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Getting Started with Predictive Safety Analytics

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Contents

2500 Regency Parkway
Cary, NC 27518
P: (919) 521-5519 F: (202) 318-4485

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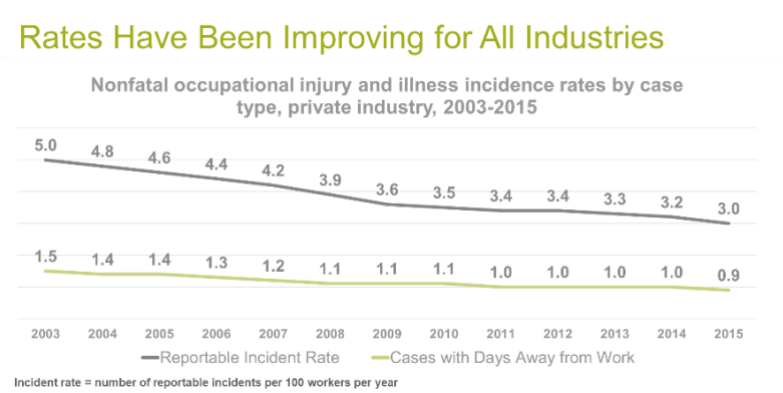
Getting Better at Safety with Analytics

Companies in all industries have strived in the 21st century to improve safety. And it has worked. Incident rates have been on a continual decline since 2003, as shown by data from the U.S Bureau of Labor Statistics (Figure 1).



[5] *Figure 1- Improving Safety Rates*

This is certainly good news. But safety professionals are not satisfied, as demonstrated by the appearance of programs such as "zero incident goal" initiatives. The fact is, as we get better it becomes harder to improve.

This was the dilemma facing a manager when he approached the co-founder of First Analytics, Tom Davenport. Tom is a well-known author and speaker on the topic of advanced analytics, which includes such technologies as statistical (predictive) modeling, machine learning, and artificial intelligence.

In what we might term "the plateau problem", the manager explained "*that safety was a top priority for the company and that it had improved considerably on this front, but it got harder to keep improving."*[1] Furthermore, he said "*the company had already used some data to identify likely risks, but there was a lot more that could be explored."*

The answer to his dilemma was data. Not just data alone, but data in conjunction with predictive analytics. The result for his company was breaking through the plateau, and several sustained, subsequent years of record-breaking safety performance.

While this company's solution was operational – providing risk assessments at the employee/day/shift level which required a lot of data – there are many higher-level, strategic applications that are possible which can be established in short order and without onerous data requirements.

This paper illustrates, with real-world examples, how companies can use Predictive Safety Analytics on top of data they already have to further improve employee and public safety.

[1] Thomas H. Davenport, "Competing on Analytics: The New Science of Winning", Harvard Business Press, 2017, pp. 112-114.

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Case Examples

These short examples use real data from real clients of First Analytics. They demonstrate that even with small and highly aggregated datasets, decision-supporting insights are possible.

For variety, we have selected several industries and various focal metrics. We draw from our work with several railroads, utilities, oil and gas companies, and manufacturers. Metrics are typically some version of an incident or injury rate (reportable or non-reportable), lost time metrics, or associated measures like first aid counts. Beyond these example metrics, virtually any safety-related metric is amendable to predictive analytical methods.

To preserve confidentiality, even with some publicly reported data, we have disguised, hidden, or slightly modified some data. In what follows, data originally displayed in company dashboards or formatted reports and visualizations are recast as simplified spreadsheet examples.

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Incident Rate Forecasting

The company publishes a monthly report on four key safety metrics over 26 geographies as well as for the company as a whole. Charts, like the one shown in Figure 2, provide a visual view of recent safety performance. But they are also forward looking, in that they use statistical models to project the trends into the future. There are three considerations:

Past Perspective
Is there anything in the past that we missed and should better understand?

Current Perspective
Did anything change last month?

Future Perspective
Will these trends continue?

The future perspective, which relies on predictive analytics, is an added capability to traditional safety reports. It helps safety managers focus on what is coming, rather than on past history, which is a common practice.

