

# Goal-Based Decision Making

## Using Goal-Oriented Problem Structuring and Evaluation Visualization for Multi Criteria Decision Analysis

Qin Ma<sup>1(✉)</sup> and Sybren de Kinderen<sup>2</sup>

<sup>1</sup> University of Luxembourg, Luxembourg City, Luxembourg  
qin.ma@uni.lu

<sup>2</sup> University of Duisburg-Essen, Essen, Germany  
sybren.dekinderen@uni-due.de

**Abstract.** [Context and motivation]: Goal-Oriented Requirements Engineering (GORE) and Multi Criteria Decision Analysis (MCDA) are two fields that naturally complement each other for providing decision support. Particularly, GORE techniques complement MCDA in terms of problem structuration and visualization of alternative evaluation, and MCDA techniques complement GORE in terms of alternative elimination and selection. Yet currently, these two fields are only connected in an ad-hoc manner. [Question/Problem]: We aim to establish a clearcut link between GORE and MCDA. [Principal ideas/results]: We propose the Goal-based Decision Making (GDM) framework for establishing a clearcut link between GORE and MCDA. We provide computational support for the GDM framework by means of tool chaining, and illustrate GDM with an insurance case. [Contribution]: With GDM, we contribute (1) The GDM reference model, whereby we relate MCDA concepts and GORE concepts; and (2) The GDM procedural model, whereby we provide a decision making process that integrates GORE modeling and analysis techniques and MCDA methods.

## 1 Introduction

Multi Criteria Decision Analysis (MCDA) concerns itself with decision aid for problems with multiple alternatives based on multiple criteria [2, 14]. However, MCDA techniques, tools, and frameworks often start from a well specified decision making problem [6]. By themselves, they provide little aid to structure a decision making problem, e.g. in terms of the alternatives to be considered, the actors involved, and the actor goals. As a response an increasing number of problem structuring methods are used in conjunction with MCDA, see also Sect. 2. In addition, to support decision analysis it is deemed useful to have visualization of a decision making problem by means of software tool support [5, 22]. Such tool support has the potential to foster visual interaction with decision makers,

---

Both authors are members of the EE-Network research and training network ([www.ee-network.eu](http://www.ee-network.eu)).

and/or to facilitate simulation of proposed decision making techniques, which, for example, can *dynamically* visualize the impact of alternative selection on the constituent parts of a decision making problem.

In this paper, we propose to leverage modeling and analysis techniques from Goal-Oriented Requirements Engineering (GORE) for decision problem structuring and evaluation visualization in the context of MCDA. More specifically, we use goal models to capture decision making problems including actors, objectives, alternatives and criteria, and use GORE analysis techniques and associated tool support to visualize the impact of alternative selection on actors' objectives.

Indeed, GORE modeling and analysis techniques have been increasingly used for decision support, e.g., in [1, 11, 21]. To make GORE techniques fit decision making they (loosely) borrow ideas from MCDA literature. For example, [21] provides quantitative (i.e., relying on quantifiable information) decision support for task plan selection in line with enterprise goals. To this end, it first relies on a part of the well established Analytic Hierarchy Process (AHP) [27] to determine the relative priorities of preferences. Subsequently, it follows the Weighted Additive decision making strategy to select the most preferred plan. Another example is [11], which provides a qualitative GORE decision technique (instead of relying on numeric data). It relies on pairwise comparison of alternative outcomes, called consequences, to reason about the satisfaction of goals.

While individual GORE-based decision making approaches often make a valuable contribution, each is a "one-off" approach. This means that they follow a specific selection of decision making strategies and suit one particular decision making situation. However, from decision making literature we know that decision making strategies are adaptive [13, 24, 28]: as one may intuit, rather than having a one-size-fits-all decision making strategy, different situations call for different combinations of strategies.

Furthermore, we observe that the mix of ideas from decision making literature and ideas from goal modeling is usually opaque. For example: [21] foregoes a large part of the decision making technique AHP, picking only a small part to determine importance weights by means of AHP's pairwise comparison. Why only a small part is used, or if alternatives such as ANP (a generalization of AHP) were considered, is left implicit.

As a response to the above, we argue for a clearcut relation between GORE and MCDA. Prominently, such a link would establish a structured connection between two fields that naturally complement to each other, yet are still connected in an ad-hoc way. Furthermore, for the GORE field, this relation would foster flexibility in selecting decision making strategies, as opposed to the "one-off" approaches currently in use.

This paper introduces the Goal-based Decision Making (GDM) framework, to establish this relation. The novelty of GDM is two-fold: (1) The GDM reference model, whereby we elucidate the relation between concepts used in decision making literature, and the concepts used in goal-oriented requirements engineering literature; (2) The GDM procedural model, whereby we provide a decision making process that integrates GORE modeling and analysis techniques and decision

making techniques. We provide computational support for the GDM framework by chaining an example GORE modeling and analysis tool with Microsoft Excel, whereby the latter is used to simulate decision making strategies. Moreover, we apply the GDM framework to an illustrative enterprise architecture case.

Note that as a pilot study to systematically relate GORE and MCDA, this paper only considers a subset of basic decision making strategies (such as the Weighted Additive strategy, or the conjunctive/disjunctive decision rule) in the current version of the GDM framework. The purpose is more to explore their many touching points, rather than to claim complete coverage of the diverse and complex field of MCDA.

The rest of this paper is structured as follows. Section 2 discusses related work. In Sect. 3, we present the GDM framework and elaborate on its key ingredients. In Sect. 4, we apply the GDM framework to an illustrative case in the enterprise architecture domain. Finally Sect. 5 provides a conclusion and outlook.

