MX Analyze

User Guide Supplement: Risk Scores

Manifest
MEDEX

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Purpose

The purpose of this document is to provide detailed documentation on the creation and use of risk models within MX Analyze.

Risk Scores and Risk Classes

What is a risk score?

A risk score is a number that represents the probability for an individual incurring a cost, experiencing a specific event or developing a specific condition within a specified time frame. The risk score is visible in the patient/member list when hovering over the risk class icon, and enables the list to be sorted numerically in any risk column. In addition, the risk score is displayed in the Individual Profile on the Future Risk table and Risk Trend graph.

What is a risk class?

A standard approach was developed based on population relative risk to define standard Risk Class categories across all risk models. A standard approach was used to segment the patients into the new Risk Classes of Low, Moderate, High, and Very High.

Relative risk is calculated based on the risk bin rate compared to the overall population rate. Using inpatient admission Risk Classes as an example, if the Very High Risk Class has an inpatient admission rate of 60% and the overall population rate is 10%, the relative risk is 6 (60% / 10%); or 6 times the rate of the overall population.

The Risk Classes use the following relative risk ranges:

- Low Risk = relative risk < 1
- Moderate Risk = relative risk between 1 - 3
- High Risk = relative risk between 3 - 5
- Very High Risk = relative risk > 5

The following table is an illustrative example of the Risk Classes with the respective rates and calculations.

Risk Class:	Low	Moderate	High	Very High	Total Population
Relative Risk:	<1	1-3	3-5	>5	
Population	80,000	10,000	7,500	2,500	100,000
Population %	80.0	10.0	7.5	2.5	100.0
True Positives	3,500	2,000	3,000	1,500	10,000
Positive Predictive Value (PPV) %	4.4	20.0	40.0	60.0	10
Sensitivity %	35.0	20.0	30.0	15.0	100
Relative Risk	0.4	2.0	4.0	6.0	1.0

What risk models are available in MX Analyze?

Risk scores are produced for every patient/member on each risk model.

	Population Risk	Acute Episode Risk	Transition Risk
Timeframe	• Future 12 Months • Risk change period 30 days or 90 days	• During the Active Encounter	• Within 30 Days of Encounter Discharge
Utilization Cost	• Total Cost		
Utilization Event	• Emergency Department Visit • Inpatient Admission		• IP Readmission • ED Revisit
Disease Event	• Acute Myocardial Infarction • Asthma Exacerbation • Mortality • Suicide Attempt • Opium / Narcotic Overdose • Hip / Lumbar Spine / Pelvic Fracture in the Elderly • CVA/Stroke • Community Sepsis • COVID-19 Mortality	• Mortality • Sepsis • Length of Stay • 30 day IP Readmission • 30 day ED Visit	

Condition	• Alzheimer's • Back/Spine Disorder • Cancer, Lung • Cancer, Prostate • Cardiac Dysrhythmias • Coronary Heart Disease • Chronic Kidney Disease • Chronic Obstructive Pulmonary Disease (COPD) • Congestive Heart Failure/HF • Heart Valve Disorder • Essential Hypertension • Opioid Abuse • Type 2 Diabetes

How are risk scores developed?

Risk model development

The data science team researches previous publications to understand methods and critical risk drivers, then works with the product team to refine the definition of the condition or event they are trying to predict.

Once the definition is set, they will use any and all data available including clinical, claims and social determinants in the modeling process. This process typically starts with tens of thousands of variables and ends with a few hundred important ones. In risk modeling, these variables are referred to as *risk features*. They can generally be thought of as data elements that most influence the risk of the cost, event or condition.

Machine learning

Analyze utilizes custom machine learning. That means instead of deploying a standard model developed on a pristine, engineered data set, we use the real MX data and run the machine learning process on it. The process consists of taking multiple years' worth of data and constructing two cohorts: *a case cohort and a control cohort*. The first two years of data to develop, prospectively test and calibrate model performance, and an additional two years to validate the performance before placing the models into

the client production environment. Different algorithms are applied in the process and the one that yields the best result for each risk type is ultimately packaged up and deployed to the client. The following algorithms are typically applied and compared during the machine learning process:

1) Linear Regression
2) Random Forest
3) Deep Learning
4) XGBoost
5) Logistic regression

Evaluating the models

The two primary ways the models are evaluated are by looking at the Receiver Operating Characteristic Curve and a statistical table showing sensitivity, positive predictive value, and relative risk by Risk Class.

