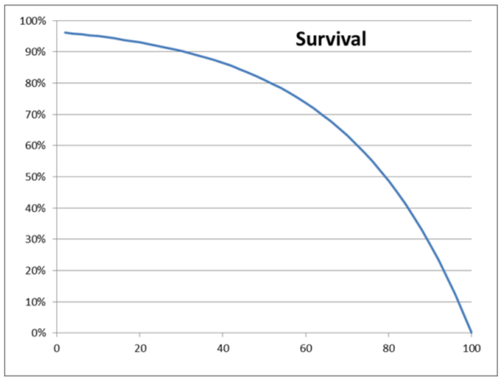
Survival Analysis using Cox Regression

"*On a long enough timeline, the survival rate for everything drops to zero*" –Tyler Durden

In the domain of Survival Analysis, the Cox Proportional Hazards model is a commonly used technique that calculates the relative risk of an event occurring as a function of any number of covariates. It's called Survival Analysis because the "event" typically represents the end of something, such as a component failure, a customer being lost, or any other type of "end of life." The Cox Regression model quantifies the effect that each independent variable has on the Hazard Rate, or the likelihood that an event, assuming it has not occurred yet, will occur at any point in time. For each record, the model outputs the Hazard Ratio, representing the Hazard Rate for that customer divided by the Hazard Rate for the average customer.



Hazard Ratio:
Greater than One → Sooner than Average
Equal to One → Average
Less than One → Later than Average

$$HR_{i-vs-Avg} = e^{(\beta_1 x_{i1}+\ldots+\beta_k x_{ik}) - Avg_{j=1}^{n}\left[\beta_1 x_{j1}+\ldots+\beta_k x_{jk}\right]}$$

For more detailed information on Cox Regression, please consult section 3 of the paper entitled "Cox Proportional-Hazards Regression for Survival Data" [3].

This R Script has two functional modes:

- Training creates a model and persists it in an .Rdata file while returning its predictions.
- Scoring uses the model created during training to make predictions on a new dataset.

How to Deploy to MicroStrategy:

Prerequisite: Please follow the instructions in the R Integration Pack User Guide [1] for configuring your MicroStrategy environment with R and that the R Script functions have been installed in your MicroStrategy project(s).

1) Download the SurvivalAnalysis.R file from the R Script Shelf [2] and place it in the RScripts folder where the R Integration Pack is installed (usually C:\Program Files (x86)\R Integration Pack\RScripts).
2) From the R console, run the SurvivalAnalysis.R script to verify the script runs correctly. For details, see the "**Running from the R Console**" section below.
3) Cut-and-paste the appropriate metric expression below in any MicroStrategy metric editor. Map the arguments to the appropriate MicroStrategy metrics. A description of each output is shown below.
4) Use the new metric in reports, dashboards and documents.

Metric Expressions:

The metric expressions shown here assume that the SurvivalAnalysis.R file has been downloaded to the server. If using the URL-based approach where the SurvivalAnalysis.R file is accessed directly via URL, please consult the R Script Shelf [2].

1) **Risk:** For each record, returns the risk of an event occurring relative to the average. For instance, a value of 120% means that an event is 20% more likely to occur to this record than a record which had the average values for each independent variable.

   If using R Integration Pack V 1.0 with 27 pre-defined parameters:

   For training, use this metric expression:
   ```
   RScript<_RScriptFile="Survival.R",_InputNames="Time,Status,Vars",
   StringParam9="Survival", BooleanParam9=TRUE>(Time, Status, Vars)
   ```

