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Article

Value-based analysis of the negotiation for the construction of a church dome

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Abstract: In the construction industry, the signing of contracts between contractors and clients is a common practice. The entities signing these contacts have vastly different objectives in the context of the project: the contractor is motivated by the achievement of profit, while the client has objectives that can be economic, aesthetic, related to completion time, etc. According to negotiation theory, the greater the difference between the objectives of the sides, the better the contracts that can be achieved in the negotiation. Therefore, the analysis of a contractor-client negotiation in the building industry should be based on a complete understanding of the objectives of the sides. Kenney's Value-Focused Thinking (VFT) provides a framework on which such understanding can be achieved. This paper presents a VFT-based methodology to analyze the contractor-client negotiations in the context of construction projects. The methodology is illustrated by analyzing, in retrospective, the negotiation between a construction company and a client regarding the construction of a dome for a church. The results show the usefulness of analyzing the negotiation from the point of view of the sides' objectives.

Keywords: negotiation; decision analysis; construction

1. Introduction

In the business of constructing houses and buildings, there are specialized entities (contractors) that carry out the actual construction activities and deliver the finished product to a client or buyer. Before starting the building activities, the contractor and client must agree on a contract specifying the characteristics of the work. The contract contents (physical characteristics of the building, materials, delivery time, building price tag, etc.) are settled in a negotiation process between the client and the contractor.

The objectives of the client and contractor in the context of the project are quite different. The main objective of the contractor is economic, so his worries about other negotiation elements (for example, delivery time and building characteristics) derive from the effect of these issues on the profit. In contrast, the client has several essential objectives beside the monetary one, as, even though he prefers to pay less money than more, he is willing to accept a cost increase in exchange for changes in other elements, such as improved aesthetics or a reduction in delivery time. This indicates that, for the customer, cost, aesthetics, and completion time are all essential objectives.

In a negotiation in which several issues (themes) need to be decided, the potential of finding contracts that are convenient for both sides (win-win contracts) depends on the difference in the sides' objectives. The analysis of contracts between clients and contractors in the construction industry, then, must begin with analyzing and structuring the objectives of the parties. Keeney's [1] Value-Focused Thinking, which states that the analysis of a decision situation should begin by structuring and understanding the decision-maker's objectives, provides a framework for analyzing the contractor-client negotiation from the point of view of the parties' objectives.

Regarding related research, Verheij and Augenbroe [2] propose a method for planning architectural, engineering, and construction projects applying collaborative decision-making concepts, and Murtoaro and Kujala [3] provide a framework for dealing with client-contractor negotiations to support the work of professional negotiators. Specific negotiation elements relevant to construction negotiation are treated by Branconi and Loch [4], who deal with the influence of business leaders' philosophies on negotiation proceedings; Koskinen and Mäkinen [5], who analyze the effect of the boundary object (or the interface between the sides) in the final agreement; and Oliveira et al. [6], who study the effect of contractor technical competence on the contracts.

There are several reports of the application of game theory for analyzing construction contracts. Lippman et al. [7] use game theory and the Nash equilibrium concept for managing outsourced projects with cost uncertainty, with Tosselli et al. [8] adding process simulation to these elements and developing an automatized negotiation protocol; Ng and Li [9] design an automated bargaining protocol for contracting suppliers when parent companies are participating in tenders; Shang et al. [10] analyze the distribution of the economic incentives of energy-saving contracts using Rubinstein's game theoretical model; and Tang et al. [11] study the fair sharing of the project risks. Applications of game theory to the analysis of build-transfer-operate projects are shown in Kang et al. [12] for calculating royalties, Zhang et al. [13] for determining the optimal lifetime and concession period, and Bao et al. [14] for identifying the concession period for a project under conditions of incomplete information. Finally, Song et al. [15] develop a bargaining model for setting compensations in road projects that had to be finished early.

