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Benchmarking the efficacy of team decisions using game theoretic approach

RESEARCH ARTICLE

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Abstract

In a consensus team decision-making process involving the allocation of resources, decision-makers arrive at a mutually beneficial and satisfying solution or strategy by unanimous agreement. However, this consensus agreement is often masked by behind-the-scene maneuvers involving the consensus (or coalition) of subgroups, which then exert their influence (or threats) to advance the total team towards the masked consensus decision the subgroups had sought to institute. Finding the actual roles and motivations of parties in these behind-the-scene maneuvers is difficult. However, the question we seek to answer is as follows: Was it a true consensus decision that was arrived at? We answer the question by developing algebraic models of the decision-making problem within a game theoretic framework, for n decision makers and m (pure) strategies involving resource apportioning. Using the Nash equilibrium as the basis for the coalition of subgroups, we identify the continuum cases of "win-win", "win-lose", and "lose-win" and "lose-lose" decision outcomes. By means of a real-life case example, we then propose and apply this continuum of decision outcomes and their properties of regret, strategy selections and defining player sub-groups, as standard benchmarks to assess the efficacy of the actual consensus team decision.

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1 Introduction

In the highly popular book by Stephen Covey on the "Seven Habits of Highly Effective People" (Covey, 1989), the author enumerated among others, HABIT NUMBER 4, the *"Think Win-Win"* principle, in which he strongly advocates as the most desirable or ideal decision outcome for all team decision making. The "win-win" principle is highly popular, and is being touted today by decision-makers from school boards to business executive boards (Covey, 1999). Also, among academics, many are advocating consensus decision-making to increase team effectiveness [see for example, (Katzenbach & Smith, 1993) and (Straus & Layton, 2002)]. In both *"win-win"* and consensus decision making, the emphasis is in getting everyone on the team. A consensus decision, according to Pokras (1989) is one which everyone in the team,

- sees it as a fusion of the information, logic, and feelings expressed,
- understands and essentially agrees that it represents a common reality,
- can live with, go along with, support and accept it,
- believes is a worthwhile approach in the best interests of the team.

In considering the problem of apportioning a finite set of resources among a number of involved parties, the problem is to find a way, the "best procedure," which each party would consider it fair and thus find it acceptable. In most real situations, there exists more than one way, or procedure, to apportion shared resources. Each valid procedure has a rational justification on its own right. Obviously, any one of the procedures is more advantageous to one of the parties than to the others. It seems intuitive that any (convex) combination of these procedures itself has a rational justification. Chong & Benli (2005) argued that in team decision-making, though they may not be in complete agreement with the final result, all involved parties must be "satisfied" with it. The problem is how to operationalize this concept of "being satisfied," and provide a foundation and a structure for it. That study discusses what such a foundation can be and presents a structure for it. An analytical framework is provided for consensus in team decision-making, thus making it an operational decision making tool. Butler & Rothstein (2001) state that each involved party "must be flexible and willing to give up something to reach an agreement." The analytical framework developed in Chong & Benli (2005) presumes that the "best procedure" should be an agreement in the sense that each party should be saying: "I will go along with the decision, provided everyone in the team including myself, shares in the 'regrets' of not getting their highest payoffs in as equal a fashion as possible."

The question is how to make this operational. One way is to quantify regret. When a party makes a concession, it is accepting a "regret" procedure in lieu of the procedure that is providing it with the maximum payoff. The difference in payoffs between what a party's maximum payoff and the payoff resulting from the concession procedure is the opportunity loss, which we refer to as that party's regret. With the same reasoning as in minimizing the sums squared residuals, for example, in least-squared estimates of coefficients in regression analysis, our goal is to find a way of apportioning the finite set of resources among involved parties such that the sum of squared regrets for the parties involved is minimized. In other words, we are looking for a procedure that minimizes the variance of "regret" of the parties. Furthermore, it turns out that, when the problem is posed in a game-theoretic framework, the best procedure, as defined above, can be interpreted as the Nash equilibrium. The importance of this study is that it provides a well-structured operational tool for team decision-making based on an analytical framework.

