

# Enriching What-If Scenarios with OLAP Usage Preferences

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**Abstract:** Nowadays, enterprise managers involved in decision-making processes struggle with numerous problems related to market position or business reputation of their companies. Owning the right and high quality set of information is a crucial factor for developing business activities and consequently gaining competitive advantages on business arenas. However, retrieving information is not enough. The possibility to simulate hypothetical scenarios without harming the business using What-If analysis tools and to retrieve highly refined information is an interesting way of achieving such advantages. In this paper, we propose an approach for helping to optimize enterprise decision processes using What-If analysis scenarios combined with OLAP usage preferences. We designed and developed a specific piece of software, which aims to discover the best recommendations for What-If analysis scenarios' parameters using OLAP usage preferences, which incorporates user experience in the definition and analysis of a target decision-making scenario.

## 1 INTRODUCTION

What-If analysis (Golfarelli et al., 2006) processes allow for creating simulation models aiming to explore the behavior of complex business systems. More pragmatically, they contribute for analyzing the effects on the behavior of a particular business system caused by a change of variables and values, which usually cannot otherwise be discovered by a historical data manual analysis process (Koutsoukis et al., 1999). In a real system, the main advantage of creating a simulation model through What-If analysis is to be able to implement changes in characteristics of the business without endangering it (Kellner et al., 1999). What-If analysis techniques are one of the most recently ways to achieve these goals. Decision-makers need to create What-If analysis scenarios to test and validate their business hypothesis and support their decisions. In fact, What-If analysis can be the safer solution towards some doubt and the decision maker needs to assess to ensure, if possible, that the subsequent decision will have some success. Moreover, it allows for analyzing different scenarios and perspectives of business, anticipating some solutions.

Online Analytical Processing (OLAP) (Harinarayan et al., 1996) systems are one of the most predominant tools for decision-support systems. They

provide specialized means for business analytics as well as multidimensional view over business data that are very efficient logical ways for analyzing businesses activities and organizations. A decision-support analysis process is an interactive exploration of multidimensional databases, often performed in ad hoc manner that allows for users to see data from different perspectives of analysis. Decision-makers frequently post complex queries to OLAP systems, which originate answers containing huge volumes of data that are quite difficult for analysis and consequent usage on business scenarios. Thus, it is essential to filter this information in a way that contents do not lose significance, being adjusted according to users needs and business requirements. The extraction of usage preferences according to each analytic session promoted by users may come as an advantage to decision-makers, since it provides a very effective way to personalize analytical sessions and multidimensional data structures acting as their decision-making support. Currently, OLAP systems technology already provides means for doing interactive analysis of multidimensional data based on a set of navigational operations usage and patterns (Jerbi et al., 2009).

In this paper we present and discuss the integration of OLAP usage preferences in conventional What-If scenarios as a mean to improve

the quality and effectiveness of decision models related to problems requiring perceptions from the user point of view. This will avoid the lack of expertise of the user in the implementation of What-If scenarios and models. Thus, we designed and implemented a decision-support system with the ability to receive a What-If scenario supported by analytical preferences, which provides us strong arguments for improving the simulation of a given system's behavior based on the preferences of its users. The system has the ability to suggest OLAP preferences, providing to the user the most adequate scenario parameters according to its needs. It was a way that we find to enrich and make more valuable What-If scenarios.

This paper is organized as follows. In section 2 we present an overview about OLAP preferences and applications. Next in section 3, we describe the entire process: the database used for test case study, how the association rules algorithm works, a brief formal description of OLAP preferences and how we extract the association rules of the data cube. In section 4 we describe the last steps of our methodology: showing how the What-If scenarios are created and enhanced using the extracted OLAP preferences, moreover we show how the application works, showing all the steps between the extraction of the rules until the definition of the What-If scenario. Finally, section 5 concludes the paper and discusses some possible future research directions.