Models foreseeing changes or deviations in original plans are shown in Chen and Wang [16], who apply multi-agent concepts to develop a compensatory model for the dynamic scheduling of projects. Badenfelt [17] proposes a framework to address the problems generated when contracts must be adjusted, using risk sharing and social influence theories, and Miranda-Sarmento and Renneboog [18] deal with the renegotiation of public-private deals, highlighting the impact of the strategic behaviors of the parties caused by electoral cycles and changes in the companies strength.

Considerations of non-economic objectives in construction negotiations appear in Kumar et al. [19], who discuss public-private deals for energy projects. Stapper [20] mentions the inclusion of citizens in the negotiations of public projects, showing how citizens' objectives can influence negotiation results. Adebayo and Werker [21] quantitatively model mining companies' benefit-sharing agreements with communities, where the communities' gains of job creation and economic opportunities are balanced by the health risks of the miner's activity, and Jalbert et al. [22] analyze the effect of the risk perception of the owners of the land on which gas lines are to be built on the contracts they find acceptable as the owners balance their payment against the pipe risks.

The research just described, although treating negotiations between sides with objectives of different natures (e.g., economic, environmental, and related to health or security), neither analyzes nor structures the objectives of the parties. This is done by the methodology put forward here to analyze contractor-client negotiations, which is based on applying decision analysis concepts [23,24], and in particular value-focused thinking [1] to the situation. Decision analysis is a discipline dealing with decision-making from a prescriptive-normative point of view, that is, how to make better decisions given the cognitive limitations and the preferences of the decision-maker [25].

2. Negotiation analysis methodology

It is assumed that two sides, the contractor and the client, must reach an agreement on the characteristics, delivery time, and payment for a construction job. The methodology for analyzing the negotiation, based on the steps put forward by Raiffa [26], is described below.

1) Analysis of the objectives of the sides. In this step, each side identifies its objectives and proceeds to divide them into fundamental objectives (objectives that are essentially important) and means objectives (important because they promote other objectives). The objectives are structured into the fundamental objectives hierarchy and the network of means-ends objectives. In case one of the sides has objectives that are non-monetary (for example, the client may have objectives related to the building aesthetics), scales should be constructed to measure the achievement of these objectives, and the trade-off between objectives of different natures must be defined.
2) Definition of the frame of the negotiation. The negotiation frame consists of the issues that need to be settled and the levels they may take. A “contract” is set by selecting a level of each negotiation issue.
3) Development of models mapping the levels of the issues to the fundamental objectives of the negotiating sides. For the contractor, whose fundamental objective is monetary, this model is based on factual knowledge (for example, how much a change in the design or in the target completion time represents in cost). In the case of the client, who may have non-economic fundamental objectives, this model reflects his preference for different issue levels, so his model relies heavily on subjective preferences and value judgments.
4) Using the derived models, the sides’ preferences for the possible contracts can be calculated and plotted. From the produced graph, acceptable contracts are identified, and the non-dominated contracts (i.e., contracts for which there is no other contract that is better for both parties) that make up the “efficient frontier” of the problem are pointed out as candidate final contracts.
5) Using concepts of fairness and equity, a contract from the efficient frontiers is selected as the final contract to be agreed by the parts.

3. Application of the methodology to an example

The described steps are applied to a contractor-client negotiation case study that is based on a real-life situation involving one of the authors of this work. The “contractor side” is a construction company, while the “client side” is a committee representing a religious congregation needing a dome for a church. The dome should serve as a roof to cover a square-shaped space of approximately ten meters per side. The committee is made up of five people, representing around one hundred sponsors of the dome purchase.

3.1. Analysis of objectives

For the analysis, the parts are assumed to be monolithic.

