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# Logikós: Augmenting the web with multi-criteria decision support

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**Abstract.** There are activities that on-line customers daily perform, which involve a multi-criteria decision challenge. Choosing a destination for traveling, buying a book to read, or buying a mobile phone are some examples. Customers analyze and compare alternatives considering a set of shared characteristics, and under certain criteria. E-commerce websites frequently present the information of products without special support to compare them by one or many properties. Moreover support for decision making is limited to sorting, filtering, and side-by-side comparison tables. Consequently, customers may have the feeling that the merchants interests influence their choices, which are no longer grounded on the rational arguments they would like to put in practice. Moreover, the alternatives of interest for the customer are frequently scattered across various shops, with no support to collect and compare them in a consistent and customized manner. In this article, we propose empowering users with multi-criteria decision making support on any website, and across different websites. We also present Logikós, a toolbox supporting multi-criteria decision making depending on the presentation layer of any Web page.

**Keywords:** E-commerce · Multi-criteria decision support · Web Augmentation

## 1 Introduction

Buying online has become a widespread and increasing practice in the world. According to a report on July 2017 by Statista <sup>3</sup>, the number of worldwide online buyers is expected to increase from 1.32 billion in 2014 to 2.14 billion in 2021, with no decreases in the middle years.

Buying online can be seen as a multi-criteria decision challenge since it usually involves comparing not one but many properties of a same kind of product (evaluating different alternatives), under the same criteria to make a decision

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<sup>3</sup> <https://www.statista.com/statistics/251666/number-of-digital-buyers-worldwide/>

using a concrete process. For instance, Akarte et al. [1] identified 18 criteria for casting supplier assessment (as sample delivery time, maximum casting size or minimum section thickness).

A problem with today's e-commerce websites is that they do not help users to make decisions in a personalized and user-controllable way. There are e-commerce aids to compare products, but these are usually limited to ranking, filtering, and side-by-side property tables. In this sense, e-commerce seems to ignore years of development in decision support systems, which successfully offer straightforward criteria aggregation operators such as the Weighted sum and even richer ones such as the "Ordered weighted sum", "Choquet Integral". After using existing e-commerce platforms, the customers may be left with the feeling that the merchants' interests influence their choices, which are no longer grounded on rational arguments.

Another problem is that the alternatives the customer wants to consider might not all be available in a single e-commerce website, or that the information composing a specific alternative might be available across different sites and with different prices. Customers are not very well supported to collect and compare the alternatives available in various sites in a consistent manner. A solution to this challenge is available in the form of meta-search engines but only for some domains, as Trivago<sup>4</sup> for hotels and flights.

In this article, we propose an approach to empower users with multi-criteria decision making support on any website, and across different websites. We illustrate our approach with a descriptive evaluation in the domain of agricultural machinery. We also present Logikós, a toolbox supporting such decision making approach.

The article is organized as follows. Section 2 introduces key background concepts regarding decision support systems and multi-criteria decision making. Section 3 presents the approach. A descriptive evaluation in the form of a scenario is presented in Section 4. Related Work and the conclusions follow.

## 2 Background

### 2.1 Informed decision making

The information and the tools we might have to support purchase decisions are disconnected. Even though the Web is full of information that we could use to make rational purchase decisions, we hardly use it. Information is ill-structured and incomplete. Information is hard to find. Making a decision based on information sometimes requires complex (e.g., multi-criteria) decision processes, which many people do not know.

When the circumstances make it worthwhile, some decision-makers resort to spreadsheets [6]. A simple web-search for "spreadsheet car shopping" will return multiple hits referring the reader to a variety of prepared spreadsheet templates to help buyers compare and select cars. Such spreadsheets serve two purposes.

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<sup>4</sup> <http://www.trivago.com> Last accessed December 2018

First, they help users to identify key attributes to look for and record them in a structured manner (although, they still need to harvest the information manually). Second, once attributes have been recorded for all alternatives, the spreadsheet helps to make a decision with calculations and comparisons that reflect the priorities and weights that the template's author gave to each criterion.