Receiver Operating Characteristic Curve

ROC Curve: ROC curve is used to measure true positive rate against false positive rate. The closer the curve follows the left boarder and then the upper boarder, the more accurate the model is. The closer the curve comes to a 45 degree, the less accurate the model is.

The value given to the ROC Curve, called the Area Under the Curve (AUC) can range from 0.5 to 1.0, where 0.5 is an essential coin flip and 1.0 is a perfect predictor. This is also called the C-Statistic.

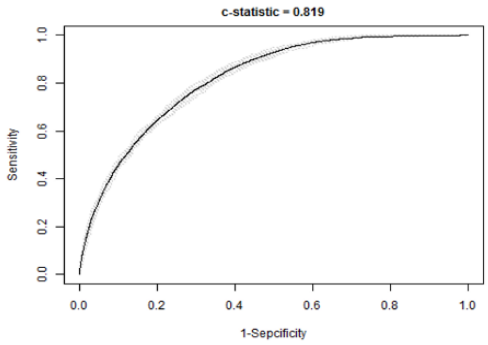


Figure 1: Example ROC Curve

In this section we are using a sample Future 1 Year IP Admission model statistical table to provide definitions and tie together the Risk Score with the Risk Class. First the description, followed by the definitions.

In the example below, looking at the “Total” column, the total population size is 100,000. Out of that population, 10,000 people were actually admitted to the hospital (“True Positives”). Therefore, the Positive Predictive Value, or true positive rate, for this population is 10% (circled). This is the foundation for defining the Risk Class bins.

Risk Class:	Low	Moderate	High	Very High	Total Population
Relative Risk:	<1	1-3	3-5	>5	
Population	80,000	10,000	7,500	2,500	100,000
Population %	80.0	10.0	7.5	2.5	100.0
True Positives	3,500	2,000	3,000	1,500	10,000
Positive Predictive Value (PPV) %	4.4	20.0	40.0	60.0	10
Sensitivity %	35.0	20.0	30.0	15.0	100
Relative Risk	0.4	2.0	4.0	6.0	1.0

Using the definitions of Risk Class covered on page 4 coupled with the table above, let's walk through the process.

- The Low Risk class contains the members who have a predicted IP Admission rate below 10%, as this is the overall rate for the population. The actual rate for this population (PPV) was 4.4%.
- The Moderate Risk class contains the members who have a predicted IP Admission rate that is 1-3 times the overall rate for the population (1*10 – 3*10), or 10-30%. The actual rate for this population was 20%.
- The High Risk class contains the members who have a predicted IP Admission rate that is 3-5 times the overall rate for the population (3*10 – 5*10), or 30-50%. The actual rate for this population was 40%.
- The Very High Risk class contains the members who have a predicted IP Admission rate that is 5 times or greater the overall rate for the population (5*10), or >50%. The actual rate for this population was 60%.
- Using the PPV, the Relative Risk is calculated for each risk class. This is calculated by dividing the PPV for the risk class by the PPV for the entire population. Using the table above, the Low Risk Class mean relative risk is calculated 4.4/10 = 0.44
- This calculation is repeated for each Risk Class. Pulling it all together, the first row of the table provides the general relative risk per Risk Class, while the last row (relative risk) provides the actual relative risk for the population and falls within the general relative risk range in the first row. Using the table above to illustrate:

Header Row:	Risk Class:	Low	Med	High	Very High
	Relative Risk:	<1	1-3	3-5	>5
Row 6:	Relative Risk	0.4	2	4	6

Special Situations

There may be times when the incidence rate for the population requires an adjustment to the standard approach. Two examples:

- The incidence rate (PPV) for the overall population is very high, i.e., 22% of the population visited the ED within a 12 month period. The Very High Risk Class would therefore be >100% of the population >(5*22%), so the Low Risk is set at 15 rather than 22, and Very High at >75.

