WHITE PAPER

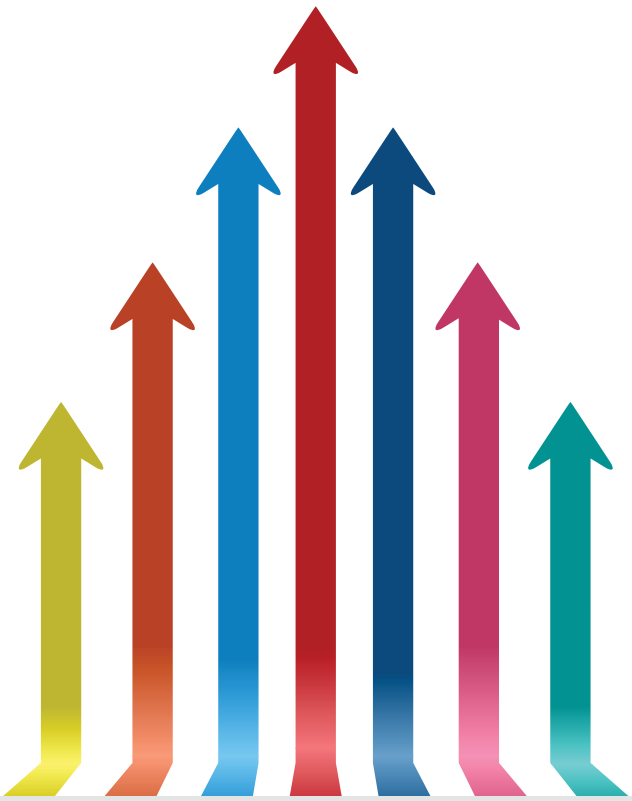
Reach New Heights:
Six Best Practices in Planning and Scheduling

aspentech

Overview

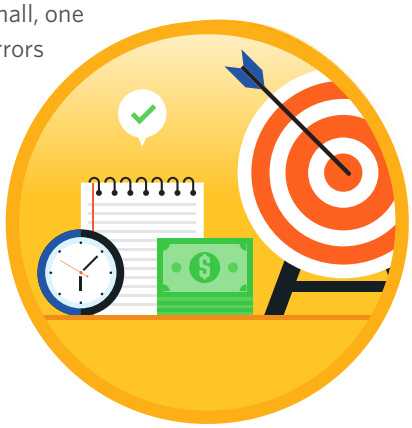
Since mid-2015, the price of oil has fallen from close to $100 USD/bbl down to about $25, and back up to over $45. These fluctuations have halted offshore projects and greatly impacted the midstream industry. The lower price of oil benefitted refiners in the short term, but because the price remains volatile, refiners are focusing on operational excellence to protect their profits, while looking for ways to improve their business. In addition to price volatility, the global shale plays have dramatically increased the number of feedstock options. In fact, according to Rystad Energy, the US holds more oil reserves than Saudi Arabia or Russia, making this the first time the country's reserves have surpassed those held by the world's biggest exporting nations. The new feedstocks can be much lighter or much heavier (depending upon the source) than the crudes traditionally run, in some cases driving the need to change refinery configuration. With continued price volatility and new feedstock availability, refiners are faced with increased optionality. Accurate planning and advanced scheduling tools can be the tipping point in the effort to protect already declining profits.

Technology advancements in the past several years can enable refiners to use their existing assets in the most efficient way. In the refining and olefins industries, this means optimizing feedstock selection, production plans and schedules to reduce operating costs and maximize profitability. To do this, planning and scheduling teams need the expertise to support optimization. The main objective of the planning and scheduling team is to boost refinery or olefins plant profits, and this is enabled by advanced software tools. The decisions which could lead to the highest profits are very complex, and incorporate information that may include the myriad of options of feedstock selection, the trade-offs of severity optimization, or the complexity of the refinery schedule. The following six best practices in planning and scheduling will help planners and schedulers better improve their decision-making and boost the bottom line.



