JOURNAL OF MULTI-CRITERIA DECISION ANALYSIS
J. Multi-Crit. Decis. Anal. **18**: 77–89 (2011)
Published online in Wiley Online Library
(wileyonlinelibrary.com) DOI: 10.1002/mcda.473

Multiple Criteria Decision Making (MCDM): From Paradigm Lost to Paradigm Regained?*

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ABSTRACT

Because trade-offs (Pareto optimal, non-dominated or efficient sets) are not properties of criteria or objectives, but of sets of feasible alternatives, the proper task of decision making is to work on designing proper sets of alternatives rather than assuming them to be fixed and given *a priori*. In fact, decision making takes place only when multiple criteria *and* trade-offs are present. All the rest (single criteria, aggregates or utilities) are simply analysis, measurement and search, *not* decision making.

Similarly, optimization must involve design of the configuration or 'shape' of sets of alternatives because no given and fixed system can be optimized. Traditional 'optimization' is therefore measurement and search, or just computation. Anything given and fixed *a priori* cannot be optimized. Multiple criteria or objectives can never be conflicting *per se* because their properties emerge only when applied to different sets of alternatives. Criteria are only 'measure tapes' and no trade-offs can exist among them. Because decision making is incompatible with a single criterion, *all* decision making involves multiple criteria: thus, Multiple Criteria Decision Making (MCDM) becomes a redundant designation.

These and similar insights and conclusions call for MCDM paradigm re-assessment: is it about decision *making*, or about analysis, measurement and search (explication) through computation? Eight different concepts of optimality are presented, as well as theories and models of trade-offs elimination, conflict dissolution, optimal system design, *de novo* programming, theory of the displaced ideal and other advances related to feasible set optimal re-design and re-configuration. Copyright © 2011 John Wiley & Sons, Ltd.

KEY WORDS: decision making; multiple criteria; optimality; trade-offs; MCDM; *de novo* programming

1. INTRODUCTION

A *paradigm* is a generally accepted perspective, frame or matrix of a particular discipline or field of inquiry at a given time of its development. It is exemplified by a host of unquestioned premises, definitions, axioms and conventions of the discipline. After some 40 years of MCDM, such beliefs are often considered unchangeable—*fixed*, *given* and taken for *granted*.

For example: it is asserted here that no decision making (DM) can take place along a single dimension or with respect to a single criterion. If this is true, then Multiple Criteria Decision Making (MCDM) is a *misnomer* because the adjective 'multiple criteria' implies that there is another form of DM *without* multiple criteria: yet, that there is not. Human DM occurs under *multiple criteria only*. All the rest is analysis, measurement and search. So, it should be useful to define what DM is. Similarly, with all such concepts like optimization, trade-off, constraint, solution, conflict, etc. What are they? How are they defined?

Ronen and Coman (2009) describe how the '*valuable discipline of MCDM was abused by the Analytical-Hierarchy-Process* (AHP)', and use MCDM as an example of analytical overdose—a '*cumbersome and time-consuming process*.' How is MCDM to regain its initial promise (Cochrane and Zeleny, 1973; Zeleny, 1982) and reputation for seeking valuable distinction from the analysis and computation of *operations research*? Any discipline without reliable definitions, clear concepts and explicitly shared purposes is risking dissipation under the encroachment of the 'anything goes' culture of excessively mechanistic algorithmization, freezing out essential *humanity* and *human* dimensions of DM.

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*Parts of this paper are based on the keynote speech delivered at the MCDM conference in Chengdu, June 22–26, 2009, addressing its theme of '*The New State of MCDM in 21st Century*'.

Received 01 June 2011
Accepted 09 June 2011

Decision making is pre-eminently a human function. Machines, algorithms and complex aggregates can never be good decision makers. *Computation* is the last and the least important—albeit the simplest—of all DM components and functions. Vitally more important are *problem formulation*, *criteria selection*, *alternatives generation*, *feasible set design*, *weights, priorities and preferences assessment*, *decision process sequencing and timing*, *decision context capturing*, *problem reformulation and reframing*, *post-decision regret assessment*, *implementation strategy*, etc. Once we go through all this in a reliable and systemic way, very little need for computation remains. Humans thrive on well prepared decision scaffolds—it allows them to *take responsibility* for their decisions. No machine has ever taken responsibility for anything.

2. DEFINING MULTIPLE CRITERIA DECISION MAKING

It is always useful to review basic definitions of a field of inquiry. In our case, we have to define what is DM in general and MCDM in particular. If MCDM turns out to be a *misnomer* (because the adjective 'multiple criteria' implies that there is some other form of decision making without multiple criteria), then MCDM should reclaim the entire field of DM. Changing MCDM to (MC)DM or even DM would signal a bold new strategy, worldwide paradigmatic debate and opening new spaces for research and practice. Only bold people undertake bold strategies.[†]

All human DM takes place under *multiple criteria only*. All the rest is analysis, measurement and search. A very simple example shows a suitable definition of decision making. Consider a basket of apples, simulating any feasible set of alternatives. Assume further that *analysis* [perhaps Multi-Attribute Utility Theory (MAUT) or Multi-Criteria Decision Analysis (MCDA)] determines *weight* (or any other aggregate) to be a *single criterion*; we proceed to find (identify, choose, select) the heaviest apple (Zeleny, 2010a, 2010b).

How do we solve the problem? First, we *measure*. Then, we *search*. Measurement and search is necessary and sufficient for finding the heaviest apple. So, this is *not* a problem of decision making or optimization, but simply a task of measurement and search. It is the problem of *computation* (measurement and search), merely a technical challenge. No value judgments, no trade-offs and no decisions go into single-criterion problems.

Next, we consider (disaggregated) *multiple criteria*. Consider an identical basket of apples. Now, we wish to find the heaviest *and* the sweetest apple. Our *criteria* are weight and sweetness. We use the same necessary procedures of measurement and search and identify the heaviest (as before) and then the sweetest apple. But this time, the function of measurement and search is *not sufficient*. There are two different apples; our criteria are 'conflicting' (Are they?). Which apple do we choose? Now, we must go *beyond measurement and search* and perform an additional function: we have to *decide*.

