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The feasibility of sophisticated multicriteria support for clinical decisions

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Abstract

Background—Multi-criteria decision making (MCDM) methods are well-suited to serve as the foundation for clinical decision support systems. To do so, however, they need to be appropriate for use in busy clinical settings. We compared decision making processes and outcomes of patient-level analyses done with a range of multi-criteria methods that vary in ease of use and intensity of decision support, two factors that could affect their ease of implementation into practice.

Methods—We conducted a series of Internet surveys to compare the effects of five multi-criteria methods that differ in user interface and required user input format on decisions regarding selection of a preferred method for lowering risk of cardiovascular disease. The study sample consisted of members of an online Internet panel maintained by *Fluidsurveys*, an Internet survey company. Study outcomes were changes in preferred option, decision confidence, preparation for decision making, the values clarification and decisional uncertainty subscales of the decisional conflict scale, and method ease of use.

Results—The frequency of changes in preferred option ranged from 9% to 38%, $p < 0.001$, and rose progressively as the level of decision support provided by MCDM method increased. The proportion of respondents who rated the method as easy ranged from 57% to 79% and differed significantly among MCDM methods, $p=0.003$, but was not consistently related to intensity of decision support or ease of use.

Conclusion—Decision support based on multi-criteria decision methods is not necessarily limited by decreases in ease of use. This result suggests that it is possible to develop decision support tools using sophisticated multicriteria techniques suitable for use in routine clinical care settings.

Introduction

Medical decision analysis has been defined as “... a collection of formal approaches which seek to take explicit account of multiple criteria in helping individuals or groups explore decisions that matter”. (1) The field of multi-criteria decision making (MCDM) provides a number of methods designed to facilitate decision making in complex situations requiring preference-based trade-offs between the advantages and disadvantages of decision

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alternatives. (1–3) Many clinical decisions meet this description. (4) This raises the hypothesis that multi-criteria methods could serve as the basis for new clinical decision support tools that will effectively promote the consistent provision of evidence-based, patient centered care throughout the health care system. (5) However, a clinical decision aid will never be useful unless it can be effectively implemented and regularly used in practice. In the past, many promising decision-aiding strategies have failed to improve real-world decisions, in large part because they have not been appropriate for use in the applied context. (6, 7) Similar difficulties have affected attempts to incorporate patient decision aids into routine clinical practice settings. (8–10)

Multi-criteria methods differ in several ways that could affect their ease of implementation and dissemination into practice including theoretical basis, underlying assumptions, model structure, and required user inputs. They can be viewed as a spectrum of techniques that ranges from simple methods with little or no underlying theory to more complicated ones with firm theoretic underpinnings and an expanded set of preference techniques and other capabilities. The extent to which it is necessary to sacrifice the simplicity and ease of use likely to promote implementation in busy practice settings to ensure useful, high quality multicriteria-based clinical decision support is currently unknown.

The goal of this study was to address this knowledge gap by comparing decision making processes and outcomes of patient-level analyses done with a variety of multi-criteria decision methods that vary in procedural simplicity and intensity of decision support. There were two study hypotheses: 1) Increasing levels of multicriteria-based decision support will have a bigger impact on decisions made by untrained members of the general public and 2) Increasing levels of multicriteria-based decision support will be associated with decreased ease of use.

Methods

We conducted a 5 group, cross-sectional study comparing the effects of five multi-criteria methods on decisions regarding selection of a preferred method for lowering risk of cardiovascular disease.

Study population

The study population consisted of members of an Internet survey panel who responded to requests made through *Fluidsurveys*. (11) *Fluidsurveys* was an Internet survey company that, for a small fee, distributed surveys to members of their Internet survey panel and ensured a minimum number of survey respondents. (It has since been acquired by SurveyMonkey, another Internet survey company.) We hired *Fluidsurveys* to distribute our study interventions. The goal was conduct five surveys (one for each MCDM method) each of which had a study sample that was demographically representative of the general US population aged 35 years and over for whom routine cardiovascular disease prevention is recommended. Because the surveys were written in English, all respondents had to be able to complete an English-language survey. There were no other exclusion criteria.