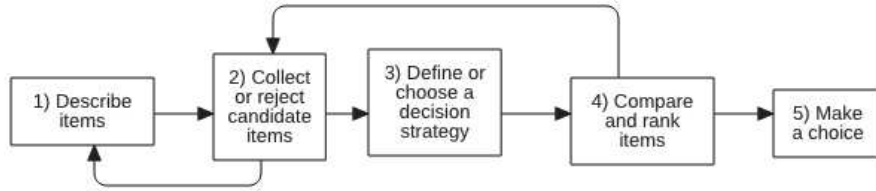
We have observed that some students that are proficient in the operation of spreadsheets use them to create similar templates to buy smart-phones, cameras or personal computers. However, in those cases, the use of the spreadsheet is limited to reproducing the comparison functionality commonly offered by e-commerce websites. That is: a) select candidates, b) have a general overview of the available properties of all candidates, b) compare candidates attribute by attribute, c) sort and filter candidates.

The effort that customers invest in making a decision is directly related to the outcome. There is a trade-off between effort invested and perceived outcome. High stake decisions motivate users to make a more significant effort. When decision makers understand the stakes are not that high, they settle for a sub-optimal alternative, like the first option that meets some threshold criteria or a suggestion from a trusted colleague. This is what the theory of bounded rationality terms "satisficing" [3].

The approach followed by decision makers, like the ones described above, can be characterized by the following process (see Fig. 1. We call it "The spreadsheet strategy for rational purchasing". First, the decision maker describes the items to be purchased (1). The description of the items includes the properties to look for when collecting information. Then, the harvesting starts. The decision maker browses various websites recording information about the items that are a good candidate for purchase (2). The URL of the collected candidates must be recorded so the decision maker can find them again. At some point, the decision maker may identify a new and valuable property, not considered so far. He consequently updates the description of the items and starts collecting the new information from that moment on (1). Ideally, he goes back and updates the information of already collected items that did not include the new properties (2). When an interesting list of candidates is available, the decision maker attempts a decision. For that, he needs to define a decision strategy or use an existing one, like the one created by other users as a spreadsheet template (3), and apply it to rank the so far collected items (4). Applying the decision strategy on already collected items might trigger the need for collecting more items and ever getting rid of some bad performing candidates (2). This iterative process of item modeling, harvesting, and evaluation continues until the optimal candidate is found or the "satisfying" threshold is met.

## 2.2 Multi-criteria Approach

Several schools of thought widely study Multi-Criteria Decision-Making Analysis (MCDA), and the output of the studied techniques is to obtain a ranked list of alternatives. There are two well-known schools of MCDA: the American school and the European school. The American school is based on an evaluation



**Fig. 1.** A model of the spreadsheet strategy for rational purchasing

of a utility function of each alternative. One of the most well-known methods in this school is called the Analytic Hierarchy Process (AHP) that is a mature and widespread process to support decision makers to choose among various alternatives in a context where the decision involves comparing the alternatives according to multiple aspects, each of which contributes differently to the decision. Our approach is based on this method AHP. On the other hand, the European school is not based on the evaluation of a set of matrices but the evaluation of thresholds for each criterion. For each criterion, a preference, indifference and veto thresholds are defined. These thresholds are used to compare alternatives two by two on each criterion and then on several criteria. The two main methodologies are Promethee and Electre. They are less heavy to use than AHP, but the definitions of the thresholds are quite difficult.

AHP helps to identify the aspects to be considered (criteria), supports the exploration of relations among them and their use to choose an alternative. It relies on pairwise comparisons and the judgment of experts to obtain priority scales [8]. AHP has been used a wide variety of domains, as in education, health-care, public administration, telecommunications, manufacturing, and various branches of the Industry (like airlines, defense, entertainment, manufacturing) [7].

At its core, AHP consists of three well-defined steps. First, the decision problem is decomposed into a hierarchy of sub-problems (commonly referred to as decision criteria). Then, decision makers compare the identified sub-problems to each other in order to obtain a model for their relative importance regarding solving the higher level problem. This pairwise comparison among elements in the decision hierarchy is used to obtain the weight or priority of each decision criteria. Such weights represent how much each of the decision criteria contributes to the final decision. At this point, a consistency check can be performed. In any given level, if there are  $C$  criteria,  $\sum_{n=1}^{C-1} n$  pair-wise comparisons are required.

