Resolving Indifferences in Multiple Attribute Business Information System Selection with Social Choice Methods

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Abstract: The evaluation of Information Systems (IS) is a critical process for the successful development of any organizational IT capability. An important class of decision making techniques used in practice is based on conflicting criteria applied to the available alternatives, and the results are consolidated into a single ranking. In this process it is often the case that investment alternatives receive equal evaluations for some of the criteria. In this work various methods of social choice voting rules are considered that accept criteria rankings with indifferences for rank aggregation in two case studies. The properties of the results they deliver are compared with the outcomes of traditional multiple attribute decision making, taking special note of the resolving of indifferences.

Keywords: multiple attribute decision making, information systems, social choice, voting rules, rank aggregation

1 Introduction

As systems have become more complex and interconnected the need for accountable evaluation processes that allow the whole spectrum of consequences of an information system (IS) to be recognized has increased. In the area of the IS evaluation literature, numerous articles accept multiple attribute decision making (MADM) techniques to capture the whole range of IS contributions [BS06, BM05, Ira02, RS04, RB97]. The choice of multiple attribute IS decision making techniques can be observed in all major business branches, e.g., in healthcare [Han99] or in construction [KZT07]. In these decision making approaches the decision maker seeks the best alternative to maximize achievement of the goals reflected by the attributes.

In general, the implementation of the model requires identifying all relevant alternatives and evaluation of each. The latter task comprises the definition of attributes and their single-attribute value functions and is seen as an exhausting and difficult process where certain assumptions have to made. Consequently, some kind of super scale needs to be derived that reflects the value system and the preferences of the decision maker. To generate this super scale, the multiple single-attribute value functions are consolidated, most regularly by a simple additive procedure supported by an attribute weighting scheme. In the weighted sum method, the overall suitability of each alternative is thereby calculated by averaging the score of each alternative with respect to every attribute with the corresponding importance weighting.

In business practice, important pre-conditions of this methodology are often violated. Regularly, scale types are misused or scale transformations made are invalid, e.g., ordinally scaled values are used as if they were cardinally scaled. Another major problem lies in the necessity of defining attribute weights, which is known as a major challenge for decision makers. The practicality problems can still be explained by the early works of Simon [Sim77] with the concept of “bounded rationality” or the work of Lindblom who saw the decision-making as incremental, “muddling through” [Lin59].

In this article we incorporate popular social choice methods in the selection process. These methods should appeal to business practices since they demand less rigorous information from the decision maker. No single-attribute value functions need to be derived and no weighting of attributes is needed. The analogy between voting and multiple criteria decision support is easily found. If attributes are replaced by voters, and alternatives by candidates, a social choice problem is designed. In other words, the preferences of an individual in social choice problems play the same role as the preferences gained along a single dimension or attribute in MADM [BMP$^+$00]. A major motivation for this analogy lies in the fact that voting theory has developed since the original works of Borda, Condorcet and Arrow [Bor81, Con85, Arr63] to a large amount of results at disposal for use in MADM.

The goal of this article is to apply specific social choice voting rules in practical case studies that allow for the common property of indifferent rankings of alternatives with respect to some attributes. The characteristics of the results they deliver are compared with the outcomes of traditionell multiple attribute decision making.

2 Rank aggregation

In social choice problems a set of n voters provide rankings for m alternatives, resulting in a ‘profile’, e.g., alternatives a, b, c and rankings $a \succ b \succ c, b \succ c \succ a, c \succ a \succ b, b \succ c \succ a$ for four voters. The problem of rank aggregation consists in finding an aggregate ranking $x \succeq y \succeq z$ such that the preferences stated by the voters are expressed in the aggregate ranking; e.g., a suitable aggregation from the example above is $b \succ c \succ a$; alternative b is the only element in the winner set.

While in social choice problems it is typically assumed that the profile consists of strict orderings we allow for indifferences, such as $x \succ y = z$ which means that alternatives y and z are considered equal, while x is better than both y and z. The resulting aggregation may contain indifferences, and the winner set may contain more than one alternative.

There are several demands that are usually placed on aggregation rules. One of the most important is the Condorcet criterion. If an alternative x exists that beats all other alternatives in pairwise comparisons, x is a Condorcet winner [Fis77], and an obvious demand on an aggregation rule is that it select x as a winner. Another demand on an aggregation rule is that the aggregate relation should not contain any cycles and represent a weak order of the alternatives. Different voting rules fulfill these demands to differing degrees.

As already stated, in the MADM context the voters can be replaced by the dimensions or attributes considered. The evaluation of the alternatives is reduced to finding the n rankings of alternatives for the m dimensions or attributes, instead of defining n single-attribute value functions. Since indifferences are allowed it is straightforward to obtain a weak ranking from utility values; this is the method we will apply in our ex-post case studies.

