jewish State, without jeopardizing the rights of its minority Israeli citizens.	P6
5. Evacuation of Israeli settlers from the Palestinian territories that are not included in the land swap.	I13
6. Palestinian full control of the borders of the Palestinian State and its outlets, and deployment of a temporary agreed upon multinational military monitoring system in the Jordan Valley.	I2 & P3
7. Solve the Palestinian refugee problem in a just and agreed upon manner.	I16 & P19
8. Limited arms of the Palestinian state and international guarantees from the international community against aggression from other parties.	P9
9. Agreed upon international monitoring mechanism and agreed upon binding international arbitration mechanisms.	
10. The full implementation of these principles concludes end of the conflict and claims of the two parties.	

By now it is clear that this possible agreement is just an example of what the theory could accomplish if political forces were not the current ones. But let us think about what this approach could bring to us if we were able to analyze conflicts prior to seating at the negotiation table. The automation of this approach is one of the objectives of the International Center for Conflict Resolution (IC4CR) of the University of Pittsburgh.

4. The Cognitive Components of the Model

In the example given above, we had people who had experience and knowledge about the conflict. It took about two and a half years to get the result shown. It took another three years to construct a fully developed agreement with all the minimum details necessary for its implementation. Each principle was studied using the same mechanism as was used to obtain the declaration principles. A summary of this can be found in (Saaty et al. 2015). The conflict in the example is one of the better known and longer conflicts of the 20th century. But imagine how we could learn about other conflicts if we were able to:

1. Identify/develop concessions by both parties.
2. Identify benefits, costs, perceived benefits, and perceived costs from the concessions.
3. Prioritize the benefits, costs, perceived benefits, and perceived costs from each party perspective.
4. Construct gain-to-loss ratios for pairs of concessions for both parties.
5. Sensitivity analyses.
6. Scenario simulations.

All the information that is digitally available contains knowledge about polarity (i.e., in favor or against a position), intensity (i.e., how strongly people prefer something), theme (i.e., the topic of interest), and number of opinions (i.e., number of people that express the opinion). What is abstracted from this knowledge is priorities. Priorities are fundamental for human thinking. Of course, these priorities are not the priorities developed by our neurons, but the process is similar (Saaty and Vargas 2017). It is because of this belief that we think that to develop a negotiating system that starts by collecting information and knowledge about a conflict, we need to endow the system with the capability of generating priorities. To get to this stage we need to represent the knowledge about a conflict within the framework described above. This will require the use of natural language understanding to abstract knowledge about a conflict in terms of concessions, benefits, costs, perceived benefits, and perceived costs. It is possible that priorities about concessions may be obtained from existing writings by finding about polarity, intensity, theme, and number of opinions.

On the other hand, if parties are willing to negotiate through a neutral party, we could use our platform as the neutral party, an AI Negotiating System (Figure 3). The reader must now think that the AI interface is the repository of the information the parties share with each other. We discuss below the functioning of the AI Negotiation System. Assuming this system is configured according to a suitable architecture, these are the sequences of exchanges that we envision that the parties will have to go through to obtain the necessary information (knowledge) to create gain/loss ratios necessary to make tradeoffs (Figure 4) (Moreno-Jimenez and Vargas 2018). These exchanges are equivalent to the meetings we have with both parties to obtain the concessions, benefits, cost, perceived benefits, and perceived costs. The interface (Figure 3) is the repository of all this information. Each exchange is presented as a figure to make the reader understand that if we were

sitting in front of the actual AI Negotiation System, the computer screens would appear as shown below.

An AI Negotiating System



Figure 3. The Interface

Step 1: Party A (Green party) asks Party B (Red party) what concessions they want (Figure 4).