Clearly, there can be no DM without multiple criteria. DM is that which must be performed *after* we have measured and searched. Problems with a single objective function, no matter how complex, important or aggregate [the function], are *not* problems of DM or optimization, but only problems of measurement and search. Methodologies like MAUT, MCDA, AHP and their derivatives belong to analysis, measurement and search as long as they employ a *single* aggregate objective function. It appears that we have no need for the prefix 'MC' in front of DM: *all DM is with multiple criteria*.

Note. There is the perennial 'sugar example': Is not 'deciding' whether to put two or three lumps of sugar in a cup of coffee a DM process along a single dimension? No, it is not. The 'decision' is between cups with two, three or other number of lumps, that is, *sweetness*. We find the sweetest cup through measurement and search only, trying different number of lumps and tasting. It is the same as finding the sweetest apple.

There is another issue here: we do not always look for maximum or minimum, but for the most preferred, or optimum (like sugar, pepper or spice). We can always find this optimum if we can 'construct' the alternative like the perfect cup of coffee, pepper steak or amount of vanilla in ice cream. Problems occur when we have five lumps in a cup already, *a priori* given, then we cannot reach the optimum sweetness of two lumps; we cannot optimize what is improperly fixed. Similarly, if we have only one lump available, we cannot bring it up to the optimal two lumps. Either way, these are not problems of DM but those of measurement and search. They have obvious solutions if we construct or design proper alternatives.

[†]Niels Bohr once said: 'Every valuable human being must be a radical and a rebel, for what he must aim at is to make things better than they are'. We should welcome youthful rebels because they are the key to the future of MCDM. Persistent conformity to old ideas can be lethal; it is the rebellion that is going to change the ways we do things. MCDM founders were once youthful rebels, but they no longer are.

If the alternatives are given *a priori*, we face the problem of sub-optimality: being stuck with the second best or the 'lesser evil'. This kind of Simon's '*satisficing*' with *good enough* solutions (Brown, 2004) leads to badly designed systems, mediocre decisions and growing social ills. The 'good enough' is *never* good enough for people accepting responsibility for the impacts of their decisions. Choosing the 'lesser evil' becomes a greater evil by the very act of its choice.

We still have to ask: Are all problems with multiple criteria problems of DM? The answer is *no*. Let us return to our basket of apples. It is the same basket and we are searching for the heaviest and the sweetest apple. But this time we can 'construct' our apples by searching 'outside the basket' in order to bring new apples in.

Suppose that an apple, which is both the heaviest and the sweetest, has been added to the basket. This particular apple would be preferred by all decision makers aiming to maximize the two criteria. All and any processes of measurement and search would safely identify such a prominent apple. Clearly, measurement and search can be necessary and sufficient even under multiple criteria.

This thinking 'outside the box' is the key to effective DM. There are *no trade-offs* in our last basket: there is a prominent (or 'ideal') alternative dominating the entire basket—an obvious choice of every rational decision maker. So, the existence of trade-offs is the key to DM: there can be no trade-offs along a single dimension (criterion) or in the presence of a prominent alternative. No DM is needed, measurement and search are sufficient. So, we can state the following:

Decision making is a function beyond measurement and search, aimed at managing, resolving or dissolving the conflict of trade-offs.

Therefore: no trade-offs → no DM—and *vice versa*. The existence of trade-offs is a *necessary and sufficient* condition for DM. Our task is to control, reduce or eliminate trade-offs from decision-making situations. Trade-offs are not good and they are not necessary; they are neither preferred nor desirable; they are a testament to badly designed, inefficient and wasteful systems, the legacy of *satisficing* and the source of human discontent. Trade-offs beg and challenge to be eliminated (Zeleny, 2000).

3. SYSTEMS DESIGN OF OPTIMALITY

The key issue of systems optimization or optimal DM is: should we consider a feasible set of alternatives as given and fixed *a priori*, or should we construct, design or re-design the feasible set so that it satisfies our values and criteria of optimality?

Optimality and optimization fields grapple with this difference between what is already given and what remains to be determined, that is, designed optimally or simply optimized. These two modes, *optimizing the given* and *designing the optimal*, are two mutually exclusive endpoints of a spectrum of mixed combinations. We cannot optimize what has already been given and fixed. It is essential to draw a distinction between *optimization* and *computation*. Within already given systems, we can only compute; we can optimize only by designing new systems *de novo*.

There are at least four *fundamental rules of optimization*:

1. What is strictly determined and fixed *a priori* cannot be subject to subsequent optimization: *it is already given*.
2. What is *not yet fixed* can still be selected, chosen or identified and is therefore subject to optimization.
3. One cannot optimize *a posteriori*, after the fixation. True optimization takes place during the stage of construction or design, that is, *a priori*.
4. Consequently, *different optimality concepts* can be derived from the distinction between what is given and what is yet to be determined—in problem solving, systems design, optimization or DM.

Clearly, there cannot be just one optimization concept, but many; we have counted at least eight different and mutually irreducible concepts of optimality. In Table I, the *eight concepts of optimality* are summarized. In Table I, we list what is given in four rows and the number of criteria in two columns. Individual cells then represent the eight optimality concepts (Zeleny, 1998).

Observe that the first cell of *Traditional optimum* is the only one that does not involve *any* optimization whatsoever. There is a single given criterion (or objective function) and all alternatives are fixed *a priori*, either through enumeration or through well-defined and fixed constraints. There is nothing to be optimized. Observe also that this is a problem of *search only* because the criterion (measurement) is fully (even mathematically) pre-specified. A more precise designation for this cell would be *computation*. The solution is implicit and given through problem formulation, it is made explicit through computation.