We first present a general algebraic model of the hypothesis for consensus in team decision-making, and show that this hypothesis can be interpreted as a Nash equilibrium involving mixed strategies. We define the solution to this model involving consensus among all parties as the win-win decision outcome. In a zero-sum resource apportioning problem, the antithetical decision outcome occurs when a deal cannot be made. Hence we define a "no-deal" decision outcome as the "lose-lose" decision outcome. Next, we extend the model to solve for situations in which a majority or minority consensus group determines the outcome of the problem, and show the decision outcomes are cases of "win-lose" and "lose-win" decisions, respectively.

By means of an illustrative, but real, case example of budget allocation among department chairs in a college of business administration, we will show how these continuum cases of win-win, win-lose, lose-win, and lose-lose decision outcomes from the model are used as benchmarks to evaluate the efficacy of the actual team decision made by the department chairs.

2 Algebraic representation of the consensus model

We will begin by developing a general algebraic representation of the model for consensus team decision-making. Next, we discuss an approach to find the best procedure, a consensus, which we define as the "win-win" decision outcome. Interestingly, this best procedure can be interpreted as a Nash equilibrium involving mixed strategies when the entire problem is viewed in game theoretic-framework. Finally, we will present a game-theoretic interpretation of this problem.

The problem to be modeled is the following. There are m different ways (which will be referred to as *strategies*) to apportion shared resources among n involved parties (*players*). The aim is to find a compromise (*mixed strategy*) by choosing a convex combination of pure strategies that minimizes the variance of the total regret of all players.

Let $i = 1,\ldots, m$ be the index of (pure) strategies, $j = 1,\ldots,n$ be the index of players, and q_{ij} be the payoff to player j according to pure strategy i. The sum of payoffs, $\sum_{j=1}^{n} q_{ij}$ to all players, $i = 1,\ldots, m$, add up to total available resources, a constant.

A mixed strategy can be constructed as a convex combination of available pure strategies, $i = 1,\ldots, m$, such that the payoff to player j is

$$x_j = \sum_{i=1}^{m} \alpha_i q_{ij},$$

where $\sum_i \alpha_i = 1;\quad \alpha_i \geq 0,\quad i = 1,\ldots,m.$ α_i is the multiplier associated with each strategy i in constructing the mixed strategy.

The regret of player j when the mixed strategy is adopted is defined as

$$r_j = b_j - x_j, \quad j = 1,\ldots,n.$$

where $b_i = \max_{1\leq i\leq m} q_{ij}$ is the best payoff for player j among all available pure strategies, $i = 1,\ldots, m$.

The variance of regret of the mixed strategy is proportional to $\sum_j r_j^2$. Thus, in order to minimize variance of regret, it is sufficient to minimize $\sum_j r_j^2 = \sum_j (b_j - x_j)^2$. That is, the consensus strategy is the optimal solution to the following quadratic program:

$$\min_{\substack{\alpha_i \geq 0 \\ x_j \geq 0}} \sum_{j=1}^{n} (b_j - x_j)^2 \tag{1}$$

subject to:

$$\sum_{i=1}^{m} q_{ij}\alpha_i = x_j,\; j = 1,\ldots,n;$$

$$\sum_{i=1}^{m} \alpha_i = 1.$$

3 A game theoretic interpretation of consensus model

Consider an *n*-player game in which the players are indexed by $j = 1, \ldots, n.$ The set of pure strategies available for each player, S_j, is identical for all players, that is $S_j = S = \{1, ..., m\},\ j = 1, \ldots, n.$

Let s_j denote the strategy chosen by player *j*, $s_j \in S$; and $(s_1, \ldots, s_n)$ denote the combination of strategies, one for each player, and let u_j denote player j's payoff function: $U_j(s_1, ..., s_n).$ This game requires that an identical strategy be chosen by all players (hence, a "consensus.") This implies that for all players $j = 1, ..., n,$

$$\begin{aligned} U_j(s_1, \ldots, s_n) &= U_j, \quad \text{if} \quad s_1 = \cdots = s_n = s; \\ &= -\infty, \quad \text{otherwise.} \end{aligned}$$

where $U_j(s)$ is the payoff (percentage of total available resources) to player j when strategy *s* is used.

