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A combined AHP-GP model for selecting and awarding design-build construction contracts

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Abstract
In public works or government construction contracting, as well as in private sector construction contracting, selection of a winning design for contract award in design-build contracts involves ranking and determining the design and contractor combination that yields the best value for the government. Currently, these decisions are made subjectively, where the contracting authority analyzes each received proposal in terms of price and technical design, while also attempting to incorporate harder-to-analyze factors such as a contractor's risk level through their history of past performance or other methods. Attempting to mentally combine all of these factors and produce an objective ranking is very challenging. This paper presents a mathematical model that combines the analytic hierarchy process (AHP) with goal programming (GP) to select the contractor whose proposal is truly the best value given the priorities of the project. The developed model is also flexible and is able to adapt to different project requirements.

Key words: analytic hierarchy process; goal programming; design-build

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INTRODUCTION

In a typical design-build (DB) construction contract, a request for proposal (RFP) is sent to multiple contractors, who each then submit their own individual designs based upon the criteria set forth in the RFP. The winning contractor then oversees construction work to build his own design. This is a departure from the more traditional method of design-bid-build, in which the architectural firm that designs the project is completely separate from the construction firm that executes those designs. Many federal agencies have started favouring the design-build process over design-bid-build because it results in streamlined projects that complete faster, cost less, have innovative features, greatly reduces the number of claims after construction, and results in significantly higher customer satisfaction (Hines 2010) (USDOT - Federal Highway Administration 2006).

Since each construction project is unique, creating a relevant and thorough list of criteria upon which to evaluate the relative merits of proposed designs is very difficult. As Puthamont and Charoenngam demonstrate, many factors play into whether a public work project is deemed a success or a failure and it is often not enough that the project is functional and complete (Puthamont and Charoenngam 2007). In general, most customers desire their project to be done with the minimal cost, as quickly as possible, and with the best possible materials and techniques. Unfortunately, these three macro-requirements often conflict with each other and it is rarely possible to have all three. Underneath the macro-requirements of cheap, fast, and good quality there are other design considerations such as energy efficiency and environmental sustainability, functionality, maintenance costs, security, and lifecycle costs, just to name a few. Even a project as mundane as a schoolhouse has a long list of factors that must be considered when evaluating potential designs (mdk12.org n.d.). Once the designs have been evaluated, there are also many risk factors that may lead to project failure, including the selection of a contractor that performs poorly. Karim, et al., detail the risks that construction contractors face on a typical project (Karim, et al. 2012). Most of these risks are transferred to and assumed by the contractor that is awarded the contract, so it behoves contracting officers to take them into account when evaluating the quality and reliability of the contractor. Clearly, construction contracting involves making decisions using multiple criteria, some