DOI: 10.1002/mcda

Table I. Eight concepts of optimality

Eight concepts of optimality		
	Number of criteria	
What is given	**Single**	**Multiple**
Both criteria and alternatives	**Traditional optimum** measurement and search	Traditional **MCDM**
Criteria only	**Optimal design** *De novo* programming	**Optimal design** Tradeoffs elimination *De novo* programming
Alternatives only	**Optimal valuation** of alternatives Search for criterion	**Optimal valuation** of alternatives Search for criteria
Neither criteria nor alternatives Value complex only	**Optimal matching** criterion and alternatives Cognitive equilibrium	**Optimal matching** criteria and alternatives Cognitive equilibrium

All other cells of Table I can be similarly analysed. Of special importance is the last cell of the second column, *optimal matching*. That is how humans typically make their decisions: very little is given in advance, some alternatives are generated and some criteria chosen to narrow down the feasible set. Then additional alternatives are brought in, some others are dropped, and criteria are re-examined. New sets or combinations of criteria are tested on changing configurations of alternatives. External and internal points of reference are sought and evaluated. This complex process of *matching* criteria with alternatives goes through many iterations of filtering the choices. Finally, a desirable *equilibrium* between alternatives and criteria is reached, and the final prominent (or closest to prominent) alternative identified and its feasibility is established (Zeleny, 1994).

What is a desirable equilibrium? The one with trade-offs between criteria either eliminated or significantly reduced by successive re-configurations of re-configured alternatives.

One can readily see that the gap between the first and the last cell of Table I is formidable indeed. Traditional computation cannot approximate the complex layers of recurrent optimization involved in optimal matching in search of cognitive equilibrium. The arrow signifies the challenge of moving from computation to optimization. Our optimization procedures must resonate with human values and systems in order to improve and achieve optimal performance. Merely confirming the existing spurious sub-optimality of systems through high-powered computation is not good enough.

4. TRADE-OFFS-FREE DECISION MAKING

The purpose of DM is reducing or eliminating trade-offs. Trade-offs are the sign of inefficient design and suboptimal solutions. Consumers and effective decision makers are repulsed by trade-offs because they make their DM harder, less transparent and redolent of *post-decision regrets*.

With multiple criteria, trade-offs bring forth the use of solution concepts like Pareto efficiency (or optimality), efficiency, non-dominance, non-inferiority, etc. They lead to trade-offs-based alternatives being selected for solutions. Large, small or vast sets, boundaries, frontiers, etc. of non-dominated trade-offs-based alternatives are tirelessly calculated, graphically displayed, colour coded and interactively traversed back and forth—thus framing any MCDM progress within the second cell of the first row of Table I.

Conventional wisdom of MCDM then associates trade-offs with the criteria or objectives used to evaluate sets of alternatives (our 'baskets of apples'). This lies at the root of frequent statements about *conflicting* objectives, criteria or goals. Novices to MCDM then speak freely about trade-offs or conflicts *between objectives*—as if these notions were the properties or attributes of criteria measures. This leads to often misguided efforts to elicit, reveal, describe or quantify trade-offs from comparing and analysing the criteria or attributes *alone*, in a context-free fashion. Such results are clearly inapplicable across changing contexts of recurrently adapted and re-configured sets of feasible alternatives.

It is important to appreciate *at least* four principles informing the concept and attributes of trade-offs:

1. Trade-offs are the *properties of the means* (sets of alternatives), *not* of criteria or objectives.
2. Criteria are merely measures or 'measure tapes' for evaluating (measuring) objects of reality (things, alternatives, options, or strategies). There is a fundamental difference between employed *measures* and *measured objects*.
3. There are *no trade-offs between measures* (or measure tapes). Measures of cost and quality do not produce trade-offs—the set (or configuration) of measured choices (alternatives, options) does.
4. It is the *configuration* (shape, structure) of the feasible set of alternatives that produces or *brings forth all trade-offs*.

These characteristics are represented in Figure 1. Two objective functions, f_1 and f_2, are maximized independently over a series of configurations of different shapes (baskets of apples, feasible sets). Although both functions are fixed and do not change in the process, their relationship is not characterized by any specific form of trade-offs. Depending on the shape of measured objects, trade-off sets emerge or disappear accordingly, ranging from extensive frontiers to single trade-offs-free points, as in Figure 1.

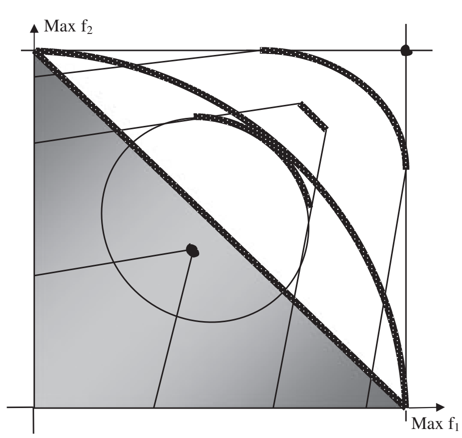

Figure 1. Trade-offs are properties of measured objects.

The shape, size and properties of trade-offs are generated by 'baskets' of alternatives, *not by criteria*.

If we combine this insight with the earlier conclusion that DM is about trade-offs reduction or elimination, then DM must be primarily about designing superior (preferably optimal) sets of alternatives, as emphasized in Table I.

Can we define economic efficiency through trade-offs? Can it be efficient if one side, person or criterion gains only what the other side loses? Is it a desirable state? At the Pareto-efficient point no free transaction is possible because the gain of one person (or one criterion) implies the loss to the other. Free-market transaction postulates that both sides must benefit. How can 'efficient allocation' imply that scarce resources are squandered through inefficient allocation? Elimination of trade-offs is the key (Zeleny, 2009, 2010b).

4.1. *De novo* programming

How do we eliminate trade-offs technically? In linear cases, we can use *De novo programming* with all its many variations (Zeleny, 2005b). Here, we outline just a simple example in order to avoid delving into theoretical and computational details.

Traditionally, linear programming (LP) occupies just the first row of Table I–it is concerned with computation, not design. The methodology of LP requires that constraints of feasible set (levels of resource availability and technology) are given *a priori*. Why is it that in a free-market economy LP resources do not have to be purchased and market prices are not needed for optimization? How can any *resource allocation* become optimal without considering market prices of resources?[‡]

In order to achieve true optimization, we have to transform the feasible set configuration from the one on the left to the one on the right in Figure 2. Then the trade-offs are eliminated, and we have achieved a solution preferred by all rational decision makers. Such *configuration transformation* can be achieved by *De novo* programming (most simply in linear cases) as in Table II.