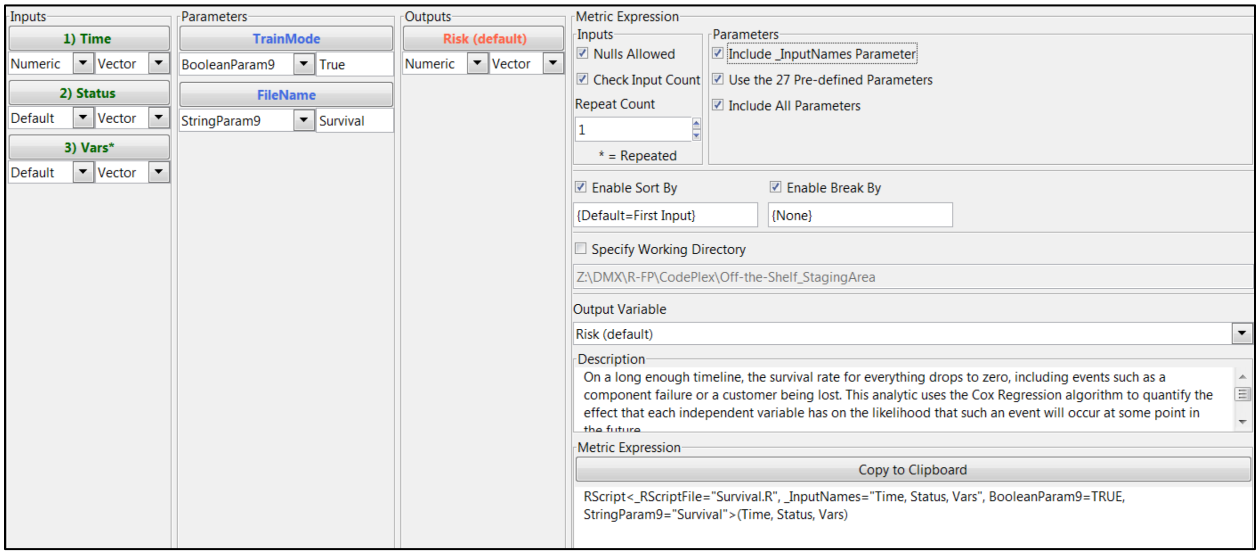
   For scoring, use this metric expression:
   ```
   RScript<_RScriptFile="Survival.R",_InputNames="Time,Status,Vars",
   StringParam9="Survival", BooleanParam9=FALSE>(Time, Status, Vars)
   ```

   If using R Integration Pack V 2.0 with named parameters:

   For training, use this metric expression:
   ```
   RScript<_RScriptFile="Survival.R", _InputNames="Time,Status,Vars",
   _Params="TrainMode=TRUE, FileName='Survival'">(Time, Status, Vars)
   ```

   For scoring, use this metric expression:
   ```
   RScript<_RScriptFile="Survival.R", _InputNames="Time, Status, Vars",
   _Params="TrainMode=FALSE, FileName='Survival'">(Time, Status, Vars)
   ```

Analytic Signature:



Inputs
1) Time: Numeric, Vector
2) Status: Default, Vector
3) Vars*: Default, Vector

Parameters
TrainMode: BooleanParam9, True
FileName: StringParam9, Survival

Outputs
Risk (default): Numeric, Vector

Metric Expression
Inputs: ☑ Nulls Allowed; ☑ Check Input Count; Repeat Count: 1; * = Repeated
Parameters: ☑ Include _InputNames Parameter; ☑ Use the 27 Pre-defined Parameters; ☑ Include All Parameters
☑ Enable Sort By: {Default=First Input}
☑ Enable Break By: {None}
☐ Specify Working Directory: Z:\DMX\R-FP\CodePlex\Off-the-Shelf_StagingArea
Output Variable: Risk (default)

Description: On a long enough timeline, the survival rate for everything drops to zero, including events such as a component failure or a customer being lost. This analytic uses the Cox Regression algorithm to quantify the effect that each independent variable has on the likelihood that such an event will occur at some point in the future

Metric Expression:

```
RScript<_RScriptFile="Survival.R", _InputNames="Time, Status, Vars", BooleanParam9=TRUE,
StringParam9="Survival">(Time, Status, Vars)
```

Inputs:

Time: The amount of time that it took for the event to occur. If Status=0, then the event has not occurred and the time should be either 0 or null.

Status: A variable that represents whether or not the event occurred. Usually, this metric should be 0/1, meaning that the value is 0 if the event did not occur and is 1 if the event did occur.

Vars: The independent variables that are used as the basis for generating risk scores. Since the Vars argument is a repeated input, it can be mapped to any number of MicroStrategy metrics. In this way, we enable Cox Regression models to consider any number of variables when generating risk scores.