Russo and Camanho conducted a literature review regarding how criteria is being defined and measured [7]. In a few cases, criteria were obtained from literature on the domain. More cases involved experts in defining/selecting criteria. In this study, we use decision makers in a generic way and the proposed approach is designed for a single user or decision maker. The decision makers preferences are modeled in matrices; if the number of used criteria is  $n$ , then the number of matrices to fill in is  $n+1$  depending of the decomposition structure. So, in order to avoid an overload of comparisons, it is important to limit the number

of criteria. Literature suggests that the number of criteria and alternatives be kept at seven or less.

Up to this step, the method does not require an analysis of the available alternatives (e.g. products that the customer considers buying). In fact, an interesting aspect of AHP is that it aims to force the decision maker to explicitly reflect on the decision criteria without focusing his attention into the concrete alternatives (thus reducing the preference bias). AHP is about focusing on the factors; it facilitates the decision making by decomposing a decision-problem into factors and organizing them in order to exhibit the forces that influence a decision [8].

In a final step, the alternatives are compared to each other with respect to the decision criteria, which can be tangible (e.g. price) or intangible (e.g. aspirational appeal). If  $A$  is the number of available alternatives, and  $C$  is the number of criteria, the decision maker needs to make  $C * \sum_{n=1}^{A-1} n$  pair-wise comparisons.

Although pairwise comparisons among criteria and among alternatives are not complex per se, the number of required comparisons rises fast. If 4 criteria are considered, and 5 alternatives are available, the number of pair-wise comparisons is computed as  $(\sum_{n=1}^3 n) + 4 * \sum_{n=1}^4 n = 6 + 4 * 10 = 46$ . Moreover, as the number of pairwise comparisons increases, so does the probability of introducing inconsistencies in the resulting model. This methodology is easy to use but very heavy in real life situations.

### 3 Approach

Our approach is to reduce the cognitive workload of applying the spreadsheet strategy (and similar ones) by offering supporting tools for each of the steps of the process. The resulting platform is called Logikós. Tools for the management of *web information objects* support the earlier activities while *shared decision profiles* support the later ones. Figure 2 provides an overview of the resulting approach. To model items of interest, the decision makers use the templates editor. The result is a template that indicates how to extract an information object from pages that match a given URL pattern. Templates are shared via the templates repository. The items collector uses the available templates to help the user collect items of interest. Collected items are stored in a private repository in the user's web-browser. Using the Multi Criteria Decision Making tool, the decision maker explores the various applicable decision profiles (available in a shared repository) to explore alternative ranking of the collected items. Decision profiles are created and shared by a community of like-minded users, supported by AHP modeling tools. A community of like-minded users is easy to detect thanks to similarity measures introduced in Social Networks.

The following sections discuss each of these elements in more detail.

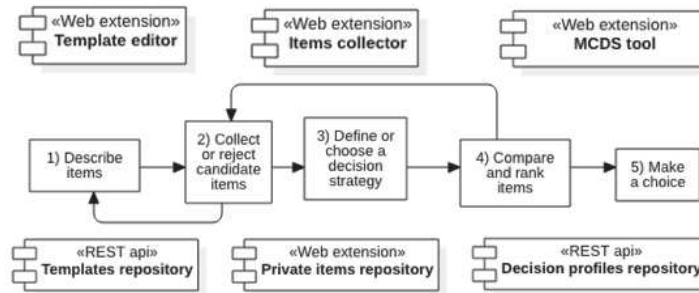


Fig. 2. Approach overview.

### 3.1 Web Information Objects

This approach draws on the facilities offered by Web Objects Ambient (WOA), a platform for collaborative web augmentation [5]. It helps final users collect, structure and share information available on the web, and wield it to attach new functionality to the sites and applications they visit. For this, they do not require any programming skills.

WOA is as a toolbox. Tools can be combined to support different scenarios. The core tools support extraction and storing of information objects from the web. They are the templates editor, the information objects collector, a repository of templates, and two repositories for the collected information objects (a private one and a shared one).

A template editor tool lets users define templates to collect information objects available on websites. A template has a type (identified by a Semantic Web class resource), a URL pattern, and a list of properties that make up the information object. Objects of the same type can be available in various sites. A template for a given object type tells how to obtain such objects from pages with a particular DOM structure. The URL pattern of the templates tells in which pages the template applies to. Properties have a name and an XPath selector. The selector indicates the specific route in the DOM tree that must be followed to obtain the value of the property.