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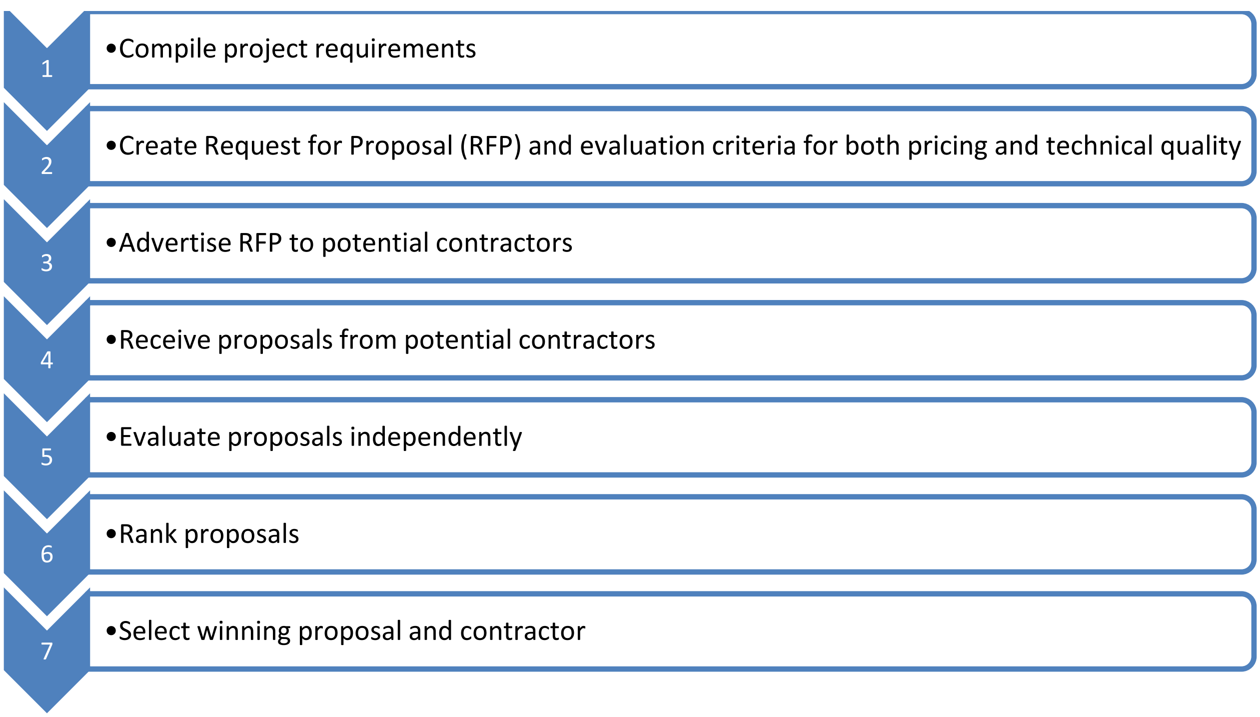
of which are interrelated, others that are unrelated, and some that directly contradict one another. Multiple criteria decision making (MCDM) tools such as Analytic Hierarchy Process (AHP) and Goal Programming (GP) can be utilized to bring structure to the contracting process.

The Connecticut Department of Administrative Services utilizes the flowchart in Figure 1, which is typical of that found in public works or governmental contracting (State of Connecticut Department of Administrative Services n.d.). The focal point of this paper is integrating AHP and GP into steps 5 and 6 in order to evaluate, rank, and select the winning proposal for contract award. As will be further explained in the Methodology section, AHP uses a set of criteria to analyze and rank alternatives relative to each other, whereas GP allows decision makers to combine multiple and potentially conflicting or unrelated objectives into one model that then attempts to yield the best solution. Combining AHP with GP will allow contracting officers to analyze and compare relative merits of different bid proposals under AHP while subject to the overall objectives of the project under GP. Unlike traditional public works contracting, which merely awards to the contractor who submits the lowest bid, the goal of RFP contracting is to select the design that returns the best value for each dollar spent. Under this mindset, the winning contractor is often not the one with the lowest proposed price but rather the one that, in the opinion of the selecting authority, provides the highest utility to cost ratio. Apart from design quality and price, contractors are also evaluated based upon their history of past performance on similar projects as an indication of the risk of project failure if that contractor were to be selected. Other factors, such as the company's financial health and if there are any current or pending lawsuits or financial liens against the company, may also play a part in the final decision.

As might be expected, determining which proposed design, price, and risk combination yields the best value is often a matter of debate and is often highly subjective based upon the factors discussed above. Rarely, the best design is also the cheapest and submitted by the lowest-risk contractor.

Figure 1. Request for Proposal flowchart (State of Connecticut Department of Administrative Services n.d.)



OPTIMIZING SELECTION DECISIONS IN LITERATURE

Many research papers have previously focused on using operations research methods and mathematical modelling to aid in business decisions that are very similar to the ones faced in construction contracting, such as selecting the best of many choices, managing scarce resources, and weighing benefits against risk.

Many have applications to the scope of this current paper, and it is based upon these works that this current paper may directly address how to select the best of many options in a construction contracting environment. The following three sections summarize existing literature that use AHP, GP, and combined AHP-GP methodologies as an aid in related situations. There is also a fourth section devoted to non-AHP and non-GP researches that are found insightful and helpful in formulating a mathematical model to help make important business decisions. The theory behind AHP, GP, the combination of the two, and the specifics of how they are applied to public works construction contract selection are presented in detail in the Methodology section.