Study intervention

The study intervention is illustrated in Figure 1. It consisted of: a) a brief introduction and description of a heart attack prevention decision scenario, b) an initial choice of preferred option based on information presented in a tabular balance sheet, c) assessment of this initial decision making process, d) a short background questionnaire, e) analysis of the heart attack prevention decision using one of 5 multi-criteria decision making methods, f) selection of a post-MCDM preferred option, and g) a short questionnaire that assessed health numeracy, personal history of cardiovascular disease and prevention activities, and family history of cardiovascular disease.

The decision scenario was as follows: “Imagine you have a 20% chance of having a heart attack during the next 10 years and are considering different ways to reduce your chance of a heart attack. You have 4 options (A, B, C, and D).”

The information provided in the initial decision balance sheet is shown in Figure 2. The four prevention options were modeled after recommended approaches to cardiovascular risk reduction including aspirin, statins, exercise, and diet. Data were provided with regard to five decision criteria: expected reduction in heart attack risk, additional health benefits of the intervention, side effects, out of pocket expenses, and time required.

We assessed the decision making process using the Preparation for Decision Making Scale, the values clarity and uncertainty sub-scales of the Decisional Conflict Scale (low literacy version), and decision confidence using a 1–10 scale ranging from very unsure to very sure. The Preparation for Decision Making scale is a validated measure of patient perceptions of the ability of a decision aid to prepare them to communicate with a provider about a decision affecting their health care. (12) The Decisional Conflict Scale is a validated, widely used measure of decision aid effectiveness based on a decision that has been made. (13–15) Because our study subjects did not make an actual decision, we only measured the two subscales pertinent to our study context: values clarity and uncertainty. We created the decision confidence scale for use in a brief Internet Survey. Although not previously validated, it is similar to many common rating tasks such as the 1 to 10 Numeric Rating Scale for Pain and past scales that have been used to measure decision confidence. (16, 17)

We measured the perceived difficulty of performing the MCDM analyses using the single ease of use question and health literacy using the Chew subjective health literacy measure. Although consisting of only one item, both of these measures have been shown to perform as well as more complex measures while being faster and easier. (18, 19) Finally, we assessed numeracy using the short form of the Numeracy Understanding in Medicine Instrument (NUMI), which has been validated and shown to perform well in Internet surveys. (20, 21)

The 5 MCDM methods included in the study were: 1) a repeat decision using the same balance sheet (which served as a control), 2) a decision dashboard, 3) ordinal multicriteria decision analysis using Multi-Attribute Global Inference of Quality (MAGIQ), 4) the Technique of Order Preference Similarity to the Ideal Solution (TOPSIS), and 5) the

Analytic Hierarchy Process (AHP). Information about these methods is summarized in Table 1.

We chose these methods to be representative of multi-criteria decision making techniques with varying degrees of decision support ranging from simply providing a decision making framework through increasingly complex methods of assessing decision preferences. Collectively they also include the most common methods used to elicit users' preferences in health-related MCDM analyses. (22) They therefore allowed us to test our study hypotheses that there is a negative relationship between ease of use and methodologic complexity. We assumed that, of the methods used, the balance sheet was the easiest to use and the AHP the most complex. (3) Additional details about the methods used in the study are included in a supplemental file.

Analysis

We summarized the characteristics of the study sample and responses to the outcome variables using descriptive statistics. We assumed that, in practice, all multicriteria methods would be administered after review of a tabular summary of information indicating how well the alternatives performed across the criteria being considered. Therefore our main study endpoints were: a) comparisons between pre- and post MCDM choice of preferred option, decision confidence, preparation for decision making, values clarification, and decision uncertainty and b) the one-time ease of use ratings of the multicriteria methods.

To facilitate analysis and interpretation we grouped ease of use ratings, values clarity, and uncertainty scores into categories. We combined the 7 point ease of use ratings into easy (5–7 on the original scale) and not easy (1–4 on the original scale), the five point values clarity scores into high, moderate, and low values clarity (original scores 0 to 2, 4, and 6 to 8 respectively), and decisional uncertainty scores into low, moderate and high (original scores 0 to 2, 4, and 6 to 8 respectively). Because none of the outcome data were normally distributed, we performed group comparisons using Chi Square analysis and the one-factor Kruskal-Wallis test. We examined the impact of differences in baseline characteristics between groups using multiple and logistic regression.