## 2 RELATED WORK

As stated before, the main purpose of this work is to improve What-If scenarios using OLAP preferences; in this section we show how preferences are used to improve decision-making process, either in relational databases, in OLAP environments, or even in daily tasks, like traffic analysis. The research on databases preferences goes back to Lacroix and Lavency (1987), which was one of the first works that presented and discussed a preference mechanism as an extension of a query language. Later, in Agrawal and Wimmers (2000) it was proposed a formal framework for expressing and combining user preferences to address the problem of the high quantity of available on-line information. After this, in Chomicki (2003) it was presented a logical framework for formulating preferences and embedding them into relational query languages, which does not impose any restrictions on the preference relations, and allows for arbitrary operations and predicate signatures in preference

formulas. After this, a different approach to database preferences queries presented in Hadjali et al. (2008) discussed the way we can deal with preferences in a logic manner using symbolic weights. At the same time new approaches emerged, new applications areas arose as well. See for example the work presented in Letchner et al. (2006) in traffic analysis where authors presented a set of methods for including driver preferences and time-variant traffic condition for in route planning.

OLAP preferences reflect the most interesting data that decision-making agents selected and analyzed in past OLAP sessions, using a specific set of data cubes during certain periods of time (Harinarayan et al., 1996). More recently, preferences capture the attention of many researchers in the field of databases, especially in the field of on-line analytical processing, approaching the extraction of preferences using data mining techniques over users' MDX queries logs (Aligon et al., 2011) or the specification of an algebra for OLAP preferences (Golfarelli and Rizzi, 2009). Meanwhile, in Giacometti et al. (2009) it was presented a recommender system for OLAP users having the ability to recommend to the user discoveries detected on former sessions and in Ahmed et al. (2012) it was introduced a new approach for user profile construction based on the information contained in OLAP query logs. Two years later, in Varga et al. (2014), it was proposed another framework, but this one to support users assisting them generally in the automation of their activities in the context of the next generation of business intelligence systems using query recommendation support. Next, in Marcel (2014) it was summarized various contributions for developing user-centric OLAP, focusing on the use of former queries to enhance subsequent analyses. They show how it can be used in various query personalization processes or query recommendation approaches, which vary in terms of formulation effort, pro activeness, prescriptiveness and expressive power. To finish this section, just refer the work presented in Kozmina (2015), which provided a method for generation of report recommendations that takes into consideration the preferences of the users, and, more recently, the work presented in Bimonte and Negre (2016) that showed the usefulness of OLAP recommender systems on decision-making activities.

### 3 EXTRACTING OLAP PREFERENCES

#### 3.1 A General Overview

As stated before, we want to discover the best recommendations for What-If analysis scenarios based on past usage information. The main difference between our approach and standard What-If analysis methods is the introduction of a process of extraction of usage preferences on a business multidimensional database and using them before the simulation of the model, which allows for having the basis to predict the behaviour of a given scenario. The process of extracting OLAP preferences considers five distinct phases (Figure 1):

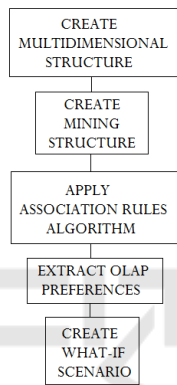


Figure 1: Enriching a What-If scenario.

Thus, firstly we start with a view selection process over the data cube we selected to support our work. We start with a small case study, which considers a single fact table - “Internet Sales” - and related dimension tables – “Dim Currency”, “Dim Customer”, “Dim Product”, “Dim Promotion”, “Dim Sales Territory”, and “Dim Date”. All these data objects were extracted from the “AdventureWorksDW2014” (Microsoft SQL Server Product Samples: Database, 2015), a small data warehouse provided by Microsoft as a product sample for Microsoft SQL Server. In the second phase, we create and analyze a specific data cube using the previous data objects as an example for future complex cases. With the reduction of the size of the cube, the complexity of the database reduced as well, and the same happens with the time need to extract the data we use and process it. Next, we create the mining structure and define the mining model to support a mining association process that runs in the third phase over the cube we created (Han, 1997). To do that we selected the Microsoft Association Rules

