Building and Analyzing Goal-Oriented Decision Models

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Abstract. Goal-oriented business decision modeling is driven by the need to simplify communication between business analysts and operational business decision models while extending the capabilities of traditional business rules and decision management systems. The proposed goal-oriented approach aims at creating business decision models which cover certain business domains and can reach multiple business goals by providing answers to various questions in terms of automatically calculated decision variables. Such decision models can be designed by defining the hierarchy of business goals and subgoals with relationships between them described in business-friendly decision tables. The supporting tools should be able to automatically execute decision models without asking human modelers to specify any additional relationships. This paper also introduces a new web-based graphical tool "Decision Model Analyzer" that allows human decision modelers (who are assumed to be business analysts and not programmers) to easily add their decision models to the analyzer. Then the analyzer shows all goals supported by the selected decision model, automatically calculates their execution paths, executes the selected goals against various test cases, and explains why certain decisions were made on the way to the goal. The analyzer is publicly available online as a component of the popular open source business rules and decision management system "OpenRules".

Keywords: Business Rules, Decision Models, Goal-Oriented Decision Modeling, Decision Model Execution, Decision Explanation

1 Motivation

Nowadays operational decision models are at the center of modern enterprise-level applications that help humans to make better business decisions. The DMN standard [1] helps business users to define their decision models by using standardized decisioning constructs such as decision tables. Helpful books and guidelines for building decision models are described at the Decision Management Community website [2]. However, real-world decision modeling experience shows the need to simplify communication between business analysts and operational business decision models while extending the capabilities of business rules and decision management tools currently available on the market [3]. In the paper [4] we have shown how DMN-based decision models can be extended to determine multiple feasible decisions and even find decisions which minimize/maximize certain business objectives. In this paper we introduce a goal-oriented approach to business decision modeling that makes it simpler for business users to create and maintain their decision models.

The proposed approach aims at creating business decision models which cover certain business domains, and which are capable of reaching multiple business goals by providing answers to various questions in terms of automatically calculated decision variables. Such decision models can be designed by defining hierarchies of business goals and subgoals with relationships between them described in business-friendly decision tables and/or other DMN constructs. This approach assumes the use of more powerful decision modeling and execution tools which free business users from necessity to provide additional information that can be automatically calculated.

For example, various inferential (as opposite to sequential) rule engines are capable to automatically determine an execution order for different rulesets and rules within decision models. Whether they do it in run-time or in design-time, they free a user from necessity to provide rules sequencing information making the decision models more declarative. However, the current DMN guidelines usually recommend human decision modelers to specify knowledge and information requirements defined by DMN as follows:

- Information Requirements may be drawn from Input Data elements to Decisions, and from Decisions to other Decisions. They represent the dependency of a Decision on information from input data or the results of other Decisions
- Knowledge Requirements may be drawn from Business Knowledge Models to Decisions, and from Business Knowledge Models to other Business Knowledge Models. They represent the invocation of business knowledge when making a decision.

These requirements are specified as arrows within DMN decision requirements diagrams (DRDs) and can be useful to visualize a high-level view of a decision model even before considering its future execution. These requirements can also be effectively used by an execution engine "when making a decision" even if such an engine does not possess inferential capabilities. However, when a human modeler specifies DMN business knowledge models (BKMs) such as decision tables, s/he already implicitly specifies these requirements. So, if an execution tool is capable to automatically extract knowledge and information requirements by analyzing all provided BKMs, it means it also should be able to figure out the execution sequence of the related BKMs. Without asking a human to manually specify these dependencies, an inferential execution engine will be able to automatically execute the decision models.

Decision models created in accordance with the current DMN standard usually address only one question and expect to determine a single answer given different input data. The goal-oriented approach extends the decision model concept to go beyond one business objective (goal) and allows a user to determine different business goals supported by the decision model.