- The incidence rate (PPV) is extremely low in the population. In this case, a 0.5% cutoff is used rather than 1. An example of this using an Opium/Narcotic Overdose risk model. The overall incidence rate is only 0.06%.

	Low 0-.5	Moderate 0.5-1.5	High 1.5-2.5	Very High 2.5-15	Total
Number of Patients	1,089,421	3558	56	523	1,093,558
Percentage of Patients	99.62	0.33	0.01	0.05	100
True Positive	509	74	2	46	631
PPV (%)	0.05	2.08	3.57	8.8	0.06
Sensitivity (%)	80.67	11.73	0.32	7.29	100
Relative Risk	0.81	36.04	61.89	152.43	1

What is impressive here is that while the overall incidence rate is extremely small, 0.06%, we can identify the 0.05% of the population at the highest risk.

The individuals in this risk class have a 152x greater risk of overdose than the average person in the population.

Definitions

Risk Score: Each model (except for the cost model and length of stay model) yields a risk score between 0-100 that show the probability of the event. For example, if a patient scores 70 for the Risk of ED visit model, that patient is 70% likely to have the ED visit in the next 12 months.

In the cost model, individuals are assigned a value expressed in dollars that represents the expected future 12-month cost average for all the individuals in that risk class.

In the predicted length of stay model, individuals are assigned a value expressed in days that represent the expected number of days for that encounter.

Population: This is the total number of individuals in the population studied assigned to the Risk Class by the algorithm.

Population %: This is the percent of the total population that fall into the specific Risk Class.

True Positive: This is the total number of true positive cases within those individuals assigned to the risk class.

Positive predictive value (PPV%): This is the true positive rate, measuring the percentage of positive cases within the Risk Class over the total population within the Risk Class. For example, the PPV% for Moderate Risk class in the above model is 20%. That indicates that each of the 10,000 individuals in the group has roughly a 20% chance of the condition or event. Or said another way, 20% of the group will have the condition or event (2,000/10,000).

Sensitivity (%): measures the percentage of true positive cases within a Risk Class out of the total true positive cases within the total population. For example, the Moderate Risk Class sensitivity for the above model is 20% (2,000/10,000).

Incidence Rate: measures the total number of cases over the total population in a given time period. In the above example, it equals 10% (=10,000/100,000). This is the PPV% for the Total Population in the table above.

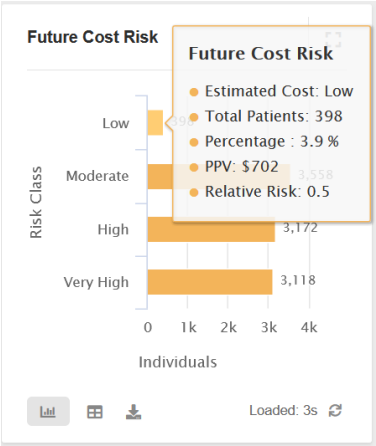
Relative Risk: In tandem with probability, it is important to understand the relative risk to the population. As in the above example, the general population has a 10% incidence rate, those in the Moderate Risk Class have a 20% incidence rate, so the relative risk for the Moderate Risk Class is 2 (20/10).

Maintaining the models

As a rule, machine learning is performed semi-annually, if new data or data sets are incorporated or if performance deteriorates. Model performance is monitored continuously.

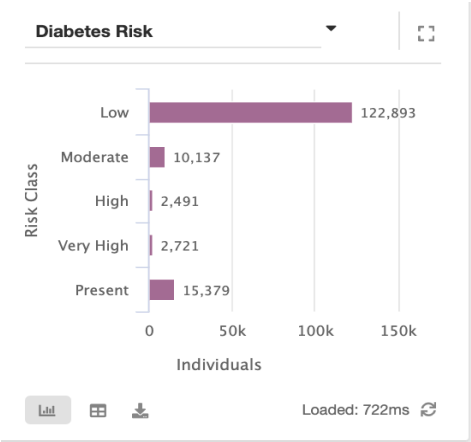
How should population risk scores be interpreted?