LITERATURE ON OPTIMIZING SELECTION DECISIONS USING THE ANALYTIC HIERARCHY PROCESS

Abdelrazig proposed an AHP model to help contractors decide whether or not to bid on a potential contract. His objective was "to develop a structured methodology supported with a computerized decision model to help contractors to make their decision to bid or not to bid" (Abdelrazig 1995). His work focused not simply on whether it was probable to win a bid, but whether it was in the best interests of a particular contractor to even submit a bid. The problem addressed by this paper is the counterpart of his and from the reverse perspective. It is useful to understand how AHP may be applied to decisions within a contracting environment and it also sheds insight into factors a contractor may consider when submitting a bid.

Similarly, Nandi, et al., use AHP to help contractors analyze for which projects they should submit bids if they have a pool of available potential projects (Nandi, Paul and Phadtare 2011). Contractors often have more than one job open to them at any given moment but they cannot generate proposals for all of them and must concentrate their efforts on winning projects that will give them the best return. Nandi, et al., reinforce AHP as a powerful decision-making tool that is superior to intuition or traditional "rules of thumb to analyze and assess risks and gains". As with Abdelrazig, the focus is entirely on the contractor's side of the contract.

Al-Tabtabai and Thomas used AHP to help resolve conflicts that naturally arise in project management (Al-Tabtabai and Thomas 2004). Since government construction is often focused on large-scale projects of relatively long duration with large monetary sums involved, this paper again shows that AHP is a useful tool once a project is already underway. Included within their model is an application of AHP for cost-benefit analysis, which is also the focus of this paper. The difference, however, is that Nandi, et al., focus on projects already in progress and attempts to give neutral guidance to both parties involved. This paper focuses only on the party responsible for contract award and helps them to perform a cost-benefit analysis without regard for the contractors on the other end of the project. It is instead assumed in this paper that those contractors have already found it in their best interest and have properly calculated their costs and benefits so that, if their proposal is selected, they are willing and able to perform the work.

Pastor-Ferrando, et al., discuss combining AHP with Analytic Network Process (ANP) to help public works contracting officers determine what criteria they should use to evaluate received bids (Pastor-Ferrando, et al. 2010). These criteria are to be determined prior to advertising or soliciting bids from contractors. Since large public works projects often have multiple and wide-ranging requirements, sometimes numbering in the hundreds, it is difficult to know which criteria are the ones that should take priority in analyzing bids once they have been received. Their model helps contracting officers narrow down the numerous requirements of each project into a manageable number and is useful for determining which bids should be kept for consideration and which should be discarded. It may also help contracting officers develop the AHP and GP priorities that will feed into the combined AHP-GP model presented in this paper.

Daim, et al., present an AHP model to help private companies select a third party logistics (3PL) provider (Daim, Udbye, & Balasubramanian, 2013). The model used AHP to help select the better of two very similar 3PL providers based upon pairwise rankings developed by the results of a questionnaire presented to experts in the export business. Though not focused on the construction industry and limited to only a small pool of two choices, the model nonetheless yields insight into how AHP may be used in similar "select only one" situations.

Kendrick, et al., apply AHP to the problem of deciding which projects a business should pursue given limited resources (Kendrick and Saaty 2007). Their model focuses on deciding which business priorities, such as brand reputation or product development, should take priority when attempting to select future projects. This may help government agencies decide which construction projects to pursue at a strategic level.

LITERATURE ON OPTIMIZING SELECTION DECISIONS USING GOAL PROGRAMMING

Polat uses a combination of ANP and GP to help construction companies select from various potential marketing activities (Polat 2010). The goals of his model are not simply to maximize benefits, but also to minimize potential negative outcomes. This is quite similar to a government contracting officer who is faced with selecting the bid that will provide the best facility for the money spent but also minimizes project failure or delays on the part of the contractor.