All statistical analyses were performed using MedCalc. (23) This study was approved by the University of Rochester Institutional Review Board.

Results

The characteristics of the study sample are summarized in Table 2. The overall sample size is 636 divided into five separate survey groups ranging from 112 to 147 participants. The overall mean age was 56.6 years. Group mean ages ranged from 51.7 to 60.1, a statistically significant difference, $p < 0.01$. The majority of respondents were female (56%), non-Hispanic (95%), and white (87%), with no significant differences among study groups. Overall 279 (45%) survey respondents reported a personal history of heart disease, hypertension, or high cholesterol. Differences in prevalence of these conditions among the groups were marginally statistically significant ($p=0.07$). Regression analyses, however, indicated no statistically significant association between these conditions and the main study

outcomes. There were no statistically significant among-group differences in percentage of respondents with a family history of cardiovascular disease or who were actively engaged in cardiovascular disease prevention activities.

The pre- and post-MCDM decision choices and decision-making process assessments are summarized in Table 3. Option C was the most commonly preferred option in all groups both before and after the multi-criteria analyses. As illustrated in Figure 3, there is a statistically significant difference among the groups in the frequency of pre- to post-MCDM changes in preferred option, ranging from 9% in the repeat balance sheet group to 38% in the AHP group, $p < 0.001$.

There are also statistically significant among group differences in pre- post MCDM decision confidence scores, preparation for decision making, and decisional uncertainty. Differences in decision confidence scores ranged from 0.4 to 0.6 ($p=0.002$). Changes in preparation for decision making scores ranged from -2 to 1.1, $p=0.005$. In both cases there are statistically significant differences between the TOPSIS group and the repeat balance sheet, dashboard, and ordinal MCDA groups. The frequency of changes in decisional uncertainty level ranges from 12% to 29%, $p=0.0005$. All three MCDM methods with values clarification exercises had greater amounts of decisional uncertainty change. Uncertainty decreased in the Ordinal MCDA group and increased in the TOPSIS and AHP groups.

The ease of use ratings for the dashboard, ordinal MCDA, TOPSIS, and AHP groups are summarized in Table 3 and illustrated in Figure 4. (This information was not obtained from the control balance sheet group.) The proportion of respondents who rated the method as easy ranged from 57% (TOPSIS) to 79% (dashboard), $p=0.003$. There are statistically significant differences among groups, $p=0.0005$, and between the TOPSIS group and both the dashboard and the AHP group, $p<0.01$.

Discussion

These results support our first study hypothesis: that higher levels of multi-criteria decision support have a greater impact on decisions made by untrained members of the general public. They do not support our second study hypothesis, that increasing levels of multicriteria decision support are associated with decreased ease of use. The AHP, the most complex method studied, was rated second easiest to use.

The AHP has several design characteristics that enhance usability including an intuitive hierarchical decision model and the use of pairwise comparisons to reduce the complexity of the judgmental tasks required of the user. However, it is also well known for requiring a substantial amount of input by users. As shown in Figure 4, our study results indicate that this feature did not affect its usability ratings. The AHP pairwise comparison process was judged easier than the simple ordinal ratings used in the MAGIQ procedure and 1–10 numeric ratings used in TOPSIS. These findings are consistent with prior studies that have consistently found that most patients are able to perform complicated AHP analyses, find the experience worthwhile, and would like to use it to make important decisions about their health. (24–28)

Differences among the multicriteria methods were also found with regard to decision confidence, preparation for decision making, and decisional uncertainty. Mean decision confidence and preparation for decision making scores, indicating lower confidence and readiness to discuss the decision with a healthcare provider, were lower for the TOPSIS group, who used a direct weighting scale to compare alternatives and prioritize decision criteria, than the balance sheet, dashboard, and ordinal groups. All groups had highly statistically significant differences in decisional uncertainty with reductions in the table, dashboard, and ordinal groups and increases in the TOPSIS and AHP groups.