In the risk bins, the risk class is on the vertical axis, while the number of individuals is on the horizontal axis.



Population cost model scores

In the Future Cost Risk model, scores assigned are in dollars and represent the expected future medical spend for the individual. Here, there are 398 individuals in the population with a low expected future spend of $702 each on average in the next 12 months, and 3,118 individuals with a very high expected future spend of $13,982 each in the next 12 months. Score ranges and distribution depend upon the population data.

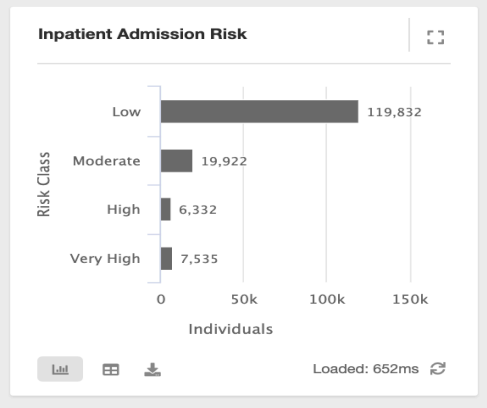


Population condition model scores

In condition models like Diabetes, numeric scores assigned are equal to the probability that the individual will develop the condition within the next 12 months. Here, there are 122,893 individuals in the population with a low chance of being diagnosed with Diabetes in the future 12 months, and 2,721 individuals with a very high chance. There are also 15,379 individuals who already have been diagnosed with Diabetes. Score ranges from Low to Present with the distribution dependent upon the population data.

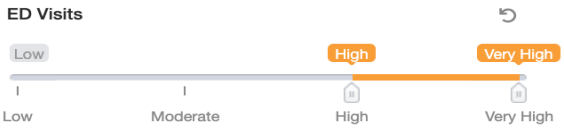
Population event model scores

In event models like IP Admission in Future 12 Months, numeric scores assigned are equal to the probability they will experience the event within the next 12 months. Here, there are 119,832 individuals in the population with a Low chance of an inpatient admission in the future 12 months, and 7,535 individuals with a Very High chance of an inpatient admission in the next 12 months.



How are population risk scores used?

MX Analyze users often use the risk scores to stratify a large population into a smaller cohort for outreach and intervention. For example, the user can create an outreach list of individuals with an elevated risk for an ED visit by sliding the lower limit on the filter.

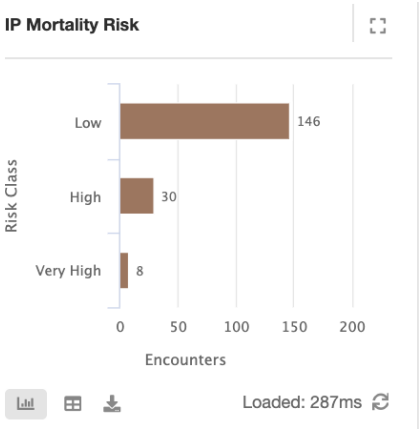


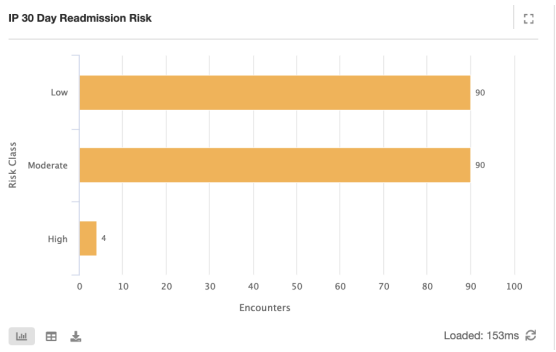
Others use the risk distribution to better understand and manage resources, resource assignments or program enrollment, like Diabetes Management.

How should acute episode risk scores be interpreted?

