Temporal Reasoning: Manage Complex Changes in Rules, Rates, and Circumstances
Executive Summary

Many public and private sector organizations work in a complex environment where calculations are required to determine the entitlements and obligations of customers or citizens. When policy rules and customer status are ever changing, determining eligibility and the resulting benefits can be challenging. This white paper outlines Oracle’s sophisticated temporal reasoning solution for dealing with change in a complex, dynamic policy environment. It also illustrates Oracle’s temporal reasoning process through fictionalized tax credit and pension examples.

Introduction

Complex eligibility environments are a characteristic of major government agencies that are responsible for taxation, social security and social services, immigration, and compensation. Private organizations such as financial services, insurance, and commercial must also manage eligibility requirements and benefit payouts based on complex rules. Early solutions to the problem of constantly changing rules invoke a less-than-optimal approach. Generally, they involve creating multiple time periods that demand a great deal of input and output data, particularly when complex calculations rely on many input factors.

Oracle’s approach vastly simplifies this calculation process by enabling host applications to take advantage of the capabilities in Oracle Policy Modeling and Oracle Policy Automation. Comprised of these two products, Oracle’s policy automation solution is easy to implement in conjunction with existing enterprise applications. It has a lower total cost of ownership (TCO) for both development and ongoing maintenance than traditional calculation methods. In addition, Oracle’s policy automation solution is transparent so that both customers and end users understand decision processes.
Characteristics of a Complex Rule Environment

To accurately calculate a customer’s entitlement and obligation, there are three critical elements—all of which can constantly change—that must be considered.

• **Changes to rules that apply to a customer.** These are rules and policies that are either legislated by government or implemented by businesses to determine a customer’s eligibility for a program or benefit. In the public sector, a new benefit component might be legislated by government for social security payments. In the commercial sector, a bank might introduce a special rule for high-risk debtors.

• **Changes to payment rates and other reference data.** This data is used to determine the specific benefit due or the rate of payment a customer might receive. For example, a government agency might update its thresholds for tax credits and payments on a quarterly basis, or an insurance company might review its risk thresholds monthly.

• **Changes to individual circumstances.** This is information that defines and describes the customer’s personal situation or circumstances. For example, a customer’s marital status could change from single to married to divorced. This would affect the benefits that this individual might receive from an insurance company or the government.

To accurately calculate a customer’s entitlement and obligation, governments and businesses must review policy rules that apply to a customer, reference data used to calculate payment rates or benefits due, and data that defines a customer’s personal circumstances.

Because each of the elements described above is subject to constant change, the role of an IT administrator becomes more challenging. To support such changing requirements, most IT groups require the following capabilities:

• **A simple way of representing data over a period of time.** This enables calculations to be made that cover these time periods, such as the benefit to be received over a year.

• **A simple way of showing calculation results.** By identifying the rates applied to each time period and then aggregating these into a total amount, IT groups can show the result of a calculation.

• **The capacity to quickly change rules and reference data.** Before a rule is changed, it is useful to measure the impact of the change on affected customers.

• **Confidence in the performance of the system.** IT groups must know that throughput and scalability are as good as, or better than, alternative approaches.

Together, Oracle Policy Modeling and Oracle Policy Automation form a business rules and policy automation solution that simplifies complex calculation processes. The solution has the following capabilities:
• Natural-language authoring means that initial rule definition and deployment as well as ongoing maintenance is at least three times faster than conventional coding.

• Concise logic expression is more comprehensible than application code, especially for business analysts.

• Calculations can be explained to end users and customers even after the calculation has occurred. The explanation is stored for future review or appeal. Such transparency reduces customer escalations.

• The calculation engine supports a broad range of platforms that include Oracle’s Siebel Customer Relationship Management (CRM) and other service-oriented architecture–compliant case management systems.

Oracle’s policy automation solution features natural-language rules authoring, concise logic expression, audit trails for calculations, and a calculation engine preintegrated with Oracle’s Siebel Case Management—part of the Siebel CRM platform. The solution can also be integrated with other case management systems.