algorithm (Agrawal and Srikant, 1994) that comes with Microsoft Analysis Services. This Apriori based algorithm fits well on mining processes that involves recommendation engines or processes for finding correlations between different attributes in a given dataset – in our case we have a recommendation engine for the suggestion of the items that are most likely to appear together in a particular search of a What-If scenario. As other Apriori based association algorithms, we can define the minimum and the maximum support values to control the number of item sets that are generated, and we can also restrict the number of rules that a model produces by setting a value for a minimum probability. Even in this stage, all the rules and item sets extracted are stored in the mining model. An association mining model has a simple structure organized in two blocks: 1) the information about itself and its metadata, and 2) a flat list containing item sets and rules. Item set nodes include the definition of the item set, the number of cases that it contains, and other diverse information for support. In turn, a rule node describes a general pattern for the association of items. Every node has detailed information about the item set or the rule that will be relevant in the next steps of the process. All this is use for defining the OLAP preferences on the fourth stage.

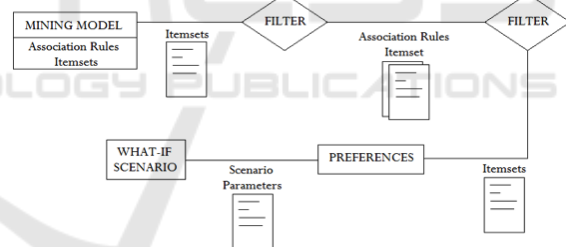


Figure 2: Extracting OLAP preferences.

The process of extracting OLAP preferences (Figure 2) starts with the choice of a user preference item from a list of frequent item sets of the mining model (ordered by probability). Next, it filters the list of association rules taking in count the chosen item set, returning only the association rules having the support and confidence previously defined and containing the chosen item set. The returned association rule list is used then to form the set of OLAP preferences for the user. This means that the item sets of the association rules returned as outcome are suggested to the user as its business preferences and then they will be taken into consideration in the What-If scenario as configuration parameters. Knowing beforehand cube preferences can have a significant impact on the outcome results of the

analytical system. Using OLAP preferences, it is possible to provide exactly the most relevant and useful information to each specific user in a specific analysis scenario. Aftermath, there is a significant reduction of the cube implementation costs, processing time and memory usage. The cube will include in its structure only the data that match user preferences and so it will returns only the data that interest to user. Moreover, the entire analysis process can be improved. As already noticed, a cube is a very complex data structure and it can be difficult for an analyst to acquire the information he want. With a simple interface having the ability to recommend the right queries based on the history of past analytical sessions makes much simpler the process of extracting information.

### 3.2 Dealing with Preferences

Now it is time to define formally what is a preference, introducing it with a simple working example based on the works presented in (Kießling, 2002; Ore and Ore, 1962). Thus, given a set of attributes A, a preference P is a strict partial order defined as  $P(A, \langle P \rangle)$ , where  $\langle P \rangle$  is an irreflexive, transitive and asymmetric binary relation  $\langle P \subseteq \text{dom}(A) \times \text{dom}(A)$ . If  $X \langle P Y$ , then 'Y is preferred to X'. A preference  $P = (A, \langle P \rangle)$  is an irreflexive, transitive and asymmetric binary relation  $\langle P$  on the domain of values of attributes set A. Let see how this works. If we consider to analyze how sales vary with the number of costumers having children living at home, to set its preferences a user need to choose one of the elements included in the set of the frequent item sets. This will allows for choosing the rules that will be used to set user preferences. Thus, assuming that the user chooses "Number Children At Home", using the previous defined semantics, we have:

```
"Marital Status" ≅ "Gender"
"Gender" ≅ "Yearly Income"
"Yearly Income" ≅ "Number Cars Owned"
"Number Cars Owned" ≅ "Birth Date"
"Birth Date" ≅ "English Education"
"English Education" ≅ "Total Children"
"Total Children" <P "Number Children At Home"
```

In other words, the attribute "Number Children At Home" is preferred to the attribute "Marital Status", "Gender", "Yearly Income", "Number Cars Owned", "Birth Date", and so on. Thus, "Marital Status" is equivalent to "Gender"; "Gender" is equivalent to "Yearly Income", "Yearly Income" is equivalent to "Number Cars Owned", and so on. Based on this set of previous preferences, it is possible to select a set of association rules that contains the attribute "Number Children At Home" (Figure 3).