Planning

Production planning in the refinery is essential to profitability. For example, the crude planner alone in a 200,000 bbl/day refinery is responsible for decisions which, over the course of a year, spend over $1B USD in raw materials (assuming just $35 USD/bbl for crude). Even a small, one percent error will cost about 35 cents per barrel or $10M USD per year. Larger errors could easily shatter the already thin margins that most refineries operate with today. Making these decisions with a mathematical optimizer is the only way to adequately represent reality. There are three recommended practices for achieving the best results with your optimizer:



- Select the correct modeling parameters
- Solve the optimization problem reliably
- Analyze the solution for robustness

Select the Correct Modeling Parameters

From the simplest single-crude refinery to the most complex integrated refinery or chemical complex, production planners have the freedom to make decisions as to how the refinery will make the products that go to market. This freedom is just like climbing a mountain — there are many possible paths to the top, but depending on various factors like the weather and time of day, one will be the best. The path must then be successfully navigated to gain the summit — the prize of sustained profitability. The best path to the summit is the most optimal production plan, which is achievable only with the appropriate information.

To gain this information, planners need a map of the mountain. Typically, this map would be a linear program model to adequately represent the complexity of real refinery and olefins operations. The linear program model, also known as a planning model, will include many hundreds of variables. It is imperative to select the right parameters that influence yield, energy consumption and other economic drivers. For example, necessary inputs include feed quality from current assays, yields during different operation modes and ratios of feed to reboiler and condenser duties on distillation towers, all of which drive plant profitability.

Solve the Optimization Problem Reliably

Linear programs have long been the trusted method for refinery optimization. However, over the last five to ten years, linear programs have incorporated more non-linear equations and relationships, enabled by technology advances for quicker and easier solving. Since linear equations simplify reality, including non-linear equations will greatly increase model accuracy. The most impactful applications for non-linear modeling include blend correlations and conversion units, such as fluid catalytic crackers (FCCs) and pyrolysis (steam cracking) furnaces. Upgrading cheap feedstock such as heavy gas oil or ethane is often the most profitable area of the plant, and increasing accuracy there has proved to be valuable for many refiners and olefins producers in the industry.

Non-linear equations also allow for more accurate blend correlations. With traditional linear programs, inaccuracies in blend correlations cause deviations between the blend plan and the actual results. In order to prevent off-spec events which are very costly, and to ensure the blend is always on-spec, the quality target must exceed the specification. When blend targets are higher than needed, this is known as quality giveaway, which also results in lost profits. The inaccuracies in traditional linear blend correlations also force operators to manually correct blends by adding high-value blend stocks in non-optimal ways. As a result, the planning team can increase profitability with more accurate blend correlations in the planning model.

Once the model is built to the right level of accuracy, including non-linear relationships, the real test of the tool begins. Does the model converge reliably? Are the results repeatable? Troubleshooting the model can become a major endeavor at this stage. Recall that mathematical models will inherently have false positives (local optima), as well as true global optimum, and although non-linear equations do increase accuracy, they are also more prone to local optima. The traditional way to troubleshoot involved a tedious process to prevent executing the plan at a local optima using several different starting conditions. New features in some advanced optimization programs now enable the planners to detect local optima by solving cases from any number of starting conditions. This greatly increases confidence in the results, and prevents lost profits by avoiding local optima.

One example of this is olefins producer Borealis, who implemented non-linear advanced optimization tools in their plants. Initially, Borealis reported that their complex models had convergence and local optima problems. After implementing advanced optimization, they were able to converge all cases with virtually no local optima. Also, by using non-linear equations to model key plant constraints, Borealis improved the fidelity of their models and planned closer to the actual plant limits.

