CORIOS LIGHTNING

Solution Overview

by Robin Way

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Overview

For electric utilities who need to support grid modernization initiatives with load forecasts that meet top-down regulatory requirements and bottom-up DER impacts, and who want a transparent, proven, modular approach built on a scalable analytics platform, Corios is pleased to introduce our Lightning solution.

Corios Lightning is a distribution planning and forecasting solution that provides a 10-year hourly (8760) forecast of MW demand for every substation and feeder on your grid, adjusted for economic growth, load growth projects, capacity transfers and DER adoption.

Corios Lightning is a white-box, modular solution that grows with your requirements, and focuses on cleaning and standardizing the data you have to develop a reliable trusted forecast to the most rigorous standards.

Business process: building a load forecast

The target user profile of Corios Lightning is a distribution or grid planning engineer, or grid operations planner. While many electric utilities employ data scientists, and we expect they will find value in using Lightning, this is not required to get the most out of Corios Lightning, as we have baked the insights and knowledge of our own data scientists into the solution.

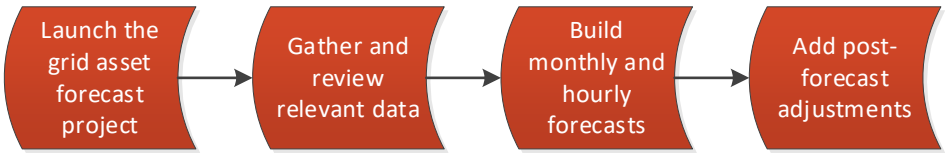


Figure 1: Corios Lightning business process overview

To get started, the grid planner begins by building a grid asset forecast project. Lightning provides a series of task-oriented user interface screens to the grid planner along the journey.

Next, Lightning gathers the relevant data for that asset, which is typically a feeder or circuit, from the Lightning data mart. This includes grid interconnects, economics, weather, load growth projects, permanent capacity transfers, load shapes, and distributed energy resource (DER) data. Lightning pulls all the relevant data into a dashboard enabling the grid planner to review all these forecast inputs in a heads-up display to establish the ground truth which will be used to construct the forecast.

The grid planner uses Lightning to select the ideal monthly and hourly forecasts and generate the next stage of dashboards, allowing the planner to override the model projections and build alternate scenarios.

Finally, Lightning helps the grid planner add post-forecast adjustments such as load growth projects, planned capacity transfers and top-down regulator projections, and publish to the final set of dashboard reports for sharing with colleagues, asset managers and distribution planning colleagues.

Value drivers for this process

Corios has built Lightning to provide compelling value to our electric utility clientele:

- Corios Lightning is built as a suite of software tools that support **integrated grid planning and time-series forecasting**. This includes a library of integrated components, running on a standard, scalable analytics platform from SAS. This platform offers value to the utility who is starting with addressing regulatory requirements and grows with you as your utility progresses on its journey to digital transformation.
- From the beginning Corios focuses on building **quality, reliable data** for forecasting from the varied sources of raw source data that the utility possesses today. Many of our clients have fractured, incomplete or yet-to-be-rationalized data sources, but we've proven you can start with the data you have, and we can point you to the most valuable and reliable ways of enriching, enhancing, completing and refreshing this data asset.
- Lightning is effective at **integrating DERs into grid planning**. We have decades of experience, dating all the way back to demand-side planning and end-use demand forecasts, back when AMI and DER was merely a gleam in someone's eye.
- Corios Lighting provides your electric utility with a10-year **hourly forecast for every grid asset in the territory** that disaggregates MW load by economic growth, load growth projects, DER resources by type, including photovoltaics (PV), energy efficiency, demand response, time of use (TOU) rates, electric vehicles and energy storage.

What makes Corios Lightning distinctive

Hard-fought lessons learned about **data quality, stability, reliability and believability** have been baked into the Corios Lightning solution. This helps you avoid paying the penalty for learning these lessons all over again.

Corios Lightning is a **production-ready software application**, including a robust set of functional processes, user interface, data model and dashboard reports.

Lightning is **scalable and reliable**. We have field tested and received acceptance of Corios Lightning in production at Southern California Edison, one of the country's most forward-thinking and progressive utilities facing some of the most advanced set of challenges posed in the California market.

Lightning addresses all the functional expectations for **California regulatory requirements**, which other states are expected to eventually follow.

Corios Lightning is **transparent**. Unlike other solutions that are compiled, black-box and one-size-fits-all, Corios Lightning is an open, white-box and customizable solution.