In section 2 we explain how to build goal-oriented decision models. To demonstrate the proposed approach, we use a well-known decision model [5] and the latest release of the open source decision management system "OpenRules" [7]. The section 3 introduces a new, web-based graphical tool "Decision Model Analyzer" [8]. It allows a human decision modeler (who is assumed to be a subject matter expert and not a programmer) to easily add new decision models, execute different goals against various test cases, and to analyze the execution results using automatically generated explanations. The major capabilities of the Analyzer are demonstrated using the already described decision model.

2 Building Goal-Oriented Decision Models

The goal-oriented approach aims at creating business decision models which cover certain business domains. Such models specify different business concepts, decision variables, and relationships between them using business logic specific for the selected domain. The business logic is usually presented using business-friendly decision tables and other decisioning constructs such as those defined by the DMN standard. The decision models should be capable to provide answers to questions expressed by users in terms of the decision variables and which allow them to reach various business goals.

To build such decision models business analysts usually start with defining a hierarchy of business goals/subgoals and relationships between them. Let's consider an example of the well-known decision model originally described by Nick Broom [5]. This is a relatively simple decision model that is supposed to determine a loan application status based on an applicant eligibility. While this decision model addresses only one specific business goal from the Credit Card Processing domain, in the real-world credit card processing systems, there are many other business goals, e.g. determine whether it is worth requesting additional information from an external credit reference agency, or instead of rejection an application offer an applicant a different rate. But even in this, simple problem formulation, the decision model may provide answers not to one but to multiple questions which lead to different goals. We may consider goals and subgoals as decision variables that can be determined within a decision model based on input data and other decision variables.

Let's consider a goal-oriented implementation of this decision model using OpenRules. The top-level goal "Application Status" depends on two subgoals: "Applicant Demographic Suitability" and "Applicant Credit Card Eligibility". These relationships are defined by the decision table in Fig. 1:

DecisionTable ApplicationStatus			
If	If	Then	Message
Applicant Demographic Suitability	**Applicant Credit Card Eligibility**	**Application Status**	**Message**
Suitable	Eligible	Accepted	
Suitable	Ineligible	Rejected	Reason: Applicant Credit Card Eligibility is Ineligible
Unsuitable	Eligible	Rejected	Reason: Applicant Demographic Suitability is Unsuitable
Unsuitable	Ineligible	Rejected	Reasons: 1) Applicant Demographic Suitability is Unsuitable; 2) Applicant Credit Card Eligibility is Ineligible
		Rejected	IMPOSSIBLE: Check for an error in rules

Fig. 1. Defining Application Status

The subgoal “Applicant Demographic Suitability” depends on several Applicant’s attributes and two other subgoals "Applicant Private Credit Card Demographic Suitability” and “Applicant Student Credit Card Demographic Suitability” as defined by the decision table in Fig. 2:

DecisionTable ApplicantDemographicSuitability			
If	If	If	Then
Applicant Years of Age	**Applicant Card Type**	**Applicant is Existing Customer**	**Applicant Demographic Suitability**
<18			Unsuitable
	Student, Private	FALSE	Unsuitable
	Private	TRUE	Applicant Private Credit Card Demographic Suitability
	Student, Private	TRUE	Applicant Student Credit Card Demographic Suitability
			Suitable

Fig. 2. Defining Applicant Demographic Suitability

In turn these two subgoals are defined by the decision table in Fig. 3 and Fig. 4:

DecisionTable ApplicantPrivateCreditCardDemographicSuitability			
If	If	If	Then
Existing Customer Sole Annual Income Amount	**Existing Customer Outstanding Mortgage Borrowings Amount**	**Existing Customer Saving and Investments Balance Amount**	**Applicant Private Credit Card Demographic Suitability**
>= 100000			Suitable
	>= 300000		Suitable
		>= 100000	Suitable
< 100000	< 300000	< 100000	Unsuitable

Fig. 3. Defining Applicant Private Credit Card Demographic Suitability

DecisionTable ApplicantStudentCreditCardDemographicSuitability	
If	Then
Existing Customer Current Account Type	**Applicant Student Credit Card Demographic Suitability**
Student	Suitable
	Unsuitable