## 2 Related Work

Several efforts have been made to complement MCDA with problem structuring theories such as the value-focused framework [20], a way of thinking for uncovering desired (end-) values of a decision problem; the Soft Systems Methodology (SSM) [23], an intervention for problem space exploration that consists of guidelines, processes and basic models of means-ends networks; and the use of formal problem structuring methods such as causal (or cognitive) maps [9]. The value-focused framework and SSM are more geared to providing a way of thinking, guidelines (such as SSM's CATWOE), and problem exploration processes. Similar to many techniques from the GORE domain, formal problem structuring methods use models (e.g., causal maps) as the main artifact across the whole process. However, as pointed out by [22], causal maps are not integrated with multi-attribute decision making techniques.

As an answer to this, the authors of [22] proposed an enhanced version of causal maps with integrated support for both problem structuring and evaluation, called reasoning maps. Reasoning maps consist of a network of means-ends concepts and relations between them, plus a specification of relationship strengths [22]. Similar to Gutman's means-ends chains for uncovering customer motivations [17], reasoning maps perform problem structuring by relating detailed attributes (e.g., "fluoride" for toothpaste) to high-level values (e.g., "being healthy") via intermediary consequences (e.g., "avoiding cavities in teeth"). For evaluation, then, reasoning maps can propagate the satisfaction of detailed attributes to the satisfaction of high level values via strengths of relations.

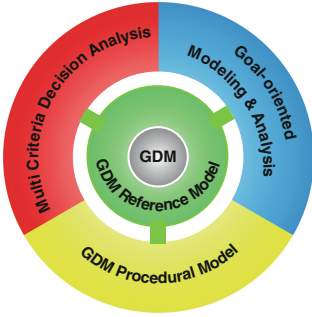
Reasoning maps enable a smooth and seamless transition from decision problem structuring to evaluation, by using a unified modeling notation for both the two phases. However, the modeling power of reasoning maps is limited: (1) only positive/negative contribution links from means to ends are provided; richer relations such as logical (X)OR/AND decomposition from ends to means are not supported; and (2) only qualitative assessments are supported, while quantitative and mixed modes are left out. Such extra expressiveness will enable

additional perspectives from which the problem space can be explored. More importantly, reasoning maps have little visualization tool support: the visualization of decision analysis outcomes is done manually and provides only a single static view. Indeed, software tool support for automated, dynamic, and multi-perspective visualization of decision analysis outputs is regarded as an important future research direction for reasoning maps by [5, 22].

Having discussed problem structuration and visualization from the perspective of MCDA, we now turn to our core contribution: GDM, which systematically links GORE to MCDA.

### 3 The GDM Framework

The main idea behind the GDM framework is to elucidate the connection between MCDA literature (e.g., as found in business discourse) and GORE literature, so as to provide an *integrated* approach towards problem structuring and multi criteria evaluation. To accomplish this connection, the GDM framework consists of four key parts, as depicted in Fig. 1.



**Fig. 1.** The Goal-based decision making (GDM) framework

decision making strategies, both exhaustive ones (acting under full information, no time constraints, etc.) as well as heuristic ones (allowing one to select alternatives that are “good enough”, using limited decision making effort). In addition, we exploit guidelines on selecting decision making strategies (extracted from decision making literature); (3) *The GDM Reference Model* represents the static aspect of the GDM framework. It incorporates key concepts (and their relationships) from GORE literature and MCDA literature, and makes explicit the bridge between the two domains; (4) *The GDM Procedural Model* represents the dynamic aspect of the GDM framework. Whereas the GDM reference model underpins conceptually the GDM framework and captures the relevant concepts, the GDM procedural model defines a process to guide decision makers to perform a decision making activity according to the GDM framework. During the process, we use the aforementioned goal-oriented modeling techniques, analysis techniques and decision making techniques, and operationalize the concepts captured in the GDM reference model.

(1) *Goal-Oriented Modeling and Analysis*, borrowed from GORE literature. On the one hand, the conceptual modeling techniques allow for expressing the decision making problem of interest. Here, conceptual models refer to visual artifacts that provide an abstraction of the situation under investigation, expressed in terms of concepts whose understanding is shared by the involved modeling stakeholders [7, 29]. On the other hand, the goal-oriented analysis techniques allow for analyzing a particular alternative and visualizing the impact of choosing this alternative; (2) *Decision Making Techniques*, borrowed from MCDA literature. These decision making techniques consist of

The GDM framework is generic with respect to application domains. This is partially the result of the two domain independent streams of literature that we base ourselves on, namely GORE and MCDA literature. On the one hand, GORE techniques have been applied to a variety of domains, such as enterprise architecture [1], regulatory compliance [15], and business-IT alignment [12], to name a few. On the other hand, decision making techniques are applied similarly across domains [16] e.g., the legal, business, and medical domain. Moreover, we assume the design of the GDM reference model and GDM procedural model that bridge between GORE and MCDA can also be kept generic. This is exemplified by the application of the GDM framework in an insurance case study discussed in detail in Sect. 4.

In addition, the GDM framework can support quantitative, qualitative and hybrid reasoning techniques. For example, the insurance case study reported in Sect. 4 works with hybrid data on the GORE side and employs quantitative analysis on the MCDA side.

### 3.1 Goal-Oriented Modeling and Analysis

GDM uses GORE modeling techniques, such as GRL [18], TROPOS [8] and  $i^*$  [30], to structure decision making problems in terms of goal models. The prominent intentional concept “goal” is used to capture actor purposes. Other intentional concepts such as “resources” and “tasks” can be used to indicate alternative means for achieving these goals. Furthermore various relationship types can be used for specifying relations between intentional elements. For example, a means-ends relation (e.g., a contribution relation or a decomposition relation) can be used to specify that the goal “Rabbit be fed” is fully satisfied by executing the task “Give three carrots to the rabbit”.