Lightning is **modular**. If you want to revise or customize part of the Lightning modules, we support that and will tailor to your specifications.

Business process description

As described above, there are four phases of work involved in building a grid asset load forecast in Corios Lightning:

1. Project initiation
2. Data gathering and pre-forecast review
3. Forecast development
4. Post-forecast adjustments and publication

Phase 1: Project initiation

The first phase of building a grid asset forecast is simple. The grid planner launches the forecast project via the user interface, which creates the project container, including all the reference information needed to pull together the forecast input data.

Phase 2: Data gathering and pre-forecast review

Using the results from phase 1, the grid analyst uses the Lightning user interface to launch the collection of all the relevant data to be used in building the forecast. Prior to computing the forecast calculations, it's an important exercise for the grid planner to review the data to be used, so that there is confidence there is reliable, actionable data being plugged into the forecast process.

Lighting gathers all the data from multiple sources to assist the grid planner, including:

- Grid asset connections and mappings
- Weather data: historical and projected hourly and monthly profiles
- Economic data: historical and projected monthly profiles
- Load profiles: historical hourly and monthly data
- DER load shapes and DER adoption projections
- Asset-level sector-specific historical load shapes (typically this includes residential, commercial, industrial, agricultural and other sectors)
- Permanent capacity transfer history and projections
- Load growth projects (LGPs), both incremental and embedded

Once Lightning gathers all this data for the grid planner, Lighting runs computing tasks on the grid planner's behalf, including the following tasks:

- Adjusts the time series data for time zones and daylight savings time
- Extrapolates load shapes to the 10-year forecast horizon
- Maps region-specific baseline load shapes and DER load shapes to the individual grid assets in those regions
- Applies the sector-specific (i.e., residential, commercial, industrial, agricultural, and other sector) load shapes to the annual LGP forecasts in order to produce hourly LGP forecasts
- Applies the DER-specific shapes to the annual DER forecasts to produce hourly DER forecasts
- Aggregates circuit-level forecasts up to collector nodes in the grid asset hierarchy (i.e., substations, planning regions)

Lightning loads all of this cleansed, rationalized data to the pre-forecast dashboards, providing a variety of reports and KPIs that should be scrutinized by end users to ensure that the data quality is sufficient before beginning the forecast process.

Phase 3: Forecast development

Once Lightning has prepared all the forecast input data, and the grid planner has reviewed and approved all the pre-forecast data inputs, we are ready to move on to monthly and hourly forecast construction.

MONTHLY LOAD FORECASTS

On behalf of the grid planner, Lightning computes the following tasks, starting with the monthly forecasts:

- Create monthly model specifications
- Select forecast drivers for each grid asset: monthly economic and weather drivers, permanent transfer information, customer counts, sector energy consumption
- Estimate all the candidate monthly forecast models in the model specification list
- Rank all monthly models
    - Create flags for economic driver and weather variables to determine if they were positive and/or statistically significant
    - Flag economic drivers that do not meet the business rule criteria for employment share and/or employment concentration

    - Flag economic drivers that do not meet the business rule criteria for customer segment shares
    - Assess and determine how to construct the forecast for assets where there is a pending capacity transfer during the holdout period
- Load the pre-override monthly forecast results to the Lightning dashboard for review

HOURLY LOAD FORECASTS

After the monthly forecast models have been prepared and published to the dashboard for review, the grid planner can decide to override the results of the monthly model for the grid asset by selecting a different model specification and to selected forecast inputs. At this point, the grid planner uses Lightning to build the hourly forecast model as follows:

- Gather user-specified monthly model overrides
- Generate final monthly forecasts
- Load the final monthly model projections with overrides to the dashboard
- Create hourly model specifications
- Select hourly forecast drivers: weather, day of week, permanent transfer information, etc. for each asset
- Estimate the hourly load forecasts
- Rank and select the champion hourly forecast specification
- Generate the final hourly forecast for the champion specification
- Load the hourly forecasts to the Lightning dashboard for review

Phase 4: Post-forecast adjustments and publication

The final phase in the grid asset load forecast is to apply post-forecast adjustments for factors like load growth projects, and top-down regulatory load forecast reconciliation. Lighting assists the grid planner by tackling the following tasks:

- Incorporate engineering-validated load growth project impacts (timing, magnitude) on each asset's demand
- Compare LGP growth projection to regulator growth projection to adjust for timing

- Incorporate regulator top-down load growth projections and reconcile the top-down forecast with the monthly and hourly bottom-up forecast
- Calculate the load shapes for LGP impacts and aggregate them up from circuits to the rest of the grid assets
- Calibrate top-level grid asset forecasts to state regulator projections
- Publish the final adjusted forecasts into the Lightning dashboard
- Export forecasts for workload projections and asset management

What you need to know first

Anyone could choose to build their own forecasting process, similar to the approach we followed when building Corios Lightning. What you'll find is that all the hard-fought lessons learned in the trenches will simply be the price you'll pay all over again. Any forecast is especially at-risk to the garbage-in / garbage-out challenge.