Note: **Repeated inputs must all be the same type (i.e. all variables must be numeric or all variables must be strings)**

Parameters:

TrainMode: Uses BooleanParam9 with a default of TRUE. When set to TRUE, the R script will train (i.e. create) and save a Cox Regression model using the dataset provided. When set to FALSE, the R script will score the records on the report against a pre-existing model. In practice, one first trains a model and once that model has been validated, scores unknown records against that model.

FileName: Uses StringParam9 with a default of "Survival". This parameter specifies the file name where the trained model is stored in an Rdata file . Please note the R Script automatically appends the ".Rdata" file extension to this file name. This parameter is only used when TrainMode=TRUE; when TrainMode=FALSE, no Rdata file is saved.

Outputs:

Risk: For each record, returns the risk of an event occurring relative to the average. For instance, a value of 120% means that an event is 20% more likely to occur to this record than a record which had the average values for each independent variable.

Additional Results Generated by the R Script:

Two files are stored in the working directory:

Rdata File: This file persists the state of several objects from the R environment for later inspection, analysis, and reuse, including dfTrain (a data frame containing the data read in from MicroStrategy used to train the model), model (the Cox Regression model object), and Risk (the relative risk of each record). This file is loaded when scoring new records to reference the model that was trained based on past history.

Running from the R Console:

In addition to processing data from MicroStrategy during execution of a report or dashboard, the R script is also configured to run from the R console. Running the script for the R Console verifies that the script is functioning as expected, a good practice when initially deploying this analytic to a new system (for more details, see "Configuring dual execution modes" in [1]).

When run from the R Console, if the script is executing properly, a "Success!" message will appear in the console. If a "Success!" message does not appear, then please note the error in order to take appropriate action. For common pitfalls, please consult the **Troubleshooting** section below.

Troubleshooting:

This section covers certain situations you might encounter but it's not intended as a comprehensive list of possible errors.

1) If an error occurs, the report may fail with an error message, or nulls returned as the output. In these cases, please refer to the RScriptErrors.log file generated for further guidance and the DSSErrors.log. Please consult the User Guide [1] and the R documentation for additional guidance.

2) The script will attempt to install the required R package.
   survival: This R package contains functions that support Survival Analysis, including the creation of the Cox Regression model used to calculate the relative risk of an event occurring.
   If the package is not successfully installed, you can install using the R console using the command:
   ```
   install.packages("survival", repos="http://cran.rstudio.com/")
   ```

3) If a mix of string and numeric variables is passed in to the Vars argument, the report will fail with an error message indicating that a variable with unexpected type was passed in. This can be remedied by using all strings or all numeric variables corresponding to the Vars argument.

4) If the error message "cannot open the connection" is returned, that means that the R script either cannot load the .Rdata file from the specified location (when scoring) or does not have access to the working directory to write the .Rdata file (when training). Please make sure that the value passed in to StringParam9 is an existing file. For instance, if StringParam9 is set to Survival, then there must be a file Survival.Rdata in the working directory. Please consult the User Guide [1] for more information. Additionally, please make sure that the working directory is a writable location.

Example (using MicroStrategy Tutorial Project):

In order to combat an escalation in the number of customers who are churning, or leaving the company in the midst of their contracts, a large Telco organization wants to create and deploy a Cox Regression model that identifies which customers are most likely to churn. By proactively identifying the most at-risk customers, the organization can implement different measures aimed at assuaging these disgruntled customers.

The first step in building our model is creating a metric that captures the time it took for each of our customers to churn. This metric's value should be 0 or null for all customers who have yet to churn. The following metric expression meets both of the requirements:

```
IF((TelcoChurn = 1),(((Month(CancelDate)+(12 * Year(CancelDate)))- Month(StartDate)) -
(12 * Year(StartDate))), 0)
```

A metric with this definition named Months Before Cancellation can be found in Tutorial -> Public Objects -> Reports-> MicroStrategy Platform Capabilities -> MicroStrategy Data Mining Services -> Imported PMML -> Telco Churn -> Cox Regression.