***Figure 1**. Borealis implemented advanced optimization, including non-linear models, to achieve more accurate results and realize dramatically faster run times*

Analyze the Solution for Robustness

The biggest challenge facing refinery and olefins manufacturers today is ensuring production plans remain profitable within a range of operating conditions, including variability in feedstock and product prices. The figure below shows the CBOE Crude Oil ETF Volatility Index, which is a measure of the market's expectation of volatility of crude oil prices within a 30-day period. It is evident that the oil price is more volatile now than at almost any time since the 2008 economic crisis. Due to this volatility, the plan that is optimal today could be suboptimal next week. The best way to avoid this is to use a robust and repeatable model to build contingency plans which test a wide variety of inputs into your routine workflow. For example, planners should test the values of many crudes and products in a range that's several dollars per barrel above and below the current price.

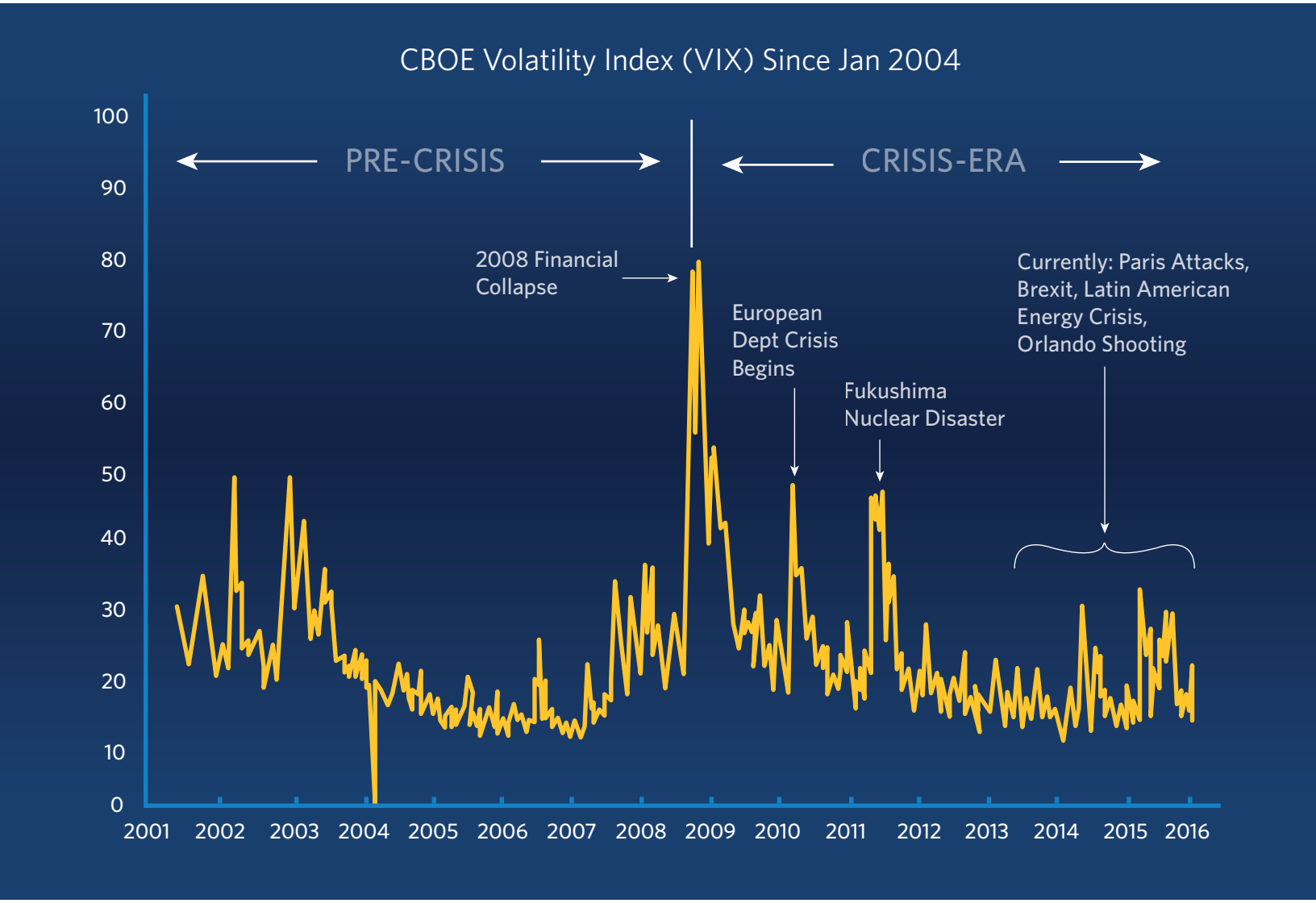


***Figure 2**. CBOE Crude Oil ETF Volatility Index (VIX) since January 2004, showing higher market volatility, underscoring the need for contingency plans when making refinery and olefins production plans.*

Recall that optimizers find a highest objective function, which is one point in the space of all possible solutions. In reality, it is impossible to achieve the perfect point solution at all times, and so another very important aspect of contingency planning is understanding the variables that have the strongest effect on profitability. For example, it is probably obvious that cutting overall crude rate reduces refinery profitability, but what about reducing one crude and substituting it for another? These are the important questions that contingency planning enables the planning team to answer.

Knowing which cases to solve when contingency planning is very challenging, especially for less experienced planners. Thus, documenting the recommended contingency cases week-to-week and month-to-month, and incorporating advanced data analysis techniques to find patterns is the best way to achieve sustained profitability in the face of volatile prices.

The largest barrier to implementing contingency planning is running the vast amount of cases it requires. Most mid-size refineries today run about 20 cases per period. The contingency plans described above would increase this number to nearly 100 cases per period. For a world-scale, integrated refinery/chemical complex, increase these numbers by an order of magnitude, and the solve time would follow suit. Such a high case load and solve time could inhibit the planner's ability to draw timely conclusions and communicate results to traders. There is an elegant solution to this, also enabled by recent advances in computing power. Solving cases in parallel on