[‡]This dilemma can be partially explained by the fact that LP is the product of central planning and command resource allocation in the USSR of the 1930s. First formulated and solved by the late Nobelist L.V. Kantorovich, LP was accepted in the West after World War II (e.g. G. Dantzig and his simplex method) but, curiously, with the Soviet 'given resources' stipulation–contrary to all free-market economy assumptions, practices and DM.

DOI: 10.1002/mcda

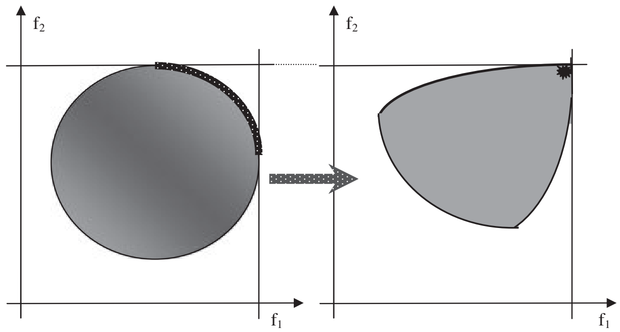

Figure 2. Trade-offs can be eliminated by design.

In Table II, we face a simple resource allocation problem with five resources, two objective functions f_1 and f_2, market prices of resources and a portfolio of initially given (available) resources. The cost of this 'given' portfolio is \$2600 at current prices. We can restate the problem as an LP formulation and solve it via *De novo* methodology (Zeleny, 2005b, 2010a):

$$\text{Max } f_1 = 400x + 300y$$

$$\text{Max } f_2 = 300x + 400y$$

subject to		*NEW*
$4x$	≤ 20	≤ 16.12
$2x + 6y$	≤ 24	≤ 23.3
$12x + 4y$	≤ 60	≤ 58.52
$3y$	≤ 10.5	≤ 7.62
$4x + 4y$	≤ 26	≤ 26.28

Maximizing with respect to f_1 gives x^*=4.25 and y^*=2.25, f_1^*=2375. With respect to f_2, the maximal solution is x^*=3.75 and y^*=2.75, with f_2^*=2225. Total cost of resource portfolio (20, 24, 60, 10.5, 26) is B=\$2600. (For the prices of the five resources see Table II).

Assuming that we live in a free-market society, let us purchase the amounts listed in the NEW column of the above formulation. This NEW portfolio of resources, calculated via *De novo programming*,[§] allows maximizing both criteria f_1 and f_2. The optimal allocation is x^*=4.03 and y^*=2.54 with f_1^*(4.03, 2.54)=2375 and f_2^*(4.03, 2.54)=2225. Both of the maxima are now achievable simultaneously. *Trade-offs have been eliminated*.

[§]The meaning of *De novo* is anew, afresh, from the beginning; without consideration of previous instances, proceedings or determinations, that is, designing the portfolio of resources anew, disregarding the 'given'.

How much do we pay for the NEW portfolio? Assuming the same prices of resources as in Table II (p_1=30, p_2=40, p_3=9.5, p_4=20, p_5=10), the total cost of the NEW portfolio is \$2386.74; that is *less* than the original \$2600. So, a better performance has been achieved at lower costs (itself a trade-offs-free deal) because no resources are being wasted; the system can be further improved. Trade-offs remain eliminated.

Optimization is not about valuation or confirmation of the 'bad' (given, feasible) set of alternatives, but about *enabling* the 'best' (designed, optimal) set of alternatives. Obviously, the better the alternatives are, the better the final results will be. Trying to make the best of the worst situation is not good enough; creating the best possible situation–and then improving on it—brings forth the best possible, that is, good enough, results.

Traditionally, we first determine and fix the feasible set, *then* search for a solution. It is simple, computationally trivial and economically wasteful. It is more effective to reverse the paradigm: first propose a solution, *then* establish its feasibility and cost and make the necessary adjustments. That is how *De novo* programming works: it postulates the best (trade-off-free) affordable solution, then it designs its feasibility. To summarize the *De novo* philosophy:

1 Identify a desirable and *affordable* optimal solution.
2 Construct its *requisite* feasibility set.
3 Evaluate its *cost* and adjust the solution.
4 *Re-configure* the requisite set.
5 Design the optimal *enabling* set.
6 The *optimal solution* is implied and enabled.

In short, first get the solution, and then construct its *enablers*, not constraints.

5. CONFLICT DISSOLUTION

We live in the age of conflict. Yet, our conflicts do not ever seem to be adequately resolved, they tend to persist or come back after a period of apparent but *de facto* artificial and false 'resolution'. It is time to consider *dissolving* conflicts, rather than simply *resolving* them.

Conflict is an exemplary multiple criteria problem. There can never be a conflict unless there is a confrontation of *multiple* criteria, goals, purposes, points of view or preferences. Conflict should be a pre-eminent area of study within MCDM. Unfortunately, one of the paradigmatic fictions is the notion

DOI: 10.1002/mcda

Table II. Resource allocation problem

Material resource	Market price $/unit	Units needed to produce $x=1$	Units needed to produce $y=1$	Available units/period
1. Cotton	30.0	4.0	0.0	20.0
2. Wool	40.0	2.0	6.0	24.0
3. Silk	9.5	12.0	4.0	60.0
4. Gold thread	20.0	0.0	3.0	10.5
5. Silver lining	10.0	4.0	4.0	26.0
f_1 : *Profits $/unit*		***400***	***300***	
f_2 : *Sales $/unit*		***300***	***400***	

that multiple objectives or goals can be 'conflicting'. Such perception leads to *tautological definition* of conflict as the problem of conflicting goals. Once we accept that 'conflict is when we are in conflict', then it should not be surprising that our culture is unable to 'resolve' such evidently tautological circularity.

We use just a simple example to demonstrate the distinction between *resolution* and *dissolution* of a conflict—there is no space for the underlying theory. Let us assume that Man *M* and Wife *W* plan to go for vacations together: they examine a number of destinations proposed by their travel agent. After they look over the situation in Figure 3, they evaluate their preferences and present their rankings of prospects. It turns out that *M* prefers Las Vegas (LV) and *W* prefers Miami (MI). A prototypical human conflict emerges because they cannot go to both places at once. (It has recently become fashionable to vacation separately, which is elegant, but for us unacceptable and not a very interesting solution.)