Fig. 4. Defining Applicant Student Credit Card Demographic Suitability

The decision table in Fig. 5 defines the subgoal "Applicant Credit Card Eligibility":

DecisionTable ApplicantCreditCardEligibility		
If	If	Then
Applicant Card Type	**Applicant Credit Score**	**Applicant Credit Card Eligibility**
Student	>= 500	Eligible
Student	< 500	Ineligible
Private	>= 750	Eligible
Private	< 750	Ineligible
Balance Transfer	>= 750	Applicant Balance Transfer Credit Card Eligibility
Balance Transfer	< 750	Ineligible
		Eligible

Fig. 5. Defining Applicant Credit Card Eligibility

So, we may conclude that this subgoal depends on two variables: “Applicant Card Type” that is an attribute of the Applicant and “Applicant Credit Score”, another subgoal. This subgoal can be determined by the decision table in Fig. 6:

DecisionTableMultiHit ApplicantCreditScore					
If	If	If	If	Conclusion	
Applicant Number of Default Payments in Last 12 Months	Applicant had declared Bankrupcy	Applicant Years with Current Account Bank	Applicant Amount of Available Credit Used Percentage	Applicant Credit Score	
[1..3]				+=	100
[4..6]					50
>6					0
0					250
	TRUE				0
	FALSE				250
		< 1			50
		[1..3]			150
		>3			250
			[0..24]		200
			[25..49]		249
			[50..74]		150
			[75..100]		100
			>100		0

Fig. 6. Defining Applicant Credit Score

And finally, here is a decision table that defines the subgoal “Applicant Balance Transfer Credit Card Eligibility” mentioned in Fig 5:

DecisionTable ApplicantBalanceTransferCreditCardEligibility				
If	If	If	If	Then
Applicant Sole Annual Income Amount	Applicant Residential Status	Applicant Application Credit Card Previously Applied in Last 6 months	Applicant Number of Years Address History	Applicant Balance Transfer Credit Card Eligibility
>= 10000	UK Resident	FALSE	>= 3	Eligible
< 10000				Ineligible
	Non-UK Resident			Ineligible
		TRUE		Ineligible
			< 3	Ineligible

Fig.7. Defining Applicant Balance Transfer Credit Card Eligibility

To complete our decision model, we need to put all input and output decision variables used by all decision tables described above into the following business glossary:

Glossary glossary			
Decision Variables	**Business Concept**	**Attribute**	**Domain**
Existing Customer Sole Annual Income Amount	Applicant	existingCustomerSoleAnnualIncomeAmount	
Existing Customer Outstanding Mortgage Borrowings Amount		existingCustomerOutstandingMortgageBorrowingsAmount	
Existing Customer Saving and Investments Balance Amount		existingCustomerSavingAndInvestmentsBalanceAmount	
Existing Customer Current Account Type		existingCustomerCurrentAccountType	Student, Standard, Silver, Platinum, Black, Balance Transfer
Applicant Years of Age		yearsOfAge	
Applicant is Existing Customer		existingCustomer	
Applicant Sole Annual Income Amount		soleAnnualIncomeAmount	
Applicant Residential Status		residentialStatus	UK Resident, Non-UK Resident
Applicant Application Credit Card Previously Applied in Last 6 months		applicationCreditCardPreviouslyAppliedInLast6Months	
Applicant Number of Years Address History		numberOfYearsAddressHistory	
Applicant Number of Default Payments in Last 12 Months		numberOfDefaultPaymentsInLast12Months	
Applicant had declared Bankrupcy		declaredBankrupcy	
Applicant Years with Current Account Bank		yearsWithCurrentAccountBank	
Applicant Amount of Available Credit Used Percentage		amountOfAvailableCreditUsedPercentage	
Applicant Card Type	Application	cardType	Student, Standard, Silver, Platinum, Black, Balance Transfer
Applicant Credit Score		creditScore	Eligible,Ineligible
Applicant Credit Card Eligibility		creditCardEligibility	Eligible,Ineligible
Applicant Balance Transfer Credit Card Eligibility		balanceTransferCreditCardEligibility	Eligible,Ineligible
Applicant Demographic Suitability		demographicSuitability	Suitable, Unsuitable
Applicant Private Credit Card Demographic Suitability		privateCreditCardDemographicSuitability	Suitable, Unsuitable
Applicant Student Credit Card Demographic Suitability		studentCreditCardDemographicSuitability	Suitable, Unsuitable
Application Status		applicationStatus	Accepted,Rejected