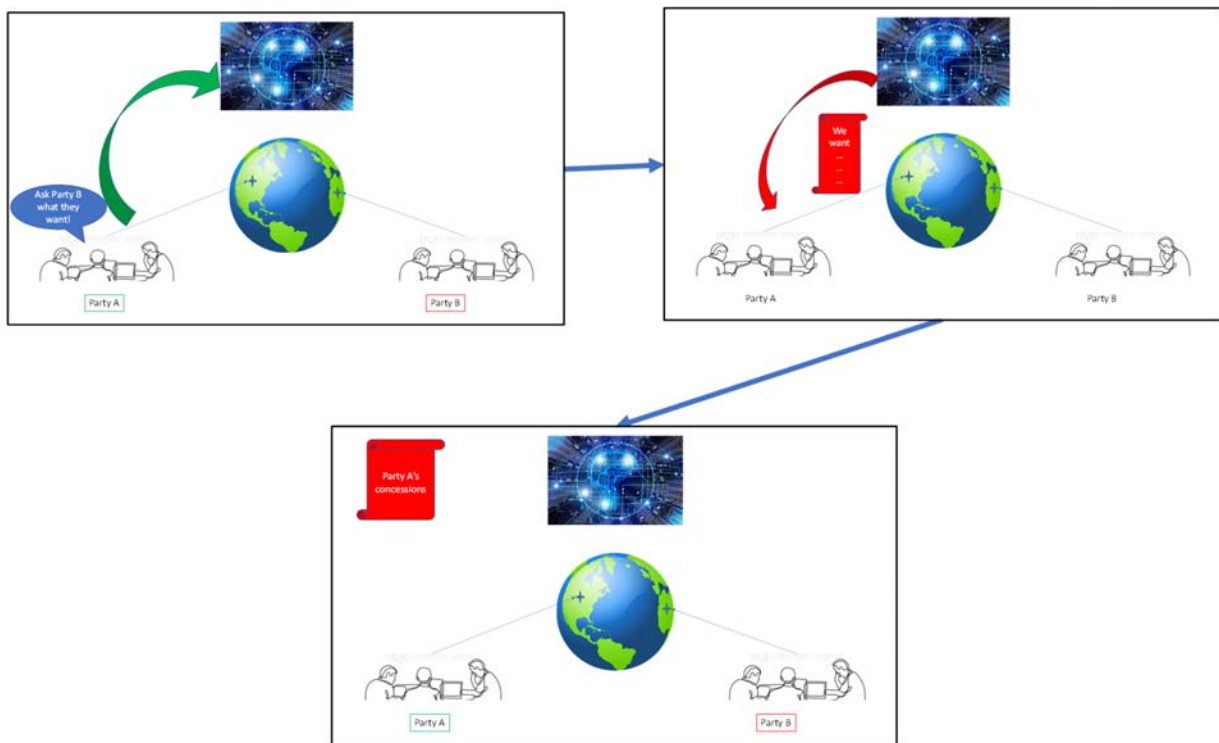


Figure 4. Party A's concessions

Thus, Figure 4 shows that Party A has a list of concessions that Party B wants. The same happens in Figure 5.

Step 2: Party B (Red party) asks Party A (Green party) what concessions they want (Figure 5).