There are several possible explanations for these findings. One is that the higher rates of changed preferences seen in the TOPSIS and AHP groups resulted in both a more informed choice of preferred option and a greater feeling of uncertainty due to revising the originally stated option preference. (29, 30) It is also possible that the higher level of uncertainty reflected the change in the decision making process from a more routine, intuitive system 1 activity to one requiring greater use of more deliberative, effortful system 2 decision making. (31, 32)

Our findings are subject to several limitations. First, our hypothetical decision scenario was designed for use in an Internet survey and was therefore deliberately kept simple. While this study design allowed us to efficiently assemble a large sample for this early phase study, it precluded us from determining if these same findings would apply to more complex, real-world decision making situations. However, although subject to some limitations, vignette-based studies have been shown to be valuable tools in assessing behavior in actual practice. (33–36) It also makes it impossible to determine if the poorer scores on the preparation for decision making scale found for the more complex methods are true findings or artifacts of our study design. Finally, we were only able to study a small number of the multicriteria methods available, so cannot generalize our findings beyond the methods included in the study. However the methods we chose represent common MCDM frameworks and methods used to elicit users' preferences.

Despite these limitations, our findings indicate that multi-criteria based decision support is not necessarily limited by inevitable decreases in ease of use. This result suggests that it is possible to develop decision support tools using sophisticated multicriteria techniques suitable for use in routine clinical care settings, for less complex decisions. It remains to be determined whether this association will continue for more complex decisions and in real-life situations. Further research is also warranted to determine if the decreases in decisional confidence and increased decisional uncertainty associated with use of TOPSIS and AHP are reactions to new insights that alter existing mental models or reflect unexpected negative consequences of using more complex decision support methods in this context.

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Figure 1.

The study intervention. AHP, analytic hierarchy process; CVD, cardiovascular disease; NUMI, numeracy understanding in medicine; TOPSIS, technique of order preference similarity to the ideal solution.

Considerations	A	B	C	D
Lower risk of Heart attack	Reduced from 20% to 15%	Reduced from 20% to 15%	Reduced from 20% to 17%	Reduced from 20% to 16%
Other health benefits ☒ = yes; ☐ = no	☒ Reduced risk of cancer ☐ Weight loss likely ☐ Increased energy ☐ Improved sleep	☐ Reduced risk of cancer ☐ Weight loss likely ☐ Increased energy ☐ Improved sleep	☒ Reduced risk of cancer ☒ Weight loss likely ☒ Increased energy ☒ Improved sleep	☒ Reduced risk of cancer ☒ Weight loss likely ☐ Increased energy ☐ Improved sleep
Side effects	Somewhat risky <ul style="list-style-type: none"> 8 to 11 severe episodes of internal bleeding per 1,000 people; common minor side effects also possible 	Somewhat risky <ul style="list-style-type: none"> 20 to 110 people per 1,000 develop persistent muscle aches; 5 people per 1,000 develop severe muscle inflammation common minor side effects also possible 	Safe <ul style="list-style-type: none"> Possible mild, transient muscle aches and pains 	Safe <ul style="list-style-type: none"> No risk of side effects
Out of pocket expenses	\$1 per month	\$15 per month	\$30 per month	\$45 per month
Time required	Minimal.	Minimal	2.5 hours a week.	2 hours per week

Figure 2.
Balance sheet comparing the four decision options.

Figure 3.

Changes (before versus after) in multicriteria decision making–preferred options. AHP, analytic hierarchy process; MAGIQ, multi-attribute global inference of quality; TOPSIS, technique of order preference similarity to the ideal solution.

Figure 4.

Ease of use ratings for multicriteria methods. AHP, analytic hierarchy process; MAGIQ, multi-attribute global inference of quality; TOPSIS, technique of order preference similarity to the ideal solution.