Fig. 8. Glossary

All decision variables are placed in the first column of the glossary table. They are distributed between two business concepts “Applicant” and “Application”, to which they naturally belong – see the second column. The third column contains technical names (without spaces) of these variables that will be used for the integration of the decision model with an IT system. The fourth (optional) column may specify acceptable

values for some variables. A user may add more columns such as definitions of the used decision variables.

In practice, the glossary is created when the first goal is specified, and a human modeler adds more goals and other decision variables to the glossary as more decision tables being specified. Please note that all goals in the glossary are hyperlinked to the decision tables defined in different files – it's dome by using the familiar Excel hyperlinks. When a glossary is defined this way, it becomes the focal point of any decision model providing an easy access to all its components.

Thus, our decision model supports the following hierarchy of goals and subgoals:

- *Application Status*
  - *Applicant Demographic Suitability*
    - *Applicant Private Credit Card Demographic Suitability*
    - *Applicant Student Credit Card Demographic Suitability*
  - *Applicant Credit Card Eligibility*
    - *Applicant Credit Score*
    - *Applicant Balance Transfer Credit Card Eligibility*

For every Applicant and Application, the top-level goal "Application Status" may answer the question "Will this application be Accepted or Rejected?". However, other goals may produce answers to other useful questions such as "What is the Applicant Credit Score?" or "What is Applicant Demographic Suitability?".

It is important to note that the goal-oriented approach doesn't require a human decision modeler to specify any execution sequence or any other dependencies between goals and subgoals. This information can be automatically inferred from already provided decision tables.

We already have enough information to add test cases and to execute this decision model using a rule engine such as OpenRules as described in [7]. When a rule engine determines a goal and its subgoals, this information may provide valuable explanations why the decision model made certain decisions.

Our simple example demonstrates the basics of the goal-oriented approach to decision modeling:

1. Define goals and subgoals
2. Use decision tables and/or other decisioning constructs to specify business logic that determines all goals/subgoals
3. Let a rule engine to figure out all other knowledge and information relationships within the decision model and to automatically execute the model to determine different goals.

More complex decision models can use more complex decisioning constructs, for instance to iterate through lists of business objects, that also can be automatically analyzed. This approach allows a subject matter expert to add more business concepts and related goals/subgoals from the same business domain and let a supporting rule engine to figure out how to execute the decision model to determine new goals.

3 Graphical Decision Model Analyzer

Decision Model Analyzer [5] is a stand-alone web application built on top of OpenRules [6]. Its main purpose is to allow a business user to analyze different decision models to better understand why certain decision were made. The Analyzer comes with a collection of the goal-oriented decision models from different domains including loan origination, retail, healthcare, and some interesting decision models offered as Decision Management Community challenges[1]. Fig. 9 shows the top-level view of the Analyzer:

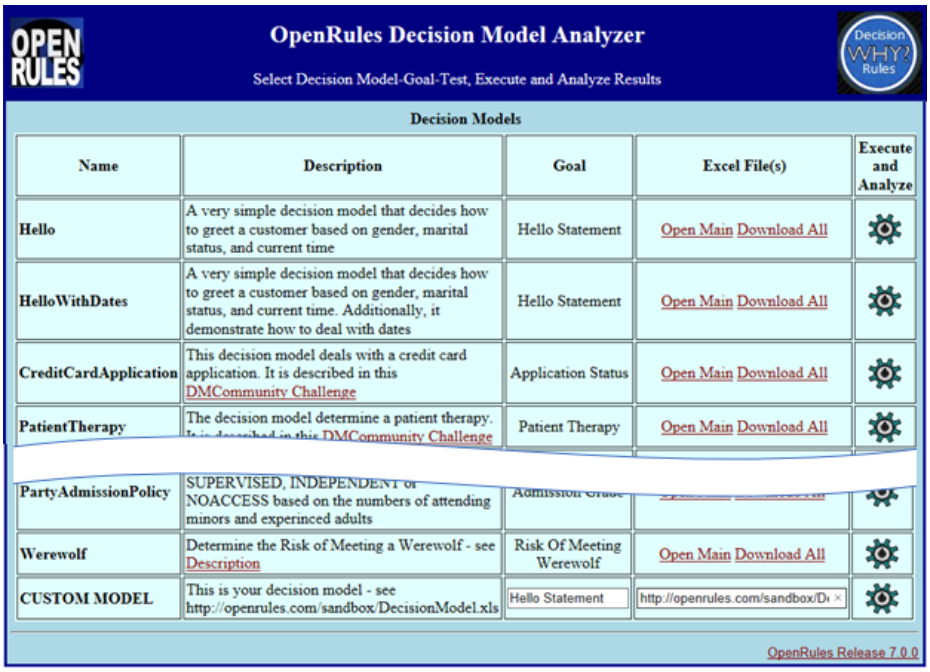

Fig. 9. Selecting Decision Models

A user may easily add new decision models by adding names of their Excel files to a simple configuration table also defined in Excel. Custom models resided on a remote server can be added on the fly.

[1] https://dmcommunity.wordpress.com/challenge/

From the view in Fig. 9 a user may select any decision model, click on the engine icon, and start working with this model. When a user selects a decision model, the Analyzer automatically discovers all supporting goals, calculates their execution paths, and executes the first available test case. Then the Analyzer shows a decision model view allowing a user to select different goals, test cases, and to analyze the execution results. Fig. 10 is an example of such view when our decision model "Credit Card Application" was selected.