Encounter event model scores

There are two types of event models in the Acute Episode Risk Solution. The first are models predicting an event during the encounter (i.e. before discharge) and the second is predicting an event within 30 days after the encounter discharge. In both types of event models, numeric scores assigned are equal to the probability they will experience the event within the defined timeframe. In the IP Mortality risk distribution, there are 146 individuals in the population with a Low risk of death during the encounter, 30 individuals with a High risk of death during the encounter, and just 8 with a Very High risk of death.

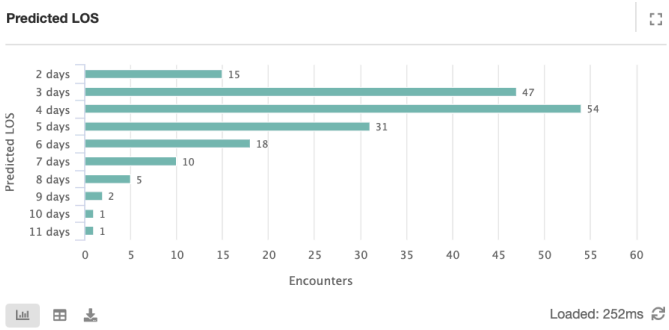




The IP 30 Readmission Risk distribution shows 90 active inpatients at Low risk for readmission, 90 at Moderate risk and just 4 at High risk for readmission.

Predicted length of stay model scores

In the predicted length of stay model (LOS), numeric scores assigned are in days. Here, 54 active inpatients have an expected length of stay equal to 4 days and 5 active inpatients have an expected length of stay equal to 8 days. Score ranges and distribution depend upon the population data.

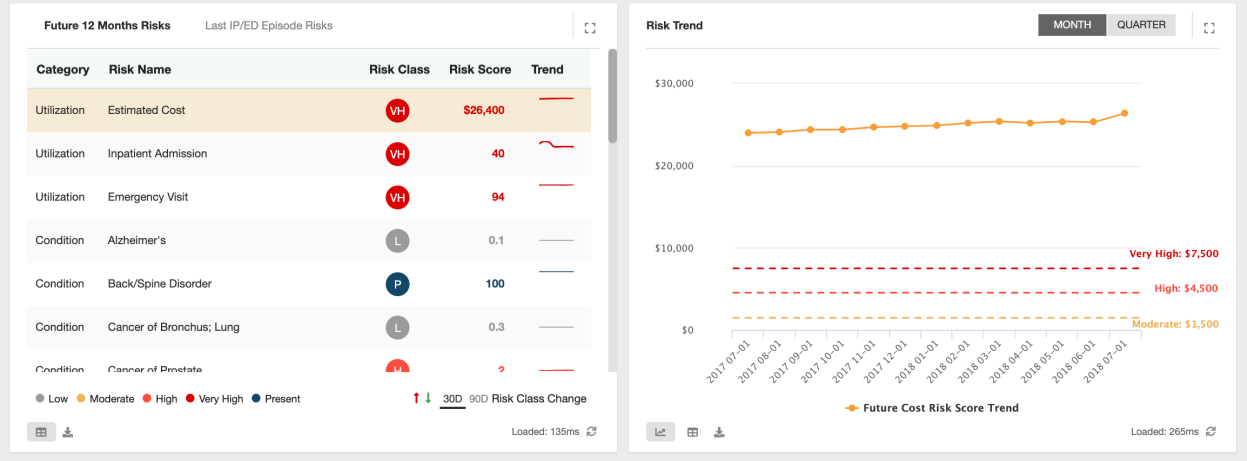


How are the individual risk scores applied?

Individuals are assigned a score for each model. The following rounding rules apply. For cost and utilization models, the scores are rounded to the nearest integer starting with 1. For other models, scores from 0.0 to 0.149 are rounded to 0.1, while scores from 0.15 to 1.49 are rounded to 1, 1.5 to 2.49 are rounded to 2, etc.

How should individual risk scores be interpreted and used?

Each individual in the population has a summary view that includes all of the risk scores and risk score trends in addition to the risk features that are picked up by each model.