Number Children At Home >= 4, Yearly Income = 37386.1278744576 - 74999.9999942656 -> Total Children >= 4
Birth Date < 9/14/1946 7:00:54 AM, Yearly Income < 37386.1278744576 -> Number Children At Home < 1
English Education = Graduate Degree, Yearly Income < 37386.1278744576 -> Number Children At Home < 1
Total Children < 1, Yearly Income = 37386.1278744576 - 74999.9999942656 -> Number Children At Home < 1
Total Children < 1, Yearly Income < 37386.1278744576 -> Number Children At Home < 1
Birth Date < 9/14/1946 7:00:54 AM, Yearly Income = 37386.1278744576 - 74999.9999942656 -> Number Children At Home < 1
Birth Date < 9/14/1946 7:00:54 AM, Number Cars Owned = 2 - 3 -> Number Children At Home < 1
Number Cars Owned < 1, Total Children < 1 -> Number Children At Home < 1
Number Cars Owned = 1 - 2, Total Children < 1 -> Number Children At Home < 1
Total Children < 1, English Education = Bachelors -> Number Children At Home < 1
538.English Product Name = LL Road Tire, Total Children < 1 -> Number Children At Home < 1
Total Children < 1, Number Cars Owned = 2 - 3 -> Number Children At Home < 1

Figure 3: The association rules for a given preference - 'Number Children At Home'.

Accordingly its own business preferences, the user may choose N association rules, for example the top 3 association rules (Figure 4) of the previous set (Figure 3), which will be used later to define his OLAP preferences. This means that the item sets contained in the filtered association rules will be suggested to the user as preferences. For example, if the returned list of association rules is the list in Figure 4, the recommendations to the user will are "Number Children At Home", obviously, "Birth Date", "Yearly Income", "English Education" and "Total Children". After this step, the user chooses the item sets of his preference that will be used as configuration parameters in the What-If scenario.

Number Children At Home >= 4, Yearly Income = 37386.1278744576 - 74999.9999942656 -> Total Children >= 4
Birth Date < 9/14/1946 7:00:54 AM, Yearly Income < 37386.1278744576 -> Number Children At Home < 1
English Education = Graduate Degree, Yearly Income < 37386.1278744576 -> Number Children At Home < 1

Figure 4: A list of some filtered association rules.

## 4 ENRICHING What-If SCENARIOS

Basically, What-If analysis can be described as a data simulation technique whose goal is to inspect the behavior of a complex system under some given hypotheses, usually called as scenario. More pragmatically, What-If analysis measures how changes in a set of independent variables impact on a set of dependent variables with reference to a given simulation model. The integration of OLAP usage preferences in What-If scenarios for business analysis enhancement is not a very common thing.

The main focus of a What-If application is a simulation model (Figure 5). Commonly, this model is a representation of a real business model that usually is organized into several application scenarios. Each one of these scenarios considers a set of business variables (the source variables) and a set of setting parameters (scenario parameters). It is the user that has the responsibility to edit such variables and obtain some kind of prediction (a new scenario) for the previous business application.

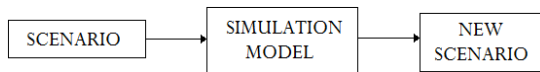


Figure 5: A general overview of a What-If analysis process.

The use of What-If analysis allows for the user to inspect the behavior of a given complex system. The implementation of a What-If process provides for several advantages to a business user. It makes possible to study the behavior of a system without building it or creating the circumstances to make it happen in a real world system, clearly saving time and reducing costs. Besides that, it provides the means to modify business variables as needed in order to find potential unexpected behaviors of the business system, which gives to business managers the possibility to be aware of the conditions that may lead to an erratic system behavior and so create the basis to avoid it in the future.