It's vital that you are able to generate a load forecast that is reliable, understandable, believable and scalable. By successfully delivering Corios Lightning to the specifications for the most advanced clientele, we're prepared to take on your requirements. More importantly, our clients are taking advantage of the insight-based design that results from having encountered and surpassed many of the sources of project setbacks and delays, many of which come from the source of incomplete, unstructured or yet-to-be-rationalized source data, all of which needs to be properly treated.

This section of the Corios Lightning solution overview covers the bases of all these hard-fought lessons learned.

Econometric load forecasting is often a new practice for power planners and grid engineers

In introducing load forecasting to power planners, engineers and grid operators, we've learned to create and teach a shared vocabulary with all our constituents. We've found that everyone builds better forecasts through collaboration and mentoring.

The grid interconnect model is complicated

One of the most important early tasks we help our clients tackle is to cleanly represent and reconcile the grid interconnect model hierarchy. This reconciliation of the grid interconnect model is vital for clean mapping of circuit-to-substation loads, and for accounting on capacity transfers.

Here's a picture of the simple, idealistic grid model on the left, compared with a realistic but complicated grid model on the right.

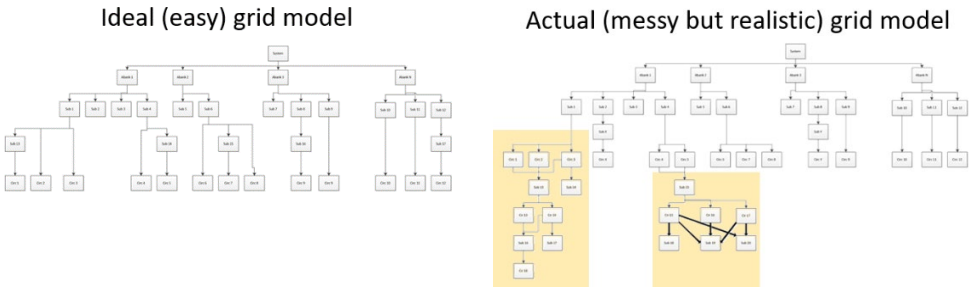


Figure 2: Comparison of idealistic and realistic grid models

With the grid on the left, every parent node has one or more children, and no child has more than one parent. However, this doesn't capture the real world nature of the grid as it evolves, and in particular doesn't capture the presence of transient and persistent capacity transfers.

Furthermore, the presence of capacity transfers, if not properly incorporated into the forecast, can lead to some surprising results. In the picture below, the chart on the left shows a forecast representing strong load growth (because the transfer wasn't properly accounted for), compared with the forecast on the right that took the capacity transfer completely into stride.

Figure 3: Historical capacity transfer not properly accounted (left) vs properly accounted (right)

The load forecasts based on these grid interconnections need to reflect these important nuances. Leading to our next subject…

Accounting for capacity transfers is important but overlooked

If the domain of capacity transfers was simple and clean, then the load forecasting on grid assets would be so much simpler. But, capacity transfers not only exist, they exhibit numerous characteristics that makes it challenging to keep up:

- Each asset can have one or more transfers over time
- The timing between those transfers varies
- There can be multiple transfers within a neighboring set of grid assets
- If the transfers only recently were applied prior to the start of the forecast horizon, that makes accounting for their volume impact tricky

- Even more tricky, what if the onset of a planned transfer is scheduled to kick in shortly after the beginning of the forecast horizon?

Here's a picture from a recent engagement that shows the comparison between a grid asset that needs some simple data cleaning (on the left hand side picture), and the impact of a likely capacity transfer that wasn't recorded properly, but clearly appears to be present (on the right hand side).