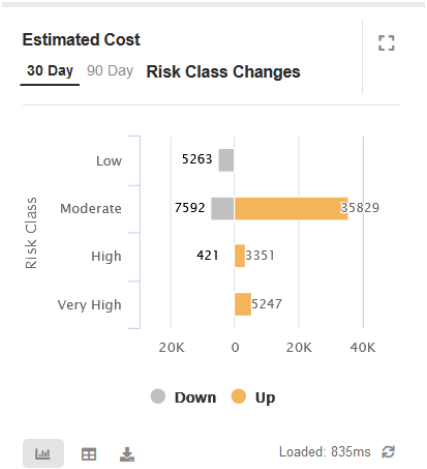
Any score that is elevated above the threshold for risk is denoted by red font and a red spark line. Elevation points are rounded to the nearest integer starting with 1. The risk trend is made more easily interpretable with a red line to indicate the elevated risk threshold value. Elevated risk scores and rising trends can be investigated to reveal risk features picked up by the models.

Risk Change

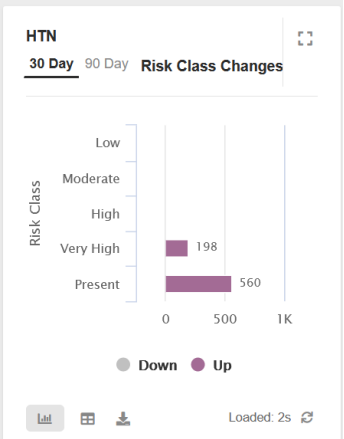
A significant change in an individual's risk score is an indication that something has changed within that individual's clinical profile, community or other circumstances to force a change in the assessment of the risk. It may bring to the forefront individuals who were not previous at high risk but have since breached a threshold of importance.

How is Significant Change Communicated?

MX Analyze defines *a significant change as a change in Risk Class*. This includes a decline in risk as well as an increase in risk. In the image to the right, the number of individuals with increasing risk are depicted in the orange bars projecting to the right. The number of individuals with declining risk are depicted in the grey bars to the left.



How should risk change be interpreted and used?



Individuals may have a rising risk without being the HIGHEST risk individuals. However, care providers may have a better chance to impact these patients, prevent or slow them from sliding down the risk curve further. In fact, individuals may be more receptive to behavior / lifestyle changes when a new diagnosis is made (which, in addition to showing up as a new diagnosis for a specific condition risk, may drive up other condition or event risks). For example, a new diagnosis of hypertension is likely to increase risk of stroke, AMI and chronic kidney disease. Individuals with this new diagnosis may be more motivated to start a healthier diet or exercise regime to control the hypertension and thus reduce those other risks.

On the flip side, individuals with significant decreases in risk may warrant a different (lower) level of care management intensity or even graduation from a complex case management program.

Risk Features

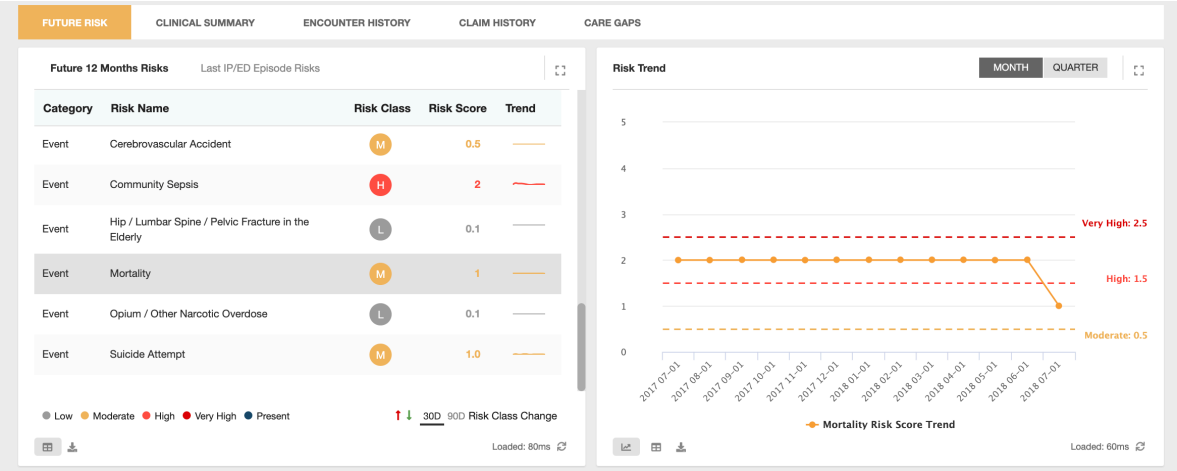
What are risk features and how can they be used?