3.1.1. Contractor

The contractor's objectives are related to profit and safety. The profit is calculated as the price paid by the client minus the construction costs, so objectives such as "maximize price" and "minimize costs" are identified and arranged into the contractor's fundamental objectives hierarchy (**Figure 1**). The mean objectives, that are valuable for their impact on fundamental objectives, make up the network of mean-end objectives, shown in **Figure 2**. This figure shows, for example, that a way to decrease labor costs is to reduce the number of workers. As it is assumed that the alternatives do not impact the project's safety, only economic objectives are considered going forward.

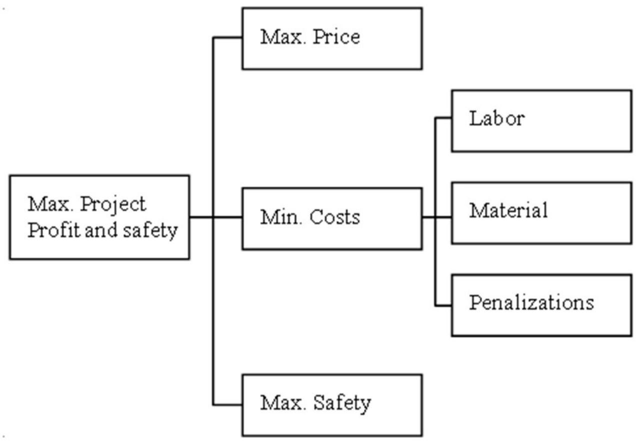

Figure 1. Contractor's fundamental objectives hierarchy.

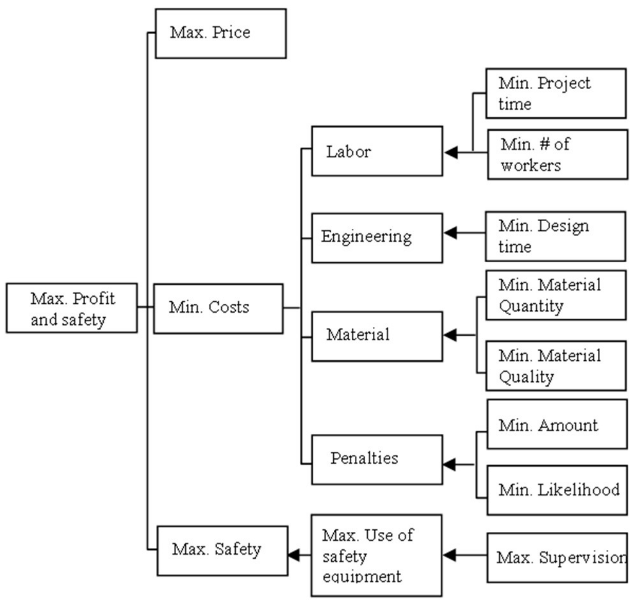

Figure 2. Contactor's mean-ends objective network.

The impact of project decisions on the total cost (called COST) is shown in the influence diagram of **Figure 3**. In these diagrams, rectangles represent decisions, ovals represent uncertain events, and ovals with double edges represent deterministic calculations.