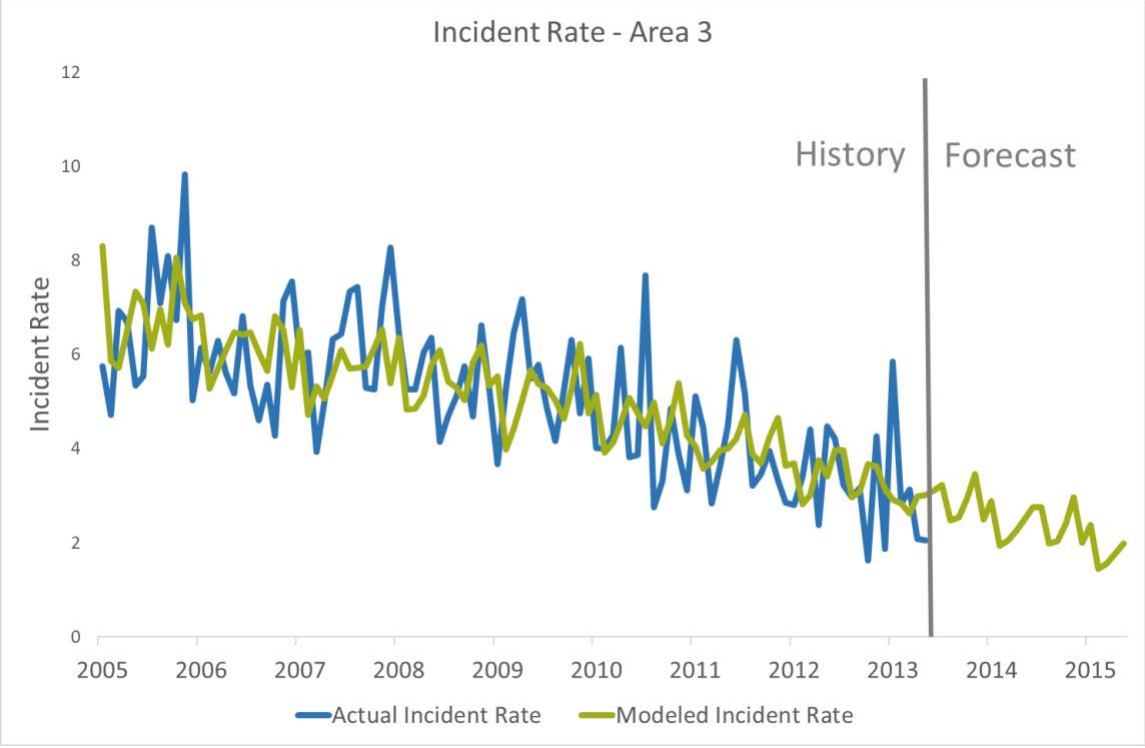

Figure 2- Forecasted Incident Rate

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These monthly reports showing historical data have been augmented to be predictive. Figure 3 shows a tabular report from May 2013. The numbers in red, from June 2013 forward, represent the expected future rates from the model.

Personal Injuries - Rates

Month	Incidents	Reportables	Lost Time
Jan-2013	1.73	1.07	0.51
Feb-2013	1.60	1.23	0.58
Mar-2013	1.34	0.88	0.39
Apr-2013	1.20	0.82	0.36
May-2013	1.49	1.08	0.38
Jun-2013	1.61	1.14	0.42
Jul-2013	1.72	1.18	0.42
Aug-2013	1.72	1.21	0.51
Sep-2013	1.62	1.09	0.42
Oct-2013	1.38	0.93	0.38
Nov-2013	1.25	0.92	0.41
Dec-2013	1.31	0.98	0.42

Future expected rates from the May forecast model

Figure 3- Forecasted Injury Rates Table

With the future expected rates in-hand, as the actual values come in, a comparison can be made between actual and expected. The expected rates provide a benchmark as part of a variance analysis. If a rate comes in much different than expected, something has changed and needs to be investigated. See Figure 4 as an exhibit of this kind of analysis.