In risk modeling, variables are referred to as *risk features* and can generally be thought of as elements that influence the risk of the cost, event or condition. In MX Analyze, there are 10 categories of features as described below.

Category	Description	Example
Acute Disease	An acute diagnosis code applied in the last 12 months	Patient diagnosed with acute disease [K20 Esophagitis] in the last 12 months
Chronic Disease Burden	A chronic diagnosis code applied in the last 24 months	Patient diagnosed with chronic disease [E11 Type 2 diabetes mellitus] in the last 24 months
Community Social Determinants	A characteristic of the zip code where the individual resides	Patient's zip code has a Very High % of residents with Medicaid insurance
Demographics	Gender and age	Female age group (75-84)
Disease Events	An inpatient, outpatient or ED event diagnosis in the last 12 months	Patient had 8 outpatient visits [Nausea and vomiting] in the last 12 months

Factors Influencing Health Status	A Lifestyle Diagnosis [Z-code] applied in the last 12 months	Patient diagnosed with [Z72 Problems related to lifestyle: Z72.0 Tobacco use] in the last 12 months
Laboratory Test	An abnormal laboratory test result during the encounter and/or in the last 24 hours	High MEAN PLATELET VOLUME during episode
Medication	A medication prescribed or billed in the last 12 months	Patient had 2 inpatient medications [methylxanthine] in the last 12 months
Utilization	Inpatient, outpatient or ED visits had in the last 12 months	Patient had 3+ (9) Emergency Room visit(s) in the last 12 months
Procedure	An inpatient, outpatient or ED procedure in the last 12 months as evidenced from an ICD10 procedure code	Patient had (B51 Imaging, Veins, Fluoroscopy) procedures in the last 12 months

The analytics engine runs against the population data, identifying risk features in the individual's history. These Risk Features are displayed below the Future 12 Months Risks table, specific to the selected Risk.



In the illustration above, when the user selects the Mortality Risk, a table of features and associated odds ratios display immediately below the Future 12 Month Risk Table.

Risk Feature

Mortality Risk

Risk Category	Risk Description	Odds Ratio
Demographics	Female age group (75-84)	7.01
Utilization	Patient had **18** (**Very High**) Inpatient day(s) in the last 12 months	16.04
Utilization	Patient had **3+ (4)** Inpatient Admission(s) in the last 12 months	13.41
Utilization	Patient had **$47,785** (**Very High**) Medical Cost(s) in the last 12 months	7.82
Utilization	Patient had **6+ (18)** Outpatient visit(s) in the last 12 months	5.44
Utilization	Patient had **3+ (9)** Emergency Room visit(s) in the last 12 months	2.12
Factors Influencing Health Status	Patient diagnosed with [**Z99 Dependence on enabling machines and devices, NEC**] in the last 12 months	24.88
Factors Influencing Health Status	Patient diagnosed with [**Z95 Presence of cardiac and vascular implants and grafts**] in the last 12 months	12.52
Factors Influencing Health Status	Patient diagnosed with [**Z45 Encounter for adjustment and management of implanted device**] in the last 12 months	11.14
Factors Influencing Health Status	Patient diagnosed with [**Z72 Problems related to lifestyle: Z72.0 Tobacco use**] in the last 12 months	2.61
Chronic Disease	Patient diagnosed with chronic disease [**J96 Respiratory failure, not elsewhere classified**] in the last 24 months	25.94
Chronic Disease	Patient diagnosed with chronic disease [**I50 Heart failure**] in the last 24 months	18.94
Chronic Disease	Patient diagnosed with chronic disease [**I12 Hypertensive chronic kidney disease**] in the last 24 months	15.97