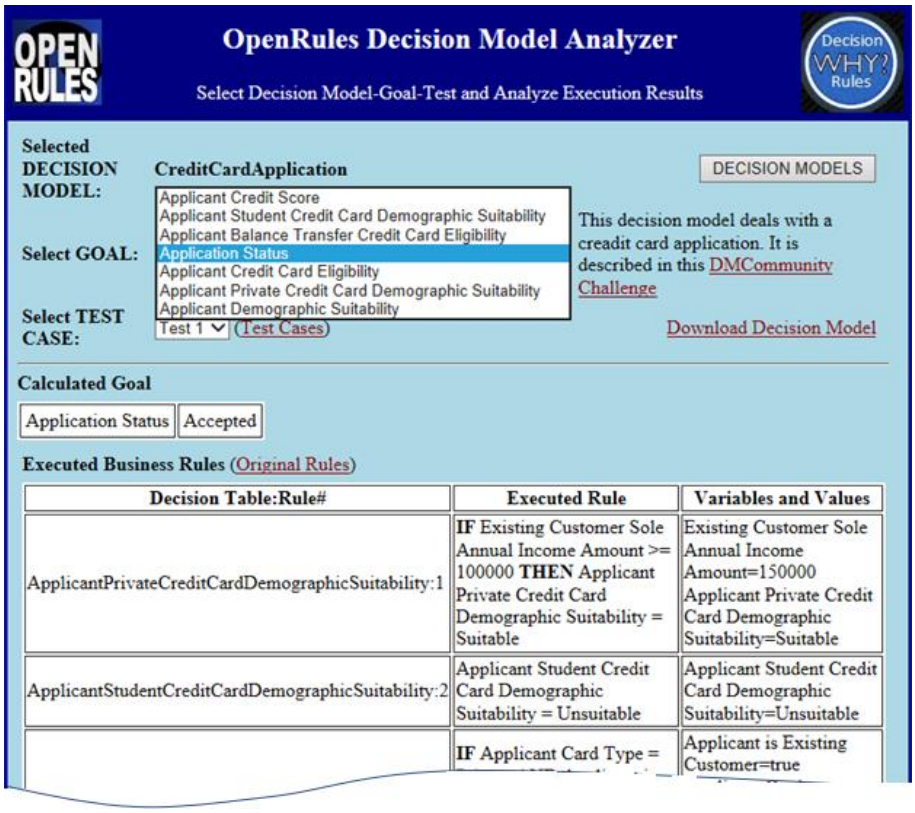

Fig. 10. Selecting Goal and Test Case to be Executed

From this view of the decision model a user may do the following:

- Select a business goal from an automatically generated list of the goals supported by this model
- Select a test case and run an underlying rule engine that automatically determine the selected goal by executing the decision model against the selected test case
- Analyze the automatically determined results and produced explanations that help to understand why certain decisions were made on the way to the goal.

Executed Business Rules (Original Rules)

Decision Table:Rule#	Executed Rule	Variables and Values
ApplicantPrivateCreditCardDemographicSuitability:1	**IF** Existing Customer Sole Annual Income Amount >= 100000 **THEN** Applicant Private Credit Card Demographic Suitability = Suitable	Existing Customer Sole Annual Income Amount=150000 Applicant Private Credit Card Demographic Suitability=Suitable
ApplicantStudentCreditCardDemographicSuitability:2	Applicant Student Credit Card Demographic Suitability = Unsuitable	Applicant Student Credit Card Demographic Suitability=Unsuitable
ApplicantDemographicSuitability:3	**IF** Applicant Card Type = Private **AND** Applicant is Existing Customer = true **THEN** Applicant Demographic Suitability = Applicant Private Credit Card Demographic Suitability	Applicant is Existing Customer=true Applicant Card Type=Private Applicant Demographic Suitability=Suitable Applicant Private Credit Card Demographic Suitability=Suitable
ApplicantCreditScore:4	**IF** Applicant Number of Default Payments in Last 12 Months = 0 **THEN** Applicant Credit Score += 250	Applicant Number of Default Payments in Last 12 Months=0 Applicant Credit Score=250
ApplicantCreditScore:6	**IF** Applicant had declared Bankrupcy = false **THEN** Applicant Credit Score += 250	Applicant had declared Bankrupcy=false Applicant Credit Score=500
ApplicantCreditScore:8	**IF** Applicant Years with Current Account Bank = [1..3] **THEN** Applicant Credit Score += 150	Applicant Years with Current Account Bank=3 Applicant Credit Score=650
ApplicantCreditScore:10	**IF** Applicant Amount of Available Credit Used Percentage = [0..24] **THEN** Applicant Credit Score += 200	Applicant Amount of Available Credit Used Percentage=20 Applicant Credit Score=850
ApplicantBalanceTransferCreditCardEligibility:1	**IF** Applicant Sole Annual Income Amount >= 10000 **AND** Applicant Residential Status = UK Resident **AND** Applicant Application Credit Card Previously Applied in Last 6 months = false **AND** Applicant Number of Years Address History >= 3 **THEN** Applicant Balance Transfer Credit Card Eligibility = Eligible	Applicant Sole Annual Income Amount=120000 Applicant Residential Status=UK Resident Applicant Application Credit Card Previously Applied in Last 6 months=false Applicant Number of Years Address History=3 Applicant Balance Transfer Credit Card Eligibility=Eligible

Fig. 11. Executed Business Rules (beginning)

ApplicantCreditCardEligibility:3	**IF** Applicant Card Type = Private **AND** Applicant Credit Score >= 750 **THEN** Applicant Credit Card Eligibility = Eligible	Applicant Card Type=Private Applicant Credit Score=850 Applicant Credit Card Eligibility=Eligible
ApplicationStatus:1	**IF** Applicant Demographic Suitability = Suitable **AND** Applicant Credit Card Eligibility = Eligible **THEN** Application Status = Accepted	Applicant Credit Card Eligibility=Eligible Applicant Demographic Suitability=Suitable Application Status=Accepted

Fig. 12. Executed Business Rules (continuation)

In Fig. 10 we can see seven different goals that can be selected from a combo-box "Select GOAL". It may be useful to select and analyze all of them to better understand the behavior of our decision model. In this case, the goal "Application Status" and the test "Test 1" have been selected. The Analyzer shows the goal "Application Status" is determined as "Accepted".