Personal Injuries - Rates

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	Actuals		
	1.86	1.11	0.49

June Incidents and Lost Time about 13-14% higher than forecast, but within expected range

	Forecast	Actual	Percent Difference
Incidents	1.61	1.86	13.3%
Reportables	1.14	1.11	-2.4%
Lost Time	0.42	0.49	14.3%

Figure 4- Variance Analysis

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Detecting an Adverse Upward Trend

As an extension of the previous case, “Incident Rate Forecasting”, these reports can be used to uncover adverse trends. See Figure 5 as an example, where a particular geography had a recent uptick in incidents. The model estimates this will be on ongoing increasing trend and presents estimates of the rates in future months if mitigating action is not taken.

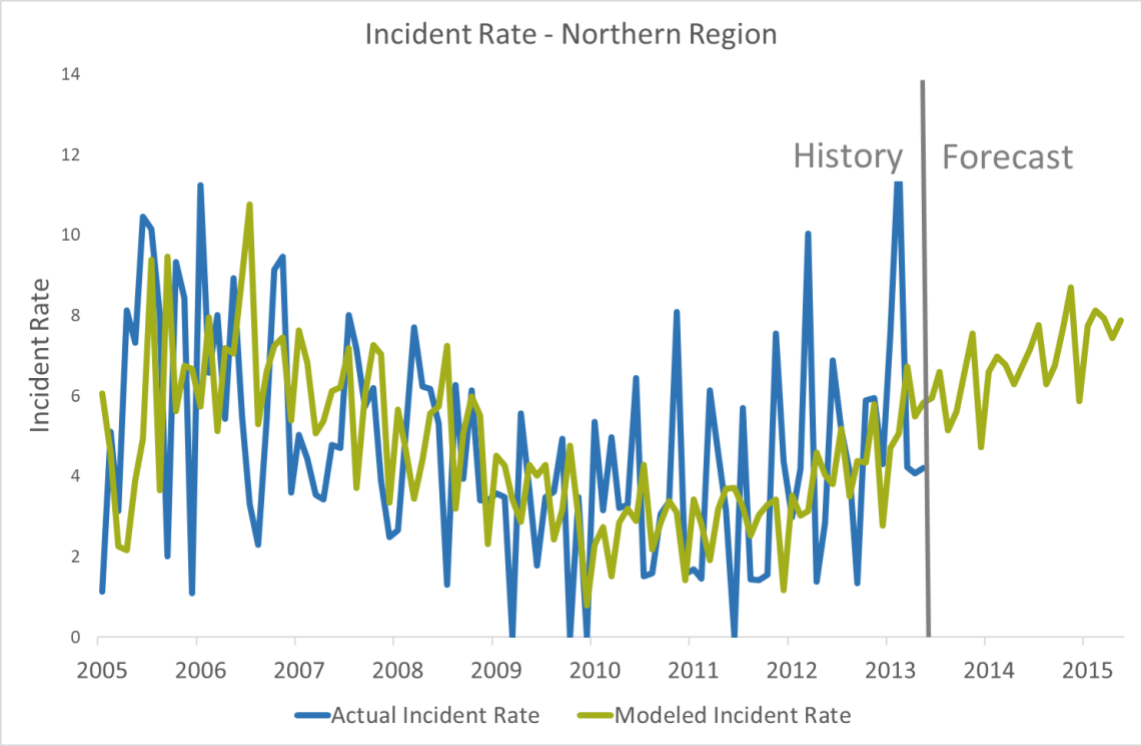

Figure 5- Adverse Upward Trend

The example cases that follow demonstrate additional extended applications of this concept, albeit with data from different clients. For example, they show how forecasts can be summarized by heat maps, or other visualizations. Additionally, a formal statistical analysis on the underlying trend is presented.

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Understanding Seasonality

This company felt there was seasonality in various safety-related metrics. But this is hard to quantify, and is masked in the raw data, which has many contributing factors besides seasonality.