Odds Ratio: Odds ratio (or hazard ratio) is the measure of the association between a risk feature and the predicted outcome. If the odds ratio is greater than 1, that feature is associated with higher odds of the outcome. If it's lower than 1, that feature is associated with lower odds of the outcome. The feature does not affect the outcome if the odds ratio equals to 1. In the example above, a diagnosis of Z99: Dependence on an Enabling Machine or Device has an odds ratio of over 24, meaning this diagnosis makes the individual 24 times as likely to die as individual in the population without that diagnosis.

Sort the odds ratio from high to low to identify the most important features and determine the most appropriate interventions or avenues for exploration and discussion with the population member. For example, individuals with high risk of mortality in the future 12 months may benefit from palliative care or end of life discussions as illustrated below in this partial features list. In the last 12 months this patient had 33 OP visits, was an Inpatient for 32 days over the course of 6 IP admissions, was diagnosed with acute kidney failure, sepsis, and pleural effusion and is over 85 years old. In the last 24 months she was diagnosed with hypertension heart and kidney disease, anemia, and pulmonary heart disease. Also captured in the features is a Do Not Resuscitate status.

Risk Feature

Mortality Risk , ordered by **Odds Ratio** descending.

Risk Category	Risk Description	Odds Ratio
Chronic Diseases	Patient diagnosed with chronic disease [**I13** Hypertensive heart and chronic kidney disease] in the last 24 months	20.90
Utilization	Patient had 3+ (**6**) Inpatient Admission(s) in the last 12 months	17.71
Acute Diseases	Patient diagnosed with acute disease [**J90** Pleural effusion, not elsewhere classified] in the last 12 months	15.81
Chronic Diseases	Patient diagnosed with chronic disease [**D63** Anemia in chronic diseases classified elsewhere] in the last 24 months	15.63
Acute Diseases	Patient diagnosed with acute disease [**N17** Acute kidney failure] in the last 12 months	14.12
Utilization	Patient had **32** (Very High) Inpatient day(s) in the last 12 months	13.17
Acute Diseases	Patient diagnosed with acute disease [**J96** Respiratory failure, not elsewhere classified] in the last 12 months	12.69
Chronic Diseases	Patient diagnosed with chronic disease [**I27** Other pulmonary heart diseases] in the last 24 months	12.00
Chronic Diseases	Patient diagnosed with chronic disease [**I11** Hypertensive heart disease] in the last 24 months	11.91
Acute Diseases	Patient diagnosed with acute disease [**A41** Other sepsis] in the last 12 months	11.86
Demographics	Female, Age Group (85+)	11.65
Chronic Diseases	Patient diagnosed with chronic disease [**I12** Hypertensive chronic kidney disease] in the last 24 months	11.51
Chronic Diseases	Patient diagnosed with chronic disease [**N25** Disorders resulting from impaired renal tubular function] in the last 24 months	10.74
Acute Diseases	Patient diagnosed with acute disease [**E87** Other disorders of fluid, electrolyte and acid-base balance] in the last 12 months	10.22
Acute Diseases	Patient diagnosed with acute disease [**D64** Other anemias] in the last 12 months	8.78
Chronic Diseases	Patient diagnosed with chronic disease [**I21** Acute myocardial infarction] in the last 24 months	8.43
Chronic Diseases	Patient diagnosed with chronic disease [**E83** Disorders of mineral metabolism] in the last 24 months	7.76
Primary Payer	Patient has (**Medicare**) Insurance	7.61
Disease Events	Patient had **1** Inpatient Admission(s) with [**R06.02** Shortness of breath] in the last 12 months	7.36
Factors Influencing Health Status	Patient diagnosed with [**Z66** Do not resuscitate] in the last 12 months	3.69

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https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2938757/

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