So the *process of conflict resolution* ensues: communication, education, information, compromise, negotiation, bargaining, arbitrage, promises, threats, force, violence, war... all has been tried and proposed, all costly, ineffective and time consuming practices. All such conflict resolution rituals are based on the presumption that one party is less adequate than the other, its preferences less reasonable, etc. Yet, the assumption of two mature people, both knowing what they want and why, is most appropriate for understanding the persistence of conflicts.

In the end, nothing changes for *M* and *W* in Figure 3. Whether they communicate, compromise, bargain or threaten, in the end they still have to go to MI, X, Y or LV—there are no other options. Either at least one of them feels miserable, or they both do–*tertium non datur*. The conflict can be *resolved*, but it has not been eliminated; it persists, lingers and often returns in one way or another. This is the problem (and the curse) of the 'givens'. Let us now look at Figure 4.

The travel agent suddenly called with a new prospect: now the city of Chengdu can be added to the list. Both *M* and *W* reapply their long-established preferences to the new set: *M* prefers LV and CH, whereas *W* reaffirms her MI and adds CH. When they compare their notes, CH becomes their natural, uncontested and conflict-free choice. No communication, re-education, brainwashing, threats or marriage counselling was needed. Their conflict has been *dissolved*.

In the middle of the night, the agent calls: '*Oops, Chengdu is no longer available*.' Right away the conflict re-emerges with a vengeance. Put the CH

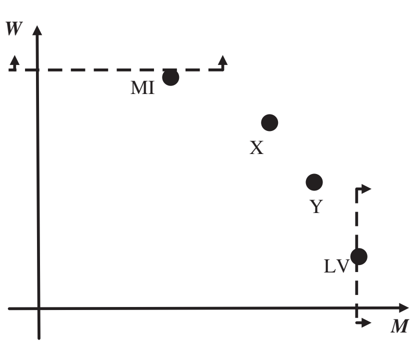

Figure 3. Conflict and its resolution.

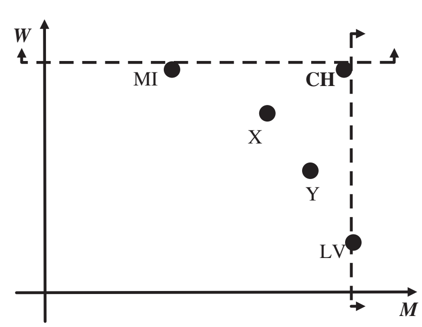

Figure 4. Conflict and its dissolution.

DOI: 10.1002/mcda

back in → no conflict; take the CH out → conflict. That's how powerful the innovative *design* of alternatives can be. Conflict is *not* when two sides, their preferences or objectives 'are in conflict or conflicting', that is true and always the case.

Definition
Conflict is the absence of a prominent (trade-offs-free) alternative.

6. THEORY OF THE DISPLACED IDEAL

In the last row of Table I, we have entered a cell for *optimal matching* criteria with alternatives. As the contents of the 'basket' of alternatives or the configuration of a feasible set are changing, the ranking of alternatives cannot remain fixed but is continually adapted (and so are the criteria). In other words, there is *no independence of ends and means*. Adding and subtracting alternatives always affects preferences for the remaining alternatives; Arrow's famous axiom of *Independence of Irrelevant Alternatives* notwithstanding.[¶]

We have shown that so called 'irrelevant' alternatives are in fact *highly relevant* because they serve as *preferential reference points*, like prominent alternatives, ideals or trade-offs-free targets. The axiomatic approach to non-machine DM has certainly ran its paradigmatic course. Human DM is *context dependent*. Analyses of what is available and of what is desirable, are closely interdependent and interactive. One can recall the 'Let me see what they have, *then* I will tell you what I want' attitude of a young shopper. Let us demonstrate the effect of the Ideal displacement in a simple example (Table III):

Alternatives $\boldsymbol{A}$, $\boldsymbol{B}$, $\boldsymbol{C}$ and $\boldsymbol{D}$ are characterized by two attributes x and y and ranked according to the Euclidean distance $d=[(x^*-x)^2+(y^*-y)^2]^{1/2}$ from the Ideal. In the first case, the ideal point $\mathbf{I}=(x^*, y^*)=(13, 13)$ and the order of preferences thus induced is $\boldsymbol{A}>\boldsymbol{B}>\boldsymbol{D}>\boldsymbol{C}$. Clearly $\boldsymbol{A}$ is the closest to $\mathbf{I}$ and therefore the most preferred.

Let us assume that point D has shifted from (2, 13) to (2, 8). This can be due to an error in measurement, replacement of one alternative by another, addition or deletion of an alternative, a change in perception, etc. In this second case, there is a new ideal $\mathrm{I}=(x^*, y^*)=(13, 8)$, Table III. Using the same distance measure implies the ranking: $\boldsymbol{B}>\boldsymbol{A}>\boldsymbol{C}>\boldsymbol{D}$.

The preferences between A and B have been reversed because of the change in ('irrelevant') D. Also, consider the second case separately and note that B is optimal, followed by A, etc. Let us extend the second case of four alternatives by adding a fifth one, say $E=(2, 13)$. The reader should check that although E is not optimal, the optimality ranking of previously considered alternatives would be reversed: A is now optimal, followed by B, E, D and C. Non-optimal alternative A has been made optimal by adding E to the feasible set. All such examples contradict Arrow's axioms, as does human behaviour and DM.

In comparing A with B, humans use I as a point of reference. Points A and B are rarely compared directly with each other. Rather, A is compared with I and B is compared with I separately and a comparison of A and B becomes an indirect consequence of such a referential process. The so-called *intransitivity of preferences* remains a myth about the essential dynamics of human preferences.

To summarize:

1 There is *no independence* of means and ends or of alternatives and objectives. Both sets evolve together, through mutually matching one another in search of equilibrium.
2 What is available (means) and what is desirable (ends) are interdependent and interactive aspects of the decision-making *process*.
3 Human preferences are derived from referential points: *ideals* or *anchors*. If correct or effective anchors are not provided, spurious and ineffective anchors will be used, destabilizing and degrading the decision-making process.