In this case, a sophisticated time series statistical model is used to parse out various latent factors underlying a key metric. This allows us to isolate seasonality. Here we show *Days Away and Restricted*, a subset of the *DART* measure commonly used in OSHA reporting.

Figure 6 shows the monthly seasonal pattern. The bars extending above the horizontal axis value of 1.00 represent a higher general underlying tendency in *Days Away and Restricted*. Note that the highest periods are the Summer and early Fall months running from July to October. Conversely, the bars below the axis represent months with lower underlying incidents. The value along the axis can be treated as a relative value, with 1.0 as the reference. Greater than 1 is higher, less than 1 is lower.

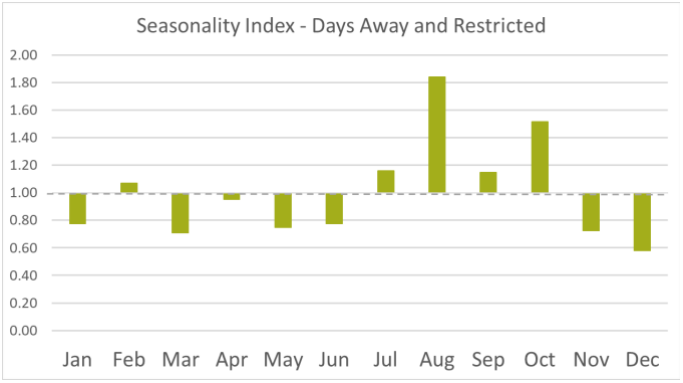

Figure 6- Seasonality Index

Figure 7 overlays the seasonal pattern bars with the actual count history, going back several years.

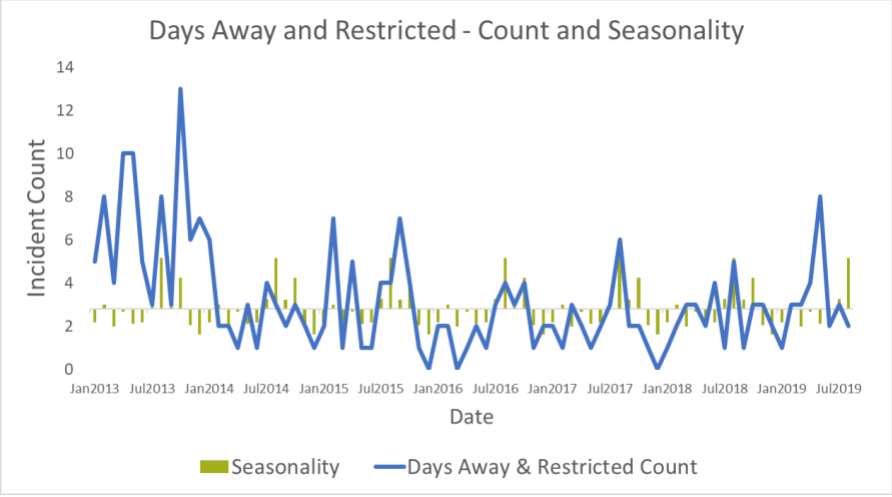

Figure 7- Count and Seasonality

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Understanding the Trajectory of a Trend

This company had enjoyed a steady decrease in the *OSHA Incident Count* for several years. But the trend seemed to be slowing. In the most recent two years, visually, it appeared to be at a plateau, or even starting to increase.

Time series statistical models can isolate trends from other factors. As part of this process, they can estimate the rate of change of the trend.

In the bottom portion of Figure 8, which we call "trend trajectory," we see that anything below the red line at zero represents a still-improving trend. The more negative the value, the more the trend is continuing to decrease. When it does cross the zero-line into positive territory, that indicates that the model believes a reversal has occurred in the underlying trend.

The chart shows the company got very close to reversing the underlying decreasing trend in 2018 and early 2019 (approaching but never crossing the zero-line) but has slightly recovered.