multi-core processors is an advanced feature that some optimization tools have included. The best in the industry are even investigating high-powered computing (widely known as cloud computing) to further reduce solve time. A great example of this comes from one Asian refining company who uses advanced optimization multi-core processing to solve its 800 routine cases. This company reduced its solve time from 36 hours to 90 minutes. Investigating a trading opportunity used to require the planner to leave cases running overnight, but now the planner can respond the same afternoon, allowing near real-time trades. The company leveraged this new agility to capture opportunities before its competitors, thereby increasing its profitability.

Scheduling

The refining industry is anything but predictable and nothing ever goes exactly as planned. Once the planner has created the plan, it is then time for the scheduler to execute that plan. Refiners face several challenges when creating a schedule that is safe, operationally efficient and feasible. While executing the plan, schedulers must adhere to stricter product specifications, market and regulatory requirements that can impact refinery profit margins if not properly managed, and as new feedstocks become available on the market and complexity increases, having a comprehensive, refinery-wide view of the schedule becomes vital.

- Schedule in a collaborative environment
- Manage operational disruptions
- Optimize product blends

Schedule in a Collaborative Environment

Execution of the plan through collaboration is an essential aspect of scheduling for any refiner. Typically, you have crude schedulers, product schedulers and other stakeholders that need access to accurate information on the company's current corporate objectives and refinery capabilities. These individuals work together on the schedule and need to be aligned on the plan, unit operations, outages, feedstock receipts, tanks, product lines, and so on to create an operationally efficient and feasible schedule for the refinery. This data is interconnected and needs to be readily available to share among various individuals within the organization, so having all this scheduling information under a single platform is a key enabler for that collaboration.

Currently, this is primarily done using spreadsheets or other homegrown solutions. Initially this approach may seem inexpensive to the refiner; however, disparate tools often lack the ability to account for operational constraints, accurate property and composition prediction, and inventory visualization. Standalone spreadsheets that are passed around amongst different stakeholders can leave room for manual errors that can be detrimental to the refinery profit margins. Also, as complexity increases and additional constraints are introduced, a scheduler often quickly turns to the first viable solution, rather than the most profitable, because of time constraints.