In order to improve this process, we use preferences as recommendations to help enhancing What-If application scenarios. The use of preferences in this case can be beneficial. The main advantage is to become possible to simulate a system behavior based on past data extracted from OLAP sessions. Preferences have the ability to recommend to the user the axes of analysis that are strongly related to each other, helping him to introduce valuable information in the application scenario he is building. Preferences are pieces of data that users give more attention in OLAP sessions, conditioning their ad hoc analysis and decision-making tasks. They can be defined based on historical data provided by a simple business application or from a more sophisticated piece of software like a data mining system. Often a preference reflects also hidden patterns that were detected in the data set. Using association rules based on preferences has the advantage that the user does not need to know the business domain. Preferences can also helping control over the returned information, providing access to relevant information and eliminating the irrelevant one. One may not know the proportions of the outcome: it may be an empty result, or an information flooding. Due to this, query runtime can be enhanced against cases without preferences. Consequently, in our process, we get more focused and refined results, which helps both a user who is not familiar with the business analysis and an analyst who is familiar with the business modeling data.

Our process proceeds as is shown in Figure 6. Firstly, we use an OLAP data cube as input. The input data will be used to define the application scenario based on historical data extract from previous OLAP sessions. Then, we define the scenario settings,

delineating the axis of analysis, the set of values for analyzing, and the set of values to change according to the goals defined previously. This last step usually differs among distinct analysis tools. Then, the What-If process proceeds with choosing a tool. To run a simulation model (a scenario based on historical data) it is required an appropriate tool (a What-If scenario analysis tool), in order to get a prediction scenario. The What-If analysis tool calculates and lets the user to explore and analyze the impact of the changes in the setting values of the entire application scenario. It is the user that is responsible to accept the new data cube, or return to change the settings of the application scenario and make the changes required over to the target data.

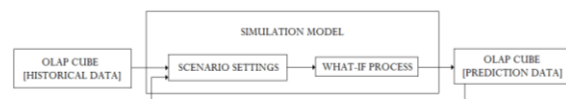


Figure 6: A general overview of a What-If analysis process.

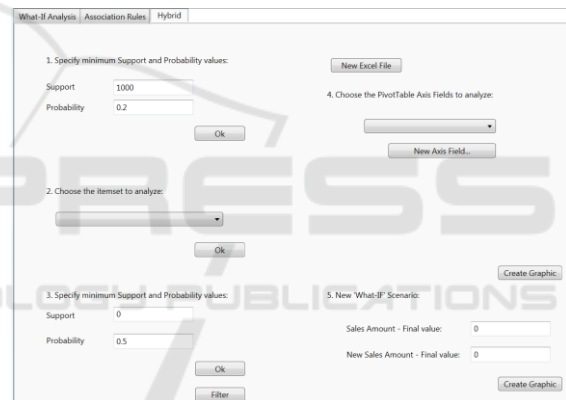


Figure 7: The user interface of the application for What-If analysis enrichment.

Now we will present an example of the business application. As stated previously, the extraction of association rules and OLAP preferences are used to define the configuration parameters of the What-If scenario. As a demonstrative example, we will consider the following business application scenario: our main goal is to analyze the evolution of the sales amount (represented by the Y axis) according to the number of customers' children at home and year (represented by the X axis) – value that is given by the attribute “Number Children At Home”.

Without OLAP preferences (see points 4 and 5 of Figure 7), an analyst may select for his application scenario the attributes “Number Children At Home”, “Sales Amount” and probably “Calendar Year”. If so, we got a chart like the one presented in Figure 8. So, with the results got it in the previous section we

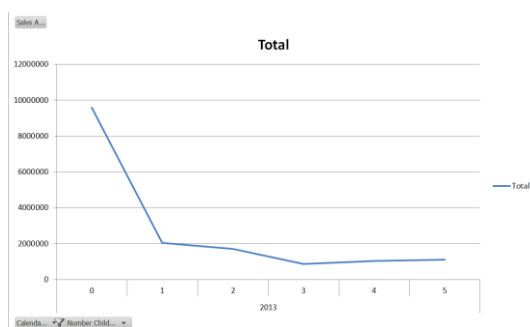


Figure 8: A scenario without OLAP Preferences.

realized that there are several attributes strongly related to our target attribute – “Number Children At Home” -, such as ‘Yearly Income’ and ‘English Education, which means that these attributes would significantly improve our analysis when take as configuration parameters in our business application scenario.