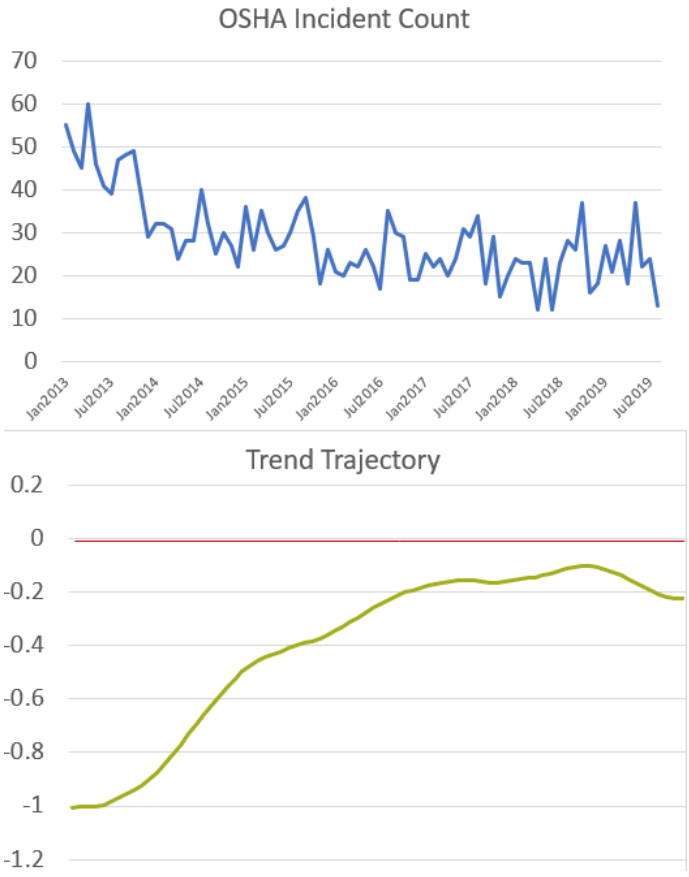

Figure 8- Trend Trajectory

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Drawing Attention to Business Units with Troubling Forecasts

This is an additional application of the concept shown in a previous case, *Detecting an Adverse Upward Trend*. In this situation, however, we are trying to uncover areas of concern at scale.

This company has many operating units and divisions. And their multi-dimensional business hierarchies allow for further drill downs, such as job function, location, etc., which results in many hundreds of contexts to track, at the lowest levels.

The same kind of forecasting models are applied here but operate on all the business entities simultaneously. As discussed previously, this turns insights into forward-looking ones, rather than relying on past history, which could be less reliable, or outright fail to reveal anything of concern.

Figure 9 shows a heat map of various operating units within divisions. In stoplight fashion, the colors range from green (no concern) to red (concern), based on the *forecasted* future expected incident count – in this case, *First Aid Incidents*.

Figure 10 is a secondary view, albeit with the addition of a longer (36-month) horizon, with visualizations of the expected patterns in *First Aid Incidents*.