6.1. Compromise programming

A significant part of the theory of the displaced ideal is *compromise programming* (CP). The original CP-method was designed to *minimize the distance* of the criteria evaluation vectors of feasible alternatives from the ideal point. If one cannot have the best solution—through making the ideal or trade-offs-free point feasible—one should aim for the *second best*.

[¶]Arrow's axiom: If A is preferred to B out of the choice set {A, B}, then introducing a third alternative X, thus expanding the choice set to {A, B, X}, must not make B preferable to A. Clearly, human behaviour and rationality cannot adhere to such a stipulation. Point X does not even have to be feasible: just being used as a point of reference could change human preferential rankings.

Table III. Displacement of the ideal

	First case			Second case		
	Attribute values		Euclidean distance from the ideal	Attribute values		Euclidean distance from the ideal
Alternatives	x	y	d	x	y	d
A	6	7	9.2195	6	7	7.0710
B	10	4	9.4868	10	4	5.0000
C	13	0	13.0000	13	0	8.0000
D	2	13	11.0000	2	8	11.0000
Ideal (**I**)	13	13	0.0000	13	8	0.0000

Compromise programming first calculates a combined n-dimensional distance for each feasible alternative as for example:

$$F_{\mathrm{CP}} = \left[\sum_{i=1}^{n} a_i^p\right]^{1/p} \qquad 1 \leq p < \infty$$

where a_i represents the normalized differences between components i of the *ideal point* and the evaluation of an alternative with respect to criterion i (1, 2, …, n). A normalized difference means that the resulting value is in the range [0, 1]. The alternative with the smallest combined distance is the best proxy for the ideal point. Computing *with respect to all* distances from $p=1$ through $p=\infty$ will produce a so-called *compromise set*, always a subset of the full Pareto-optimal or non-dominated set.

We can modify the CP method by *maximizing* the distance from the worst point (nadir). The structure of CP remains the same, but instead of *minimizing* the distance from the *zenith*, we maximize the distance from the *nadir*.** The *pull* towards the ideal is preferable to the *push* from the nadir: the zenith approach pulls towards trade-offs-free alternative (worthy of being made feasible) whereas the nadir approach pushes towards trade-offs-based alternatives (feasible already).

The value of p in the distance formula expresses how strongly each difference value is emphasized. The case of $p=1$ corresponds to simple average; the case of $p=2$ implies a simple squared distance weighting, whereas if $p=\infty$, only the largest deviation is considered, that is, moving from minimizing the sum of individual regrets to minimizing the maximum regret. In all such cases, the inferior, trade-offs-based solutions are still computed and recommended, even if re-designing towards the feasibility of trade-offs-free options is always preferred by all customers or decision makers.

**We can also perform both procedures at the same time and take their solution sets intersection: the resulting *compromise set* would be smaller than for each case separately.

7. DECISION PROCESS

Decision *making* is not just an outcome (decision) but a complex process of selecting *criteria* (and their measures), determining *alternatives* (or options) gathering, evaluating and processing *information*, producing and evaluating partial or *intermediate results*, reconsidering criteria, alternatives and information on the basis of achieved results, and repeating (recycling) the process until an actionable outcome (a decision) has been reached. Each partial decision influences and frames the context of the next one (Zeleny, 2008b).

Coordinating such a process refers to the *knowledge* or skill of DM. When mastered, this complex process becomes professionally practical and routine. The interface between decision-making knowledge and decision-making information has been established: *knowledge refers to the coordination* of the decision process (and its cyclical iterations), whereas *information is one of the inputs* into the process. The difference between process and input (or output/outcome) is fundamental: any careless confounding of knowledge and information (or DM and judgement) can only be harmful to humans (Pfeffer and Sutton, 2000). Judgement can be an input into the decision-making process, but not vice versa.

In Figure 5, we display a simplified scheme of the decision-making process. *Preceding and subsequent decisions* are important in providing or revising the necessary *context* for the current decision. No

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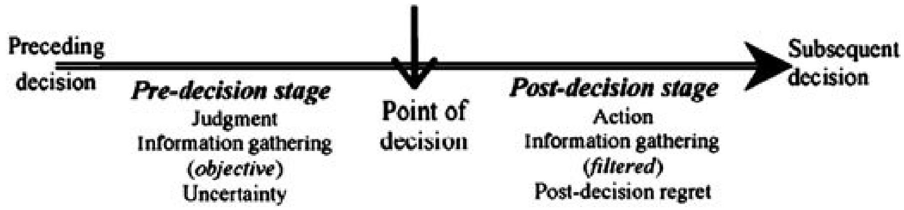

Figure 5. Pre-decision and post-decision stages.

decision is an island. Human action and purpose vary at different stages of the process:

1 *Pre-decision stage*. Basic information is collected, alternatives generated, criteria proposed, etc. Information gathering is mostly objective and unbiased at this stage.
2 *Point of decision*. The most desirable alternative is selected and commitment to its implementation declared.
3 *Post-decision stage*. Additional information is sought, rationalizing the decision, reducing post-decision regret and preparing implementation. Information gathering is now filtered and biased towards the decision already taken.

In some decision-making cultures (styles, habits), the emphasis is on the point of decision, that is, the outcome of the process. This is where the decision support (analysis, computation) is most often applied. The process itself is de-emphasized, left in the background, invisible and considered unimportant: the final outcome is all that matters. Decisions then become points in time, taken out of context, with little or no embedding within the process. They are often analysed *per se*, without their defining circumstance.

In other cultures, the point of decision is de-emphasized and focus turned towards the process itself. Both pre-decision and post-decision stages are analysed in detail, often partially overlapping and proceeding in parallel. The decision is brought forth by the process; it does not serve as the sharp *separator* of the pre-stages and post-stages, but as their integrating *linkage*.

Although *outcome-based* decision-making prevails in some western cultures (e.g. the USA), *process-based* decision-making is practiced more in Asian cultures (e.g. Japan). This dichotomy is probably temporary and is unlikely to persist with globalization of DM. The quality of a decision depends on the quality of the underlying process. The better is the process of DM, the better are the decisions—but not vice versa: better outcome does not imply a better underlying decision-making process.