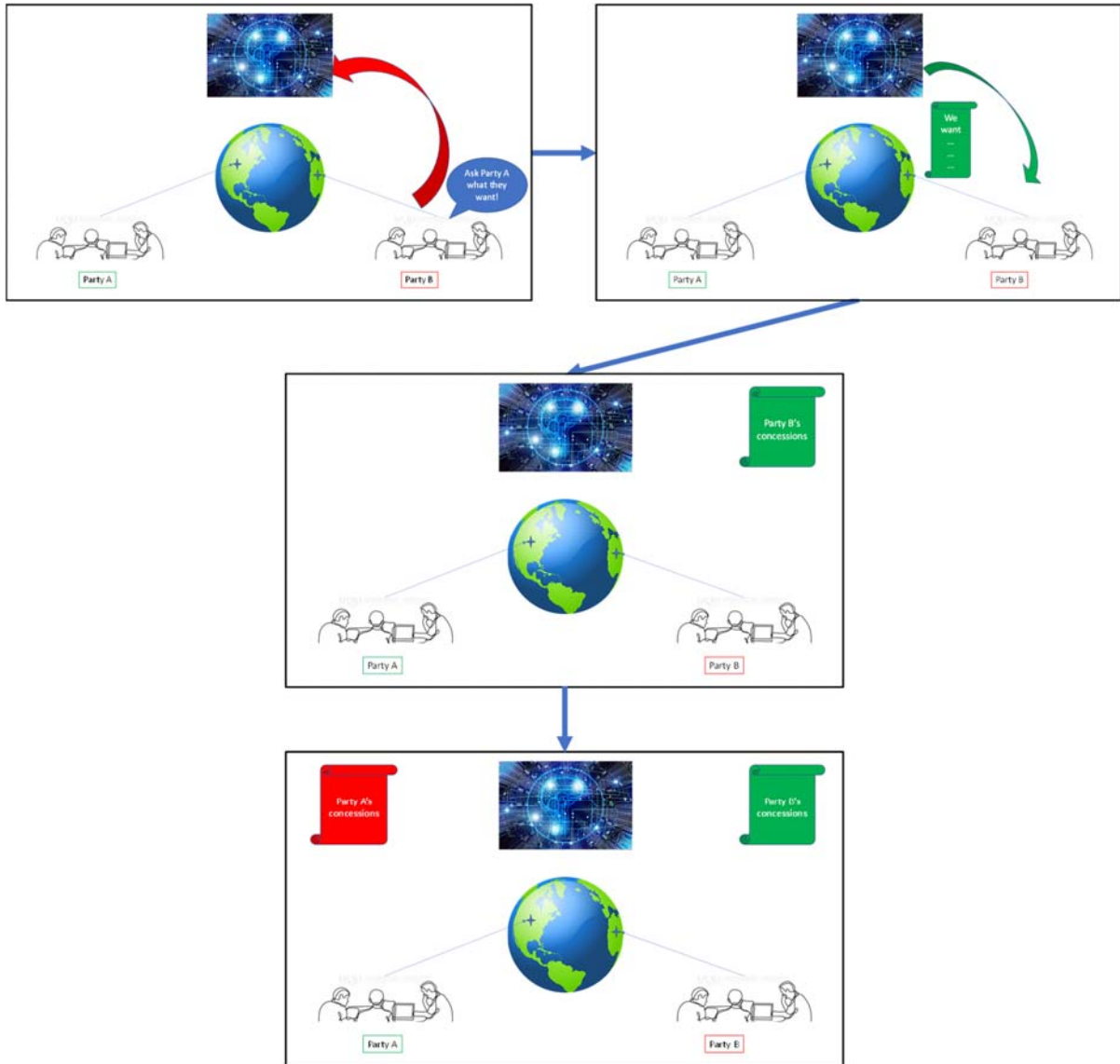


Figure 5. Party A's and Party B's concessions

Note that as the exchanges take place, the AI negotiation System keeps track of the information generated by the parties.

Step 3: Each party ask the other party, what their perceptions are of the benefits and the costs to the other party, from the concessions they give (Figure 6).