The information object collector is available in all pages that match the url-Pattern of one of the templates in the templates repository. If several templates are available for a given URL, the user can choose which one to apply to extract an information object. Extracted information objects can be stored either in a private repository (local to the user's machine) or in a shared repository.

WOA is implemented following web-augmentation techniques, which means that the functionality it provides can be attached to any website. Web Augmentation is a set of techniques aimed at providing users a means to adapt Web applications to their requirements [4]. There are multiple ways to achieve Web Augmentation (like bookmarklets or extensions at the client, DOM manipula-



tion at a proxy). WOA relies on a client-side technique: the Document Object Model (DOM) manipulation through the API of webextensions <sup>5</sup>.

### 3.2 Shared decision profiles

A decision profile captures how a group of similarly minded users would rank a set of alternatives in terms of preference. It is a decision model based on the properties available on those objects and generates a ranking (from most to less preferable). For example, the “A motor cultivator for home scale farmers” profile captures how family farmers select cultivators, weighing its features such as tilling width, tilling height, transmission type, and price. A similar profile is the one called “A cultivator for farmers cooperative”, that while looking at the same properties of the same information object, ranks giving properties different weights.

A shared decision profile is built as a reusable analytic hierarchy process model (all nodes but the alternatives). The model is the result of the collaborative work of representatives of a certain community of users (family farmers, cooperative farmers, etc.). Following a collaborative process and using existing tools (such as Superdesicions<sup>6</sup>, or GRUS [9] ), users provide the relative weights of the available features of a certain type of item. They then export the model to the repository of decision profiles. The model can be used to obtain the local and overall priorities of a given node. The repository of decision profiles includes a simple, non-collaborative, web-application to create, edit, test, and publish shared decision profiles. A shared decision profile does not depend on the specific alternatives that are the focus of the decision. It only depends on the type of items (in fact, on its properties). Therefore, it can be reused whenever a decision maker understands the profile represents her interests. Only when no available shared profiles refer to the type of item that will be evaluated, or does not represent the interests of the stakeholder, it is necessary to create and share a new one.

### 3.3 Limiting the need of pairwise comparisons among alternatives

Using shared profiles removes the need for pairwise comparisons among criteria. Still, as alternatives depend on the specific situations, pairwise comparisons among alternatives need to be performed. As we have previously discussed, the effort of conducting pairwise comparisons among the alternatives grows with the number of alternatives and criteria. To reduce or even eliminate the need of conducting such comparisons, we introduce the concept of “smart ranking strategy” (or SRS). An SRS describes how pairs of alternatives are to be compared in terms of a given attribute without the need for the decision maker’s intervention.

The UML class diagram presented in Figure 3 highlights the main elements of a shared profile using SRS. A shared profile has a title, a description and the

<sup>5</sup> <https://browserext.github.io/browserext/> - Last accessed on Nov, 2018

<sup>6</sup> <https://www.superdecisions.com/> - Last accessed on Nov, 2018

types of items it helps choose (the type of items is related to the type of items extracted by templates). The root of the decision tree (the goalModel), and the intermediate decision tree nodes (criteria and sub-criteria) are modeled as instances of class Node. The class Alternative extends Node to add the attributes that were extracted by the template. Criteria nodes that refer to tangible properties of the items (such as price, weight, transmission type, etc.) can have an SRS. Three types of SRS are presented in the model (although it can be extended by adding new subclasses in the future).

- A NormalizedNumericDifferenceSRS compares to alternatives in terms of one of their numeric attributes (e.g., price). It takes the difference of the two values, divides the difference by the largest of them and transforms its absolute value to the scale 1 to 9.
- An EquallySpreadValuesSRS has a list of all the possible values for the given item attribute. Then, to compare two alternatives, it obtains the distance between the positions (in the list of allPossibleValues) of the values of both alternatives. This difference is then divided by the total number of possible values and mapped to Saaty's 1 to 9 scale.
- A StorePairwiseComparisonsSRS stores pairwise comparisons for every pair of elements in the domain of a property. , so other decision-makers do not have to perform them. This strategy is only practical when the domain of the property has a manageable number of possible values, and when tools so aid pair-wise comparisons are available (for example, to minimize inconsistency).