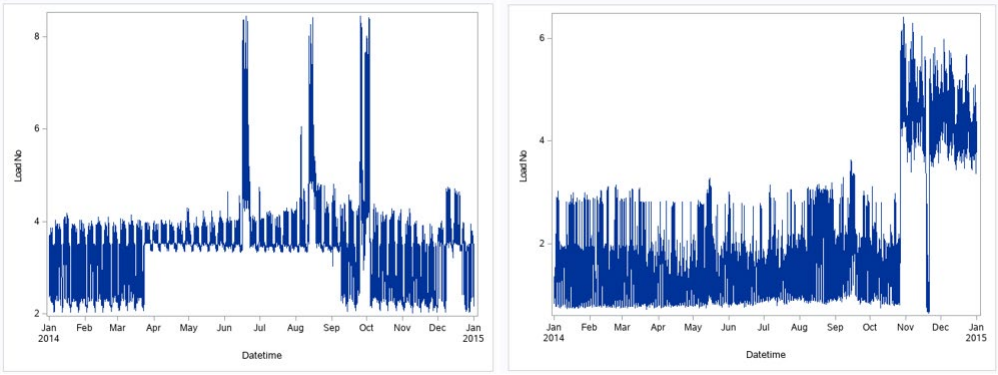


Figure 4: Data cleansing required for regular anomalies (left) vs capacity transfer accounting (right)

Mapping weather data to grid assets should be simple…

One would think that mapping weather data per weather station to the grid assets within a reasonable proximity would be a simple task. That's considerably more involved than one would really expect, so proper tuning and calibration of these geospatial effects is important. Even representing the weather history properly comes from multiple sources. A picture representing a data model for weather attributes appears below.

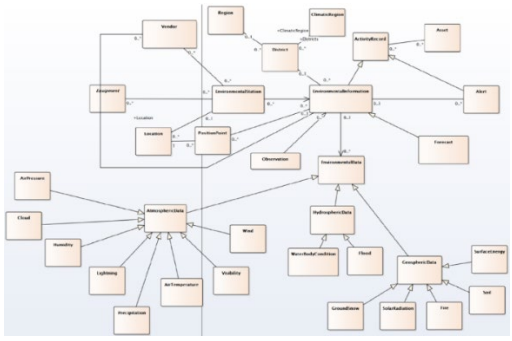


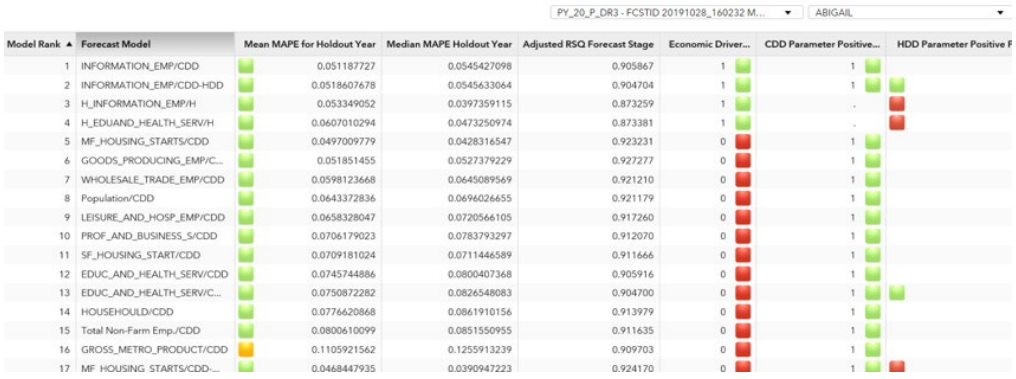
Figure 5: Data model for contemporary weather data providers

Once the weather data has been properly onboarded, then Corios Lightning takes on the task of developing typical meteorological data for the forecast horizon, by projecting the best 1-in-2 weather year or 1-in-10 weather year projections, enabling the forecaster to observe what is likely to happen with a monthly and hourly forecast in the presence of exceptional weather.

Forecasting is best as an interactive process

In our experience, forecasting is best not left to the machines. The ideal forecasting process and results are a combination of machine learning and human learning. No algorithm can ever explain why the forecast was wrong, nor can it adjust itself when the forecast is way off for reasons it cannot observe. Corios has developed the data science portion of Lightning forecasts so that complicated part is automated, but the real-world-believability factor comes from getting engineers involved on the input side and the results side as well.

In particular, we've built explicit steps in the process to account for forecast review, override, adjustment and acceptance, in the screen capture below.