Learning (and therefore improving) decision-making skills cannot take place through analysing outcomes only. Learning is intimately related to the process and its coordination. Inputs and outputs of the process are information; coordination of the properly structured process implies knowledge. The dominant function of the pre-decision process is the *generation of alternatives* (options, ends).

It is precisely the quality and nature of available decision alternatives (their identification, creation, invention or design) that determine the quality of decision outcomes. It is not the criteria, measurement or evaluations that are primary in determining decision quality–it is the configuration of the feasible set of available alternatives (Zeleny, 2008a).

8. DECISION MAKING AND KNOWLEDGE MANAGEMENT

The link between DM and knowledge management (KM) is quite natural and instrumental. Although knowledge is related to the process coordination, information is an input into the process. Let us draw a distinction between information and knowledge, so that we do not confuse DM and KM with information-processing technology (Carr, 2003, 2004).

Information is always an input whereas knowledge refers to the coordination of value-adding and information-transforming process, like decision *making* (Zeleny, 2005a, 2006a). *Knowledge is a purposeful coordination of action*. Coordinated action is the test of possessing knowledge: *All doing is knowing, and all knowing is doing*.

Repeated action leads to accumulated experience and thus to enhanced understanding of the process and better knowledge. So, the already *demonstrated ability* to act effectively towards a purpose has value. Whenever we act–make decisions, pass judgments, reorder priorities–we create a context of action, for us and for the others. Every act of knowing brings forth a new context. *Bringing forth a context of coordinated action is human knowledge*. Bringing forth a world manifests itself in all our action and all our being.

DOI: 10.1002/mcda

Information is a symbolic description of action. Also: *information is anything that can be digitized* (Dawson, 2005). Information acquires value only if it leads to action (is transformed into knowledge), which in itself is valuable only in terms of its purposes and outcomes.

A simplified taxonomy of knowledge is presented in Table IV. Although information allows us to do things right (efficiency), knowledge aspires to doing the right things (effectiveness). Doing the right thing, especially in business DM, requires not only knowing how, but also knowing why. *Explicability* of purpose is an essential ingredient of its effectiveness in attainment. *Wisdom is about explicability and ethics* of human DM (Zeleny, 2006b).

It is quite remarkable that certain strains of KM have conflated information with knowledge (tacit and explicit) and MCDM has all but ignored human knowledge. All knowledge is tacit whereas all information is explicit.

8.1. Knowledge-information cycle

To pursue any action effectively, we have to integrate knowledge and information flows into a *unified system of transformations*. The purpose of knowledge is more (and better) knowledge (action), not just more information (descriptions).

Useful knowledge can be *externalized* and codified into its descriptions. Thus obtained information is then *combined* and adjusted to yield more useful, actionable information. Actionable information is *internalized* as input into more effective coordination of action (knowledge). Effective knowledge is then socialized and shared, that is, transformed into usefully distributed knowledge. In short, the cycle (knowledge → information → knowledge) can be broken into its constituent transformations (Nonaka, 1991; Kazuo and Nonaka, 2006):

$$\text{Knowledge}^*(\text{K}^*) \rightarrow \text{Information (I) } (\textbf{E}\text{xternalization})$$
$$\text{Information (I)} \rightarrow \text{Information}^*(\text{I}^*) \ (\textbf{C}\text{ombination})$$
$$\text{Information}^*(\text{I}^*) \rightarrow \text{Knowledge (K) } (\textbf{I}\text{nternalization})$$
$$\text{Knowledge (K)} \rightarrow \text{Knowledge}^*(\text{K}^*) \ (\textbf{S}\text{ocialization})$$

The above sequence E-C-I-S of knowledge and information flows is continually repeated in a circular organization of *knowledge production*, as in Figure 6. The E-C-I-S cycle is renewed at an improved and more effective level after each iteration. All phases, not just the traditional *combination* of Information Technology (IT), have to be managed and coordinated *as a human system* (Zeleny, 2005a).

It is clear that the *internalization* of information into the process of knowledge production is the key. That is, the process I → K → K* → I* adds value to information through knowledge socialization (sharing, observing, imitating, repeating), whereas K → I → I* → K* adds value to knowledge through information combination (analysis, research, data mining, integration, synthesis, interpretation).

9. INTEGRATED DECISION SUPPORT

Decision-making support should be integrated in all five dimensions [**D**ata (D) → **I**nformation (I) → **K**nowledge (K) → **W**isdom (W) → **E**nlightenment (E)] across the entire DIKWE chain of Table IV. DIKWE chain represents an ascending, integrated whole, balancing symbolic descriptions, action and value explication towards synergy.

Data, Information, Knowledge, Wisdom and Enlightenment are all valuable resources for successful business action and DM. All such resources must *work together*, in an integrated fashion, in order to effectively bring to fruition qualitative improvement of individual and corporate DM.

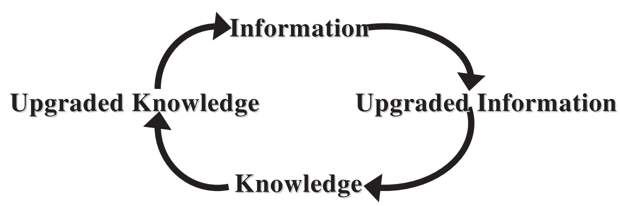

Figure 6. The knowledge-information cycle.

Table IV. Data, information, knowledge, wisdom and enlightenment chain and taxonomy of knowledge

	Technology	**Analogy** (baking bread)	**Effect**	**Purpose** (metaphor)
Data	**EDP**	**Elements: H_2O, yeast, bacteria, starch molecules**	**Muddling through**	**Know-nothing**
Information	**MIS**	**Ingredients: flour, water, sugar, spices + recipe**	**Efficiency**	**Know-that**
Knowledge	**DSS, ES, AI**	**Coordination of baking process → result, product**	**Effectiveness**	**Know-how**
Wisdom	**WS, MSS**	**Why bread? Why this way**?	**Explicability**	**Know-why**
Enlightenment	**Personal BSC**	**This bread, for sure**	**Truth, insight**	**Know-yourself**

EDP, Electronic Data Processing; MIS, Management Information Systems; DSS, Decision Support Systems; ES, Expert Systems; AI, Artificial Intelligence; WS, Wisdom Systems; MSS, Management Support Systems; BSC, Balanced Scorecard.