In an n - player game $G = \{S; U_1, \cdots, U_n\}$, the strategy s^* is a *Nash Equilibrium* if,

$$U_j(s^*) = \max_{s \in S} U_j(s), \quad \text{for all players, } j = 1, ..., n.$$

Nash's fundamental theorem on the existence of equilibrium in the game depends on mixed strategies. Suppose that each player *j* has *m* pure strategies: $S = 1, \cdots, m.$ Then a mixed strategy for player *j* is the probability distribution $(p_{1j}, \cdots, p_{mj})$ where p_{ij} is the probability that player *j* will play pure strategy *i*, for $i = 1, \ldots, m.$ (Gibbons, 1992) Since the consensus requires each player to use the same strategy, a mixed strategy should be same for all players and can be denoted by $(p_1, \ldots, p_m).$ Then Nash's fundamental theorem can be stated as in Gibbons (1992):

> In the n - player game $G = \{S_1, ..., S_n; U_1, ..., U_n\}$, if *n* is finite and S_i is finite for every *i* then there exists at least one Nash equilibrium, possibly involving mixed strategies.

Clearly, the probability distribution, $(p_1, \cdots, p_m)$, that defines the mixed strategies needed for the existence of a Nash equilibrium are the convex combination multipliers $(\alpha_1, \cdots, \alpha_m)$ of pure strategies that were discussed above.

This game is characterized by the definition of the utility function, which is defined for this game as above where s is a mixed strategy that minimizes the variance of regret of the players. Nash's fundamental theorem states the existence of an equilibrium point for this game, and the procedure presented above, the quadratic programming formulation, provides a way to compute an equilibrium point, and thus a peaceful co-operative solution to this game.

4 Consensus by a 'defining subgroup' of the players

Consider the following version of the model, the selection of the strategy is made by a coalition, which is a subgroup of the team players, as a result of consensus or, more accurately, "collusion" among these members. We call this the 'defining subgroup.' This 'defining subgroup' may be a majority of $50+\%$, or a minority of $50-\%$. We hypothesize the defining subgroup must have the property of minimum sum of squares of monetary regrets among its members in order to arrive at the consensus reached. In other words, each of the players in this subgroup is saying "I will go along with the consensus (or the 'collusion') among this defining subgroup provided that everyone in the subgroup including myself, shares in the regret of not getting the highest possible payoffs, in as equal a fashion as possible." We identify the case of the "win-lose" decision outcome in which members in the 'defining subgroup' is the majority (the "win"), whereas members in the non-defining 'minority subgroup' "lose". In the same manner, we identify the case of the "lose-win" decision outcome in which members in the 'non-defining subgroup' is the majority, and thus "lose", whereas members in the 'defining (minority) subgroup' "win". This is a situation in which members in the defining subgroup may be applying "threat" in the form of "position, power, credentials, possessions, or personality to get their way." (Covey, 1989)

The 'defining subgroup' can be defined by a binary vector, $(y_1,\cdots,y_n)$ where

$$y_j = 1, \text{ if player } j \text{ is in the defining subgroup;}$$
$$= 0, \text{ otherwise.}$$

Then the consensus strategy for the 'defining subgroup' is the optimal solution to the following quadratic program:

$$(2) \qquad \min_{\substack{\alpha_i \ge 0 \\ x_j \ge 0 \\ y_j = 0,1}} \sum_{j=1}^{n} y_j (b_j - x_j)^2$$

$$\sum_{i=1}^{m} q_{ij}\alpha_i = x_j \quad j = 1,\dots,n;$$

$$\sum_{i=1}^{m} \alpha_i = 1$$

Clearly, the original consensus model, (1), is a special case of the defining subgroup model when all players are in the "subgroup", that is $(y_1, \cdots, y_n) = (1, \cdots, 1)$.