Tan, et al., use GP to guide contractors creating bids that are competitive in many areas, and not simply competitive on pricing (Tan, et al. 2008). In addition to having a competitive price, which is traditionally the sole focus of contractors hoping to win a bid, GP is used to help maximize bid attractiveness by incorporating other strengths that a contractor may have, such as timeliness, quality, safety, and environmental performance. This is the counterpart problem to the one presented in this paper.

Taylor, et al., use integer nonlinear GP to select research and development projects and then allocate human resources that result in the highest probability of success (Taylor III, Moore and Clayton 1982). They chose to use a non-linear model because allocating more resources to a project often results in diminishing returns. Such complexity is not required here since the decision to select or not select a project has a fixed cost, but allocation of limited resources, in this case monetary funds, towards a project is a problem directly faced by contracting officers.

Badri, et al., use binary GP to assist health service institutions select an effective information system project (Badri, Davis and Davis, A comprehensive 0-1 goal programming model for project selection 2001). Their model takes into account preferences and priorities of the institution, along with many other benefits vs. costs factors such as project risk, completion time required, training time required, and the availability of other scarce resources. Similarly, construction contracts must be selected in binary fashion, meaning they either are or are not selected as the winning contract and additional bid items either are or are not awarded.

Colin presents a GP model to assist in public-sector project selection and then applies it specifically to selecting an energy infrastructure project for Trinidad and Tobago (Colin 1985). His model, taking into account factors as wide-ranging as political goals, employment goals, and encouraging foreign investment, gives useful insight in how diverse and numerous goals may be prioritized and incorporated into one model. Similarly, though on a very different topic, Oliveira, et al., use weighted GP to assign land-use allocations to industries such as farming, timber, and tourism while minimizing environmental impacts (Oliveira, Volpi and Sanquetta 2003).

Karpak, et al., developed a GP model to assist a US manufacturing company identify and allocate purchase orders among different vendors while minimizing costs and risks of defects or delivery failure (Karpak, Kumcu and Kasuganti 1999). Similar to traditional contracting practices, traditional methods for selecting vendors are unstructured and involve a team of people attempting to balance multiple criteria to select the best vendor.

Mukherjee and Bera formulated a GP model to help the Indian coal mining industry maximize returns on capital investment projects (Mukherjee and Bera 1995). As with RFP contracting, obtaining the lowest cost or the maximum return on investment (monetarily speaking) were not the only drivers defining best value.

LITERATURE ON OPTIMIZING SELECTION DECISIONS USING A COMBINED AHP AND GP MODEL

Sharma and Balan integrate AHP and GP, along with Taguchi loss functions which are not used in this paper, to help companies rank and select suppliers (Sharma and Balan 2013). Specifically, AHP is used to evaluate weights for each criterion, which then feed into the GP model that selects the best available supplier. Badri combines AHP with GP to help a customer select the best of seven potential quality control systems (M. A. Badri 2001). In a separate paper, he uses a similar combined model to determine the best location for building a new facility (M. A. Badri, Combining the analytic hierarchy process and goal programming for global facility location-allocation problem 1999). In both models, he also uses AHP to calculate weights and inputs before feeding them into the GP model. This paper will take the same approach.

Aznar, et al., focusing on the area of agricultural valuation, use AHP to analyze known tangible and intangible information and combine it with GP to incorporate personal preferences in decision making (Aznar, Guijarro and Moreno-Jimenez 2011). Percin combines AHP and Preemptive GP to evaluate "both quantitative and qualitative factors in selecting the best suppliers and allocating the optimum order quantities among them" (Percin 2006). Kruger and Hattingh use AHP to deal with qualitative risks while using GP to establish an optimal allocation of internal auditing time (Kruger and Hattingh 2006). The GP model combined the AHP results with other quantitative considerations to arrive at its final allocation. Similarly, the model presented in this paper will split quantitative and qualitative factors between AHP and GP, and allow the GP portion of the model to readily adapt to decision makers' preferences.

OTHER LITERATURE RELATED TO OPTIMIZING SELECTION DECISIONS

Charnes, et al., use linear programming to determine how much compensation a company should offer to its executives (Charnes, Cooper and Ferguson 1955). In many ways, the analysis presented is analogous to the thought-process one uses to determine what a new construction project is worth monetarily and how much extra one may be willing to spend on higher quality or lower failure risk.