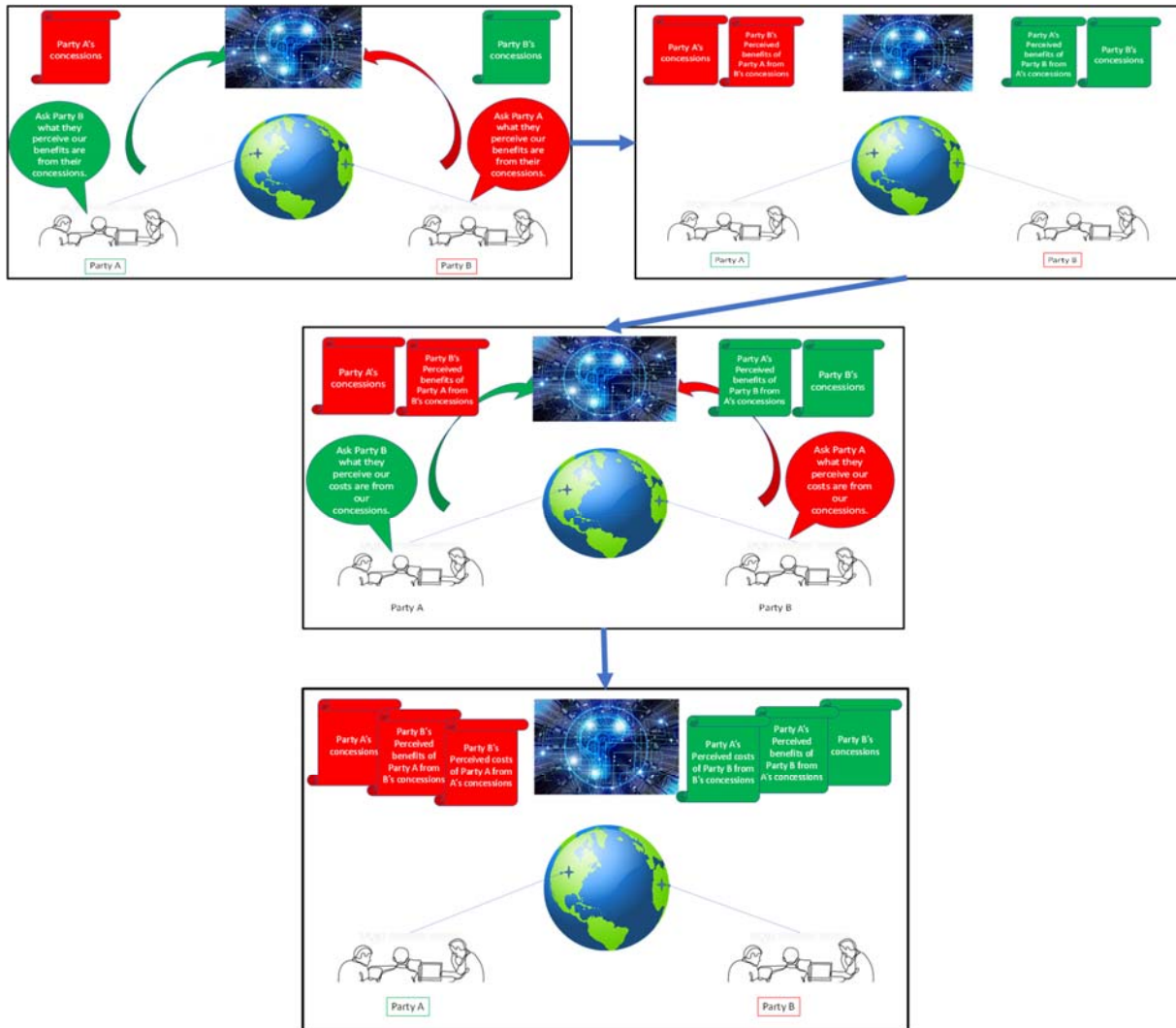


Figure 6. Perceived benefits and perceived costs from concessions

The state of the world in the AI system consists now of the concessions from each party and the perceived benefits and perceived costs from the concessions. Note that with this system the parties do not really need to face each other, just interact with the AI interface.

Step 4: The system now asks from each party what their actual benefits and costs are from receiving and giving concessions (Figure 7). This knowledge is not shared with the other party.