5 A real life case example

We show next a real-life case example involving the re-allocation of the salary budget in a college of business administration. [Chong & Runyon (2004), Chong & Benli (2005)] We will describe the three formulas (strategies 1 to 3) that were proposed by the five department chairs (players 1 to 5), provide the results of the thirty one cases of the models (one 5-person defining subgroup, five 4-person defining subgroups, ten 3-person defining subgroups, ten 2- person defining subgroups, and five 1-person defining subgroup), and show the efficacy of the actual chairs choice when benchmarked against the model solutions.

Using the benchmark classification defined in earlier sections, we can divide the thirty one standard benchmarks into:

1. One case of win-win (W-W) outcome consisting of one 5-person defining subgroup,
2. Fifteen cases of win-lose (W-L) outcomes consisting of five 4-person defining subgroups and ten 3-person defining subgroups,
3. Fifteen cases of lose-win (L-W) outcomes consisting of ten 2-person defining subgroups and five 1-person defining subgroups.

Since the case of lose-lose (L-L) outcome is synonymous with "no-deal", it is a case involving null subgroups only.

The five departments are Accountancy (player 1), Finance (player 2), Information Systems (player 3), Management (player 4), and Marketing (player 5). The first of the three strategies considered, (A), gave equal weighing to three criteria: Full Time Equivalent Students (FTES), Full Time Equivalent Faculty (FTEF), and enrollments based upon the historical relationships during the most recent four semesters; each weighed equally. The introduction of enrollments was designed to reduce the inequities that had arisen in the previous allocation mechanism in an attempt to address the issues associated with the three-unit versus four-unit courses. At the same time, in retaining the FTES component continued to give some recognition to the existing four unit strategy utilized within one of the departments. The consideration of the four most recent semester time frame was thought to be appropriate in that it would give weight to a reasonable amount of time while simultaneously removing short-term aberrations that might occur periodically.

The college is one of eight colleges at California State University at Long Beach, which is one of the largest campuses of the California State University System. The California State University System is the largest State University System in USA. The college's salary budget for instruction is provided by the State and is about US $10M for the academic year which includes the Fall Semester and the Spring Semester.

The salary budget for Summer Sessions is about 10% of the academic budget but it comes from a separate State funding. The departments experience significant changes in enrollments in recent years because they tend to reflect the demand of the marketplace for graduates. For example, in the last couple of years, Information Systems Department's enrollment is experiencing a declining trend, while Marketing Department's enrollment is experiencing an increasing trend. Seven different strategies were initially proposed including some involving three or more years. However, in order to be responsive to rapid changes in enrollment between departments, of the three options eventually selected for consideration, only one and two year time frames are considered.

During the period preceding the current department budgeting procedure, a centralized method of budgeting was in place. This practice led to many of the shortcomings evident in mechanisms that are somewhat removed from the level at which the administration of resources occurred. Thus, deans were charged with that determination of the manner in which resources were to be allocated to the various departments resulting in a multitude of inefficiencies typical in an organization in which the allocation process is one or more steps removed from the level in which expenditures occur. Centralized budgeting resulted in deans being subjected to numerous requests for resources by the department chairs. Individually each appeal seemed to have merit but much of the actual allocation of resources could more accurately be attributed to the cleverness of the demand, or perhaps the appearance of compelling issues, rather than the necessity of the funds to pursue worthwhile endeavors. Deans were often accused of showing favoritism generally associated with the discipline most closely aligned with the dean's background. Eventually the chairs, during a period of change in leadership, were successful in convincing a new dean that the college budget could be administrated far more efficiently at the department level. This then led to the birth of decentralized budgeting in the college.