Puthamont and Charoenngam detail the process by which Thailand's Ministry of Defence selects and approves strategic projects for construction while taking into account numerous factors, such as national security, feasibility, benefits, impacts on the population and the environment, and many others (Puthamont and Charoenngam 2007). Many of the factors listed in their paper are relevant to all public works construction in all countries, and contracting officers may use them as a guide to expand the model in this paper accordingly.

Karim, et al., list many of the typical risks that contractors must consider when taking on a new construction project (Karim, et al. 2012). Many of these risks are contractually transferred to the contractor, so it is of utmost importance that the selected contractor not only has a good price and design, but is competent and reliable enough to foresee and manage the risks that are unique to that particular project and complete it successfully.

METHODOLOGY

In this study we present a mathematical model that combines the analytic hierarchy process (AHP) with goal programming (GP) to select the contractor whose proposal is truly the best value given the priorities of the project. The developed model is also flexible and is able to adapt to different project requirements. In the following three sections, AHP, GP, and their combination approach are elaborated.

The analytic hierarchy process

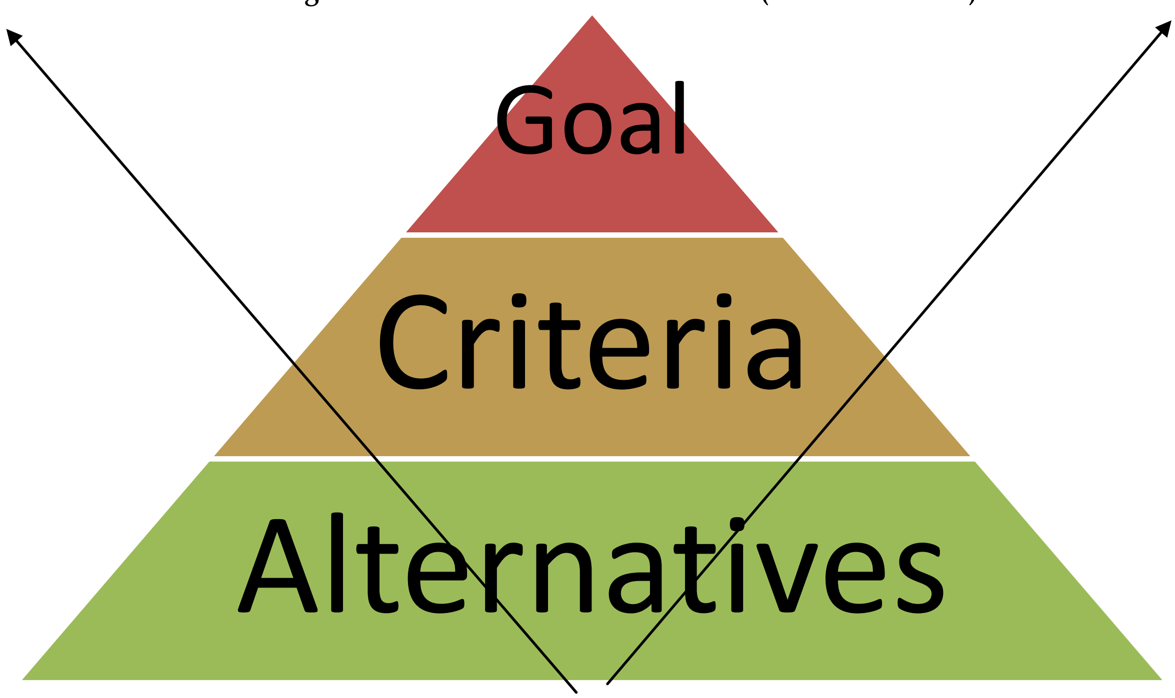
The Analytic Hierarchy Process (AHP), was first proposed by Saaty (T. L. Saaty 1994) (R. W. Saaty 1987) as a mathematical decision-making process based upon criteria that are ranked in relation to one another. These rankings are subjective and will be different from person to person, as well as from contract to contract depending upon the specific project requirements, but one may easily survey and compile rankings from the government contracting team and even the customer, if so desired, as demonstrated by Daim, et al. (Daim, Udbye, & Balasubramanian, 2013). Whenever possible, it would be highly recommended to utilize the Delphi method of polling, as covered by Lee and Kim, in order to minimize groupthink or other group behaviour problems (Lee and Kim 2001). Since its inception, it has seen application in a wide range of various decision-making scenarios, including planning, selection of the best alternative, and resource management, just to name a few (Vaidya and Kumar 2006).