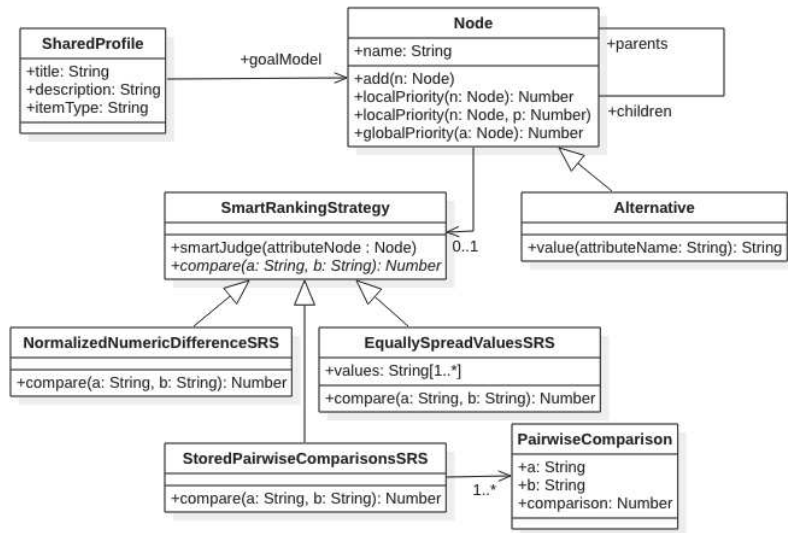


Fig. 3. UML Class model of a shared profile

## 4 Descriptive evaluation: A scenario

The following detailed scenario provides evidence of the utility of our approach to reduce the effort of using a MCDM approach in everyday purchase decisions.

Faustino is a farmer managing a family business that is expanding. He has decided to buy new motor-cultivators, expecting that these artifacts will help his employees with the tillage. He went to the local agribusiness and asked for advice. The salesperson offered multiple cultivators but never asked what he wanted the cultivator for. It did not feel right; there are cultivators better suited for certain kind of soil and dimensions to cover (e.g., having in mind depth and width of the work, type of transmission). Last time Faustino bought tools (a smartphone for everyone in the farm), he used an excel spreadsheet that a colleague suggested. When he asked for a similar spreadsheet but for motor-cultivators, his colleague pointed Faustino to the Logikós website instead <sup>7</sup>. These are the steps he followed to finally make a purchase he felt certain with.

*Getting started:* With some help from the video-tutorials in the “Installing the toolset” section, he was able to install the browser extension and learn how to use it. He first installed the web-extensions and created a new, private, list of alternatives. He didn’t install a server for the templates, he used the default shared public repository. This took about the same time as installing the spreadsheet tool. Next time, the tools will be already available.

*Collecting items:* After a web search, he identified a couple of web-sites that sold cultivators. He started by visiting the molamaq.com web-site. Molamaq.com is a site for motor-based agricultural implements. He realized that another users had already defined a template for cultivators in that site by following the steps 1,2,3 and 4 of Figure 4. The existing template extracts the name of the tool, the price, the width, height and transmission form. Faustino browsed the site looking for cultivators and, as a template was found, the Items Collector was already prepared to extract items from the site. Faustino extracted eight cultivators from this site that he considered within his budget. He did it as shown in steps 6 and 7 of the Figure 5. At this point, he realized the difference of this approach. There was not need to copy and paste all attributes and the URL of the page. He did not make any of the common copy&paste mistakes he did last time (e.g., pasting to a wrong row or column). He felt like he would collect as many candidates as he wanted.

*Defining a template:* Then, he visited mercadolibre.com.ar, a general-purpose e-commerce. He found a cultivator he likes, but he was not able to collect it. Logikós was not prepared to collect items on this website. But following the steps mentioned in Figure 4, Faustino defined an extraction template and push it to the public repository for other users to use. The template extracted the same attributes as the template he used for Molamaq. He collected other six

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<sup>7</sup> <https://sites.google.com/view/logikos/demo-videos>

cultivators from Mercadolibre. He had already collected two of those (the same brand and model) from the first website he visited. However, they were cheaper in mercadolibre.com.ar. Ok, this was something really new. It did not take much time, but he has to learn it. When he finished he realized why the previous step was so simple; someone had prepared a template. He also realized he was now helping others. A new template for this site will not be needed as long as the structure of the site does not change.

