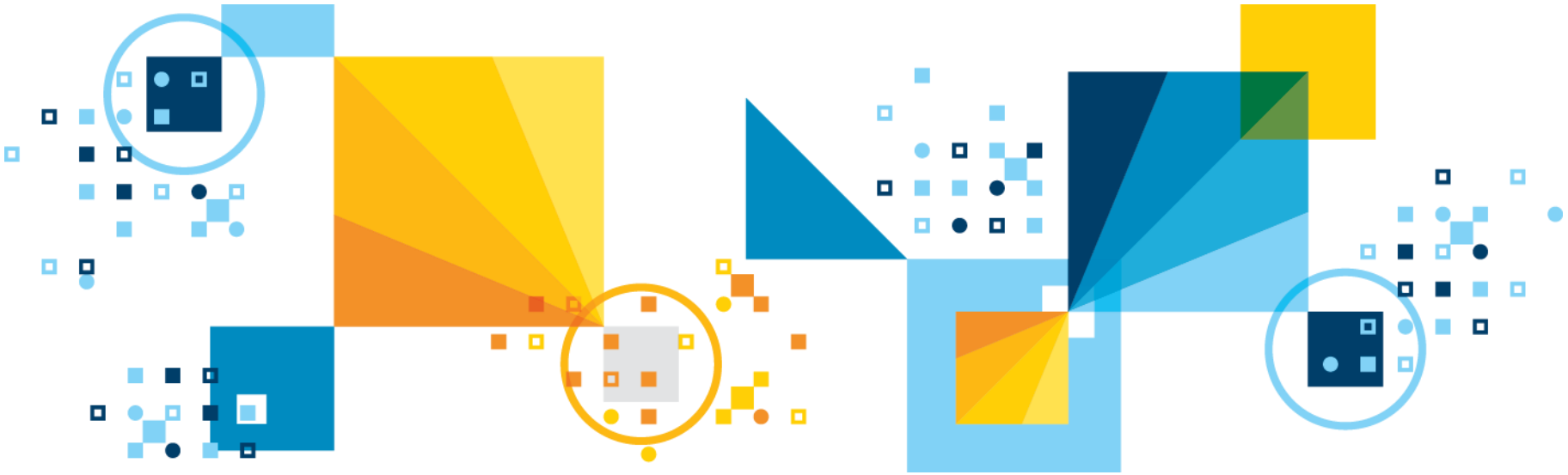
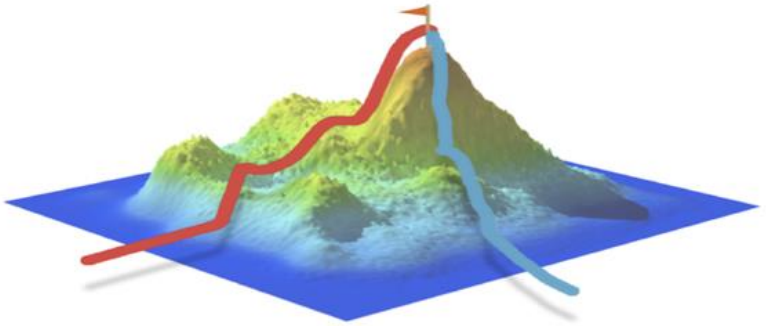
Sumeet Parashar, Technical Specialist – IBM Data Science and Decision Optimization

IBM Decision Optimization (Prescriptive Analytics)



IBM Decision Optimization



Optimization ….

Why ?

“Plans are nothing;

planning is everything”