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Model Rank	Forecast Model	Mean MAPE for Holdout Year	Median MAPE Holdout Year	Adjusted RSQ Forecast Stage	Economic Driver...	CDD Parameter Positive...	HDD Parameter Positive P
1	INFORMATION_EMP/CDD	0.051187727	0.0545427098	0.905867	1	1	
2	INFORMATION_EMP/CDD-HDD	0.0518607678	0.0545633064	0.904704	1	1	
3	H_INFORMATION_EMP/H	0.053349052	0.0397359115	0.873259	1	.	
4	H_EDUAND_HEALTH_SERV/H	0.0607010294	0.0473250974	0.873381	1	.	
5	MF_HOUSING_STARTS/CDD	0.0497009779	0.0428316547	0.923231	0	1	
6	GOODS_PRODUCING_EMP/C...	0.051851455	0.0527379229	0.927277	0	1	
7	WHOLESALE_TRADE_EMP/CDD	0.0598123668	0.0645089569	0.921210	0	1	
8	Population/CDD	0.0643372836	0.0696026655	0.921179	0	1	
9	LEISURE_AND_HOSP_EMP/CDD	0.0658328047	0.0720566105	0.917260	0	1	
10	PROF_AND_BUSINESS_S/CDD	0.0706179023	0.0783793297	0.912070	0	1	
11	SF_HOUSING_START/CDD	0.0709181024	0.0711446589	0.911666	0	1	
12	EDUC_AND_HEALTH_SERV/CDD	0.0745744886	0.0800407368	0.905916	0	1	
13	EDUC_AND_HEALTH_SERV/C...	0.0750872282	0.0826548083	0.904700	0	1	
14	HOUSEHOULD/CDD	0.0776620868	0.0861910156	0.913979	0	1	
15	Total Non-Farm Emp./CDD	0.0800610099	0.0851550955	0.911635	0	1	
16	GROSS_METRO_PRODUCT/CDD	0.1105921562	0.1255913239	0.909703	0	1	
17	MF HOUSING STARTS/CDD-...	0.0468447935	0.0390947223	0.924170	0	1	

Figure 6: Forecast review, override and adjustment report in Corios Lightning

Some circuits exhibit instability in peak load timing and volume

While the majority of circuits exhibit time series behavior that is relatively straightforward to forecast, there is always a contingent of grid assets that are more difficult to forecast well. This leads to instability in the forecasts, which is especially prominent as a challenge when we need to get the peak load timing (i.e., which hour of the day) and peak load volume (i.e., how many MW) accurate and stable. The driving factors that tend to lead to these conditions are singly or in combination:

- Less than 3 years of monthly data
- Erratic data
- No weather sensitivity in energy history

A couple of charts for circuits that exhibit these behaviors appears in the figure below.

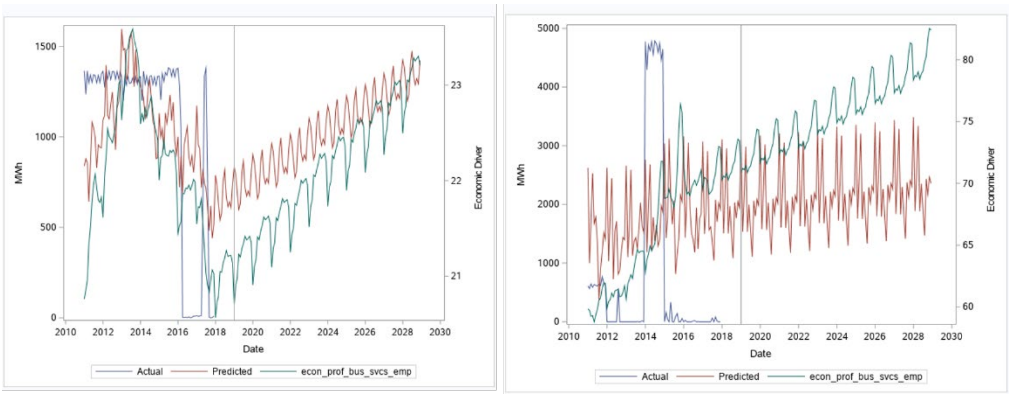

Figure 7: Circuits exhibiting problematic historical time series

Corios Lightning adjusts forecasts for these circuits through a multi-prong approach that takes into account the following tactics:

- Data issues, such as transfers or cleansing algorithm issues.
- DERs excluded from gross adjustments.
- Asset characteristics, such as industrial sites with no weather sensitivity.
- Modeling issues, such as overfitting.