In terms of individual alternative analysis, GDM uses (semi-)automated GORE analysis techniques to compute quantitatively and/or qualitatively the impact of selecting an alternative on actor goals. Such analysis techniques rely on a goal model’s intentional elements and their relations to propagate, throughout the goal model, an initial set of populated values. For example: by satisfying the task “Give three carrots to the rabbit” for  $1/3$  (i.e., to give one carrot), via the means-ends relation the goal “Rabbit be fed” is also satisfied by  $1/3$ .

Finally, the concept “soft goal” is used to distinguish amongst alternatives that satisfy equally a goal. For example, the soft goal “Healthier rabbit” can be used to distinguish between the resource “Biological carrot” and the resource “Non-biological carrot”.

### 3.2 Multi Criteria Decision Analysis

In GDM, Multi Criteria Decision Analysis (MCDA) refers to various decision making strategies to select among alternatives, and guidelines about which strategies to use in which circumstances. In line with [13, 24, 28], we distinguish between two strategy types: compensatory and non compensatory. By employing *compensatory* strategies, one evaluates alternatives on a complete set of

attributes, and, as implied by name, one allows a low score on one (or more) attributes to be compensated for by scores on other attributes. Typical examples of a compensatory strategy are Weighted Additive and Unweighted Additive decision strategies. By employing *non compensatory strategies*, one relies on heuristics to select amongst alternatives. Thereby, one eliminates alternatives that fail to meet a (small set of) minimal attribute and selecting an alternative that is “good enough”. A typical example of a non compensatory strategy is the disjunctive rule, whereby an alternative is discarded if it fails to meet a minimum cutoff for one attribute, regardless of the score on remaining attributes.

To select strategies suitable for a particular decision making scenario, we rely on guidelines established in the decision making literature. For example in the context of consumer buying decision making, [28] identifies categories of decision making scenarios, e.g., lightweight investment such as buying a pack of salt, and heavy investment such as selecting a mortgage offer, and provides guidance on when to apply a complex but comprehensive decision making strategy such as AHP, and when to use a simple heuristic, such as the disjunctive rule. Furthermore, [16] argues that under time pressure non compensatory decision strategies such as the disjunctive rule outperform compensatory strategies, and that non compensatory strategies perform well for uncertain decision problems (i.e., when acting under incomplete information, or when the impact of a decision on future decision is hard to predict and control).

### 3.3 The GDM Reference Model

The GDM reference model as depicted in Fig. 2 integrates concepts from both GORE and MCDA literature and identifies relations among these concepts to establish the bridge between them. It is specified in terms of a metamodel, and provides a formal underpinning of the GDM framework.

Regarding the GORE concepts, a core subset of the Goal-oriented Requirements Language (GRL) [18] metamodel is used. This subset covers the main concepts that are shared with other often-used goal modeling languages, such as TROPOS [8] and i\* [30]. However, we take GRL as the baseline because it is standardized by the Telecommunication Standardization Sector (ITU-T) and has a mature tool support in terms of jUCMNav<sup>1</sup>.

Regarding MCDA, a core set of concepts common to the area is extracted and formalized into a metamodel. Note here that while there exist a diverse amount of multi criteria decision making techniques, underlying them is often an unchanging limited amount of core concepts [25], such as “alternatives”, “attributes”, and “cutoff values”. This eases the formal conceptualization of concepts from MCDA literature, for example allowing us to add new decision strategies without having to change the core concepts that we rely upon.

Note that our reference model (Fig. 2) includes only a subset of basic decision making strategies from MCDA, focusing on multi attribute theory for the compensatory part and decision rules for the non compensatory part. This is because the current paper is meant as a first step to clarify the relation between

<sup>1</sup> <http://jucmnnav.softwareengineering.ca/ucm/bin/view/ProjetSEG/WebHome>.





the one-to-one correspondence between **DecisionStep** and **DecisionMakingStrategy** in the metamodel). The concatenation of multiple steps into a **DecisionMakingProcess** then continues until one alternative remains. This unique alternative is the final decision. Note that decision making strategies can themselves vary from a simple one-stage heuristic, such as the conjunctive rule, to a complex multi-stage strategy, such as AHP. The notion of a **DecisionStep** is not to be confused with the internal stages of a decision making strategy. More specifically, in case a multi-stage strategy is applied within a **DecisionStep**, the execution of the step involves several stages. But these internal stages are all encapsulated in one step and are not visible to the **DecisionMakingProcess**.

For each **DecisionStep**, we advise the decision maker to follow guidelines established in the decision making literature to select an appropriate strategy (cf. Sect. 3.2). Information about the decision making task faced by a **DecisionStep**, e.g., to reduce the size of the alternative set to a great extent within a short time interval, or to compare comprehensively limited number of alternatives, can be documented in a **DecisionRationale** connected to the **DecisionStep**, together with the relevant guidelines applicable in tackling such a task.

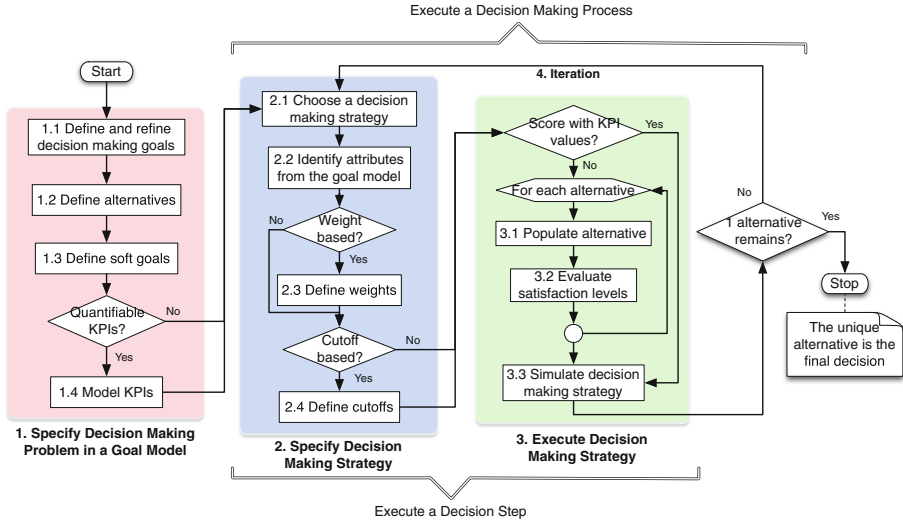
Finally, our reference model anchors attributes (used by MCDA strategies to select alternatives) also in GORE literature. This is because how well an alternative serves the purpose should be judged by how well the intended goals are achieved by the alternative. More specifically, we allow the following three intentional elements: **Goal**, **Softgoal**, and key performance indicator (KPI), to act as attributes for assessing alternatives in the GDM framework. This is formalized by an OCL constraint (omitted due to lack of space). Each individual alternative is assessed by GORE analysis techniques, and the results of all alternatives are synthesized by MCDA strategies to make a final decision.