Table 1

Summary of MCDM methods used in the study

Method	User Interface	User input	Relative level of decision support *	Relative ease of use *
Balance sheet	Tabular	None	1	5
Dashboard	Graphic	None	2	4
MAGIQ	Mixed	Rank ordering	3	3
TOPSIS	Mixed	1 to 10 rating scale	4	2
AHP	Mixed	Pairwise comparisons	5	1

* Rated using the following scale: 1 = least, 5 = most

Abbreviations: MAGIQ- Multi-Attribute Global Inference of Quality; TOPSIS - Technique of Order Preference Similarity to the Ideal Solution;
AHP - Analytic Hierarchy Process

Table 2

Study population

Characteristic	Balance Sheet	Dashboard	MAGIQ	TOPSIS	AHP	Total	P value
	N=112	N = 122	N=147	N=134	N=121	N= 636	
Mean (95% Confidence Interval)							
Age, years	60.1 (57.8 to 62.5)	54.9 (52.9 to 56.8)	60.1 (58.4 to 61.8)	55.9 (53.8 to 58.0)	51.7 (49.7 to 53.7)	56.6 (55.7 to 57.5)	p < 0.001
Mean (standard deviation)							
NUMI score	5.0 (1.8)	4.8 (1.9)	5.0 (1.8)	4.8 (1.8)	4.9 (2.0)	4.9 (1.8)	p = 0.80
N (%)							
Gender							
Female	62 (55%)	69 (57%)	83 (57%)	79 (59%)	63 (52%)	356 (56%)	p = 0.80
Male	50 (45%)	53 (43%)	64 (43%)	55 (41%)	58 (48%)	280 (44%)	
Race							p = 0.02 ^a
American Indian	5 (5%)	3 (3%)	0	0	3 (3%)	11 (2%)	
Asian	1 (1%)	1 (1%)	2 (1.4%)	3 (2%)	3 (3%)	10 (2%)	
Native Hawaiian	0	0	0	0	1 (1%)	1 (0.2%)	
Black or AA	8 (7%)	16 (13%)	4 (3%)	7 (5%)	10 (8%)	45 (7%)	
White	98 (88%)	100 (82%)	134 (91%)	122 (91%)	98 (81%)	552 (87%)	
Mixed	0	1 (1%)	6 (4%)	1 (1%)	4 (3%)	12 (2%)	
Other	0	1 (1%)	1 (1%)	1 (1%)	2 (2%)	5 (1%)	
Ethnicity							p = 0.07
Hispanic	9 (8%)	4 (3%)	6 (4%)	2 (2%)	9 (7%)	30 (5%)	

Characteristic	Balance Sheet	Dashboard	MAGIQ	TOPSIS	AHP	Total	P value
Non-Hispanic	N=112	N = 122	N=147	N=134	N=121	N= 636	
	103 (92%)	118 (97%)	141 (96%)	132 (98%)	112 (93%)	606 (95%)	
Education							p = 0.15
Less than high school	4 (4%)	1 (1%)	1 (1%)	3 (2%)	3 (3%)	12 (2%)	
High school	22 (20%)	31 (25%)	31 (21%)	20 (15%)	20 (17%)	124 (20%)	
Some college	33 (30%)	39 (32%)	40 (27%)	42 (31%)	25 (21%)	179 (28%)	
Associate's degree	12 (11%)	13 (11%)	24 (16%)	19 (14%)	14 (12%)	82 (13%)	
Bachelor's degree	29 (26%)	25 (21%)	27 (18%)	30 (22%)	43 (36%)	154 (24%)	
Post-graduate	12 (11%)	13 (11%)	24 (16%)	20 (15%)	16 (13%)	85 (13%)	
Annual Household income							p = 0.24
< \$10,000	7 (6%)	7 (6%)	10 (7%)	11 (8%)	7 (6%)	42 (7%)	
\$10,000 to \$24,999	22 (20%)	31 (25%)	29 (20%)	26 (19%)	16 (13%)	124 (20%)	
\$25,000 to \$74,999	59 (53%)	68 (56%)	79 (54%)	73 (10%)	59 (49%)	338 (53%)	
\$75,000 to \$99,999	11 (10%)	11 (9%)	17 (12%)	13 (10%)	22 (18%)	74 (12%)	
\$100,000 or more	13 (12%)	5 (4%)	12 (8%)	11 (8%)	17 (14%)	58 (9%)	
Health literacy							p = 0.16
extremely	50 (45%)	43 (35%)	65 (44%)	47 (35%)	46 (38%)	251 (40%)	
quite a bit	39 (35%)	53 (43%)	51 (35)	52 (39%)	46 (38%)	241 (38%)	
somewhat	13 (12%)	19 (16%)	24 (16%)	20 (15%)	17 (14%)	93 (15%)	
a little bit	10 (9%)	6 (5%)	7 (5%)	13 (10%)	7 (6%)	43 (7%)	
not at all	0	1 (1%)	0	2 (2%)	5 (4%)	8 (2%)	
Family History of cardiovascular disease							p = 0.02
yes	54 (49%)	41 (34%)	77 (55%)	59 (45%)	57 (48%)	288 (47%)	
no	56 (51%)	79 (66%)	63 (45%)	71 (55%)	62 (52%)	331 (54%)	
Engaged in activities to reduce risk of heart disease							p = 0.2
yes	71 (65%)	81 (68%)	107 (76%)	90 (69%)	87 (73%)	436 (70%)	
no	39 (36%)	39 (33%)	33 (24%)	40 (31%)	32 (27%)	183 (30%)	
Personal history of cardiovascular disease							p = 0.07