Once the criteria for the model are decided upon, each alternative is ranked against every other alternative and given a relative score, called a pairwise comparison. For example, if in the area of pricing option A is deemed to be 5 times better than option B, then the Pricing criterion matrix will show 5 in entry A,B and 1/5 in entry B,A. Meanwhile, perhaps B is 3 times better than A in terms of quality, and so the Quality matrix will have 3 in entry B,A but 1/3 in entry A,B. All entries ranking an option against itself, e.g. A,A or B,B, have the value 1 by necessity since an option cannot be better or worse than itself. Each criterion is also ranked into a pairwise comparison matrix against every other criterion in the same fashion to determine the relative importance of each criterion. Each entry in all matrices is then divided by its column sum in a process called normalization. The rows are averaged to generate preference vectors consisting of numerical scores for each alternative when viewed under only one criterion. The same process takes place with the criteria matrix to yield a criteria preference vector. All of the individual criterion's preference vectors are then combined into a matrix which is then multiplied by the criteria preference vector to yield the final scores and rankings of each alternative, with a higher numerical score denoting higher preference for selecting that alternative.

Applying AHP to contractor bid selection

Contract award criteria commonly found in government construction contracting include price, design quality (how well the contractor's design meets or exceeds the minimum requirements in ways that the customer values), and past performance (how well the contractor has performed on similar jobs in the past, and whether the contractor has abandoned, failed to complete projects within budget and within schedule, and whether the contractor has honoured his warranties, among other things). There may also be other factors, such as project duration, which is normally set as a fixed requirement by the contracting agency that may in certain cases be more flexible and play a role in the award decision.

Figure 2. Generic AHP model structure (M. A. Badri 2001)



Zmay not be included in the final award based upon the budget that is available. The project absolutely needs to be finished within one year or 365 calendar days, though a faster completion would be preferable.

Five proposals have been received by a contracting office but two of the proposals have been eliminated due to not meeting basic administrative requirements or the minimum technical requirements of the project, leaving three proposals open for consideration. The three projects under consideration are labelled A, B, and C, and their properties are listed in Table 1.

Table 1. Contractor proposals

Proposal A	*Price (x1000)*	*Duration (days)*
Base requirement	$ 1,200	245
Additional Item 1	$ 500	85
Additional Item 2	$ 100	22
Design quality	Good	
Past performance	Good	
Proposal B	*Price (x$1000)*	*Duration (days)*
Base requirement	$ 1,000	230
Additional Item 1	$ 450	81
Additional Item 2	$ 80	27
Design quality	Excellent	
Past performance	Acceptable	
Proposal C	*Price (x$1000)*	*Duration (days)*
Base requirement	$ 900	260
Additional Item 1	$ 450	79
Additional Item 2	$ 50	24
Design quality	Acceptable	
Past performance	Excellent	

SETTING UP THE AHP PORTION OF THE MODEL

Since AHP uses relative rankings for pairwise comparisons instead of absolute numbers, the relative merits of each proposal are summarized in Table 2.

Table 2. Relative merits of each proposal

	Price	*Design*	*Past Performance*	*Duration*
A	High	Better	Better	Middle
B	Middle	Best	Acceptable	Shortest
C	Lowest	Acceptable	Best	Longest

The relative pairwise rankings for each criteria, usually developed by a committee of experts, are then compiled into Table 3.