To support and perform What-If analysis processes we choose Microsoft Excel, since it allows for creating PivotTable reports based on OLAP source data. OLAP PivotTable Extensions is an Excel add-in, which extends the functionality of PivotTables on Microsoft Analysis Services multidimensional structures. Excel can be used as an OLAP analytical tool to easily analyze and modify data stored on data cubes. It is possible to modify data using a PivotTable and to recalculate all data as necessary, and, if the outcome is acceptable, to publish all changes so that they are copied into the OLAP cube. It is this property of Excel that allows for to do What-If Analysis and to create new application scenarios with the data that was recalculated.

After choosing the parameters for the What-If scenario, the user can make some changes – e.g. increasing the total sales values by 10%. Then, Microsoft Excel calculates how the new value will modify the old values, based on the properties of ‘What-If Analysis Settings’. Microsoft Excel allows for the user to calculate data with changes that were made manually (the user decides when the changes are made) or automatically (when each value is changed), to choose the allocation method (‘Equal Allocation’ or ‘Weighted Allocation’) and finally to select the value to allocate - the value entered is divided by the number of allocations or it is incremented based on the old value. Next, the new What-If scenario, the scenario with new calculated values, will be displayed to the user.

In our study, the application we developed allows for the user: to create What-If scenarios choosing the available attributes of his choice (first tab in Figure

7); to consult the mining models’ item sets and association rules (second tab in Figure 7); and both options together, which we call the hybrid model (third tab in Figure 7), which aims to create What-If scenarios using preferences obtained with the mining models’ association rules. For example, an analyst wants to analyze how the sales evolve within a specific customer profile (target audience), in order to know how sales may vary with the number of cars owned by the customer. The extraction of association rules and the sales preferences of the customers may show that the number of children at home is strongly related with customers’ yearly income and education. And with these three analysis axis (perspectives of analysis), the What-If scenario would be more accurate and specific, leading to better results, for example, when a company manager wants to assign a specific promotion or discount for a specific target audience.

	A	B	C	D
1	Sales Amount			
2	Calendar Year	English Month Name	Number Children At Home	Total
3	2010	December	0	25187,1482
4			1	4277,3682
5			2	3578,27
6			3	6978,26
7			4	3399,99
8		December Total *		43421,0364
9	2010 Total *			43421,0364
10	2011	April	0	349460,6948

Figure 9: Example of a business application scenario in a MS Excel PivotTable.

The Hybrid tab (Figure 7) is the main point of interest of our application. It provides users with information about association rules that were extracted from the cube structure, creates preferences, and recommends them to the user, in order to create a What-If application scenario. In the first step of this process, the user sets values to filter both the support and probability of both item set and rules (as was seen before in step 1). This way, it is possible to refine users’ preferences, leading to a specific and filtered outcome. The association rules extracted from the mining model can also be filtered as the item sets (as seen in step 3 of the process) and displayed ordered by decreasing values of probability.

In a later phase, the application suggests a set of item sets (contained in the chosen rules). The user chooses the item sets, which will be part of the What-If application scenario. For example, if the chosen item sets are “Calendar Year”, “Number of Children”, “Gender” and “Marital Status”, respectively. the application creates the (partial) PivotTable presented in Figure 9. We use this set of attributes, instead of “Yearly Income” and “English Education” in order to be easy to understand the What-If charts. The

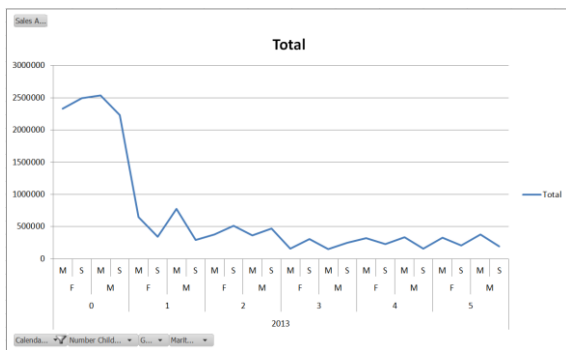


Figure 10: A possible business application scenario.