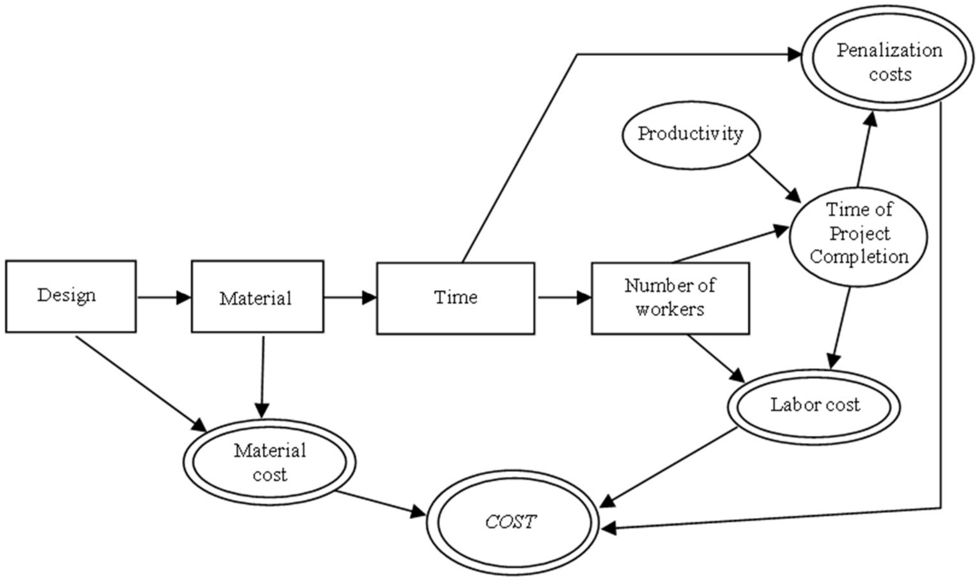

Figure 3. Influence diagram of the total cost.

If price is the monetary amount paid by the client for the building, then the contractor's profit is

$$\text{Profit} = \text{Price} - \text{Cost} \tag{1}$$

Being an early stage in the negotiation, the costs are not calculated in detail but with a simplified model. The total costs are the sum of material and labor costs. Material costs (C_{MAT}) are calculated from the total weight of the material used, which is calculated as volume times density

$$C_{\text{MAT}} = \text{Weight (kg)} \times \text{Unitary material price (\$/kg)} \tag{2}$$

$$\text{Weight (kg)} = \text{Density (kg/m}^3\text{)} \times \text{Area (m}^2\text{)} \times \text{thickness (m)} \tag{3}$$

The labor cost derives from the workers cost (C_{TR}) and manufacturing cost (C_{MAN}), the latter representing the expense of subcontracting part of the work.

$$C_{\text{TR}} = 30 \text{ (day/month)} \times T \times n \times \text{wage (\$/day-worker)} \tag{4}$$

Being n the number of workers, T the project target completion time in months, and wage the daily wage of a worker. The model relating T and n relies on the contractor's expertise. For a given design, the contractor estimates that the completion time for a given number of workers n_0 is T_0 months. With two additional points (n_1, T_1) and (n_2, T_2), a quadratic relationship $T_f(n)$ between completion time and number of workers is assumed.

$$T_f(n) = a \times n^2 + b \times n + c \tag{5}$$

Thus, for a given completion time, the workers cost is given by

$$C_{TR} = 30 \times T \times T_f^{-1}(T) \times \text{wage} \tag{6}$$

Being $T_f^{-1}()$ the inverse function of T_f. C_{MAN} depends on the building design and can be obtained through quotes from companies to be subcontracted. The total building cost is

$$\text{Cost} = C_{\text{MAT}} + C_{\text{TR}} + C_{\text{MAN}} \quad (7)$$

3.1.2. Client

The client's objectives in the context of this negotiation are:

1) Minimize construction time.
2) Maximize the aesthetic qualities of the dome.
3) Minimize the amount of money paid.

These fundamental objectives are structured into the fundamental objectives hierarchy of **Figure 4**.

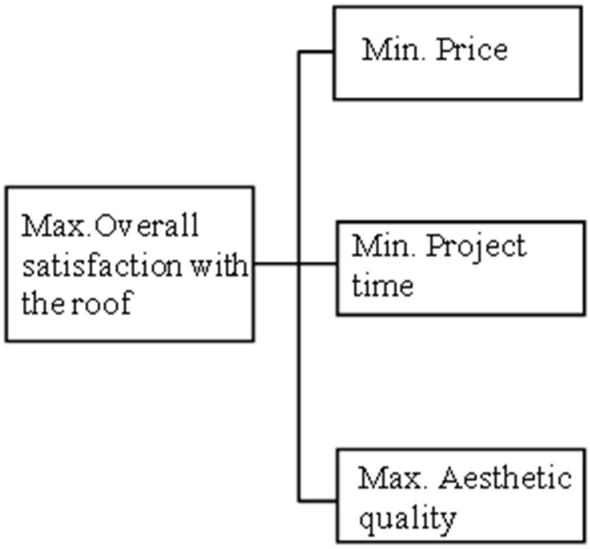

Figure 4. Client's fundamental objectives hierarchy.