Characteristic	Balance Sheet	Dashboard	MAGIQ	TOPSIS	AHP	Total	P value
	N=112	N = 122	N=147	N=134	N=121	N= 636	
yes	62 (56%)	52 (43%)	65 (46%)	54 (42%)	46 (39%)	279 (45%)	
no	48 (44%)	68 (57%)	75 (54%)	76 (59%)	73 (61%)	340 (55%)	

^aCategories combined into black, white, and all others for Chi Square analysis

Table 3

RESULTS

	N=112	N = 122	N=147	N=134	N=121	N=636	P value
	Balance Sheet	Dashboard	MAGIQ	TOPSIS	AHP	Total	
Pre-MCDA preferred heart attack risk reduction option							
A	29 (26%)	26 (21%)	26 (18%)	32 (24%)	31 (26%)	144 (23%)	
B	3 (3%)	5 (4%)	6 (4%)	10 (8%)	7 (6%)	31 (5%)	
C	54 (48%)	67 (55%)	82 (56%)	70 (52%)	66 (54%)	339 (53%)	
D	26 (23%)	24 (20%)	33 (22%)	22 (16%)	17 (14%)	122 (19%)	P = 0.52
Post-MCDA preferred heart attack risk reduction option							
A	27 (24%)	22 (18%)	42 (29%)	37 (28%)	38 (31%)	166 (26%)	
B	5 (5%)	12 (10%)	7 (5%)	15 (11%)	12 (10%)	51 (8%)	
C	53 (47%)	62 (51%)	74 (50%)	63 (47%)	47 (39%)	299 (47%)	
D	27 (24%)	26 (21%)	24 (16%)	19 (14%)	24 (20%)	120 (19%)	P = 0.11
Preferred choice change							
No	102 (91%)	104 (85%)	117 (80%)	92 (69%)	75 (62%)	490 (77%)	
Yes	10 (9%)	18 (15%)	30 (20%)	42 (31%)	46 (38%)	146 (23%)	p < 0.001
Ease of use							
difficult	na	15 (13%)	22 (16%)	34 (26%)	17 (14%)	88 (17%)	
neutral	na	10 (8%)	23 (16%)	23 (18%)	12 (10%)	68 (13%)	
easy	na	95 (79%)	96 (68%)	74 (57%)	92 (76%)	357 (70%)	P = 0.0029
Clarity of values							
Pre-MCDA choice							
High	93 (83%)	104 (85%)	121 (82%)	106 (79%)	103 (85%)	527 (83%)	
Moderate	13 (12%)	9 (7%)	17 (12%)	18 (13%)	12 (10%)	69 (11%)	
Low	6 (5%)	9 (7%)	9 (6%)	10 (8%)	6 (5%)	40 (6%)	P = 0.87