### 3.4 The GDM Procedural Model

The GDM procedural model as depicted in Fig. 3 guides decision makers to reach a decision within the GDM framework. It consists of three main steps and is iterative between Step 2 and 3. More specifically, the procedure starts with Step 1 which entails framing the decision making problem in terms of a goal model and identifying alternatives and selection criteria in the goal model in terms of tasks, resources and soft goals. Then the procedure continues with executing a **DecisionMakingProcess** (cf. the GDM reference model in Fig. 2) in terms of a loop between Step 2 and 3. One iteration of Step 2 and Step 3 corresponds to the execution of one **DecisionStep** by applying one decision making strategy (strategy selection in Step 2 and execution in Step 3) to eliminate alternatives. As such, repetition of Step 2 and 3 gradually narrows down the set of alternatives until there is only one alternative left — the final decision.

**1. Specify decision making problem in a goal model.** The decision maker needs to first specify the objectives and the context of the decision making problem. This is done by goal modeling whereby he identifies key actors and their goals, and refine goals into subgoals. Next, alternative ways to achieve





**Fig. 3.** The GDM procedural model

goals are identified and an additional set of soft goals is specified. If external quantitative data sources exist to measure the satisfaction of (soft) goals on a per alternative basis, they can be models as key performance indicators (KPIs).

**2. Specify decision making strategy.** Using the goal model as input, the decision maker then proceeds with the first round of alternative elimination (realized by this and the next step). It starts by selecting a decision making strategy and uses the information from the goal model to populate the strategy. More specifically, a set of goals, soft goals, and/or KPIs is identified as attributes to be used as criteria in the selected decision making strategy. Moreover, in case the strategy involves weights and/or cutoffs, these parameters are also specified. Note that the conversion of goal related intentional elements (i.e., goals, soft goals and KPIs) to attributes (used by MCDA strategies as criteria) is enabled by the cross domain relations defined in the reference model.

**3. Execute decision making strategy.** In this step, the decision maker first needs to score each individual attribute for each alternative. These scores can come from two sources. Either the measured values for KPIs can be used directly, or the satisfaction levels of the attributes (which are goals, soft goals, and/or KPIs in the goal model) will be calculated in the goal model and used. The latter case is achieved by Step 3.1 and 3.2. In Step 3.1, the decision maker populates an alternative in the goal model by assigning initial satisfaction levels to the intentional elements constituting the alternative in terms of a *EvaluationStrategy*. Because any goals, soft goals, and KPIs in the goal model can act as attributes (see Fig. 2), these initial satisfaction levels need to be propagated throughout the entire goal model. This is done in Step 3.2, by executing the evaluation strategy following GORE analysis algorithms. The satisfaction levels of the intentional

elements that act as the attributes are then used as attribute scores for this alternative.

After scoring attributes for each alternative, in Step 3.3, the semantics of the decision making strategy is simulated to calculate a global score for each alternative by aggregating its individual attribute scores and to select/eliminate alternatives.

**4. Iteration.** Step 2 and Step 3 are iterated until there is only one alternative left. This unique alternative is the final decision.

### 3.5 Tool Support: jUCMNav + Excel

We provide tool support for the GDM framework by chaining the jUCMNav tool with Microsoft Excel. JUCMNav is used for decision problem modeling and attribute scores evaluation for individual alternatives. The macro environment of Excel is used to implement the semantics of decision making strategies for alternative selection/elimination. These two tools are used together by gathering data from jUCMNav and importing these data into Excel.

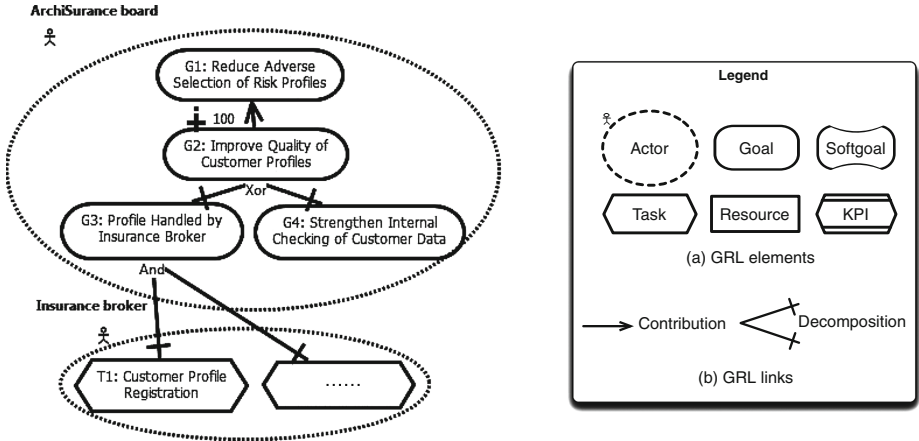
## 4 Applying GDM to Decision Making in the Insurance Domain

The GDM framework is domain independent. In this paper, we demonstrate how it can be applied to a case from the insurance domain. This case is inspired by a paper on the economic functions of insurance brokers [10], as well as the insurance case documented in an Open Group whitepaper [19]. In the remainder of this section, we illustrate the realization of this case by following the GDM procedural model (Fig. 3) whereby we focus on one particular decision problem in the case: choosing an IT solution for registering customer profiles. Note that the example is illustrated with hybrid (quantitative and qualitative) data on the GORE side and employs quantitative analysis techniques on the MCDA side.