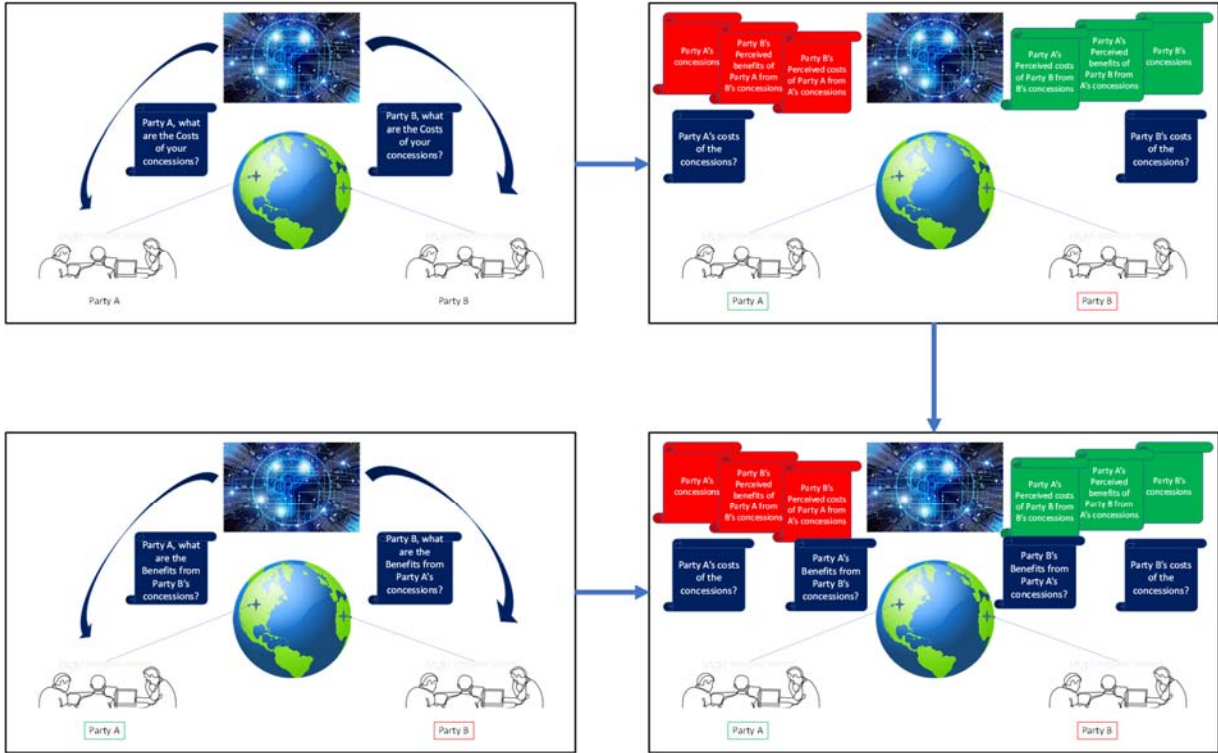


Figure 7. Actual benefits and costs from the concessions

Now all the components of the tradeoff model are available (Figure 8).