These objectives must be quantified to measure how much the client values each contract. The client's utility (U_C) is calculated additively from three elements: U_T construction time utility, U_{CE} aesthetic quality utility, and U_P construction price utility.

$$U_C = k_1 \times U_T + k_2 \times U_{CE} + k_3 \times U_P \quad (8)$$

Equation (8) reflects that the client's bottom line is made up of three dimensions: finishing time, price, and aesthetics. For instance, a given price hike (U_P decreases) can be compensated for by a better-liked design (U_{CE} increases), thus keeping U_C constant and indicating a constant client's satisfaction. In this example, the client's preference for project time is given in **Table 1**.

Table 1. Client's preference for project time.

Level	Description	Utility (U_T)
0	1 to 5 months	1.0
1	5 to 10 months	0.5
2	11 months or more	0

The quantification of the client's preference for the dome aesthetic qualities, requires the measurement of the client feelings with respect to different dome shapes and materials. The candidate dome designs in this problem are sketched in **Figure 5**.

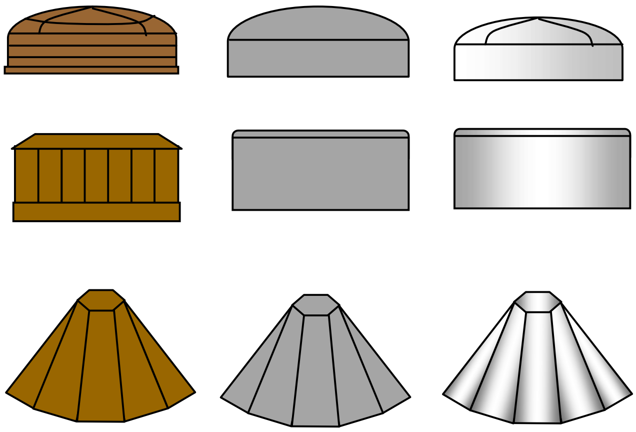

Figure 5. Candidate dome designs.

Three dome shapes are considered (S: Skirt, R: Rectangle and C: Circle) in three materials (W: Wood, C: Concrete and A: Aluminum). To begin the preference quantification, the first task is to get the client to order the nine candidate designs according to his preferences. This task would be simpler if the elements making up a dome design (shape and material) could be treated separately. As an example, let's say that if the material is concrete, the shape preference was found to be:

Skirt ▷ Circle ▷ Rectangle

With "▷" meaning "is preferred to". And, if the material is changed to wood, the preference order for shape changes to

Skirt ▷ Rectangle ▷ Circle

This would mean that the attributes of shape and material are not separable and must be considered together in the preference elicitation. A procedure for doing so is described next, with the notation "SM" being S = Shape and M = Material (e.g., SC = Skirt-Concrete and RW = Rectangle-Wood), used to denote a dome design. First, for each shape, the preference for materials is elicited, let's say the resulting orderings are:

Skirt	SA ▷ SC ▷ SW
Circular	CA ▷ CC ▷ CW
Rectangle	RC ▷ RW ▷ RA

In a similar manner, for each dome material, the client provides his preference for shape; examples of such orderings are:

Aluminum	SA ▷ CA ▷ RA
Concrete	SC ▷ CC ▷ RC
Wood	SW ▷ RW ▷ CW

Next, the client must choose his most and least preferred designs. Let the former be the Skirt of Aluminum (SA) and the latter the Rectangle of Aluminum (RA), then the relation RW ▷ RA and RW ▷ CW imply the preference order.