Weak rankings can not be used in all social choice rules. The following description gives a short overview of voting rules i.e. methods of rank aggregation from social choice theory that are based on margins, which will be used in the case studies. These margin-based rules allow for resolving indifferences in an easy and intuitive way. The margin of x versus y is $a_{x,y} = |x \succ y| - |y \succ x|$ i.e. the number of rankings where x is preferred to y minus the number of rankings where y is preferred to x. We extend this definition for profiles with indifferences by excluding the indifferent voters from the count: rankings with indifference of x and y do not contribute to the margin of x versus y.

Simple Majority (SM): The simple majority rule is a well-known procedure based on margins: a positive margin means that x wins against y in pairwise comparison and results in $x \succ y$ in the aggregate relation, a negative margins leads to $y \succ x$, and a zero margin means indifference $x = y$. This rule can easily result in cycles, such as $x \succ y, y \succ z, z \succ x$ (drop the fourth voter from the example given above to arrive at a cylce). This limits the use of the simple majority rule in practical applications.

Maximin (MM): The Maximin rule scores the alternatives with the worst margin they each achieve and ranks them according to those scores.

Copeland (CO): The Copeland rule scores the alternatives with the sum over the signs of the margins they achieve and ranks them according to those scores.

Borda (BO): The Borda rule assigns decreasing points to consecutive positions, such as 2 points for first place, 1 point for second and zero for third. The alternatives are then ranked according to their total scores.

Kemeny (KE): The Kemeny rule chooses the ordering with minimal distance to all rankings in the profile, where distance is defined as the number of different pairwise relations.

Note that both the Borda and the Kemeny relations can be computed from the margins alone; see, e.g., [Kla05]. More details on these and other commonly used voting rules and their properties can be found, e.g., in [Fis77] and [Saa01]. Some observations on the proximity of the results the rules mentioned deliver can be found in [EKMS06].

3 Case study 1

This case analysis is based on the situation found at an international wholesaler of liquid and gaseous fuels and related products. In this article we limit the case study semantics to a minimum. For a more detailed description about the company and the undertaken Enterprise Resource Planning (ERP) adoption process see [BS04].

The company's ERP decision making methodology was based on the so-called "Nutzwert-analyse" (NWA) [Zan76], formally a weighted sum approach, complemented with vendor related perceptions and a separate financial analysis. Through the NWA, they wanted the desired system to achieve a high ERP utility score through simple additive weighting based on a number of pre-selected attributes reflecting their specific range of targeted software-specific functionalities and benefits. The requirements comprised the criteria (1) controlling and reporting, (2) accounting, (3) logistics, (4) purchasing, (5) needs of local divisions, (6) services and engineering, (7) sales, and (8) business management. The weighted utility scores for the three pre-selected alternatives (we will refer to them as A, B and C) were 253, 288 and 252 respectively; cf. table 1. Alternative B outranks its opponents whereas A and C seem to have a tie, i.e. they can be considered as equally good. This situation demonstrates shortcomings of the NWA: The resulting utility scores are hardly interpretable and do not provide a clear-cut ranking. Furthermore, the common mistake of using ordinally scaled utility values in a simple additive weighting model was observed.

The application of social choice rules limits the demands placed on the data considerably. No weighting of attributes and no value judgements are needed. Instead, preference information must be gathered in terms of the alternatives for the criteria, which for our ex-post analysis were derived from the case study data. The aggregation rules described above were applied to the preferences resulting from the application of 8 criteria to 3 alternatives in the case study. The result is shown in table 2.

In terms of alternative B, the application of all methods validates B as the winner i.e. as the best alternative. In terms of the remaining alternatives, C is preferable to A, although the Maximin rule explicitely states indifference which corresponds well to the almost identical utility values of the NWA analysis.

3.1 Case study 2

In the second case study the investment decision refers to an enterprise application integration software in a large Austrian bank. There were three alternatives, and the number of criteria was 14. The utility values listed in Table 3 resulted from weighted sums over degrees of satisfaction for a large number of goals (0: none, 1: partial, 2: full, 3: excess). Again, the company relied on ordinal scales which were falsely treated as metric scales in the applied NWA with a simple additive weighting aggregation technique. The values were propagated through two additional layers with the weights W1 and W2 stated in the table to arrive at the final utility values given in the bottom line. The level of difference between the alternatives can hardly be interpreted. Nevertheless, the traditional MADM resulted in

Criteria	A	B	C	Ranking
Controlling and Reporting	13	15	14	$B \succ C \succ A$
Accounting	14	21	16	$B \succ C \succ A$
Logistics	9	6	6	$A \succ B = C$
Purchasing	8	7	5	$A \succ B \succ C$
Local Divisions	12	13	9	$B \succ A \succ C$
Services and Engineering	15	18	18	$B = C \succ A$
Sales	24	25	27	$C \succ B \succ A$
Management	13	16	14	$B \succ C \succ A$
Total Utility Scores	253	288	252	