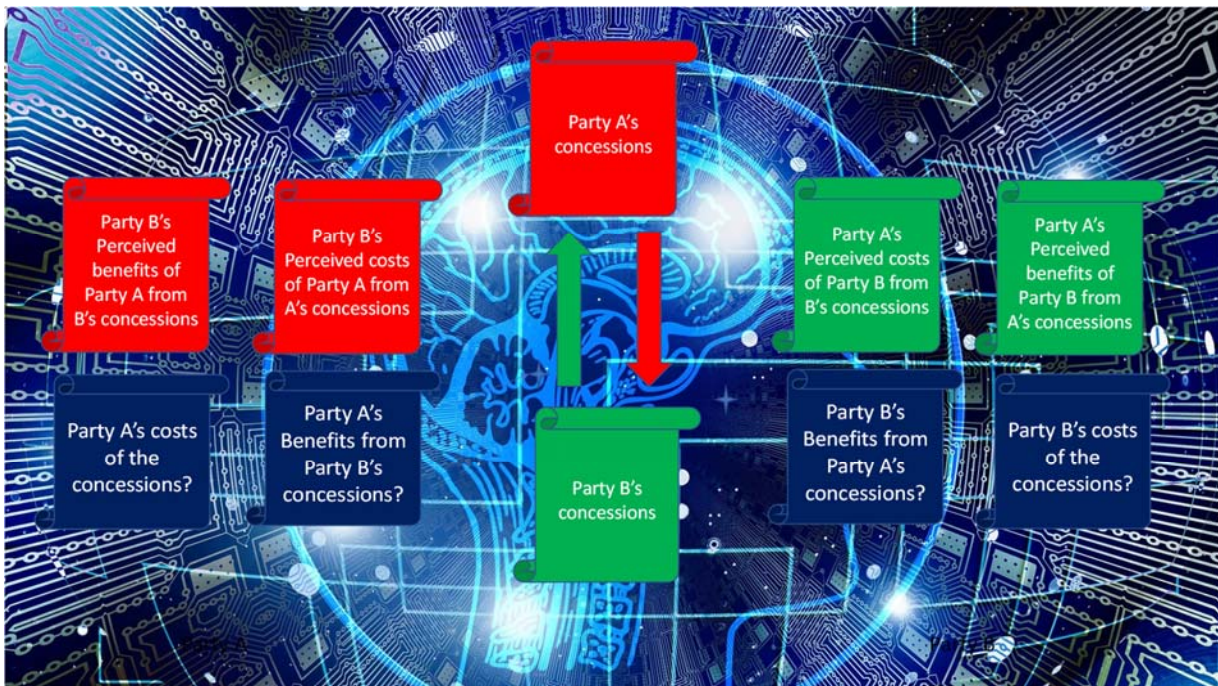


Figure 8. The tradeoff model

Note that in Figure 8, AI Negotiation System has now all the elements to start assembling gain/loss ratios.

Step 5: The gains and the losses are computed to form the gain/loss ratios for each pair of traded concessions (Figure 9).

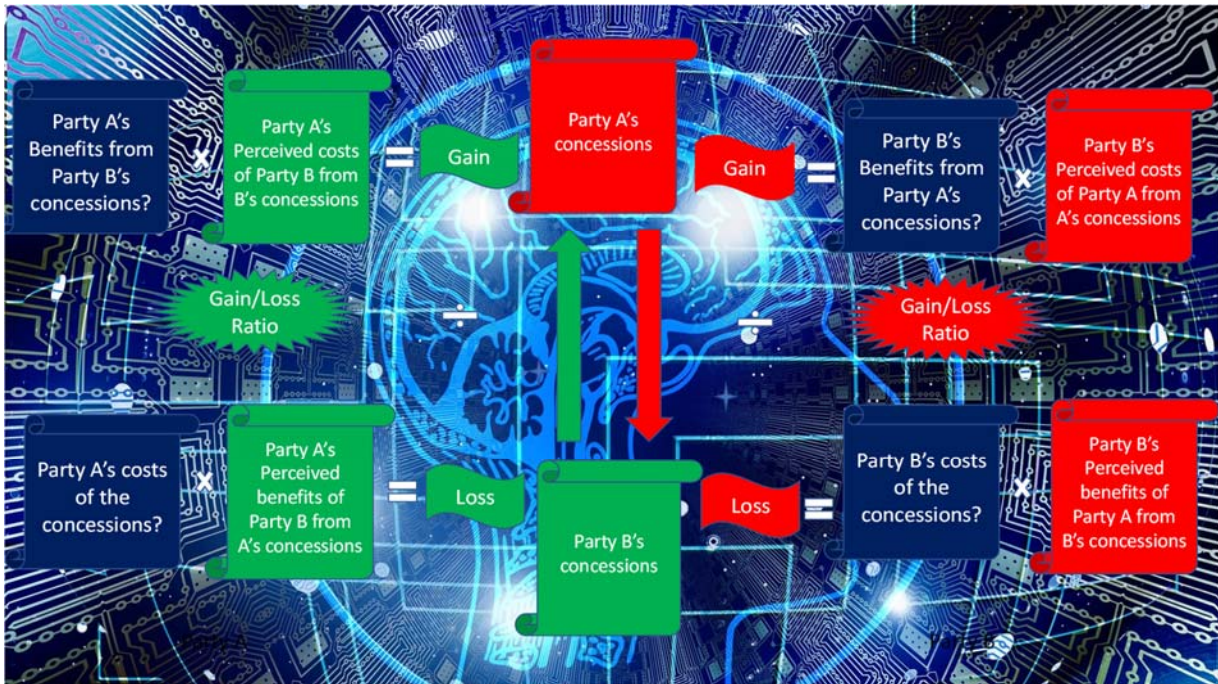


Figure 9. Gain/Loss ratios

The gain/loss ratios are not symmetric for the parties (see Tables 6 and 7). This is not a zero-sum game.