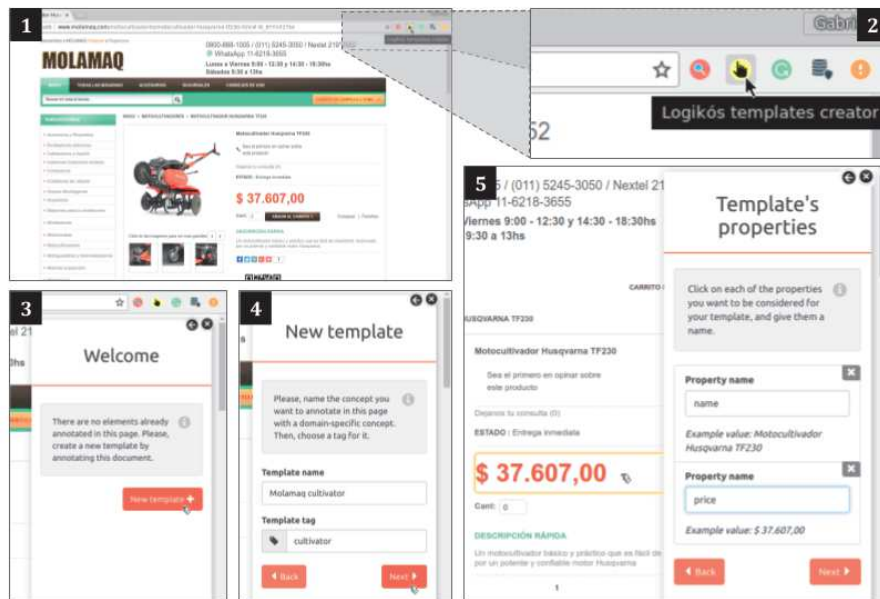


Fig. 4. Creating a template for “Molamaq” cultivators

*Exploring the alternatives list:* In step 8 of Figure 6, Faustino opened his list of collected alternatives through the “Private Item’s repository” and realized he had collected 16 candidates (for 12 different cultivators) from 2 different online agribusinesses. This part felt exactly as it was with the spreadsheet. He could sort, filter, and browse.

*Multi-criteria decision making:* Faustino explored different ranking strategies presented as “Decision Profiles”, as you can appreciate in step 9 of Figure 6. Such profiles were prepared by agronomists and farmers who were proficient in the use of AHP. Choosing a strategy re-sorts the list of candidates according to a function weighting the different features of the cultivators. There was, for example, a profile labeled “Home farmer” weighing price and transmission as the two most important criteria (0.39 and 0.35 respectively). Tilling width and tilling

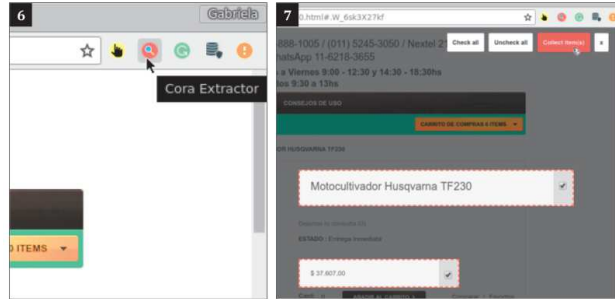


Fig. 5. Extracting items by using the “Molamaq” template

height are less important (0.17 and 0.09 respectively). Faustino learned this by looking at the pie chart diagram offered by the tool. Moreover, when comparing alternatives concerning price, tilling width, and tilling height the profile uses a strategy called “normalized difference” (basically using the numerical values of those properties to decide which one of them is better and for how much). According to that strategy, a cultivator that costs \$14000 is “extremely better” than one that costs \$38000, but only “moderately better” that one priced at \$17.000. The transmission property can have only one of three values “gears, chain, belt”. The shared profile offers a “stored pairwise comparison” for this property. Compared to the spreadsheet he used last time, this approach was more transparent. The descriptions and figures that accompanied each profile gave him a better idea of the criteria used to rank (this was not possible with the spreadsheet). Moreover, he could explore other strategies to make the same decision (the spreadsheet had only one).