Using historical information about the characteristics of customers, whether they've churned or not, and how long it took them to churn, we'll create a metric "Cox Regression Trainer" with the following definition where Time is mapped to Months Before Cancellation, Status is mapped to TelcoChurn, and Vars consists of the metrics Household_Count_ID, Income_Bracket_ID, HelpdeskCalls, and DroppedCalls:

If using R Integration Pack V 1.0 with 27 pre-defined parameters:

```
RScript<[BooleanParam9]=True,[StringParam9]="Survival",[_RScriptFile]="Survival.R",[_I
nputNames]="Months,Churn,HHCount,IB,Dropped,Helpdesk">([Months Before
Cancellation],TelcoChurn, [Household Count ID], [Income Bracket ID], DroppedCalls,
HelpdeskCalls)
```

If using R Integration Pack V 2.0 with named parameters:

```
RScript<[_RScriptFile]="Survival.R",
[_InputNames]="Months,Churn,HHCount,IB,Dropped,Helpdesk", [_Params]="TrainMode=TRUE,
FileName='Survival'">([Months Before Cancellation], TelcoChurn, [Household Count ID],
[Income Bracket ID], DroppedCalls, HelpdeskCalls)
```

Then, create a report as follows:

Rows:
- **Customer**

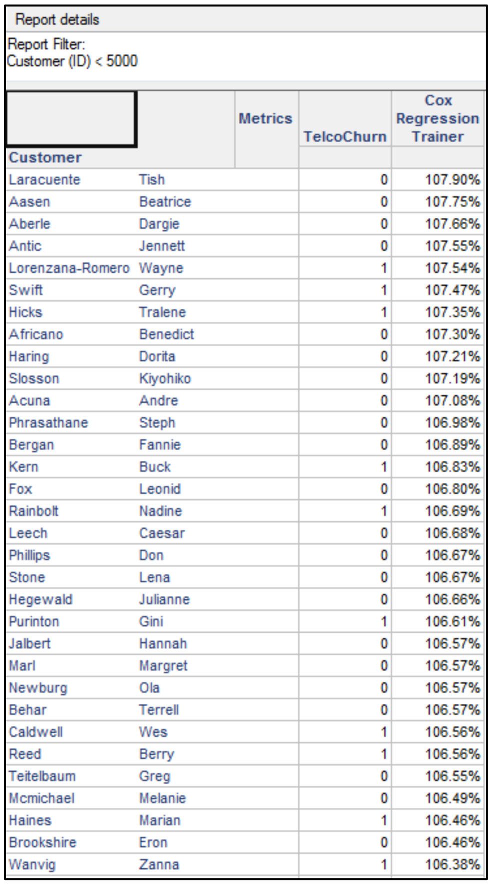
Columns:
- **TelcoChurn**
- **Cox Regression Trainer metric**

Filter:
- **Customer ID < 5000**

Formatting:
- **Cox Regression Trainer (Percentage)**

Sort By:
- **Cox Regression Trainer (desc)**

Here is how the report should look:



Report details

Report Filter:
Customer (ID) < 5000

Customer		TelcoChurn	Cox Regression Trainer
Laracuente	Tish	0	107.90%
Aasen	Beatrice	0	107.75%
Aberle	Dargie	0	107.66%
Antic	Jennett	0	107.55%
Lorenzana-Romero	Wayne	1	107.54%
Swift	Gerry	1	107.47%
Hicks	Tralene	1	107.35%
Africano	Benedict	0	107.30%
Haring	Dorita	0	107.21%
Slosson	Kiyohiko	0	107.19%
Acuna	Andre	0	107.08%
Phrasathane	Steph	0	106.98%
Bergan	Fannie	0	106.89%
Kern	Buck	1	106.83%
Fox	Leonid	0	106.80%
Rainbolt	Nadine	1	106.69%
Leech	Caesar	0	106.68%
Phillips	Don	0	106.67%
Stone	Lena	0	106.67%
Hegewald	Julianne	0	106.66%
Purinton	Gini	1	106.61%
Jalbert	Hannah	0	106.57%
Marl	Margret	0	106.57%
Newburg	Ola	0	106.57%
Behar	Terrell	0	106.57%
Caldwell	Wes	1	106.56%
Reed	Berry	1	106.56%
Teitelbaum	Greg	0	106.55%
Mcmichael	Melanie	0	106.49%
Haines	Marian	1	106.46%
Brookshire	Eron	0	106.46%
Wanvig	Zanna	1	106.38%