**1. Specify decision making problem in a goal model.** ArchiSurance, a large insurance company, aims to reduce the adverse selection of risk profiles of its customers. Adverse selection refers to incomplete or faulty risk profiles [10], which leads an insurance company to sell insurance packages at an inappropriate premium, or worse still, to wrongfully offer insurances to customers.

The ArchiSurance board starts with domain modeling in GRL (Step 1.1 in Fig. 3) to explore how to reduce adverse selection. The goal model on the left side of Fig. 4 captures such an exploration. (A brief summary of the GRL notation is given on the right side of Fig. 4.) Here we see that ArchiSurance’s approach to the adverse selection problem (modeled by G1) is to focus on the root cause of the problem, namely the quality of customer profiles in terms of both completeness and accuracy (modeled by G2).

The board identifies two measures to improve customer profile quality: to strengthen internal check of customer data (modeled by G4), or to outsource the



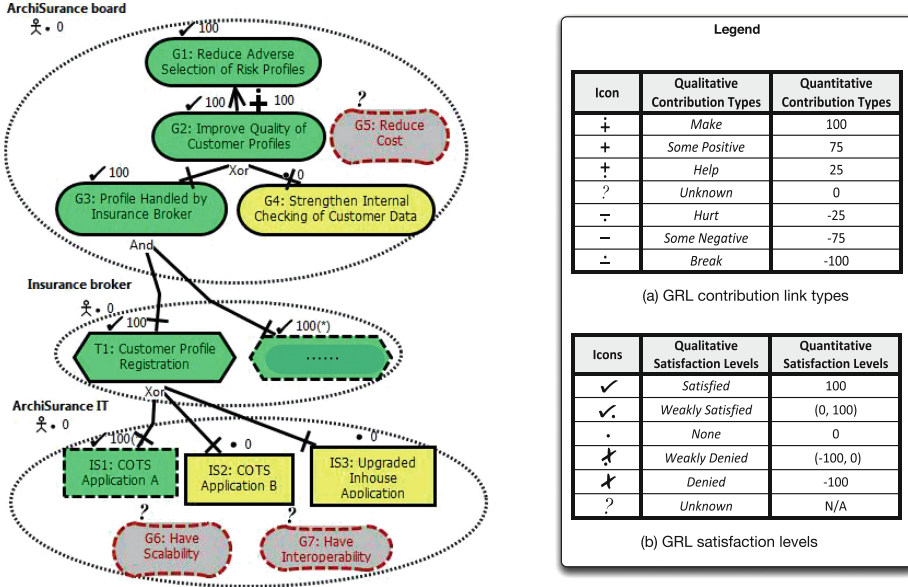
**Fig. 4.** Problem space exploration for ArchiSurance with GRL (left); Basic GRL notation (right)

customer profiles management function to insurance brokers (modeled by G3). Because the broker based model enjoys the advantage of having immediate access to qualified insurance agents with profile collection being an important part of their core competency [10], ArchiSurance first investigates the implementation of this measure.

As shown in Fig. 4, the broker based model entails a set of new tasks to be performed by the broker. For illustration purposes, we elaborate on the task of registering customer profiles (T1) and one decision making problem associated with it: choosing an IT solution for supporting T1.

The ArchiSurance IT department proposes three IT solutions as alternatives for supporting task T1 (Step 1.2 following Fig. 3): “IS1: COTS Application A”, “IS2: COTS Application B”, and “IS3: Upgraded Inhouse Application”. These IT solutions, and their contributions to achieving T1, are depicted in Fig. 5.

Each of the three alternatives can by itself fully support the realization of T1 (depicted by the XOR decomposition from T1 to IS1, IS2, and IS3), which together with other tasks contributes to the full achievement of goal G3, and the subsequent achievement of G2 and G1. Figure 5 visualizes the satisfaction of goals and tasks in case of choosing alternative IS1. This visualization is automatically rendered by the goal modeling software tool jUCMNav for GRL (see Sect. 3.5). jUCMNav can handle both quantitative and qualitative data. More specifically, for specifying contribution links and satisfaction levels, both ways are supported: a quantitative value, ranging from  $-100$  to  $100$ , and a predefined qualitative value (with a predefined icon for representation). Moreover, for visualizing satisfaction levels of intentional elements, a color coding is also implemented, i.e., green for satisfied, yellow for none or neutral, red for denied, and a lot of shades for values in between. The right side of Fig. 5 summarizes these



**Fig. 5.** Alternative IT solutions to support Task T1, and subsequent satisfaction of high level goals, illustrated for alternative IS1

values and the default mapping to convert between quantitative and qualitative values.

In case IS1 is selected, the satisfaction level of IS1 is set to 100 and the satisfaction levels of IS2 and IS3 remain 0 (not selected). Note that satisfaction levels that are set initially are shown with a suffix “(\*)”.

The satisfaction level of IS1 is propagated to T1 as a result of the XOR decomposition link between T1 and IS1-3. Subsequently, the satisfaction level of T1 is further propagated to higher-level goals, (1) via the AND decomposition link between T1-Tn and G3, which states that full satisfaction of all tasks T1-Tn implies satisfaction of G3 (whereby we assume full satisfaction of all Tn,  $n > 1$ , to fulfill the AND), (2) via the XOR decomposition link between G3-G4 and G2, which states that exactly one of the two measures should be implemented and this suffices to achieve G2, and finally (3) via the contribute link between G2 and G1, which states that satisfaction of G2 contributes 100 % to satisfaction of G1.