The table "Executed Business Rules" in Figures 11 and 12 helps a user to understand why certain decisions were made. This table includes only those rules (from all decision tables described in the Section 2) that were executed for the selected test case.

All rules are shown in the order they were executed. The first column contains a name of a decision table and an order number for every executed rule inside this table. The second column shows rule formulations being transformed into IF-THEN text format. From the decision explanation point of view, the most important column is the last one "Variables and Values". This column shows the values of all involved decision variables **at the moment when the rule was executed**. The real-world experience proves that it is critically important to be able to analyze the values of different decision variables during rules execution, otherwise it could be very difficult to understand the behavior of complex decision models.

After this table, the Analyzer generates the table "Decision Variables" presented in Fig. 13. It contains descriptions of all decision variables distributed between business concepts (as specified in the glossary in Fig. 9). Based on the interest of your analysis, you can collapse ("-") and/or expand ("+") different business concepts to concentrate only on those you are currently interested in.

For every input and output decision variable the table "Decision Variables" shows its final value after the decision model execution. You can click on "**?**" next to the decision variable and the large table presented in Figures 11 and 12 will be filtered to include only those rules that deal with this decision variable. For example, if you click on the "?" next to the variable "Applicant Balance Transfer Credit Card Eligibility", the Analyzer will show only two rules which are currently presented in Fig. 12. A click on the big button "**WHY**" will restore the entire table.

The Analyzer also produces the execution protocol that shows conclusions of all executed rules with the used values along with the execution time.

Decision Variables (Glossary)

Name	Value	WHY
Applicant		−
Existing Customer Sole Annual Income Amount	35000	?
Existing Customer Outstanding Mortgage Borrowings Amount	90000	?
Existing Customer Saving and Investments Balance Amount	55000	?
Existing Customer Current Account Type	Student	?
Applicant Years of Age	29	?
Applicant is Existing Customer	true	?
Applicant Sole Annual Income Amount	25000	?
Applicant Residential Status	Non-UK Resident	?
Applicant Application Credit Card Previously Applied in Last 6 months	false	?
Applicant Number of Years Address History	1	?
Applicant Number of Default Payments in Last 12 Months	1	?
Applicant had declared Bankrupcy	false	?
Applicant Years with Current Account Bank	4	?
Applicant Amount of Available Credit Used Percentage	40	?
Application		−
Applicant Card Type	Balance Transfer	?
Applicant Credit Score	849	?
Applicant Credit Card Eligibility	Ineligible	?
Applicant Balance Transfer Credit Card Eligibility	Ineligible	?
Applicant Demographic Suitability	Suitable	?
Applicant Private Credit Card Demographic Suitability	Unsuitable	?
Applicant Student Credit Card Demographic Suitability	Suitable	?
Application Status	Rejected	?

Fig. 13. Decision Variables with Calculated Values

You may try the Decision Model Analyzer online as it is publicly available from http://openjvm.jvmhost.net/OpenRulesAnalyzer.

4 Conclusion

Subject matter experts may apply the goal-oriented decision modeling approach to build, test, and analyze their domain-specific decision models. We demonstrated the proposed approach using a relatively simple decision model and defining its goals and subgoals in Excel-based decision tables. It is important that it is not necessary for a human decision modeler to explicitly specify any execution sequence or dependencies between goals and subgoals as the underlying rule engine is capable to automatically infer this information. Then we applied the OpenRules Decision Model Analyzer to execute this decision model and to determine different goals and subgoals for various test cases. The Analyzer provides powerful capabilities to help a user to understand why certain decisions were made.

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