A Tax Credit Example

To illustrate how rules, rates, and circumstances change, it is best to examine a representative example. In this case, a simplified fictional tax credit will be used to illustrate how Oracle manages complex changes in rules, rates, and circumstances. Although this example is taken from the public sector, virtually identical issues arise in a number of business and governmental contexts where rules and rates change over time. Some examples of similar issues might include

• Calculation of premiums payable by companies under a health insurance policy

• Payment of pensions to the elderly

• Calculation of interest rates to debtors/creditors of a bank

• Entitlement calculations for social security benefits

• Calculation of tax payable by citizens or businesses

Eligibility Determinations and Policy Rules

To determine if a family is eligible for a simple tax credit, the calculation must take into account the following personal circumstances of a family:

• Whether the family is headed by a single parent or by a couple in a recognized relationship

• Whether the claimant or their partner is working

• The income of the claimant or their partner

• For each child in the family, the age of the child
• For each child in the family, whether the child is a student

The tax credit calculation must also take into account the following legislated and policy rules:

• The income thresholds and amounts payable are reviewed quarterly in line with changes to the consumer price index.

• As of May 1, 2008, a new set of rules is applied to increase the amount of tax credit for families where one parent works and the other does not.

• By default, payments are made every two weeks by the tax office, although a person can also file a claim at the end of a tax year for all the sum of payments within that tax year.

• The tax year runs from January 1 to December 31.

Given this background, at least two cases are common. The first is a retrospective claim. In this case, a couple has their first child. Within six months of the child’s birth, the couple files a claim for payment. During that time, the mother has returned to work after a period of maternity leave. The second type of claim is a retrospective change of circumstance. In this case, a couple receives ongoing payments for two children every two weeks. During the tax year, the eldest child leaves school and becomes employed. However, the parents do not notify the tax agency until some months afterward.

Case 1: A Retrospective Claim

This section provides the input data and outlines the required outputs for the case of a retrospective claim. Key input data and dates are outlined in Table 1.

<table>
<thead>
<tr>
<th>DATE</th>
<th>RELEVANT CHANGE</th>
<th>TYPE OF CHANGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>January 1, 2008</td>
<td>Quarterly rate change</td>
<td>Rate</td>
</tr>
<tr>
<td>February 1, 2008</td>
<td>Child born</td>
<td>Circumstance</td>
</tr>
<tr>
<td>April 1, 2008</td>
<td>Quarterly rate change</td>
<td>Rate</td>
</tr>
<tr>
<td>April 16, 2008</td>
<td>Mother returns to work</td>
<td>Circumstance</td>
</tr>
<tr>
<td>May 1, 2008</td>
<td>New rules effective for families with one parent working</td>
<td>Rules</td>
</tr>
<tr>
<td>July 1, 2008</td>
<td>Quarterly rate change</td>
<td>Rate</td>
</tr>
<tr>
<td>July 10, 2008</td>
<td>Claim made by the family for the tax credit</td>
<td>Circumstance</td>
</tr>
</tbody>
</table>
The key outputs that a calculation needs to deliver to determine the family’s final benefit are

- The rate application between each change date
- The total amount of tax credit due to the family for the period from the birth of the child to the date of the claim
- The ongoing rate of tax credit due to the family assuming there are no further changes in circumstance
- The likely total amount payable to the family at the end of the tax year

Case 2: A Retrospective Change in Circumstances

This section provides the input data and outlines the required outputs for the case of a retrospective change of circumstance. Key input data and dates are outlined in Table 2.