Tabelle 1: Utility values for the three investment alternatives in case study 1 and rankings corresponding to individual criteria

Rule	Ranking
SM	$B \succ C \succ A$
BO	$B \succ C \succ A$
CO	$B \succ C \succ A$
MM	$B \succ C = A$
KE	$B \succ C \succ A$

Tabelle 2: Results of the application of the voting rules to the data of case study 1

Criteria	W1	W2	A	B	C	Ranking
Common	*10*		*1.090*	*1.180*	*1.360*	
General Information		*40*	1.450	1.300	1.750	$B \succ A \succ C$
Future Strategy		*60*	0.850	1.100	1.100	$B = C \succ A$
Business related	*40*		*1.870*	*1.810*	*1.638*	
Workflow		*23*	1.750	1.750	1.550	$A = B \succ C$
Data representation		*12*	1.650	1.950	1.450	$B \succ A \succ C$
Deployment		*6*	0.800	2.000	2.450	$C \succ B \succ A$
Data transmission		*17*	1.900	2.000	1.900	$B \succ A = C$
Operations		*12*	2.150	1.950	1.950	$A \succ B = C$
Monitoring		*23*	2.250	1.550	1.250	$A \succ B \succ C$
Application Integration		*7*	1.750	1.750	1.650	$A = B \succ C$
Architecture and Security	*25*		*0.391*	*0.243*	*0.458*	
IT Architecture		*45*	0.350	0.000	0.560	$C \succ A \succ B$
Security		*35*	0.333	0.403	0.333	$B \succ A = C$
System requirements		*20*	0.585	0.510	0.450	$A \succ B \succ C$
Commercial and procurement	*25*		*1.450*	*1.270*	*1.040*	
Delivery concept		*40*	1.450	1.000	0.800	$A \succ B \succ C$
Project Support		*60*	1.450	1.450	1.200	$A = B \succ C$
Weighted Utility Scores			**1.317**	**1.220**	**1.166**	
Sum of Scores			18.718	18.713	18.393	

Tabelle 3: Utility values for the three investment alternatives in case study 2 and rankings corresponding to individual criteria

a final ranking $A \succ B \succ C$. The simple sum of scores shows how the application of weights helped alternative A to more clearly outrank B.

The social choice rules were applied in the same manner as in the previous case study by using the second level utility values i.e. before any weighting as indicated in the table. The results are presented in Table 4. Alternative C is unequivocally ranked bottom, which corresponds to the outcome of the traditional weighted utility ranking analysis as indicated by the total utility values. However, one of the rules (BO) identifies alternatives A and B as indifferent. This seems to contrast with the weighted utility scores which seem to indicate a clear preference for alternative A. This limitation is due to the ex-post character of this case study. In a live ex-ante approach, the social choice rules would require rankings in terms of single attributes instead of single point estimates of utility scores. Nevertheless, the sum of scores shows that when the bias of the weights is removed the results correspond closely to those of the social choice rules.

Rule	Ranking
SM	$A \succ B \succ C$
BO	$A = B \succ C$
CO	$A \succ B \succ C$
MM	$A \succ B \succ C$
KE	$A \succ B \succ C$

Tabelle 4: Application of voting rules to case study 2 data

4 Conclusion

The obvious conclusion from both case studies is that the margin-based social choice aggregation rules conform very well with the ranking outcome of the more traditional weighted sum methods (implemented through the NWA). In case study 1, the distinctive winner of the NWA was ranked first in all social choice rules and a tie between the two other alternatives was identified with one rule. The interesting observation was the handling of the two almost equally good alternatives by the various selection rules. A similar outcome was observed in case study 2, where the winner of the NWA again can also be seen in the rankings supplied by the social choice rules. Here again one rule indicates a tie between the winner and the alternative on the second position. The distinctive loser is identified by all rules in accordance to the NWA outcome.

The interpretation of ties with our social choice methodology is well supported by the application of a rule set, where a number of rankings can be compared. Consequently, the decision maker should rather view the outcomes of all rules, than the outcome of a single rule in isolation. This compensates for the missing information on intervals between alternatives, which can be derived from the final utility scores in the NWA. There are no computational problems with the chosen social choice rules in our case settings.

A main difference between classic MADM and the application of voting rules lies in the limited demands the rules place on the decision maker: No weighting scheme and no single-attribute value functions are needed. The indifferent single-attribute valuations for any alternative can be handled by the margin-based social choice rules. The many mistakes caused by the bounded rationality and muddling through phenomena observed in complex human decision making, more specifically for the MADM IS setting, e.g., invalid attribute weights, utility scores or misused scales or scale transformations, can be avoided by the application of simple social choice approaches to IS decisions while providing results that are transparent and very similar to the MADM approach.

Future work will further analyse characteristics of voting rules and consequences for MADM in IS selection, such as manipulability. The main goal is to apply less information-demanding MADM selection approaches and also to support validation, since this requirement is often neglected in practice.

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