The second strategy (B) reviewed was identical to the first except the time period considered was two semesters, weighed equally. The intention here was that a shorter time period would allow a more responsive movement in the allocation of funds when the five departments experienced enrollment trend changes as a result of student shifts among majors. On the other hand, this strategy may well have had the tendency to amplify short-term inexplicable movements that could have resulted in a temporary, albeit short lived, misallocation of resources.

The third strategy (C) was in many ways a mere revision of the former strategy in that only two criteria, FTES and FTEF, each weighed equally, were to be considered, with equal weighing for the most recent two semesters. The merits, and lack thereof, have been presented in detail above.

6 Gaming for winning strategy

Each of the strategies (A, B, and C) considered gave uneven advantages to the departments. First, the recognition of FTES as the sole basis on which to distribute funds for classroom contact with students was problematic in that one department offered only four unit courses to its majors while the remaining four departments offered only three unit courses. Thus assuming other factors constant, funding on an FTES basis resulted in an additional 33 percent allocation of resources for those courses taught on a four-unit basis. Second, FTEF funding also resulted in this same department receiving full funding for a faculty member teaching three four unit classes compared to faculty in other departments teaching four three unit courses. The number of course preparations also played a role in this inequity. In spite of these shortcomings the chairs agreed to move forward with this mechanism with the assurance that this initial budgeting procedure would be modified as conditions warranted.

In many decision making situations compromise solutions are unavoidable [Plous (1993), Raiffa et al. (2002)]. It was evident at the outset that this is one of those situations where a compromise solution will have to be adopted. The new funding levels of the three strategies (A, B, and C) were provided to all the chairs in the form of a decision matrix as shown in Table 1.

(Table 1 about here.)

It is quite easy to analyze the data by first identifying the ranking of the budget strategies for each of the departments (2), and then calculating the regret (or opportunity loss) if the highest-ranking strategy for the department is not chosen as shown in Table 3.

(Table 2 about here.)

As explained in the introduction, here we are basically using Savage-Niehans Minimax Regret criterion as a surrogate measure for consensus. In decision analysis this criterion is widely used [(Clemen & Reilly, 2000), (Denardo, 2001), (Moore & Weatherwood, 2001), and (Ragsdale, 2001)].

(Table 3 about here.)

In searching for a consensus solution, it is reasonable to assume that each chair is looking out for his own department's self-interest. Based on the above assumption, and from Tables 2 and 3, one can see Management and Marketing departments favor strategy A, Accountancy department favors strategy B, and Finance and Information Systems departments favor strategy C. Also, it is reasonable to expect each department chair will try to compromise by moving to the second ranking strategy if the first ranking strategy is not achievable. The chairs will look for a "satisfying" solution [as described in (Dawes & Hastie, 2001) and (Keeney, 1996)] rather than their optimal solution. It appears that Finance, Information Systems and Marketing would be willing to move to strategy B, since this is their second ranking strategy. Since strategy B is Accountancy department's first ranking strategy, these four departments would likely be in full agreement. However, strategy B is Management's third ranking strategy.

So, on the day of selecting for the budget strategy to use, it was interesting to observe how Finance and Information Systems departments were the first to make the move to support strategy B, inviting Marketing and Management to do the same. Marketing department was hesitant. Management waited. An exchange of the pros and cons of each strategy followed. Eventually, the final strategy (allocation model which we refer to as AB because of its resemblance to a hybrid version of strategies A and B) was adopted and passed unanimously by all the chairs as follows:

- one-third based on enrollment, one-third on FTEF, and one-third on FTES of the last two academic years; and

- the four semesters will be weighted as follows - 40% for the latest semester, 30% for the second latest semester, 20% for the third latest semester, and 10% percent for the oldest semester. [(CSULB, 2001)]

The resulting budget funding amounts to the departments are shown in Table 4.

(Table 4 about here.)