Now that we have trained our model, we can score the model against the active customers that we have. In this case, we utilize the metric expression for scoring to create a metric called Cox Regression Predictor:

If using R Integration Pack V 1.0 with 27 pre-defined parameters:

```
RScript<[BooleanParam9]=False,[StringParam9]="Survival",[_RScriptFile]="Survival.R",[_
InputNames]="Months,Churn,HHCount,IB,Dropped,Helpdesk">([Months Before
Cancellation],TelcoChurn, [Household Count ID], [Income Bracket ID], DroppedCalls,
HelpdeskCalls)
```

If using R Integration Pack V 2.0 with named parameters:

```
RScript<[_RScriptFile]="Survival.R",
[_InputNames]="Months,Churn,HHCount,IB,Dropped,Helpdesk", [_Params]="TrainMode=FALSE,
FileName='Survival'">([Months Before Cancellation], TelcoChurn, [Household Count ID],
[Income Bracket ID], DroppedCalls, HelpdeskCalls)
```

Now, create a scoring report as follows:

Rows:

- **Customer**

Columns:

- **TelcoChurn**

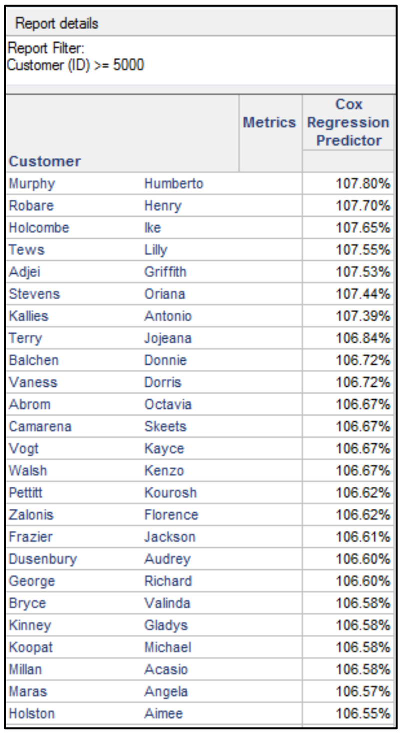
- **Cox Regression Predictor metric**

Filter:
- **Customer ID >= 5000**

Formatting:
- **Cox Regression Predictor (Percentage)**

Sort By:
- **Cox Regression Predictor (desc)**

Here is how the report should look:



Report details

Report Filter:
Customer (ID) >= 5000

	Metrics	Cox Regression Predictor
Customer		
Murphy	Humberto	107.80%
Robare	Henry	107.70%
Holcombe	Ike	107.65%
Tews	Lilly	107.55%
Adjei	Griffith	107.53%
Stevens	Oriana	107.44%
Kallies	Antonio	107.39%
Terry	Jojeana	106.84%
Balchen	Donnie	106.72%
Vaness	Dorris	106.72%
Abrom	Octavia	106.67%
Camarena	Skeets	106.67%
Vogt	Kayce	106.67%
Walsh	Kenzo	106.67%
Pettitt	Kourosh	106.62%
Zalonis	Florence	106.62%
Frazier	Jackson	106.61%
Dusenbury	Audrey	106.60%
George	Richard	106.60%
Bryce	Valinda	106.58%
Kinney	Gladys	106.58%
Koopat	Michael	106.58%
Millan	Acasio	106.58%
Maras	Angela	106.57%
Holston	Aimee	106.55%

By sorting on the customers with the highest Relative Risk as identified by our Cox Regression model, the organization can focus its efforts on assuaging the most at-risk customers rather than focusing on customers who are likely to stay regardless if they are reached out to.

References:

1) MicroStrategy R Integration Pack User Guide: https://rintegrationpack.codeplex.com/documentation
2) R Analytic Shelf:
   https://rintegrationpack.codeplex.com/wikipage?title=R%20Script%20%22Shelf%22&referringTitle=Home#
3) Cox Proportional-Hazards Regression for Survival Data
   http://cran.r-project.org/doc/contrib/Fox-Companion/appendix-cox-regression.pdf