Table 3. AHP pairwise comparison rankings

Price			
	A	*B*	*C*
A	1	1/2	1/4
B	2	1	1/2
C	4	2	1

Design quality			
	A	*B*	*C*
A	1	1/3	2
B	3	1	6
C	1/2	1/6	1

Past Performance			
	A	*B*	*C*
A	1	9	3
B	1/9	1	3
C	1/3	1/3	1

Duration			
	A	*B*	*C*
A	1	1/2	3
B	2	1	6
C	1/3	1/6	1

Performing the AHP analysis yields the following matrix containing the normalized score of each proposal broken down by each criterion, compiled into Table 4.

Table 4. AHP normalized scores

	Price	*Design*	*Duration*	*Past Performance*
A	0.14	0.22	0.30	0.66
B	0.29	0.67	0.60	0.20
C	0.57	0.11	0.10	0.14

The maximum value in each column represents the best proposal when only considering that criteria. In other words, with regards to price, Proposal C is the highest ranked with a score of 0.57, whereas with regards to design quality, Proposal B is the highest ranked with a score of 0.67. These maximum scores become the constraint values for the GP model, which will attempt to select the best proposal by minimizing the deviation from the ideal score for each category.

Creating the gp linear program using inputs from the ahp results

Staying under the maximum budget of $1.5M is not a goal, but rather assumed to be a hard constraint. The goals for this particular project are, in order of priority:

(1) Favour lower-priced designs;

(2) Award as many additional options as possible;
(3) Maximize the technical design quality of the finished facility;
(4) Complete the facility as quickly as possible;
(5) Limit risk of contractor failure by selecting a contractor with favourable past performance history on similar projects.

The variables used in the GP model are listed and explained in Table 5.

Table 5. List of variables used in Goal Programming model

$w_\$$	Weight of the budgetary goal
w_o	Weight of awarding more additional options
w_t	Weight of design quality goal
w_d	Weight of the duration goal
w_p	Weight of the past performance goal
$\delta_\$^-$	Deviational variable for the budgetary goal
δ_o^-	Deviational variable for awarding additional options
δ_t^-	Deviational variable for the design quality goal
δ_d^-	Deviational variable for the duration goal
δ_p^-	Deviational variable for the past performance goal
A_0	Binary decision variable on whether or not to select Project A's base design
A_1	Binary decision variable on whether or not to select Project A's first additional option
A_2	Binary decision variable on whether or not to select Project A's second additional option
B_0	Binary decision variable on whether or not to select Project B's base design
B_1	Binary decision variable on whether or not to select Project B's first additional option
B_2	Binary decision variable on whether or not to select Project B's second additional option
C_0	Binary decision variable on whether or not to select Project C's base design
C_1	Binary decision variable on whether or not to select Project C's first additional option
C_2	Binary decision variable on whether or not to select Project C's second additional option

π_{A_i}	Price of selecting A_i
π_{B_i}	Price of selecting B_i
π_{C_i}	Price of selecting C_i
$\$_A$	A's AHP price score
$\$_B$	B's AHP price score
$\$_C$	C's AHP price score
t_A	A's AHP design score
t_B	B's AHP design score
t_C	C's AHP design score
d_A	A's AHP duration score
d_B	B's AHP duration score
d_C	C's AHP duration score
p_A	A's AHP past performance score
p_B	B's AHP past performance score
p_C	C's AHP past performance score

In traditional mathematical linear programming format, the GP model is:

$$\min z = w_\$\delta_\$^- + w_o\delta_o^- + w_t\delta_t^- + w_d\delta_d^- + w_p\delta_p^- \qquad (1)$$