7 Analysis of results

Even though the "choice" allocation, as seen in Table 4, has a close resemblance to a hybrid version of strategies A and B, it is not an exact convex combination of the two strategies. This is expected. Since Chairs were not intentionally choosing a convex combination of the strategies A, B, and C, a slight "discrepancy" is bound to occur. We, therefore, proceed to find a convex combination, $\{\alpha_1, \alpha_2, \alpha_3\}$, of pure strategies A, B, and C, corresponding to the mixed strategy, (x_1, x_2, x_3), that is the closest match to Chairs' "CHOICE" by means of the following *goal programming model.*

Recall that q_{ij} is the payoff to player j according to pure strategy i. Let $d_j, j = 1, \ldots, n,$ be the payoff to department j in the Chairs' "CHOICE" strategy. Define the nonnegative deficiency variables, "under-" and "over-satisfaction", respectively, as $\{\gamma_j, \delta_j\}$ such that for all $j = 1, \ldots, n,$

$$x_j + \gamma_j - \delta_j = d_j,$$

and, letting as before,

$$\sum_{i=1}^{m} q_{ij}\alpha_i = x_{j,}$$

to make sure that the convex combination of the pure strategies, $\sum_{i=1}^{m} q_{ij}\alpha_i$, is equal to the mixed strategy, x_j, where x_j minus the over-satisfaction deficiency variable, δ_j, plus under-satisfaction deficiency variable, γ_j, is equal to the target value, the actual allocation by the Chairs' "CHOICE", d_j. Thus, given the actual allocation that was decided upon, in order to determine, with minimal "discrepancy", the corresponding convex combination multipliers, α_i, one has to solve the following goal program:

(3)
$$\min_{\substack{\alpha_i, x_j \geq 0 \\ \gamma_j, \delta_j \geq 0}} \sum_{j=1}^{n} (\gamma_j + \delta_j)$$

$$\sum_{i=1}^{m} q_{ij}\alpha_i - x_j = 0, \; j = 1, \ldots, n;$$
$$\sum_{i=1}^{m} \alpha_i = 1;$$
$$x_j + \gamma_j - \delta_j = d_j, \quad j = 1, \ldots, n.$$

Using the Chairs' "CHOICE" data, the optimal solution to this goal program is $\{\alpha_1, \alpha_2, \alpha_3\}$ = (0.57, 0.43, 0.00) with a "discrepancy", $\sum_{j=1}^{n}(\gamma_j + \delta_j)$, of \$31,187 out of \$7,655,300, which is less than half of one percent.

On the other hand, the true consensus solution, the one that includes all players in the 'defining subgroup', thus minimizes the "sum of squared regrets" using the quadratic program (1), is $\{\alpha_1, \alpha_2, \alpha_3\}$ = (0.51, 0.00, 0.49), which seems to be quite afar from the Chairs' "CHOICE" of $\alpha_1, \alpha_2, \alpha_3$ = (0.57, 0.43, 0.00). In order to measure how far apart these two solutions are let us assume the Euclidean measure of distance. The distance in between two points, $\mathbf{v}$ = $\{v_1, \ldots, v_m\}$and $\mathbf{w}$ = $\{w_1, \ldots, w_m\}$, in $m-$dimensional space is

$$\sum_{i=1}^{m} \sqrt{(v_i - \omega_i)^2}.$$

Thus with this distance measure, the distance between the "true consensus" solution, and the Chairs' "choice" is 0.66, which says they are 38% apart (the maximum distance in a unit cube is 1.73.)

In order to identify the collusion among the players, we need to rank all solutions according to their closeness to the final decision that was arrived at. In the Chairs' case, Table 5 presents those closeness figures, including the 'distance' of the respective solution to the Chairs' final decision. The Chairs' decision was {α1, α2, α3} = (0.57,0.43, 0.00). The 'defining subgroup' is identified by the binary vector ($y_{1,} y_2, y_3, y_4, y_5$), indicating whether or not the players ACCT, FIN, IS, MGMT, and MKT, respectively are included in the 'defining subgroup'.

(Table 5 about here.)