To distinguish the three alternatives and make a decision, the ArchiSurance also identifies three soft goals capturing their preferences. More specifically, the board prefers a solution that is cost efficient (specified by G5 in Fig. 5), while from an IT perspective, the interoperability with other information systems (G7) and the scalability (G6) are also relevant factors to consider. As a consequence, the final decision depends on how well the three alternatives satisfy these preferred requirements.

KPIs for IS1				
	T	Th	W	V
K2: # Of Intermediaries IS1	2500	500	50	2000
K3: Buying Price of IS1	3.000 €	10.000 €	15.000 €	8.000 €
K4: # Supported Interfaces IS1	5	2	1	5
K5: Training Cost IS1	2.000 €	5.000 €	8.000 €	4.000 €
K1: Cost (=K3+K5)	5.000 €	15.000 €	23.000 €	12.000 €

KPIs for IS2				
	T	Th	W	V
K6: # Of Intermediaries IS2	2500	500	50	2000
K8: Buying Price of IS2	3.000 €	10.000 €	15.000 €	12.000 €
K7: # Supported Interfaces IS2	5	2	1	5
K9: Training Cost IS2	2.000 €	5.000 €	8.000 €	4.000 €
K1: Cost (=K8+K9)	5.000 €	15.000 €	23.000 €	16.000 €

KPIs for IS3				
	T	Th	W	V
K10: # Of Intermediaries IS3	2500	500	50	2000
K11: # Supported Interfaces IS3	5	2	1	5
K12: Development Hours IS3	50 h	150 h	230 h	90 h
K1: Cost (=K12x100€/hour)	5.000 €	15.000 €	23.000 €	9.000 €

T: Target Value; Th: Threshold Value; W: Worst Value; V: Measured Value

**Fig. 6.** KPIs for alternatives IS1-3

tribution to soft goals are depicted by contribution links in the goal model. Figure 8 illustrates the case of IS1 (left) and IS3 (right). More specifically, ArchiSurance introduces the KPI “K1:Cost” to measure the cost of an alternative (depicted by the contribution link from K1 to G5). In case of purchasing a COTS application such as IS1, the cost involves both the buying price (K3) and the training costs (K5). In case of in-house development such as IS3, the cost comes from the amount of labor that is required for the development task (K12). In addition, we measure the number of supported interfaces (K4 for IS1 and K11 for IS3) as an indicator for interoperability (G7) and the number of intermediaries (K2 for IS1 and K10 for IS3) as an indicator for scalability (G6).

**2. Specify decision making strategy.** The ArchiSurance board sets an upper limit (15000€) for the application cost. Any alternative exceeding this threshold will be discarded directly. This corresponds to the disjunctive decision making rule. According to the reference model (Fig. 2), a disjunctive strategy is cutoff based. Therefore, for the specification of this strategy following the procedural model (see Fig. 3), we need to specify the evaluated attribute(s) (Step 2.2) and the cutoff(s) (Step 2.4). The cost attribute is represented by the KPI “K1: Cost” in the goal model, and the given upper limit (i.e., 15000€) denotes the cutoff.

**3. Execute decision making strategy.** This step entails executing the disjunctive rule and rejecting any alternatives whose cost exceeds the cutoff. Because the cutoff is expressed in terms of absolute amount of money (15000€), it is more intuitive and direct to use the measured values of K1 for the scores. These values, together with the cutoff, are then imported into Excel as shown in Fig. 7, left hand side. The disjunctive rule is implemented in terms of an Excel macro. The result of simulating this rule is shown in the first column: IS1 and IS3 are selected, IS2 is eliminated because its cost exceeds the cutoff value.

**4. Iteration.** Because there are still multiple alternatives left after applying the disjunctive rule, we repeat Step 2 and Step 3.

• **Repetition of Step 2.** In this iteration, the ArchiSurance board wants to make a *comprehensive* comparison between IS1 and IS3 with respect to all the

To this end, for each alternative a set of KPIs is defined (in Fig. 6) that provides measurements to enable assessment of the alternatives. More specifically, for each KPI, one needs to specify the *target value*, the *threshold value*, the *worst value*, and the current *measured value*. This enables one to calculate a satisfaction level, depending on where the measured value is in the scale marked by the other three values. Briefly, the closer the measured value is to the target value, the higher the satisfaction level.

Relations among KPIs and their con-

Disjunctive			
Decision	Alternatives	Attribute	K1: Cost
		CutOff	€ 15,000
✓	IS1: COTS Application A	KPIValue	€ 12,000
	IS2: COTS Application B	KPIValue	€ 16,000
✓	IS3: Upgrade Inhouse App	KPIValue	€ 9,000

Weighed additive					
Decision	Alternatives	Attribute	G6	G5	G7
		Weight	0,61	0,28	0,11
✓	IS1	Satisfaction level	75	30	100
		Global score	65		
	IS3	Satisfaction level	25	60	33
		Global score	36		

Fig. 7. Simulate decision making strategies in Excel

three preferences namely cost (G5), scalability (G6), and interoperability (G7). We therefore apply the Weighted Additive strategy. To decide the weights of the three attributes (G5, G6 and G7), we ask the ArchiSurance board to provide us with a relative ranking of importance. We then use the Rank Order Centriod (ROC) formula [4] from the decision making literature to convert the relative importance ranking into the quantitative weights.

• **Repetition of Step 3.** The respective satisfaction levels of the soft goals G5, G6 and G7, in case of selecting IS1 or IS3, will be used as the respective scores of the three attributes. To arrive at these scores, we repeat Step 3.1 (populating an alternative) and Step 3.2 (evaluating satisfaction levels) for IS1 and IS3 individually, by using the goal-oriented satisfaction analysis technique in jUCMNav. Figure 8 visualizes the results in jUCMNav.