We have represented the interactions between the parties as a set of computer screens to help the reader visualize the steps of the process given in Section 2 where the mathematical model used to match concessions is given. This model is a MaxMin integer programming model well known in the literature.

This set of interactions of the parties through the AI Negotiation System requires several components in the AI system:

1. A Natural Language module to communicate with the parties because the parties do not talk to each other, they communicate with the AI Negotiation System.
2. A Natural Language Understanding module to codify the responses to make the knowledge generated available for future negotiations.
3. A prioritization methodology to quantify the tradeoffs – the AHP.
4. An optimization module to find equilibrium points in the space of tradeoffs.

5. A cognitive module to extract the arguments (patterns of behaviour) that support the positions.
6. A communication module, connected to the Natural Language module, to share the knowledge extracted from the resolution process.

Once a starting solution is generated by the system, we should be able to:

- Identify the critical points of the resolution process.
- Study conflicts with incomplete and uncertain information.
- Develop strategies beneficial to both parties.
- Learn from previous conflict studies.
- Increase the knowledge about the behavior of the two parties in the CRCR-AHP approach.

These insights that characterise the AI Negotiation System associated with the proposed approach (Cognitive and Retributive Conflict Resolution based on AHP) help the actors to start and engage a negotiation from noncooperative parties and delineate the future ahead in this field.

An overview of NSSs and existing software can be seen in (Jelassi and Foroughi 1989), and (Kersten and Lai 2007). (Jelassi and Foroughi 1989) discuss negotiation structuring issues that can be considered when design a NSS (e.g., behavioural characteristics and cognitive perspectives of negotiators, communication needs of different bargaining settings, determination of each party's real interest(s), generation of options for mutual gain, and data accuracy and consistency), review negotiation theories used as the basis for designing NSS, and provide a comprehensive survey of existing software in the area of computer-supported negotiation. (Kersten and Lai 2007) discuss the broad categories of NSS from four perspectives: real-life applications, systems used in research and training, research results, and research frameworks. Recently, (Harris et al. 2017) introduce the concept of negotiated resilience and affirm that it requires engagement with diverse actors and interests, and the consideration of diverse options and tradeoffs. Both ideas are captured by the cognitive and retributive orientation of our proposal.

5. Knowledge Extracted from Previous Conflict Resolution Attempts

The definition of Knowledge in the Oxford dictionary is:

1. Acts, information, and skills acquired by a person through experience or education, the theoretical or practical understanding of a subject.
2. Awareness or familiarity gained by experience of a fact or situation.

It is pertinent to ask: What knowledge have we acquired in the process of studying conflicts with the methodology based on the AHP that we illustrated in previous sections? According to (Mayer 2015):

“When we intervene in conflict, whatever our role, we inevitably address how people think about their disputes. We may believe that we are trying to hammer out an agreement, change the way people communicate, or help them through a healing and recovery process. However, we do not really change the dynamics of a conflict unless we change how those involved see the challenges before them, the people they are in conflict with, or the way in which the conflict has arisen and developed.”

So, we must distill how the parties think about the conflict, how they communicate, how they see the other party, and how the conflict arose and developed. But using the AHP, the parties learned what the other party value and its willing to trade, what they gain and lose with the trades, in addition to the perceptions a party has of the other party losses with a trade, and the perceptions of what they gain. In the end, the parties get to know how far apart they are in the issues involved in the conflict.

Thus, knowledge of a conflict is more than what the parties think about the conflict, how they communicate, and how they see each other. Conflict resolution knowledge needs measurement. Without measurement all we have is a descriptive representation of the conflict. Knowledge representation in conflicts needs priorities. Priorities that parties assign to their objectives, concessions, benefits, costs, perceived benefits, and perceived costs. Without priorities we are left with everyday knowledge of the conflict. The real possibility to solve a conflict lies with developing scientific knowledge of the conflict, and this requires measurement, relative measurement. This will give us the possibility of creating a knowledge representation scheme that can be reused in other conflicts.