So, to answer the question: Was it a true consensus decision that the Chairs had arrived at? The answer is a qualified no/yes. It definitely is not a true consensus because the results show the model's consensus solution is ranked number 16 in its closeness to the Chair's solution! However, from the results, it turns out that Accounting, Finance and Management are the departments in the rank 1 defining subgroup with the smallest distance from the Chair's solution. In fact the same three departments along with Marketing come in as the rank 2 defining subgroup. There appears to be collusion between the four departments of Accounting, Finance, Management and Marketing. The Information System department appears to be the only department left out of the consensus decision.

In analyzing the benchmark classifications for each of the subgroups in Table 5, it is interesting to note that the (W-W) 5-player consensus outcome is ranked 16th which is the median of the thirty one subgroup rankings. The first fifteen subgroup rankings include seven (W-L) and eight (L-W) subgroups. Interestingly, the last fifteen subgroup rankings include a mirror image of seven (L-W) and eight (W-L) subgroups. The first two ranking subgroups are both (W-L) subgroups. The last three of the ranking sub-groups are all (L-W) subgroups. The average ranking of each of the three benchmarking classifications can be shown to be as follows:

BENCHMARK CLASSIFICATION	AVERAGE RANKING
W-L	14.33
W-W	16.00
L-W	17.67

We analyzed the actual consensus team decision, and list the regret values for the five departments in ascending order as follows:

DEPARTMENTS	REGRET
MKT	8.13
ACCT	27.62
MGMT	31.45
FIN	41.70
IS	76.70

Vis-à-vis the above, we list the standard deviation values of budget allocation under different strategies for the five departments in ascending order as follows:

DEPARTMENTS	STANDARD DEVIATION
MKT	21.30
ACCT	27.10
FIN	33.45
IS	43.83
MGMT	56.59

We made the observation that even though MKT and ACCT departments both ended up with lower regret values in the actual consensus team decision, their standard deviations were lower than the other departments to begin with. On the other hand, MGMT department has the highest standard deviation but ended up with a lower regret value than FIN and IS departments. The IS department ended up with the highest regret value. Therefore, it is not surprising that the first two highest ranking benchmarks exclude IS department from their defining subgroups.

8 Summary and conclusions

Team decision-making involving resource allocation abounds in all organizations, at all levels and in diverse applications [see, for example, (Bazerman, 2001), (Dawes & Hastie, 2001), and (Raiffa et al., 2002).] Examples include budget allocation among departments (Chong & Runyon, 2004), profit sharing among employees (Cotes III, 1994), and determination of compensation as innovation incentives to partners in a supply chain (Jarimo et al., 2005). However, the efficacy of actual team decisions cannot be assessed unless there are standard benchmarks to compare them with.

In this paper, we have developed general algebraic models of the "win-win", "win-lose", and "lose-win" and "lose-lose" decision outcomes involving n decision-makers and *m* (pure) strategies. We show that these models can be interpreted as the Nash equilibrium involving mixed strategies when the problem is viewed in a game-theoretic framework. We show how solutions to these models can be obtained using a real-life case example involving budget reallocation among five departments in a college of business administration. By mapping out the properties of the cases for the "win-win", "win-lose", "lose-win", and "lose-lose" conditions as a continuum of decision outcomes, we now have a continuum of standard benchmarks by which to judge the efficacy of the actual decision made by the team, by locating its approximate place in the continuum of the decision outcomes developed by our models.

STRATEGYen	ACCT	FIN	IS	MGMT	MKT	SUM
A	1,204.2	1,819.7	1,851.4	1,641.2	1,138.8	7,655.3
B	1,243.9	1,876.5	1,884.9	1,537.9	1,112.1	7,655.3
C	1,192.1	1,878.7	1,938.3	1,549.5	1,096.7	7,655.3

Table 1: New budget funding amounts in $1,000s to departments after re-allocation