By bringing all key scheduling activities under a single platform, refiners are able to streamline their workflow and gain a greater view of their entire petroleum supply chain. Scheduling automation software enables crude and product schedulers to work from the same schedule to eliminate any disconnect between the functions. This improved visibility into the refinery's activities provides better tracking of composition and movements, enabling a better understanding of what feedstock is coming in and when it should arrive. Having this visibility allows the scheduler to make the best use of the process units and push them to their limits. When schedulers are able to hit as many constraints as they can in the scheduling process, refiners can realize an increase in profit margin by maximizing operational constraints and throughput.

Before moving to an advanced refinery scheduling solution, the schedulers at the PETRONAS Melaka refinery were using disparate spreadsheets that led to suboptimal scheduling (Figure 3). Through change management and a single network database, PETRONAS was able to eliminate standalone spreadsheets and create a collaborative scheduling environment that minimized human error and saw a profit increase of $0.10 USD/bbl of crude processed.

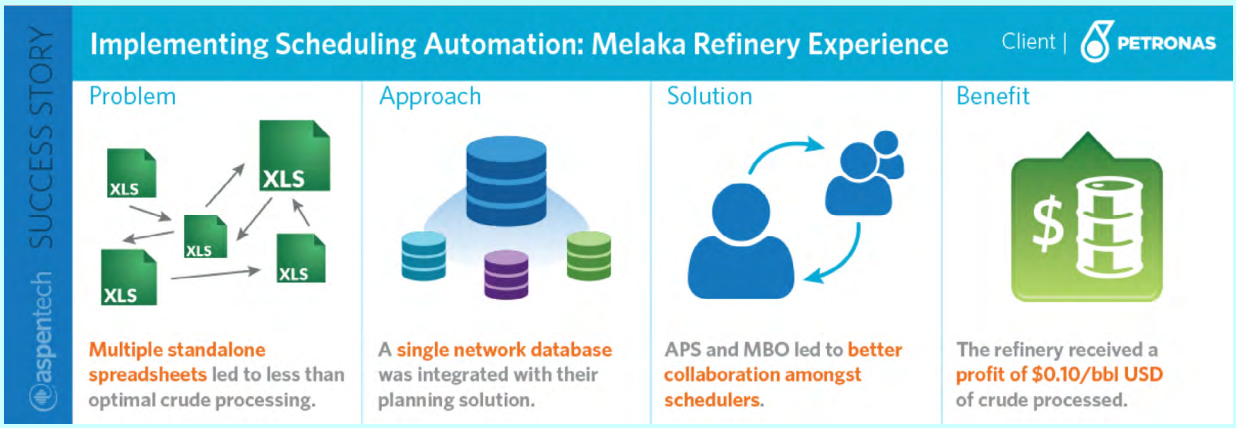


Figure 3: *Learn how a PETRONAS Refinery unlocked $0.10 USD/bbl of crude processed by eliminating their standalone spreadsheets with advanced scheduling automation*

Manage Operational Disruptions

Within a refinery and olefins plant, upsets are unavoidable. Common upsets that can occur include turnarounds, shutdowns and weather-related events. Some of these events can be anticipated, while others, such as operational issues, weather disruptions and logistical upsets, are typically unexpected and temporarily force a refinery or olefins plant to shut down for safety precautions.

Turnarounds are shutdowns that are planned, typically 30 – 90 days in duration, for plant maintenance and improvement projects. They are often scheduled many months or in some cases, several years in advance.

Unplanned shutdowns can be caused by mechanical or process-related events such as compressor trip or sever fouling.

Weather-related events such as hurricanes, typhoons and monsoons are unavoidable and may cause the plant to shut down for safety precautions.