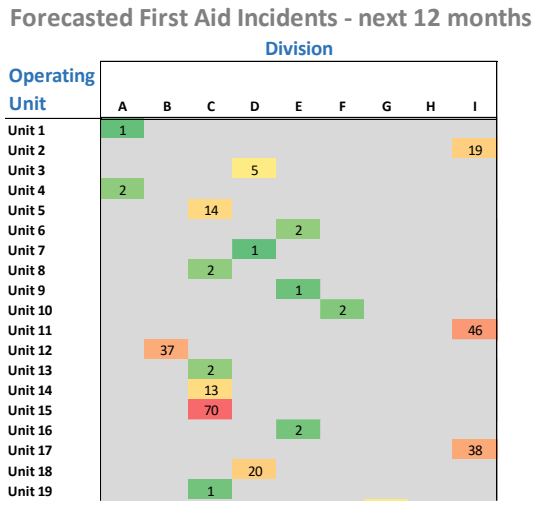

Figure 9- Heat Map

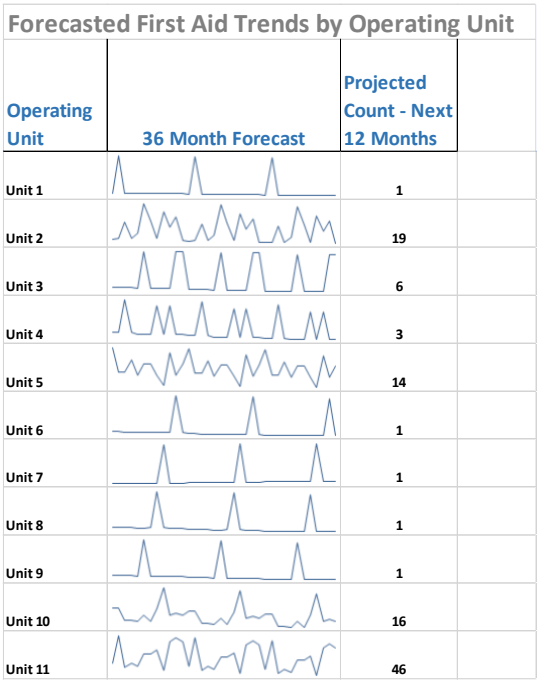

Figure 10- Forecast Visualization

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Triggering Alerts

A popular desire for companies is to look at safety data to trigger an alert when some metric has crossed a threshold of concern. A common suggested approach is a statistical process control methodology referred to as "control charts."[2] The idea is to track a process and use information about means (averages) and variances to indicate when that process has become "out of control."

Conceptually this is an appealing approach and has wide applicability in other areas of the company (e.g., six sigma quality initiatives). Applied to safety in practice, however, it suffers from several flaws.

1. Variance in safety metrics, or the spread between highs and lows, is typically large. Since these variances are used to formulate trigger points – the bound across which a metric may pass to be considered "out of control" – the resulting range can be too large and unrealistic.
2. A constant mean is assumed. Most companies across all industries in recent years have worked diligently to make safety a priority. This suggests the average has been declining over time, and not constant.
3. In similar fashion, the variance, or spread in a particular metric, has shrunk (and thus not constant), owing to good safety mitigation measures.

Figure 11 illustrates these flaws. First, the "confidence levels" – the red lines – are too far apart, and the lower level is negative. While there was one triggering event in mid-2013, the method did not alert to any events after that. Second, one can see the decline in both the mean and the variance of the green line (incident rate) starting in the first quarter of 2018. The pattern after that period deviates substantially from the overall mean (the blue line) and has a smaller variance.

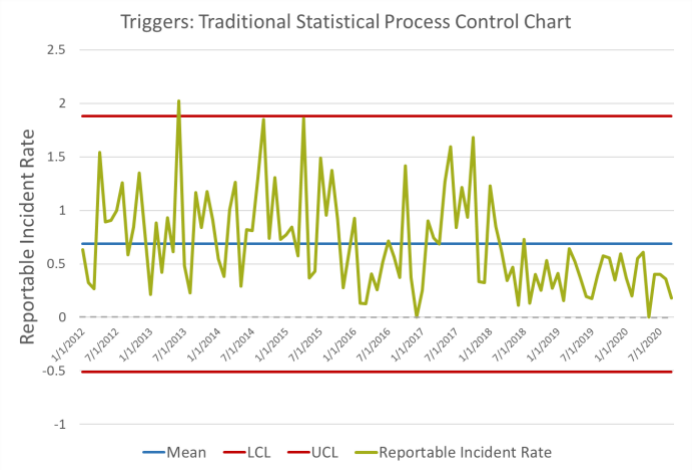

Figure 11- Traditional Control Chart

Of course, ways to remedy this include defining what time periods go into the calculation of these metrics. However, this approach is subjective and sensitive to the included data.

[2] Wikipedia: "Control Chart". https://en.wikipedia.org/wiki/Control_chart

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A better approach is to use statistical modeling and other analytical methods, which model the mean and variance as functions of time (trend, seasonality) and other factors, such as process changes. In this way, modeled means and variances – used in the same interpretive framework as control charts – can provide more realistic alerts.

Figure 12 shows these modeled means and variances, that adapt over time.