SA ▷ RW ▷ CW ▷ RA

As RC ▷ RW, CC ▷ RC and CA ▷ CC, then

SA ▷ CA ▷ CC ▷ RC ▷ RW ▷ CW ▷ RA

The location of SC and SW in this list is not completely defined by the elicited preferences of shape and material: according to these, SC is to the left of CC and to the right of SA but its precise location should be elicited directly from the client. If the client prefers SC to CC, but prefers CA over SC, then

SA ▷ CA ▷ SC ▷ CC ▷ RC ▷ RW ▷ CW ▷ RA

By locating SW in a similar manner, the complete ordered list is elicited, as illustrated below.

SA ▷ CA ▷ SC ▷ CC ▷ RC ▷ SW ▷ RW ▷ CW ▷ RA

The method of point allocation can be used to express these preferences quantitatively [23]. **Table 2** shows a likely set of results of this procedure.

Table 2. Client's utility for dome designs.

Order	Notation	Description	Points	U_{CE}
1	SA	Skirt of aluminum	100	1.0
2	CA	Circle of aluminum	80	0.8
3	SC	Skirt of concrete	60	0.6
4	CC	Circle of concrete	50	0.5
5	RC	Rectangle of concrete	45	0.45
6	SW	Skirt of wood	30	0.3
7	RW	Rectangle of wood	12	0.12
8	CW	Circle of wood	10	0.1
9	RA	Rectangle of aluminum	0	0

Finally, the client has preferences for the money he is charged for the dome. The client's utility for price, U_P can be a linear function with a value of one for a price of cero and a value of $-(k_1 + k_2)$ for the maximum monetary amount the client is willing to pay.

3.2. Negotiation frame

The negotiation frame includes the issues whose resolution may affect the fundamental objectives of at least one of the negotiating sides and the possible resolution levels of these issues. The negotiation frame of the worked example case is shown in **Table 3**.

Table 3. Negotiation frame.

Issue	Level
Shape	a) Skirt b) Circle c) Rectangle
Material	a) Concrete b) Aluminum c) Wood
Project completion time	a) 4 Months b) 8 Months c) 12 Months
Price	a) \$35,000 b) \$50,000 c) \$75,000

3.3. Contract plot

The client utility was calculated with the following weights in Equation (8): k_1 =

0.2, k_2 = 0.5, and k_3 = 0.3. The contractor's utility is calculated as his profit, equation 1, divided by 75'000, so to produce utilities on a scale comparable to that of the client's. All combinations of the levels of the issues in **Table 3** can produce 81 different contracts. The contractor's and client's utilities for these contracts are shown in **Figure 6**.

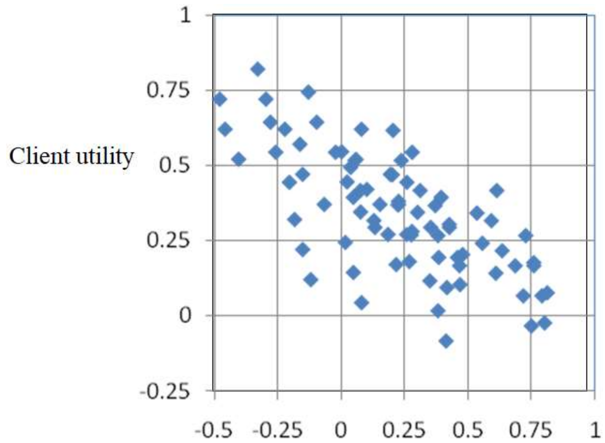

Figure 6. Possible contracts.

The contracts that are non-dominated constitute the efficient frontier (**Figure 7a**); among them, those not lying in valleys make up the "extreme efficient frontier" (**Figure 7b**), which is used as a basis for finding a final contract. **Table 4** shows the contracts on the extreme efficient frontier, where a contract number is used to label each extreme efficient contract.