Subject to:

$$\sum_{i=0}^{2}\pi_{A_i}A_i + \sum_{i=0}^{2}\pi_{B_i}B_i + \sum_{i=0}^{2}\pi_{C_i}C_i \le 1500 \qquad (3)$$
$$\sum_{i=0}^{2}A_i + \sum_{i=0}^{2}B_i + \sum_{i=0}^{2}C_i + \delta_o^- = 3 \qquad (4)$$
$$\$_A A_0 + \$_B B_0 + \$_C C_0 + \delta_\$^- = .57 \qquad (5)$$
$$t_A A_0 + t_B B_0 + t_C C_0 + \delta_t^- = .67 \qquad (6)$$
$$d_A A_0 + d_A A_0 + d_A A_0 + \delta_d^- = .60 \qquad (7)$$
$$p_A A_0 + p_B B_0 + p_C C_0 + \delta_p^- = .66 \qquad (8)$$
$$A_0 + B_0 + C_0 = 1 \qquad (9)$$
$$A_1 - A_0 \le 0 \qquad (10)$$
$$A_2 - A_1 \le 0 \qquad (11)$$
$$B_1 - B_0 \le 0 \qquad (12)$$
$$B_2 - B_1 \le 0 \qquad (13)$$
$$C_1 - C_0 \le 0 \qquad (14)$$
$$C_2 - C_1 \le 0 \qquad (15)$$
$$A_i, B_i, C_i\ binary, \text{all variables} \ge 0 \qquad (16)$$

Equation (3) is the objective function that will yield an optimal solution based upon both the priority weight and deviational variable representing each goal. Equation (4) sets the hard limit of not exceeding the \$1.5M budget (equivalently stated as \$1,500K in the equation). Equations (5) – (9) are the goal constraints that incorporate the AHP maximums computed earlier as their ideal limits for pricing, number of options selected, technical design quality, duration, and past performance history, respectively. Equation (10) limits the selection of only one proposal out of the three possible, and equations (11) – (16) require additional options to be selected only if the base or previous option, upon which it is necessarily dependent, has already been selected. Finally, equation (17) constrains A_i, B_i, C_i to hold binary values of either 0 or 1 only, respectively representing non-selection and selection, and prohibits all other variables from holding negative values as negative values are simply not possible in this scenario.

The objective function's goal weights will change depending on the requirements of each specific project.

In this particular scenario, the corresponding goal weights were chosen to be 500, 400, 300, 200, and 100, respectively. These weights were assigned based upon the goal precedence listed above and the relative importance of each goal to the others. Part of this model's flexibility is that, in addition to changing which goals are considered, the relative priorities of the goals can easily be modified simply by changing the weights.

Results of the ahp-gp model

Running the model through Excel Solver with the inputs detailed above, selecting Proposal C with both additional options for award is the optimal solution that satisfies all goals in order of precedence:

(1) The total awarded contract cost will be $1.4M, which meets the budgetary constraint of staying under $1.5M;
(2) Proposal C is the lowest-priced design, meeting goal 1;
(3) All additional options have been awarded, satisfying goal 2;
(4) Proposal C's design was the lowest in terms of quality among the three proposals, but its quality was deemed acceptable;
(5) Proposal C will take the longest duration to complete, but it will complete within the required 365 days;
(6) The contractor selected has the best past performance history on this type of project.

CONCLUSION

The proposed AHP-GP model in this paper attempts to ease the confusion and frustration often faced by contracting offices as they attempt to determine which contractor has submitted the proposal representing the best value to their customer in a design-build contract. Expertise in the ability to evaluate a proposal's pricing and technical merits will still be needed in order to set up this model, but the ability to numerically weight and prioritize what are often conflicting goals within each project will invaluable. As design-build contracts continue to be favoured in both the public and private sectors, a systematic, reliable, and legally defensible method for selecting winning proposals becomes increasingly important.

Currently, contracting officers use their own judgment to determine the best tradeoffs between price, technical quality, and other subjective factors. Legally, the burden is upon them to justify their decisions so that there is no question in a court of law that any partiality or favouritism played a part in the award decision. Attempting to objectively quantify why a more expensive design was or was not worth the extra cost is daunting, to say the least. This combined model gives contracting officers a better tool for providing evidence of an impartial award. Teams of experts within each office already generate pricing and technical reviews for each project, including ranking matrices that allow for comparison between proposals. The missing link is justification in why something is or is not worth the extra cost. Translating these reports into AHP pairwise rankings and using the customer's own requirements and priorities to generate goals is a very natural and reasonable method to ensure consistency and impartiality in the contracting process.

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