More specifically, part (a) of Fig. 8 illustrates the assessment of IS1 against the three attributes. In line with Step 3.1, to populate alternative IS1, initial satisfaction levels ( $[-100, 100]$ ) are provided in jUCMNav to the intentional elements belong to IS1 namely the task “IS1:COTS Application A”, and the KPIs K2, K3, K4 and K5.

In line with Step 3.2, the satisfaction levels of other intentional elements in the goal model are calculated, by propagating the initial values following the

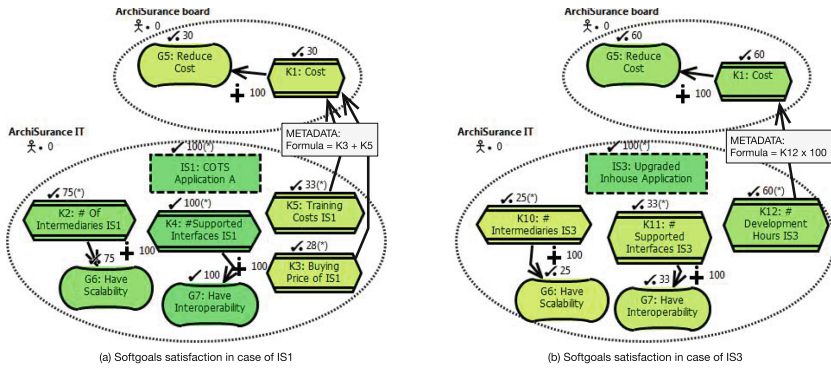


Fig. 8. Assessing soft goals satisfaction based on KPI measurements

contribution and decomposition links in jUCMNav. Following another repetition of Step 3.1 and 3.2, IS3 is similarly scored and visualized in part (b) of Fig. 8.

The visualization offered by jUCMNav shows, per alternative, what impact an alternative selection will have on the high level and low level goals of actors. This allows for a visual comparison across alternatives. For ArchiSurance, one can intuitively tell on which aspects IS1 outperform IS3, and vice versa: purchasing a COTS application (IS1) is more costly than inhouse development (IS3); however, IS1 offers better support for scalability and interoperability.

However, visualization itself can not make a comprehensive trade-off. Therefore, recall that for this iteration, the Weighted Additive strategy was chosen to make a comprehensive comparison between IS1 and IS3. Following Step 3.3, the weights and the satisfaction levels are then imported into Excel for simulation as shown in Fig. 7, right-hand side. Similar to the disjunctive rule, the semantics of the Weighted Additive strategy is implemented in an Excel macro. The result of simulating the strategy on the two alternatives is shown in the first column. Here IS1 is the final decision and IS3 is eliminated, because IS1 has a higher global score (65) than IS3 (36).

## 5 Conclusion

We have presented the GDM framework for goal based decision support, thus elucidating the relation between two streams of literature that naturally complement each other: GORE and MCDA. Particularly, we presented (1) the GDM reference model to bridge GORE concepts to MCDA concepts, and (2) the GDM procedural model to show how GORE and MCDA can be used together dynamically. Furthermore we have shown how to provide computational support for GDM by means of a tool chain. Finally, with an insurance use case we illustrated the dynamic visualization capabilities brought about by introducing GORE software tool support into MCDA.

For future research, we plan to do further practical validation of the GDM framework. This concerns the confrontation of GDM with experts from the GORE, and respectively the MCDA, domain. Informal discussions with people with GORE background already provides encouraging feedback, but this needs more rigor to support claims regarding GDM's usefulness. In addition, in-depth case studies are also on our research agenda, where the usability and effectiveness of the GDM framework will be validated in the presence of real-life data and with the involvement of actual stakeholders.

In this paper we explicitly focused on a limited set of basic decision making strategies from MCDA (see Fig. 2). To explore further the relation between GORE and MCDA we intend to include more decision making techniques into GDM, such as AHP, outranking methods, qualitative methods, and approaches that support decision making under uncertainty. Furthermore, with the expansion of supported MCDA strategies in GDM, a new challenge emerges when it comes to the correct understanding and proper selection of these strategies. In this paper, as a starting point, we advised the decision makers to follow established guidelines, which roughly explain under what conditions a decision making



strategy is appropriate. In future work, we plan to conduct a systematic literature review on this aspect of MCDA and propose a taxonomy of MCDA methods. This taxonomy will complement the GDM framework in helping decision makers in deciding which MCDA strategies are most adequate for a particular selection scenario.

**Acknowledgments.** The authors would like to thank Sepideh Ghanavati for her valuable feedback on the usefulness of the GDM framework. Furthermore, the authors thank Sepideh Ghanavati and Daniel Amyot for their guidance on using the jUCMNav tool. This work has been sponsored by the *Fonds National de la Recherche Luxembourg* ([www.fnrl.lu](http://www.fnrl.lu)), via the PEARL programme.