*Decision profiles:* When Faustino used Logikós there were three different decision profiles available for cultivators. These profiles were created by groups of users that wanted to help others make informed decisions. Each profile includes a graphical description (a pie chart) of the relative weights given to the item properties. They also include a textual description to help users decided on the applicability of the profile to them (or their needs). As the profile has been authored by a group of volunteer users, access to the group’s discussion forum is available. Faustino felt like he could be part of such community, helping them better understand what the needs of a farmer like him and his neighbors.

## 5 Related work

A key innovation of our approach is supporting the collection. Closely related work has been done by Quinn and colleagues [6]. They explored the challenges of data collection for decision makers that were proficient in the use of spreadsheets. First, they approach data gathering as a (declarative) crowd-sourcing task. The decision maker indicates the pieces of data that are needed (queries

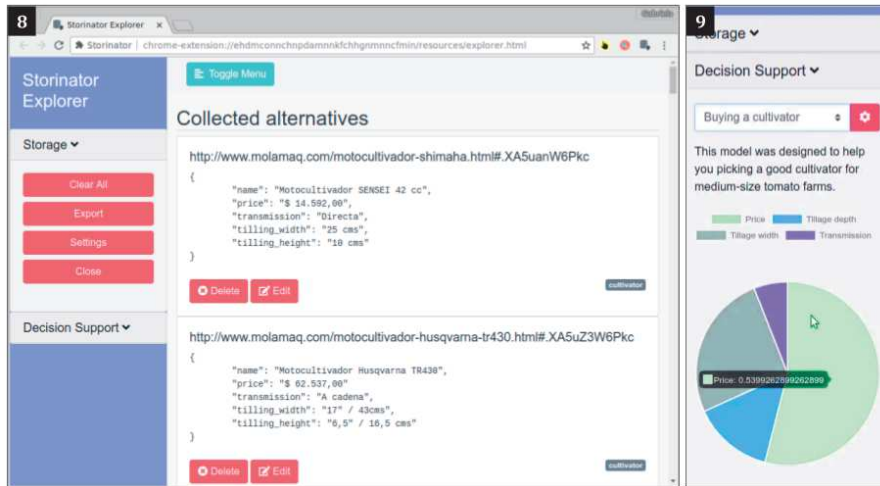


Fig. 6. Evaluating the alternatives with a decision profile

in a spreadsheet cell), and other users will try to find the data. In this sense, it differs from our approach (using a shared repository) in that users do not ask others to find information, but share information they find. In order to reduce the effort of data collection, the authors propose to focus on those pieces of data (spreadsheet cells) that will have the most impact on a decision. In our approach, as the decision maker can explore various decision profiles, data needs to be available in advance. However, a hybrid approach could be explored in the future.

Our approach (based on WOA) relies on being able to robustly abstract content from web-pages. Although it can be seen as a form of content scrapping it does not intend to cover the same goals. Extraction templates are intended to be applied by users to collect only those pieces of information they find valuable. Still, some scrapping techniques could be applied to merge information about the same object obtained from various sources, or to keep the information up-to-date. A similar connection could be made principles of the Semantic Web [2]. Our goal is not to create a semantic version of a web-page so it can be interpreted by computers but to obtain information that can be used specifically in MCD. Moreover, it as the semantic web grows, we will tap into its power to complement the information collected by users. In fact, we are gradually incorporating some of its concepts (classes and attributes) to describe the structure of collected items.

## 6 Conclusions

Literature identifies four key steps in cognitive decision making: 1) Intelligence - collecting information; 2) Conception - creating a model for the decision; 3)

Choice - using the model to select the best alternatives; and 4) Review - coming back to the intelligence step to have more information, redesign the model, and to choose again. It is an iterative process and non-linear. We argue that this process is poorly supported in the web, especially in the context of e-commerce. In this article we presented Logikós, an approach to augment any web-site with support for MCDA. Logikós supports the decision maker during the intelligence, choice, and review phases. It helps users to make decisions in a personalized way by choosing the decision profile that best matches their needs. Besides, it conceives the modeling step as a collaborative activity, giving users that are proficient with MCDA the chance to create and share reusable decision profiles. Less-experienced users can then apply such profiles, completing the cognitive decision making cycle. One perspective of this work can be to combine our approach with other MCDM methods like SWING, SMART etc...

## 7 Acknowledgement

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