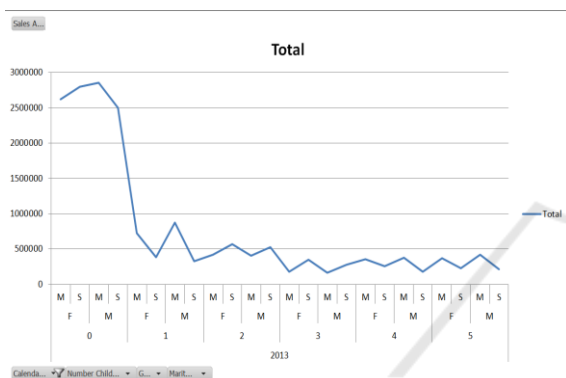


Figure 11: The enhanced What-If scenario.

business application scenario we created allows for the user to see the current sales amounts and its correspondent growth over the years (Figure 10). Consequently, after analyzing the current sales scenario (Figure 10), the user can assign an intended new final value and analyze how could have been the evolution of sales amount, in order to achieve the desired sales amount values. In this case, the pretended value is the double the final sales amount. The What-If scenario that was created (Figure 11) contains the same axis of the previous scenario, but the values involved with are slightly different. Nevertheless, there are some limitations associated to the application we developed. We used one Excel function, more specifically the What-If analysis function, performed using the 'AllocationMethod' property setting to 'Weighted Allocation' (instead of 'Equal Allocation' setting). With 'Weighted Allocation', Excel calculates the new What-If scenarios (overall values of the PivotTable) by increasing or decreasing the overall values in proportion, for example, if the new final value is 10% higher than the monthly values are increased by 10%. This must be improved in the next version of the application for having a more effective What-If scenario generation.

## 5 CONCLUSIONS

In this paper we show how OLAP preferences can contribute for enhancing a What-If scenario, improving the quality and effectiveness of decision models where perceptions from the user point of view can make the difference in a decision-making process. We implemented a decision-support system with the ability to receive a What-If scenario that incorporates usage analytical preferences for improving the simulation of a given business application scenario. The system has the ability provide to its users the most adequate scenario parameters according to its needs taking into consideration a set of OLAP preferences that were extracted from past OLAP sessions. This contributes significantly to enrich a make more valuable a What-If scenario for a particular business domain. At this point, we believe that the process we followed during the design and implementation of our system can help in the evaluation of business scenarios that integrate process solutions for analytical data exploration environments. Nevertheless there we also recognized some limitations that need to be overcome, in order to make the system more efficient, especially at the level of the usage of Microsoft Office Excel functions and within the What-If process itself. Additionally, we need to free the system from some limitations imposed by user's choices done in the most parts of the What-If process. This is must be avoid, because a user that has limited knowledge about the business domain or even about the simulation process to be implemented influences the entire process negatively, leading consequently to poor results.

Despite the several advantages of using preferences, there are some drawbacks related to this process. Due to the use of an association rules algorithm, sometimes it is difficult to interpret the results and so some information may be lost. A user, who is not aware of this process, can have significant difficulties for exploring meaningful associations. Additionally, we can face some difficulties in the What-If process. In a first stage of the What-If process, if the goal analysis is not done correctly, What-If questions and scenarios will be not correctly defined or the preferences outcome will be not reliable. Thereafter, performed What-If queries will be not the most suitable process and thus the obtained prediction will be different of what is expected as a normal behavior of a real business system. One way of avoiding this is to study potential and alternative application scenarios, in order to take the best advantages of the What-If scenario analysis tool. Finally, the What-If Analysis results depend strongly

from the data we want to analyze. If it contain some errors, which is a very common situation, the result will not be very useful. In order to overcome this kind of drawbacks, we mainly aim at restructuring automatically the What-If scenarios, discarding the user's dependency and finding a way of overcoming the limitation we found in some Excel functions.