For example, if an FCC unit is to unexpectedly shut down, the scheduler has to quickly determine the best course of action to maintain throughput and run the refinery in the most efficient way. Without an advanced scheduling solution, this can become very time consuming, and every minute becomes money lost. Best-in-class scheduling technology enables schedulers to streamline their workflow, allowing more time for analysis and more time to determine the best decisions to run the refinery during the disruption. Although the plant is not operating under normal conditions, having a sound plan and schedule can reduce lost opportunities associated with these disruptions. Planning and scheduling software enables refiners to run different scenarios to make the best decision and return to ideal operations quickly. It also enables the scheduler to compare the plan, schedule and actual to better understand where the gaps exist in refinery production.

Optimize Product Blends

The purpose of any refinery is to refine crude into different blend stocks that are eventually blended into saleable products such as distillates, gasoline or fuel oils. Refiners have obligations to deliver these products on specification (meeting specific requirements), and if not properly managed can result in re-blends and product quality giveaway. With stricter specifications and changing regulatory requirements, optimal use of a refinery's inventory to create blend recipes can have a significant impact on profit margins.

Planners generate blending targets which are later passed to the blend scheduler to execute. The problem is that these targets can be difficult to achieve and often represent an average for the planning period. They also do not account for operational constraints such as tank ullage, tank heels, discrete blend events and operational disturbances.

Most blend recipes are created by performing a single-blend optimization considering the available inventories and expected qualities at a certain point in time. The optimization, if any, is considering the maximum profits for the individual blend without considering the overall blend schedule. To truly optimize a blend schedule, refiners need to maximize the profit under a determined period of time considering all blends that will occur and the inventory predictions. This kind of optimization requires the help of an advanced multi-period blending solution, and is not something that your typical spreadsheet can handle.

As blend complexity increases and additional constraints are introduced, a scheduler's responsiveness becomes key when creating an optimal blend recipe. Typically, refiners play it safe and overcompensate in their blend recipes to ensure they meet the specification and contract obligations. With a blending solution, schedulers can accurately model the blending operation including non-linear properties, tank constraints, component availability and logistic restrictions to maximize margins and reduce quality giveaway.

Conclusion

The refining market is continuously changing and the shortage of experienced workers in the refining and petrochemical industries is becoming more prevalent every day. The need for leaders with diverse experiences is also driving many companies to rotate new engineers and managers through planning and scheduling roles in order to build credibility and expertise in economics and decision-making. Best-in-class planning and scheduling technologies have now become a must-have for refiners to streamline workflows and stay competitive in today's market. These tools have domain expertise and best practices embedded to support faster, better decision-making and thus more productive employees.

Leading-edge refiners adopting planning and scheduling technology have improved visibility across their entire petroleum supply chain and have seen an increase in their profit margins. AspenTech continues its commitment to investing in the development of new tools to support the refining and petrochemical industries in an intuitive user environment for planners and schedulers. The aspenONE® Petroleum Supply Chain suite is the most trusted planning and scheduling solution in the industry with over 30 years of refining expertise.

For More Information
www.aspentech.com/psc-resource-center

Contact Us
PSC@aspentech.com

AspenTech is a leading supplier of software that optimizes process manufacturing — for energy, chemicals, engineering and construction, and other industries that manufacture and produce products from a chemical process. With integrated aspenONE® solutions, process manufacturers can implement best practices for optimizing their engineering, manufacturing, and supply chain operations. As a result, AspenTech customers are better able to increase capacity, improve margins, reduce costs, and become more energy efficient. To see how the world's leading process manufacturers rely on AspenTech to achieve their operational excellence goals, visit **www.aspentech.com**.

Worldwide Headquarters
Aspen Technology, Inc.
20 Crosby Drive | Bedford, MA 01730 | United States
phone: +1-781-221-6400 | fax: +1-781-221-6410 | **info@aspentech.com**

Regional Headquarters
Houston, TX | United States
phone: +1-281-584-1000

São Paulo | Brazil
phone: +55-11-3443-6261

Reading | United Kingdom
phone: +44-(0)-1189-226400

Singapore | Republic of Singapore
phone: +65-6395-3900

Manama | Bahrain
phone: +973-13606-400

For a complete list of offices, please visit **www.aspentech.com/locations**