DOI: 10.1002/mcda

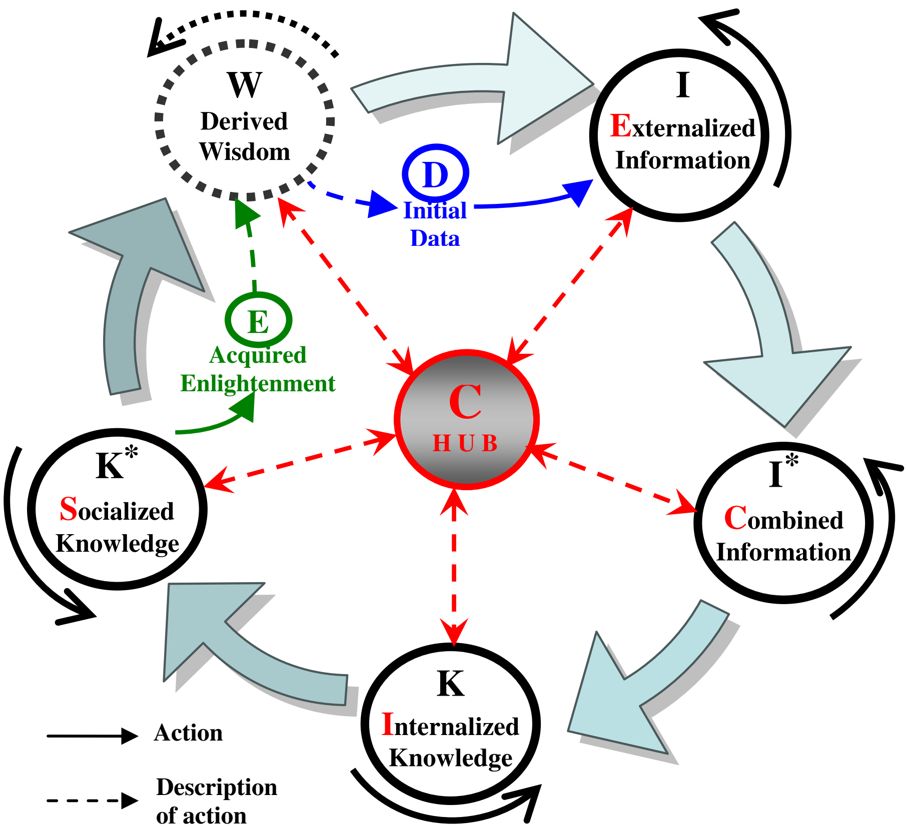

Figure 7. Integrated data, information, knowledge, wisdom and enlightenment (DIKWE) coordination system.

Separate, non-interacting and only loosely connected pursuits of vital business functions lead to wasteful competition for resources and unbalanced development of component functions (Jackson, 2004). Only through the *Hypercycle of cooperative support* can the competition of separate cycles of individual functions be transformed.

In Figure 7, we outline the *Integrated Management Support System*. Modern business management needs an integrated system, not separate and increasingly isolated parts. For example, database management and data mining make hidden information explicit and store it in data warehouses, a small part of the whole. It should not be pursued *per se*, disconnected from the rest of the enterprise. Information has to be combined and internalized into knowledge. Knowledge has to be socialized and shared. From the experience of action, new information has to be externalized and processed as input for the next cycle.

It continues. The newly produced knowledge is circulated and its purposes explicated into wisdom: knowing why to do or not to do something. Wisdom is derived from experiencing action. New initiatives can be justified and initial data collected at the start of a new or parallel cycle. D is a semi-autonomous point of entry, an input from environmental scanning. Finally, after several iterations of cycling experiences, enlightenment can be acquired to strengthen self-confidence in the acquired and in the pursuit of new ventures (Shi, Olson and Stam, 2007). That should not be carried out as separate activities of disconnected teams of experts. E is a semi-autonomous point of exit, an output into individual (and corporate) self-understanding.

Circular knowledge and information flows are stimulated, coordinated, maintained and renewed by the catalytic function of the *Coordination Hub* (C-Hub). The C-Hub functions are performed under the supervision of the coordinator who is responsible for maintaining all necessary transformations of the E-C-I-S cycle.

Clearly, *data mining* does not stand alone but must be directed towards better *information processing*. Information and knowledge are interconnected through mutual externalization and internalization in a self-reinforcing cycle of *knowledge management*: production, maintenance and degradation of knowledge. *Wisdom systems*, as explication of corporate values and experience, provide justification and ethical anchoring for human action. Finally, *enlightenment*

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directs our efforts towards human life and its purpose in social action in civilized society; not just towards technology, science and economics. In the end, it is how we live, not just how we work, produce and consume, that is the ultimate value of *enlightened business and enlightened life*.

10. CONCLUSIONS

We have certainly not explored all the paradigms that could move us towards a more desirable direction of the new (MC)DM, beyond the static computational pursuits of the first row of Table I. This is not about changing our acronym but about pushing the envelope and getting MCDM out of the box. The problem of MCDM should never be just computation, computer graphics or multicolour coding: purely technical pursuits are rapidly becoming commodities—together with information technology (Carr, 2003; Zeleny, 2001). The difficulty has always been with definitions, area delineation and distinction, problem formulation and relevance to human pursuits.

By crossing the boundaries, opening up to areas like economics, DM, management, strategy, and design, the improvement of human systems—not only taking from them but contributing to them actively—would generate a new self-confidence and a lost sense of MCDM innovative trailblazing, which has characterized its early years in the fields of paradigms.

It is certainly acceptable and desirable to *do the same things* better and more efficiently. It is surely more innovative and more promising to *do things differently*; but it is very proper and energizing to also try *doing different things*—at least sometimes.

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DOI: 10.1002/mcda