## References

1. Akhigbe, O., Amyot, D., Richards, G.: A framework for a business intelligence-enabled adaptive enterprise architecture. In: Yu, E., Dobbie, G., Jarke, M., Purao, S. (eds.) ER 2014. LNCS, vol. 8824, pp. 393–406. Springer, Heidelberg (2014)
2. Al-Shemmeri, T., Al-Kloub, B., Pearman, A.: Model choice in multicriteria decision aid. *Eur. J. Oper. Res.* **97**(3), 550–560 (1997)
3. Amyot, D., Shamsaei, A., Kealey, J., Tremblay, E., Miga, A., Mussbacher, G., Alhaj, M., Tawhid, R., Braun, E., Cartwright, N.: Towards advanced goal model analysis with jUCMNav. In: Castano, S., Vassiliadis, P., Lakshmanan, L.V.S., Lee, M.L. (eds.) ER 2012 Workshops 2012. LNCS, vol. 7518, pp. 201–210. Springer, Heidelberg (2012)
4. Barron, F.H., Barrett, B.E.: Decision quality using ranked attribute weights. *Manage. Sci.* **42**(11), 1515–1523 (1996)
5. Belton, V., Montibeller, G.: Qualitative operators for reasoning maps. *Eur. J. Oper. Res.* **195**(3), 829–840 (2009)
6. Belton, V., Stewart, T.: Problem structuring and multiple criteria decision analysis. In: Ehrgott, M., Figueira, J.R., Greco, S. (eds.) Trends in Multiple Criteria Decision Analysis, pp. 209–239. Springer, Berlin (2010)
7. Bjeković, M., Proper, H.A., Sottet, J.-S.: Embracing pragmatics. In: Yu, E., Dobbie, G., Jarke, M., Purao, S. (eds.) ER 2014. LNCS, vol. 8824, pp. 431–444. Springer, Heidelberg (2014)
8. Bresciani, P., Perini, A., Giorgini, P., Giunchiglia, F., Mylopoulos, J.: Tropos: an agent-oriented software development methodology. *Auton. Agents Multi-Agent Syst.* **8**(3), 203–236 (2004)
9. e Costa, C.A.B., Ensslin, L., Cornêa, É.C., Vansnick, J.C.: Decision support systems in action: integrated application in a multicriteria decisionaid process. *Eur. J. Oper. Res.* **113**(2), 315–335 (1999)
10. Cummins, J.D., Doherty, N.A.: The economics of insurance intermediaries. *J. Risk Insur.* **73**(3), 359–396 (2006)
11. Elahi, G., Yu, E.: Comparing alternatives for analyzing requirements trade-offs-in the absence of numerical data. *Inf. Softw. Technol.* **54**(6), 517–530 (2012)
12. Ellis-Braithwaite, R., Lock, R., Dawson, R.: Towards an approach for analysing the strategic alignment of software requirements using quantified goal graphs. *J. Adv. Softw.* **6**(1), 119–130 (2013)

13. Elrod, T., Johnson, R.D., White, J.: A new integrated model of noncompensatory and compensatory decision strategies. *Organ. Behav. Hum. Decis. Process.* **95**(1), 1–19 (2004)
14. Figueira, J., Greco, S., Ehrgott, M.: *Multiple Criteria Decision Analysis: State of the Art Surveys*, vol. 78. Springer Science & Business Media, Berlin (2005)
15. Ghanavati, S., Rifaut, A., Dubois, E., Amyot, D.: Goal-oriented compliance with multiple regulations. In: *The Proceedings of RE 2014*, pp. 73–82 (2014)
16. Gigerenzer, G., Gaissmaier, W.: Heuristic decision making. *Ann. Rev. Psychol.* **62**, 451–482 (2011)
17. Gutman, J.: Means-end chains as goal hierarchies. *Psychol. Mark.* **14**(6), 545–560 (1997)
18. ITU-T: User requirements notation (URN)–language definition, November 2008. <http://www.itu.int/rec/T-REC-Z.151/en>
19. Jonkers, H., Band, I., Quartel, D.: The archisurance case study. White paper, The Open Group (2012)
20. Keeney, R.L.: Value-focused thinking: identifying decision opportunities and creating alternatives. *Eur. J. Oper. Res.* **92**(3), 537–549 (1996)
21. Liaskos, S., McIlraith, S.A., Sohrabi, S., Mylopoulos, J.: Representing and reasoning about preferences in requirements engineering. *Requirements Eng.* **16**(3), 227–249 (2011)
22. Montibeller, G., Belton, V., Ackermann, F., Ensslin, L.: Reasoning maps for decision aid: an integrated approach for problem-structuring and multi-criteria evaluation. *J. Oper. Res. Soc.* **59**(5), 575–589 (2008)
23. Neves, L., Dias, L.C., Antunes, C.H., Martins, A.G.: Structuring an MCDA model using SSM: a case study in energy efficiency. *Eur. J. Oper. Res.* **199**(3), 834–845 (2009)
24. Payne, J.W., Bettman, J.R., Johnson, E.J.: Adaptive strategy selection in decision making. *J. Exp. Psychol. Learn. Mem. Cogn.* **14**(3), 534 (1988)
25. Payne, J.W., Bettman, J.R., Johnson, E.J.: *The Adaptive Decision Maker*. Cambridge University Press, Cambridge (1993)
26. Pourshahid, A., Amyot, D., Peyton, L., Ghanavati, S., Chen, P., Weiss, M., Forster, A.J.: Business process management with the user requirements notation. *Electron. Commer. Res.* **9**(4), 269–316 (2009)
27. Saaty, T.L.: Decision making-the analytic hierarchy and network processes (AHP/ANP). *J. Syst. Sci. Syst. Eng.* **13**(1), 1–35 (2004)
28. Solomon, M.R.: *Consumer Behavior: Buying, Having, and Being*. Pearson, Upper Saddle River (2015)
29. Thalheim, B.: The theory of conceptual models, the theory of conceptual modelling and foundations of conceptual modelling. In: Embley, D.W., Thalheim, B. (eds.) *Handbook of Conceptual Modeling*, pp. 543–577. Springer, Berlin (2011)
30. Yu, E.: Towards modelling and reasoning support for early-phase requirements engineering. In: *The Proceedings of RE 1997*, pp. 226–235 (1997)

Requirements Engineering: Foundation for Software  
Quality

22nd International Working Conference, REFSQ 2016,  
Gothenburg, Sweden, March 14-17, 2016, Proceedings

Daneva, M.; Pastor, O. (Eds.)

2016, XV, 319 p. 77 illus. in color., Softcover

ISBN: 978-3-319-30281-2