## REFERENCES

- Agrawal, R., Wimmers E., 2000. A framework for expressing and combining preferences. *ACM SIGMOD Record*. 29 (2).
- Agrawal, R., Srikant, R., 1994. Fast algorithms for mining association rules. In *Proc. 20th int. conf. very large data bases, VLDB*. 1215, pp. 487-499.
- Ahmed, E. B., Nabli, A., Gargouri, F., 2012. Building MultiView analyst profile from multidimensional query logs: from consensual to conflicting preferences. 'arXiv preprint arXiv:1203.3589.
- Aligon, J., Golfarelli, M., Marcel, P., Rizzi, S., Turricchia, E., 2011. Mining preferences from OLAP query logs for proactive personalization. *Advances in Databases and Information Systems*. Springer Berlin Heidelberg.
- Bimonte, S., Negre, E., 2016. Evaluation of user satisfaction with OLAP recommender systems: an application to RecoOLAP on an agricultural energetic consumption datawarehouse. In *International Journal of Business Information Systems*, 21(1), pp. 117-136.
- Chomicki, J., 2003. Preference formulas in relational queries. *ACM Transactions on Database Systems (TODS)*. 28(4), pp. 427-466.
- Giacometti, A., Marcel, P., Negre, E., Soulet, A., 2009. Query recommendations for OLAP discovery driven analysis. In *Proceedings of the ACM twelfth international workshop on Data warehousing and OLAP*.
- Golfarelli, M., Rizzi, S. Proli, A., 2006. Designing What-If Analysis: Towards a Methodology. In *DOLAP'06*, Arlington, Virginia, USA, pp. 51-58.
- Golfarelli, M., Rizzi S., 2009. Expressing OLAP preferences. *Scientific and Statistical Database Management*. Springer Berlin Heidelberg.
- Hadjali, A., Kaci S., Prade H., 2008. Database preferences queries - A possibilistic logic approach with symbolic priorities. *Foundations of Information and Knowledge Systems*. Springer Berlin Heidelberg. pp. 291-310.
- Han, J., 1997. OLAP mining: An integration of OLAP with data mining. ' In *Proceedings of the 7th IFIP*. p. 1-9.
- Harinarayan, V., Rajaraman, A. Ullman, J., 1996. Implementing data cubes efficiently. *ACM SIGMOD Record*. 25(2).
- Jerbi, H., Ravat, F., Teste, O., Zurfluh, G., 2009. Preference-based recommendations for OLAP analysis. Springer Berlin Heidelberg.
- Kellner, Marc I., Madachy, R., Raffo, D., 1999. Software process simulation modeling: why? what? how?. *Journal of Systems and Software*. 46(2), pp. 91-105.
- Kießling, W., 2002. Foundations of preferences in database systems. In *Proceedings of the 28th international conference on Very Large Data Bases* (pp. 311-322). VLDB Endowment.
- Kozmina, N., 2015. Producing Report Recommendations from Explicitly Stated User Preferences. *Baltic Journal of Modern Computing*, 3(2), pp. 110.
- Koutsoukis, N., Mitra, G., Lucas, C., 1999. Adapting on-line analytical processing for decision modelling: The interaction of information and decision technologies. *Decision Support Systems*. 26(1), pp. 1-30.
- Lacroix, M., Lavency P., 1987. Preferences; Putting More Knowledge into Queries. In *VLDB*. 87, 1987.
- Letchner, J., Krumm J., Horvitz E., 2006. Trip router with individualized preferences (trip): Incorporating personalization into route planning. In *Proceedings of the National Conference on Artificial Intelligence*. 21(2), pp. 1795.
- Marcel, P., 2014. Log-driven User-centric OLAP. In *Information and Communication Technology, Electronics and Microelectronics (MIPRO)*, 37th International Convention. pp. 1446-1451.
- Microsoft SQL Server Product Samples: Database (2015) Available at: [<http://msftdbprodsamples.codeplex.com/>] [Accessed 13 fev. 2016].
- Ore, O., Ore, Y., 1962. Theory of graphs (Vol. 38). Providence, RI: American Mathematical Society.
- Varga, J., Romero, O., Pedersen, T. B., Thomsen, C. 2014. Towards next generation BI systems: The analytical metadata challenge. In *Data Warehousing and Knowledge Discovery*. pp. 89-101.