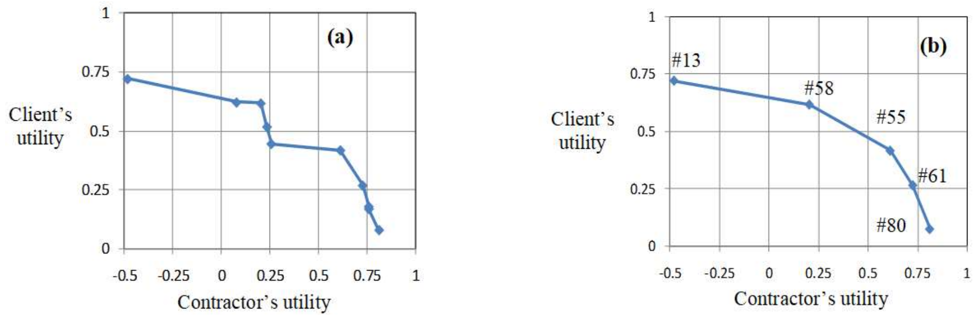

Figure 7. (a) efficient frontier; **(b)** extreme efficient frontier.

Table 4. Contracts on the extreme efficient frontier.

#	Shape	Material	Time (months)	Price ($)	Contractor's utility	Client's utility
80	Rectangle	Wood	8	75,000	0.811	0.078
61	Skirt	Wood	4	75,000	0.726	0.268
55	Skirt	Concrete	4	75,000	0.611	0.418
58	Skirt	Aluminum	4	75,000	0.203	0.618
13	Circle	Aluminum	4	35,000	−0.481	0.722

The contracts on the extreme efficient frontier that are the most beneficial to both sides are those lying the closest to a 45° line in **Figure 7a**. These contracts are labelled #58 and #55 (**Table 5**).

Table 5. Fairest extreme efficient contracts.

#	Shape	Material	Time (months)	Price ($)	Contractor's utility	Client's utility
55	Skirt	Concrete	4	75,000	0.611	0.418
58	Skirt	Aluminum	4	75,000	0.203	0.618

Of these contracts, #55 favors the contractor (his utility is 0.611 against the client's 0.418), and the other favors the client (the utility of the contractor is 0.203 and the client's is 0.618). These contracts can be used as a basis to define more equitable ones: By lowering the price of #55 (favoring the client) and raising the price of #58 (favoring the contractor), equitable contracts #55' and #58' are defined (**Table 6** and **Figure 8**).

Table 6. Final equitable contracts.

#	Shape	Material	Time (months)	Price ($)	Contractor's utility	Client's utility
55'	Skirt	Concrete	4	$65,000	0.511	0.455
58'	Skirt	Aluminum	4	$80,000	0.469	0.515

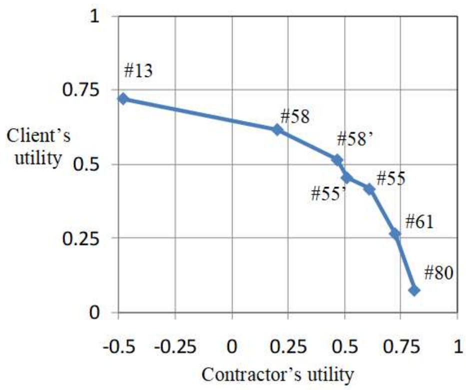

Figure 8. Final equitable contracts.

3.4. Contractor side in uncertainty of the client's preferences

We now take the view point of the construction company, who thinks that the client's preferences can be of three types: moderate, concerned about price, and concerned about aesthetics. These types of preference imply different values of the weights in Equation (8), shown in **Table 7**.

Table 7. Weights according to client type.

Client type	k_1	k_2	k_3
Moderate	0.2	0.5	0.3
Price concerned	0.2	0.1	0.7
Aesthetics concerned	0.2	0.7	0.1

For each set of values, the boundary of extreme efficient contracts (**Figure 9**) and the most equitable contracts (**Table 8**) are identified. The most equitable contract for the price-concerned client is #52 and for the aesthetic-concerned client is #55.