	N=112	N = 122	N=147	N=134	N=121	N = 636	P value
Post MCDA choice	Balance Sheet	Dashboard	MAGIQ	TOPSIS	AHP	Total	
High	93 (83%)	99 (81%)	125 (85%)	102 (76%)	98 (81%)	517 (81%)	
Moderate	10 (9%)	15 (12%)	12 (8%)	21 (16%)	10 (8%)	68 (11%)	
Low	8 (8%)	8 (7%)	10 (7%)	11 (8%)	13 (11%)	51 (8%)	P = 0.46
Pre to Post-MCDA Change in values clarity							
Greater clarity	6 (5%)	3 (3%)	13 (9%)	13 (10%)	5 (4%)	40 (6%)	
Same	99 (88%)	112 (92%)	123 (84%)	106 (79%)	104 (86%)	497 (78%)	
Less clarity	7 (6%)	7 (6%)	11 (8%)	15 (11%)	12 (10%)	52 (8%)	P = 0.13
Decisional Uncertainty							
Pre-MCDA choice							
Low	82 (73%)	88 (72%)	99 (67%)	89 (66%)	83 (69%)	441 (69%)	
Moderate	15 (13%)	17 (14%)	22 (15%)	23 (17%)	22 (18%)	99 (16%)	
High	15 (13%)	17 (14%)	26 (18%)	22 (16%)	16 (13%)	96 (15%)	P = 0.99
Post MCDA choice							
Low	88 (79%)	96 (79%)	106 (72%)	83 (62%)	75 (62%)	448 (70%)	
Moderate	14 (13%)	17 (14%)	21 (14%)	30 (22%)	24 (20%)	106 (17%)	
High	10 (9%)	9 (7%)	20 (14%)	21 (16%)	22 (18%)	82 (13%)	P = 0.03
Pre to Post-MCDA Change in decisional uncertainty							
More certain	10 (9%)	18 (15%)	18 (15%)	18 (13%)	12 (10%)	76 (12%)	
No change	99 (88%)	100 (82%)	115 (78%)	95 (71%)	88 (73%)	497 (78%)	
Less certain	3 (3%)	4 (3%)	14 (10%)	21 (16%)	21 (17%)	63 (10%)	P = 0.0005
Decision confidence							
Mean							
(95% Confidence Interval)							
Pre-MCDA	7.3 (6.9 to 7.7)	7.1 (6.7 to 7.3)	7.1 (6.8 to 7.4)	7.0 (6.7 to 7.4)	7.3 (7.0 to 7.7)	7.2 (7.0 to 7.3)	P = 0.42
Post-MCDA	7.6	7.4	7.2	6.7	7.2	7.2	P < 0.001 /

	N=112	N = 122	N=147	N=134	N=121	N = 636
	Balance Sheet	Dashboard	MAGIQ	TOPSIS	AHP	Total
						P value
	(7.3 to 8.1)	(6.9 to 7.8)	(6.9 to 7.5)	(6.4 to 7.1)	(6.8 to 7.6)	(7.0 to 7.4)
pre-post MCDA change	0.36 (0.17 to 0.54)	0.23 (0.03 to 0.43)	0.08 (-0.18 to 0.33)	-0.3 (-0.59 to -0.02)	-0.16 (-0.49 to 0.17)	0.03 (-0.09 to 0.15)
Preparation for decision making score						
Pre-MCDA	34.4 (32.7 to 36.2)	35.3 (33.5 to 37.0)	33.9 (32.3 to 35.5)	34.8 (33.1 to 36.5)	35.5 (33.9 to 37.2)	34.8 (34.0 to 35.5)
Post-MCDA	35.6 (33.7 to 37.5)	35.9 (34.0 to 37.8)	34.2 (32.4 to 36.1)	32.7 (30.9 to 34.4)	35.1 (33.2 to 37.0)	34.6 (33.8 to 35.5)
pre-post MCDA change	1.1 (0.23 to 1.97)	0.43 (-0.56 to 1.4)	0.38 (-0.48 to 1.2)	-2.0 (-3.34 to -0.64)	-0.45 (-1.5 to 0.61)	-0.14 (-0.62 to 0.33)
						P = 0.005 ¹

Abbreviations: MAGIQ- Multi-Attribute Global Inference of Quality; TOPSIS - Technique of Order Preference Similarity to the Ideal Solution ; AHP - Analytic Hierarchy Process; na – not available, data not collected

¹ TOPSIS group significantly different from all other groups;

² TOPSIS group significantly different from Balance sheet, Dashboard, and MAGIQ groups;

³ no significant between group differences.