Some examples are looking at the peak load volume across weather scenarios and across time, such as in this multi-year comparison in the chart on the left below. Another way to gauge these effects is by examining the timing impacts of DER adoption and the effect on load shapes of that adoption, as illustrated in the chart on the right below.

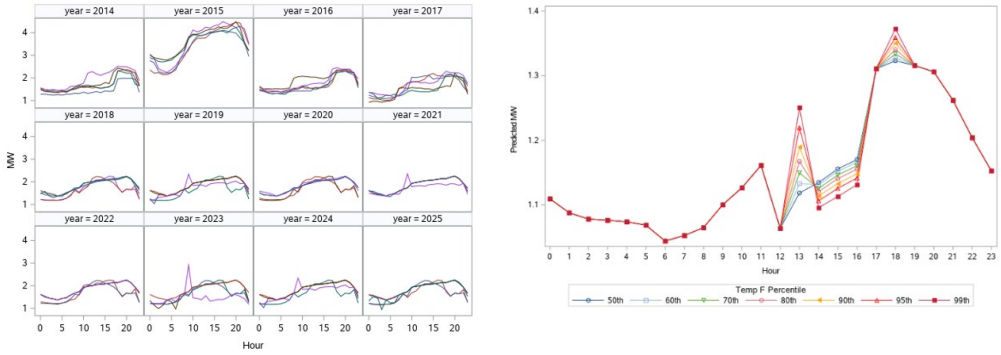

Figure 8: Data rationalization tactics for peak load volume (left) and timing (right)

Solution architecture

Corios Lightning is a services-led software application built for-purpose for electric utility grid asset load forecasting. Out of the box, Lightning offers:

- 46 interactive dashboards, divided into 6 workflow-oriented sections
- Project-oriented user interface that also mirror the asset planning and forecasting workflow described above in "Business Process: Building a Load Forecast"
- Formal data model relying on an Analytic Staging Model (Hive), Forecast Data Model (SAS), Reporting Data Model (SAS/LASR), and publishing of export data suitable for 3rd party distribution planning applications (e.g., Cyme, Synergi) and asset planning applications (e.g., Copperleaf)
- Compute services provided by the SAS Institute grid analytics platform to ensure scalability and open, modular architecture

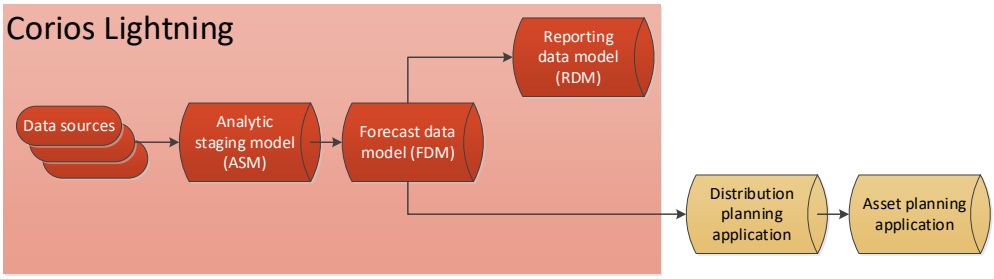

Figure 9: Corios Lightning solution summary data architecture

About the Author

Robin Way

Robin Way is the founder and CEO of Corios, a decision optimization technology and professional services agency specializing in data, analytics and machine learning. Robin has over 30 years of experience in the design, development, execution, and improvement of decision optimization for clients in the energy, banking and insurance industries.

Robin's professional passion is devoted to democratizing and demystifying the science of applied analytics. His contributions to the field correspondingly emphasize statistical visualization, analytical data preparation, predictive modeling, time series forecasting, mathematical optimization applied to marketing, and risk management strategies. Robin's undergraduate degree from the University of California at Berkeley and his subsequent graduate-level coursework emphasized the analytical modeling of human and consumer behavior.

About Corios

We guide clients towards more effective decisions about their customer relationships, risk mitigation and asset protection, by building a continuous learning cycle, using our intellectual property and expertise with big data, mathematics, technology and decision optimization. We are committed to helping you make decisions that count. Our clients drive business performance by making smart, well-informed decisions. Decision-making isn't an event, it's a continuous learning process. All the big data, machine learning and AI in the world is just an academic exercise, unless deployed in this continuous learning process to make a real business impact.

To learn more about how Corios is bridging the gap between data and business decisions, please visit **coriosgroup.com**.

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Suite 202
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