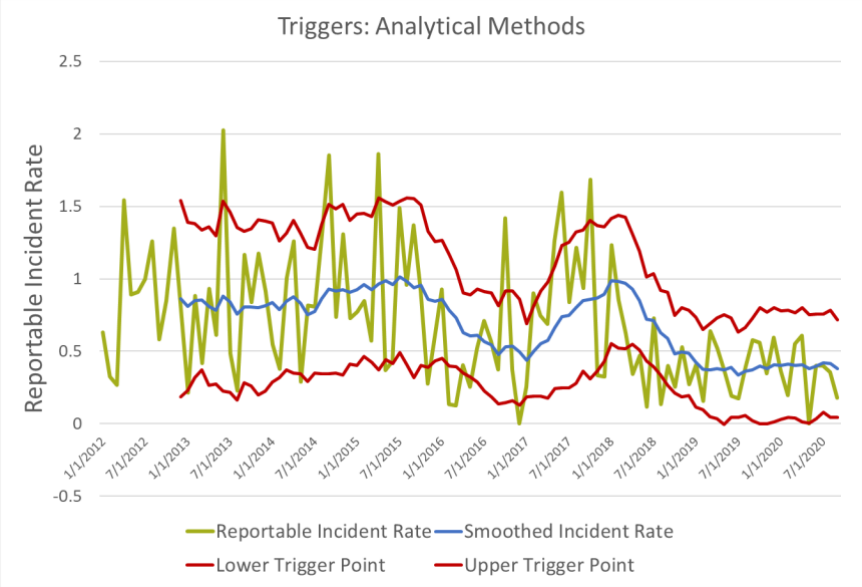

Figure 12- Model-based Approach to Triggering

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Measuring the Impact of a New Process

Safety managers are curious as to the impact or effectiveness of new safety programs or changes in processes. But quantifying these, especially with raw data, is nearly impossible, and potentially misleading (in both directions, positive and negative).

Models can help as they are well-suited for parsing out the effects of different potential factors in a holistic way.

One approach – though not the only approach, but a simpler one – is shown in Figure 13. Here, the company implemented a process change targeting safety in the first quarter of 2017. The model estimates a relationship over time to the reportable injury rate. The model is made aware of the timing of the process change event and quantifies its impact.

Then, through simulation, we project what the reportable rate would have been had the process change not been implemented. In a "what if" sense, we can compare the difference between actual (the blue line) and what the model would have expected had there been no change (the green line). The gap between the lines is the impact.

The bar chart on the bottom half shows the monthly percent improvement in the metric, as reflected by the gap in the upper chart.