STRATEGY	ACCT	FIN	IS	MGMT	MKT
A	2	3	3	1	1
B	1	2	2	3	2
C	3	1	1	2	3

Table 2: Ranking of budget strategies for each department

STRATEGY	ACCT	FIN	IS	MGMT	MKT	SUM
A	40	59	87	0	0	186
B	0	2	53	103	27	186
C	52	0	0	92	42	186

Table 3: Monetary regret if the highest ranking strategy is not chosen

STRATEGY	ACCT	FIN	IS	MGMT	MKT	SUM
CHOICE	1,225.3	1,828.3	1,872.9	1,597.2	1,131.6	7,655.3
A	1,204.2	1,819.7	1,851.4	1,641.2	1,138.8	7,655.3
B	1,243.9	1,876.5	1,884.9	1,537.9	1,112.1	7,655.3
C	1,192.1	1,878.7	1,938.3	1,549.5	1,096.7	7,655.3

Table 4: Agreed upon allocation ("CHOICE") together with the other strategies considered

RANK	DEFINING	α 1	α 2	α 3	DISTANC	CLAS
1	(1 1 0 1 0)	0.682	0.318	0.000	0.152	W-L
2	(1 1 0 1 1)	0.696	0.304	0.000	0.172	W-L
3	(1 0 0 0 1)	0.311	0.689	0.000	0.371	L-W
4	(1 0 0 1 0)	0.871	0.129	0.000	0.420	L-W
5	(1 0 0 1 1)	0.878	0.122	0.000	0.430	W-L
6	(0 1 0 1 1)	0.745	0.000	0.255	0.525	W-L
7	(0 1 0 1 0)	0.707	0.000	0.293	0.534	L-W
8	(1 0 1 1 1)	0.605	0.000	0.395	0.582	W-L
9	(0 1 0 0 1)	0.149	0.851	0.000	0.601	L-W
10	(0 0 1 1 1)	0.574	0.000	0.426	0.602	W-L
11	(0 0 0 1 1)	1.000	0.000	0.000	0.602	L-W
12	(0 0 0 1 0)	1.000	0.000	0.000	0.602	L-W
13	(0 0 0 0 1)	1.000	0.000	0.000	0.602	L-W
14	(1 0 1 1 0)	0.561	0.000	0.439	0.612	W-L
15	(0 0 1 1 0)	0.527	0.000	0.473	0.638	L-W
16	(1 1 1 1 1)	0.506	0.000	0.494	0.656	W-W
17	(1 1 0 0 1)	0.107	0.893	0.000	0.661	W-L
18	(0 1 1 1 1)	0.480	0.000	0.520	0.679	W-L
19	(1 1 1 1 0)	0.461	0.000	0.539	0.696	W-L
20	(0 1 1 1 0)	0.433	0.000	0.567	0.724	W-L
21	(1 0 1 0 1)	0.000	0.577	0.423	0.729	W-L
22	(1 1 1 0 1)	0.000	0.577	0.423	0.729	W-L
23	(1 0 1 0 0)	0.000	0.485	0.515	0.774	L-W
24	(1 1 1 00)	0.000	0.484	0.516	0.774	W-L
25	(1 1 0 0 0)	0.000	0.998	0.002	0.811	L-W
26	(1 0 0 0 0)	0.000	1.000	0.000	0.812	L-W
27	(0 0 1 0 1)	0.190	0.000	0.810	0.992	L-W
28	(0 1 1 0 1)	0.138	0.000	0.862	1.055	W-L
29	(0 1 1 0 0)	0.000	0.000	1.000	1.229	L-W
30	(0 1 0 0 0)	0.000	0.000	1.000	1.229	L-W
31	(0 0 1 0 0)	0.000	0.000	1.000	1.229	L-W

Table 5: Ranking of 'defining subgroups', with their benchmark classification, according to their closeness to Chair's decision.

Table 1. New budget funding amounts in $1,000s to departments after reallocation

Table 2 Ranking of budget strategies for each department

Table 3 Monetary regret if the highest ranking strategy is not chosen

Table 4 Agreed upon allocation (“CHOICE") together with the other strategies considered

Table 5 Ranking of ‘defining subgroups’, with their benchmark classification, according to their closeness to the Chairs’ decision

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