<table>
<thead>
<tr>
<th>DATE</th>
<th>RELEVANT CHANGE</th>
<th>TYPE OF CHANGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>January 1, 2008</td>
<td>Quarterly rate change</td>
<td>Rate</td>
</tr>
<tr>
<td>April 1, 2008</td>
<td>Quarterly rate change</td>
<td>Rate</td>
</tr>
<tr>
<td>May 1, 2008</td>
<td>New rules effective for families with one parent working</td>
<td>Rules</td>
</tr>
<tr>
<td>July 1, 2008</td>
<td>Quarterly rate change</td>
<td>Rate</td>
</tr>
<tr>
<td>August 3, 2008</td>
<td>Eldest child leaves school</td>
<td>Circumstance</td>
</tr>
<tr>
<td>October 1, 2008</td>
<td>Quarterly rate change</td>
<td>Rate</td>
</tr>
<tr>
<td>December 1, 2008</td>
<td>Family notifies tax office that child left school</td>
<td>Circumstance</td>
</tr>
</tbody>
</table>

The key outputs that a calculation needs to deliver to determine the family’s obligation are

- The rate that should have been applied beginning on August 3
- The difference between the total amount that should have been paid to the family between August 3 and December 1 and the amount actually paid to them
- The ongoing rate of tax credit due to the family assuming no further changes in circumstance
- The likely total amount payable to the family to the end of the year
Solution Options for Time-Sensitive Calculations

The tax credit scenarios provided in the previous section are common cases that occur across the world. To resolve such issues and provide the correct amount of credit, one of two calculation methods can be employed. In this section, we provide an overview of both methods.

The Time-Slicing Method

Most application software vendors solve the tax credit problem by creating two separate rule sets that interact only at defined points. The first set of rules accurately calculates the specific rate or premium applicable at a given date (point in time). The second set of rules aggregates the individual point in time calculations and sums them to a specific amount where applicable.

This approach shall be referred to as the time-slicing approach, and it suffers from the following limitations:

- Building and maintaining the rules in conceptually separate sets—even if they are in the same physical code base—has a high TCO. The time-slicing method has a TCO that is at least three times higher than in Oracle’s policy automation solution.

- Separating point-in-time calculations from those that apply over a period of time can lead to very complex data structures. Such data structures are inefficient high-volume processing environments such as tax or social security calculations, where millions of customer records need to be processed in a timely manner.

- When the point-in-time rules are separate from the aggregation rules, it is difficult to accommodate special rules such as the start date for applying a new rate.

- Separating rule sets makes troubleshooting and debugging difficult, particularly in cases involving many changes in circumstance or rate.

- Applying additional rules to two separate rule sets can be very complex. This is especially true for “grandfathering” situations where an old rate applicable to a person can continue if they applied under an old set of rules that has subsequently changed.

- Because the aggregation rules are much harder to change than the point-in-time rules in this solution pattern, the calculation method actually limits the policy options available.

The time-slicing approach is very common in mainframe legacy environments. Vendors that offer enterprise resource planning and other packaged enterprise applications frequently embed the time-slicing calculation method in their products.

Most application software vendors solve the temporal reasoning problems by creating two separate rule sets that interact only at defined points. Common in mainframe legacy environments, this time-slicing approach suffers from many limitations, including a higher TCO.
Oracle’s Policy Automation Solution

Oracle now offers a powerful solution that enables complex rule sets to be “time aware.” That is, rule sets operate simultaneously for specific points in time as well as across time periods. Available in Oracle’s policy automation solution, this patent-pending calculation method provides a revolutionary way of quickly and simply capturing and applying rules required to accurately calculate changing rates.

Oracle’s temporal reasoning solution enables complex rule sets to be time aware so that rule sets can operate simultaneously for specific points in time as well as across time periods. This patent-pending calculation method provides a revolutionary way of quickly and simply capturing and applying rules required to accurately calculate changing rates.

As the worked example in the next section will illustrate, this approach involves incorporating the notion of time as a fundamental concept in the underlying determination engine. With the time-aware calculation method, an inherent property of every data item in the rule set (both inputs and outputs) is its value at a given point in time. Inbuilt temporal operators are provided that tap into this property, including functions to calculate time-dependent items such as:

- Whether a particular condition is true for a given number of days/months/years in a specific time period
- The total amount for a data item based on complex logic spanning any given time period such as the total amount of social security benefit over any given time period
- Whether a condition is true on, before, or after a specified time period

These functions enable natural logic to be captured in an understandable way. This calculation method can easily handle conditions such as the following:

- You must not have more than three alcoholic drinks in any two-hour period.
- Retirement age is 55 if you started work before 1950, and 65 if you started work in or after 1950.
- You are eligible for a disability pension if you have been off work due to an injury for three consecutive months in any 12-month period.
- Until the end of the current financial year, the tax is 1 percent. At that time, it increases to 2 percent. However, if your age at the end of the financial year is over 65, it will stay at 1 percent and increase by 0.25 percent a year, until it reaches a maximum of 2 percent.
A Pension Calculation Example

Oracle’s policy automation solution is best understood by working through a scenario that shows how rules are represented in Oracle Policy Modeling and executed within Oracle Policy Automation.