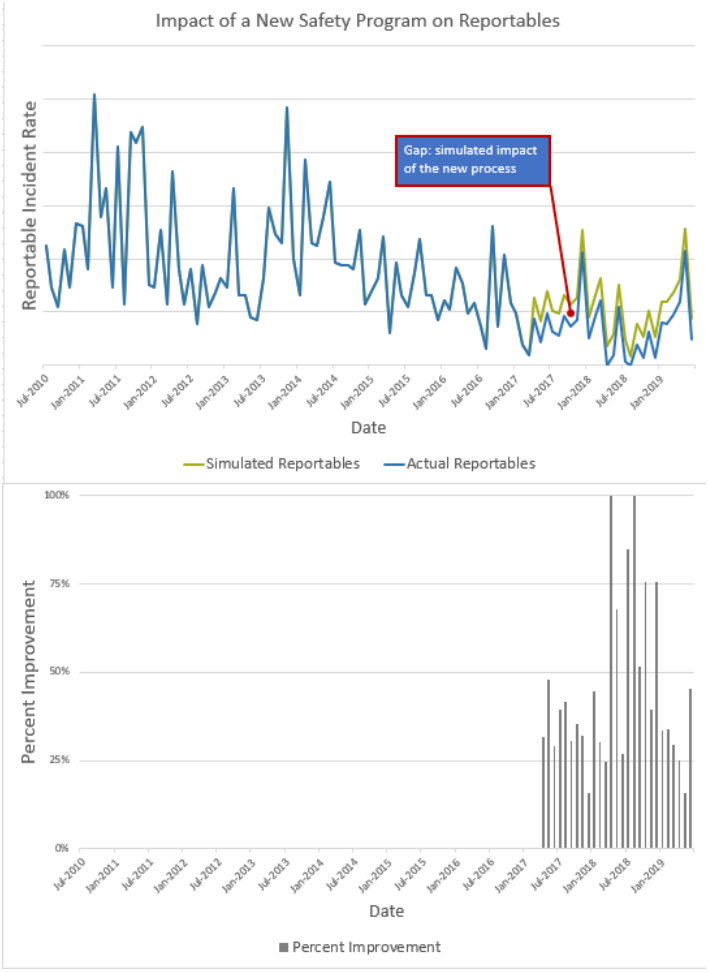

Figure 13- Estimation of an Impact through Simulation

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What Is Next for My Organization?

First Analytics is known for deploying "operational" safety analytics solutions. These solutions use comprehensive, diverse, and often very large and granular data sets. They support daily operational decisions, such as "who is likely to be injured on this shift?" They augment, but do not supplant a Safety Management System (SMS) or home-grown safety application.

But most companies are not ready to undertake the building of such a solution, due mostly to data readiness and availability. However, as these case examples have shown, virtually every company has data they can get started with today. Each of these examples came from data that fit into a spreadsheet. Your Safety Management System likely has the data you need to get started.

The key is taking the first steps and gaining experience with some level of predictive analytics. This is what sets an organization on a path to become more data driven, as they become more familiar with how Predictive Safety Analytics works.

A good first step is to look at your current SMS reports, or dashboard, and ask, "how can we make this forward looking?" Or "how can I correlate actions with results?"

These dashboards may not be stand-alone applications for safety managers. As safety has become a top corporate focus, often as part of a sustainability initiative, safety-oriented reporting is showing up in other dashboards. Examples from two other clients:

A Food Manufacturer
This innovative company has a dashboard that shows traditional, plant-oriented metrics such as OEE (Overall Equipment Effectiveness) as measures of productivity. But they have expanded the dashboard to include safety measures (among others), such as Total Incident Rate, Lost Time Incident Rate, and Hand Injury Count. Food safety is also included.

A Healthcare Services Provider
Health professionals are a scarce and valuable resource, and this human resources-oriented dashboard focuses on metrics related to turnover, retention, recruiting, and performance. They have added a section focusing on Recordable Incident Rate and Lost Time Rate, broken out by geographical facility areas.

It is likely you are in possession of data you can start applying predictive analytics to today. To help understand the potential, First Analytics offers a "free of charge, no obligation" Safety Data Readiness Assessment Workshop.[3] The most common outcome of these workshops is the most highly aspirational application – operational analytics – is not on the immediate horizon. But we identify near-term, more strategic, very feasible applications, such as the ones shown in this paper.

[3] See our website at https://firstanalytics.com/working-with-us/solutions/#safety-analytics

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About First Analytics

Analytics will play an ever-increasing role in helping businesses be more accurate and effective, overcome their greatest challenges, and compete more effectively. We have seen the power and potential of advanced analytics firsthand and know exactly how to help companies turn vast amounts of raw, unsifted data into rich and tangible intelligence they can use. To what end? To anticipate risk and drive safety; to save dollars and lives; to optimize capacity, inventory and performance; and to enable change. One-time analysis or real-time, end-to-end applications. Big data or small. On-premises or in the cloud. We help make analytics a vital element of your operations and a key to sustainable growth and success.

Spanning multiple industries and applications, our data scientists and analytical experts turn information into insight, knowledge into know-how and evidence into action. Simply put, we leverage the most up-to-date analytical tools, strategies and technologies in order to help improve your business and optimize operations.

We have a long and successful history of helping our clients with safety, always with a data analytics approach. Visit our website to view our case studies and to learn more about how we can help your company leverage the power of advanced analytics with statistical modeling, machine learning and artificial intelligence.

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