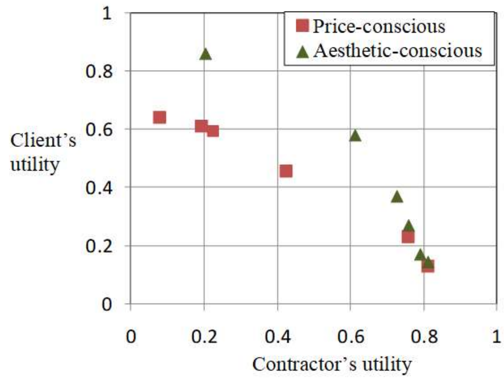

Figure 9. Extreme efficient frontier by client type.

Table 8. Equitable contracts according to client type.

Client type	#	Shape	Material	Time (months)	Price	Contractor's profit
Moderate	55'	Skirt	Concrete	4	$67,500	$38,350
	58'	Skirt	Aluminum	4	$80,000	$35,195
Price-concerned	52	Rectangle	Wood	4	$50,000	$31,800
Aesthetics-concerned	55	Skirt	Concrete	4	$75,000	$45,850

Contract #52 was not equitable to the client with moderate preferences (**Table 5**), and in that case, contract #55 had to be modified to #55' by changing the price from $75,000 to $65,000. Logically, the construction company's profit when dealing with a price-concerned client is lower than when negotiating with an aesthetic-concerned client.

If the construction company has probabilities about the type of client it is dealing with, the uncertainty tree of **Figure 10** can be constructed.

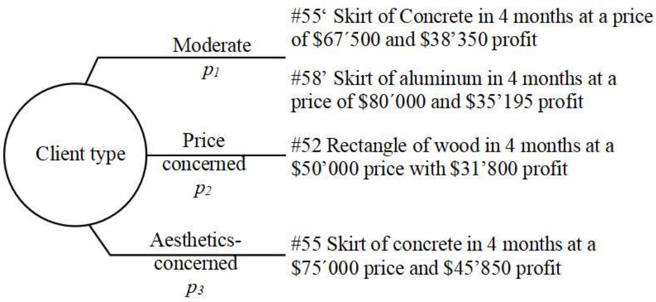

Figure 10. Probability tree for the client type.

The contractor can use this information in the following ways:

a) If the construction company has another job offer with a profit greater than the expected value of the profit in **Figure 10**, it can aggressively pursue a contract with a higher profit.

b) The construction company must open the negotiation with a contract with a high profit (for example #80 in **Table 7**), foreseeing to approach, as the negotiation proceeds, to more equitable contracts. In this sense, two situations can arise.

- The contractor may be confident in the type of client he is dealing with (one of p_1, p_2, or p_3 nears one). In this case, the contracts should tend to the equitable contract of the respective type of client, and no contract less favorable to the contractor should be accepted.

- The contractor is uncertain on the type of client across the table (p_1, p_2, and p_3 are comparable). In this case, he will try to steer the negotiations to the contract that is most beneficial to him (in the example, the equitable contract for an aesthetics-concerned client), being able to sequentially cede to the other equitable contracts less favorable to him.

4. Conclusions

This work has presented a methodology for analyzing the negotiation of construction companies and clients, taking a values-focused thinking perspective. The identification, structuring, and quantification of the objectives of the sides make it possible to find the most equitable contracts. The methodology is illustrated by a worked example related to the manufacture of a church dome. It is seen that for the contractor, the modelling effort concentrates on relating the different project elements to the cost, while for the client, more time should be devoted to eliciting his subjective preferences for the project characteristics. Additionally, taking the side of the contractor, it is shown that an effort to understand the probable objectives of the client can help the negotiation process, adjusting the designs and prices according to the perceived client preferences.

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