Pension Calculation Rules

For this worked example, a pension payment is payable based on the policy rules outlined below. To receive a payment, the employee must satisfy an age threshold.

- Up until January 1, 2007, this threshold was 55 years of age.
- From January 1, 2007, and forward, the threshold is 65 years of age.

The standard daily rate of an employee’s benefit is calculated according to the following:

- Until January 1, 2007, an employee is eligible to receive US$5 per day, regardless of marital status.
- After January 1, 2007, an employee is eligible to receive
  - US$6 per day if not married
  - US$7 per day if married

The actual daily rate paid (or the amount an employee is entitled to) is based on the following criteria, regardless of which time period they fall into:

- 1 x the standard daily rate if the person is not married
- 1.5 x the standard daily rate if the person is married

Rule Representation in Oracle Policy Modeling

The rules below are actual application code from Oracle Policy Modeling. They capture the business logic described above as rules expressed in natural language.

Total Entitlement

The business owner expresses the pension entitlement rule with an equation.

\[
\text{the person's total entitlement for pension for the period} = \text{TemporalDailySum (the person's daily entitlement for pension, the start of the period, the end of the period)}
\]

Daily Entitlement

The person’s daily pension entitlement is calculated using the rules expressed in Table 3. Again, these entitlement rules are drafted by the business owner.
TABLE 3. THE PERSON’S DAILY ENTITLEMENT

<table>
<thead>
<tr>
<th>BENEFIT APPLIED IS:</th>
<th>IF THE FOLLOWING CONDITIONS ARE MET:</th>
</tr>
</thead>
</table>
| The standard daily rate of benefit | • Person not married  
                                 | • Person satisfies age requirement |
| The standard daily rate of benefit x 1.5 | • Person married  
                                 | • Person satisfies age requirement |
| 0 | Otherwise |

Age Requirements

The following business rules express the age requirements within Oracle Policy Modeling.

the person satisfies the age requirement if

both

\[
\text{TemporalBefore}(2007-01-01) \text{ and } \text{the person's age in years} \geq 55
\]

or

both

\[
\text{TemporalOnOrAfter}(2007-01-01) \text{ and } \text{the person's age in years} \geq 65
\]

Actual Age

The person’s actual age is expressed with an equation.

the person’s age in years = TemporalYearsSince (the person’s date of birth)

Standard Daily Rate

The standard daily rate of benefit is calculated using the rules expressed in Table 4. These entitlement rules are drafted and input into Oracle Policy Modeling by the business owner.
TABLE 4. THE STANDARD DAILY RATE OF BENEFIT

<table>
<thead>
<tr>
<th>BENEFIT RATE APPLIED IS:</th>
<th>IF THE FOLLOWING CONDITIONS ARE MET:</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>• TemporalBefore (2006-07-01)</td>
</tr>
<tr>
<td>6</td>
<td>• TemporalOnOrAfter (2006-07-01) AND</td>
</tr>
<tr>
<td></td>
<td>• Person not married</td>
</tr>
<tr>
<td>7</td>
<td>• TemporalOnOrAfter (2006-07-01) AND</td>
</tr>
<tr>
<td></td>
<td>• Person married</td>
</tr>
<tr>
<td>Uncertain</td>
<td>Otherwise</td>
</tr>
</tbody>
</table>

A Sample Case

Now we will step through an example that illustrates how the rules drafted in the previous section are applied to an actual case. In this simple scenario, the person who is due to receive pension benefits was born on January 1, 1950, and was married on April 1, 2007. The assessment period is January 1, 2005, until January 1, 2020.