6. Conclusions

This paper puts forth a new cognitive and retributive methodology for conflict resolution. Following an evolutive approach based on the functioning of the human brain (gains and losses) and the vital process of the evolution of living systems (a cognitive process), the new proposal combines rewards (own benefits and perceived rival costs) to measure the gains and regrets (own costs and perceived rival benefits) to measure the losses.

The joint consideration of one's own and other people's visions (retributive conflict) allows a more effective and realistic resolution of the problem in accordance with human behavior. AHP enables, through priorities, the integration of intangibles and tangibles aspects into formal models, as well as the measurement of gains and losses. On the other hand, the use of ratios allows to solve some cognitive biases (amplification parameter for losses) that derive from the different way the brain treats gains and losses (Kahneman and Tversky's prospect theory).

The use of artificial intelligence tools facilitates the extraction and dissemination of the arguments that support the different positions and decisions. This entails a better knowledge of the conflict resolution process and the continuous learning of the actors involved in solving the problem in a key aspect of human beings: decision-making. Moreover, the availability of low-cost cloud-based

computing services recommends moving the software architecture of the CRCR-AHP to a cloud-based computing environment to support conflict resolution problems when the participants are based in the same or different locations and the decisions are made in a synchronous or asynchronous way.

The role of the facilitator and the computer agent, the communication (verbal, paraverbal and nonverbal) among the different actors, as well as the synergies with social media platforms will be the subject of a future research.

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APPENDIX. Tables

Table 1. Israelis' Concessions

Israelis' Concessions	Description
I1	Abandon the Idea of Jewish State
I2	Accept Palestinian full control of the borders of the Palestinian State and its outlets
I3	Accept the historical responsibility for the Palestinian refugee problem
I4	Accept the Palestinian refugee rights to return
I5	Accept to abide by the status quo in the holy places in Jerusalem
I6	Accept to abolish law of return
I7	Accept to respect the integrity of the West Bank and Gaza by allowing free and safe passage between the two areas.
I8	Accept East Jerusalem as the capital of the Palestinian State
I9	Accept Two-State Solution on the borders of the 4th of June 1967
I10	Allow all parties to have equal access to and control of religious sites and holy places
I11	Allow the sharing of all natural resources between Palestinians and Israelis
I12	Comply with all applicable UN Resolutions
I13	Evacuate settlers of Jewish settlements on land claimed by the Palestinians with or without compensation
I14	Release all political prisoners including those who are Israeli citizens
I15	Share Jerusalem as two capitals of two states
I16	Solve the Palestinian refugee problem in a just and agreed upon manner
I17	Stop incitement by the religious and national education and religious leaders in Israel against Muslims and Arabs

Table 2. Palestinians' Concessions

Palestinians' Concessions	Description
P1	Accept mutually agreed upon land swap
P2	Accept settlers under Palestinian sovereignty as residents
P3	Accept the temporary presence of multinational military monitoring system in Jordan Valley
P4	Accept Two-State solution
P5	Accept a Two-State solution which includes a non-contiguous state
P6	Acknowledge Israel's existence as a Jewish State
P7	Acknowledge Israel's existence as an independent State
P8	Agree to compromise to the demand of the right of return
P9	Agreeing with Palestinian demilitarized state
P10	Preserve the status quo in the Holy places of Jerusalem
P11	Allow Israel to use Palestinian airspace
P12	Declare against Iranian nuclear development
P13	Denounce & reign in violence
P14	Denounce Iranian pursuit of nuclear arms and support Israelis effort to remove the threat
P15	Lobby Arab states to allow both Israelis and Palestinians to have the right to return to their land of origin
P16	Make compromises on the status of Jerusalem
P17	Palestinians must guarantee that any agreement reached with Israel will be accepted and supported by the majority of the Palestinian people, both in Gaza and the West Bank
P18	Refrain and work against any anti-Israel sentiments in Palestinian schools
P19	Seek assistance for a legitimate settlement of refugees
P20	Sharing of natural resources
P21	Work cooperatively and in active engagement w/ Israel