Input Timeline

The person is assessed over a period from January 1, 2005, until January 1, 2020. Table 5 shows the inputs for the calculation.

TABLE 5. THE INPUT TIMELINE

<table>
<thead>
<tr>
<th>DATE</th>
<th>RELEVANT CHANGE</th>
<th>TYPE OF CHANGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>January 1, 1950</td>
<td>The person is born.</td>
<td>Circumstance</td>
</tr>
<tr>
<td>July 1, 2006</td>
<td>Rate change for single/married people.</td>
<td>Rate</td>
</tr>
<tr>
<td>January 1, 2007</td>
<td>New rules for age criteria.</td>
<td>Rules</td>
</tr>
<tr>
<td>April 1, 2007</td>
<td>The person is married.</td>
<td>Circumstance</td>
</tr>
</tbody>
</table>

Output Timeline

Over time, the inputs in Table 5 generate results that are outlined in Table 6. Note there is no change in the calculated result on April 1, 2007, even though the person’s status changes to married. This is because the preliminary age requirement is not satified and hence there is no benefit to be received.
### TABLE 6. THE OUTPUT TIMELINE

<table>
<thead>
<tr>
<th>DATE</th>
<th>CALCULATED RESULT</th>
</tr>
</thead>
<tbody>
<tr>
<td>January 1, 2005</td>
<td>• Person turns 55</td>
</tr>
<tr>
<td></td>
<td>• Person’s daily rate is US$5</td>
</tr>
<tr>
<td>July 1, 2006</td>
<td>• Person’s daily rate is US$6</td>
</tr>
<tr>
<td>January 1, 2007</td>
<td>• Person’s daily rate is US$0 per day because they no longer satisfy the changed age requirements</td>
</tr>
<tr>
<td>January 1, 2015</td>
<td>• Person turns 65</td>
</tr>
<tr>
<td></td>
<td>• Person’s daily rate is US$10.50</td>
</tr>
</tbody>
</table>

### Decision Report

The person’s total pension entitlement from January 1, 2005, to January 1, 2020, is US$23,017.50. This amount is calculated using the following decision report:

The person’s daily entitlement for pension is

- US$0.00 prior to January 1, 2005
- US$5.00 from January 1, 2005
- US$6.00 from July 1, 2006
- US$0.00 from January 1, 2007
- US$10.50 from January 1, 2015

Whether the person is married is

- False prior to April 1, 2007
- True from April 1, 2007

Whether the person satisfies the age requirement is

- False prior to January 1, 2005
- True from January 1, 2005
- False from January 1, 2007
- True from January 1, 2015

The person’s age in years is

- 55 from January 1, 2005
- 65 from January 1, 2015

Person’s date of birth is January 1, 1950
Conclusion

With its acquisition of Haley, Oracle has nearly 20 years of experience with complex, time-based rules. Oracle has deployed numerous solutions that solve the problem of rules and data that change over time across the world. This experience, coupled with our research and development investment, allowed us to develop a unique solution to handle the following three intersecting areas of change:

- Changes to policies and rules
- Changes to rates and other reference data
- Changes to individual circumstance

Oracle’s policy automation solution provides a clear and understandable way to handle cases that require calculation over a period of time when all three of the above inputs are changing constantly. From a processing perspective, Oracle’s policy automation solution is more efficient because it requires less CPU time to perform calculations that stretch over a time period. The net result for a customer is a much lower TCO for building and maintaining time-based rules and much-higher accuracy and consistency in the calculation outputs. For organizations that manage billions of dollars in payments, such a solution is a mandatory requirement.

Customers are already demanding the massive increase in productivity that comes from the temporal reasoning capability in Oracle Policy Modeling and Oracle Policy Automation. We expect this adoption to increase as organizations modernize their legacy systems and move to an architecture where time-based complexity is encapsulated in a comprehensible set of rule documents. Once encapsulated this way, packaged solutions integrated with Oracle Policy Modeling and Oracle Policy Automation will be able to deal with the complexity of government regulation and internal policy.