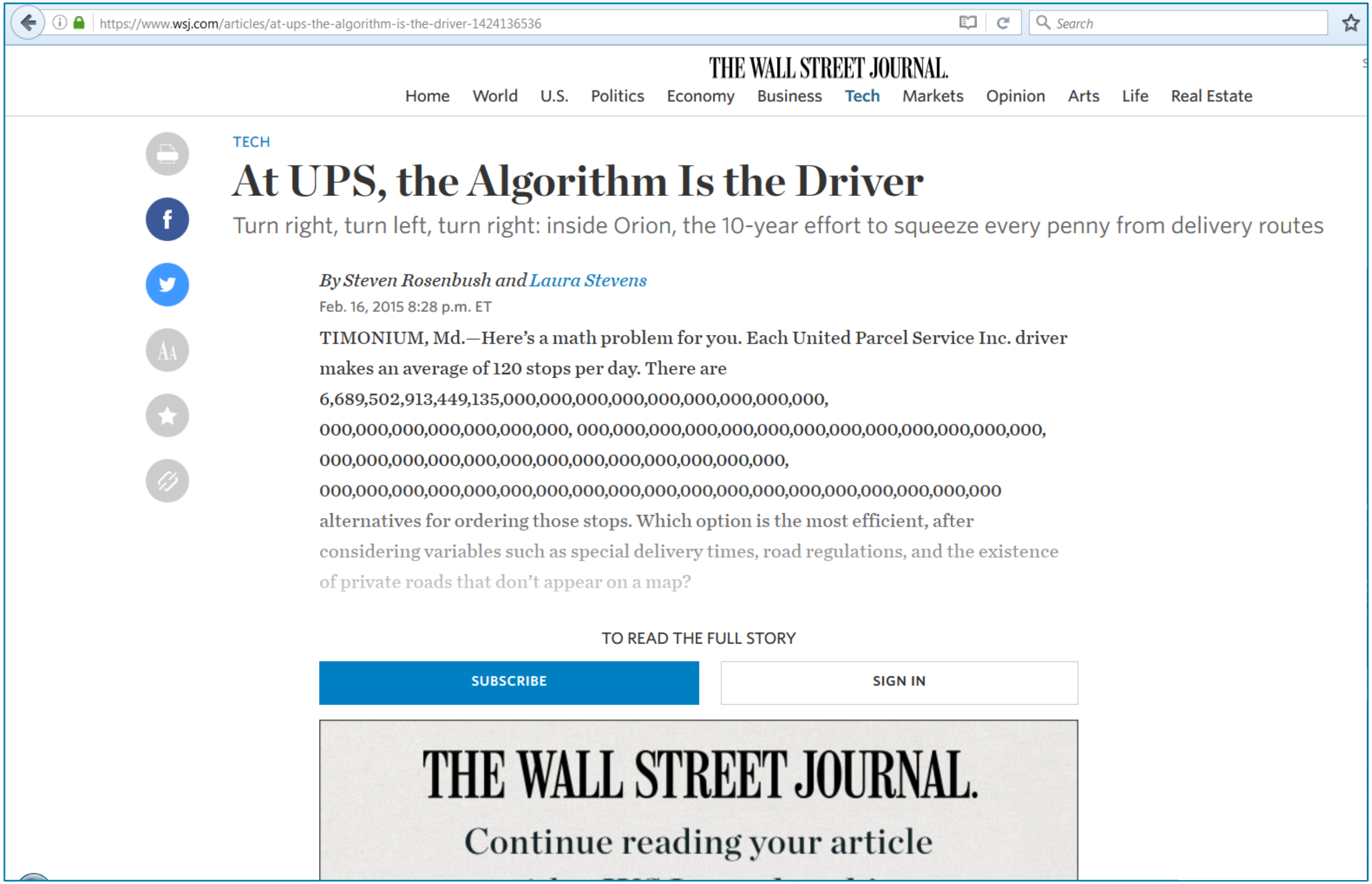
- **Dwight D. Eisenhower**

5	3			7				
6			1	9	5			
	9	8					6	
8				6				3
4			8		3			1
7				2				6
	6					2	8	
			4	1	9			5
				8			7	9

What differentiates Industry Leaders

Source: The Optimization Edge, Steve Sashihara (New York, NY: McGraw Hill, 2011) p. 3

UPS story



https://www.wsj.com/articles/at-ups-the-algorithm-is-the-driver-1424136536

THE WALL STREET JOURNAL.

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TECH

At UPS, the Algorithm Is the Driver

Turn right, turn left, turn right: inside Orion, the 10-year effort to squeeze every penny from delivery routes

By Steven Rosenbush and Laura Stevens

Feb. 16, 2015 8:28 p.m. ET

TIMONIUM, Md.—Here's a math problem for you. Each United Parcel Service Inc. driver makes an average of 120 stops per day. There are 6,689,502,913,449,135,000,000,000,000,000,000,000,000,000,000, 000,000,000,000,000,000,000, 000,000,000,000,000,000,000,000,000,000,000,000,000, 000,000,000,000,000,000,000,000,000,000,000,000,000, 000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000 alternatives for ordering those stops. Which option is the most efficient, after considering variables such as special delivery times, road regulations, and the existence of private roads that don't appear on a map?

TO READ THE FULL STORY

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Prescriptive Analytics Solutions – Documented Results

2 Chilean Forestry firms	Timber Harvesting	**$20M/yr + 30% fewer trucks**
UPS	Air Network Design	**$40M/yr + 10% fewer planes**
South African Defence	Force/Equip Planning	**$1.1B/yr**
Motorola	Procurement Management	**$100M-150M/yr**
Samsung Electronics	Semiconductor Manufacturing	**50% reduction in cycle times**
SNCF (French Railroad)	Scheduling & Pricing	**$16M/yr rev + 2% lower op ex**
Continental Airlines	Crew Re-scheduling	**$40M/yr**
AT&T	Network Recovery	**35% reduction spare capacity**
Grantham Mayo van Otterloo	Portfolio Optimization	**$4M/yr**

Source: Edelman Finalists, http://www.informs.org or http://www.scienceofbetter.org

Why invest in Pricing and Revenue Optimization (PRO)

"***For most companies, better management of pricing is the fastest and most cost-effective way to increase profits***."

– conclusion of a pioneering study by McKinsey and Associates, 1992

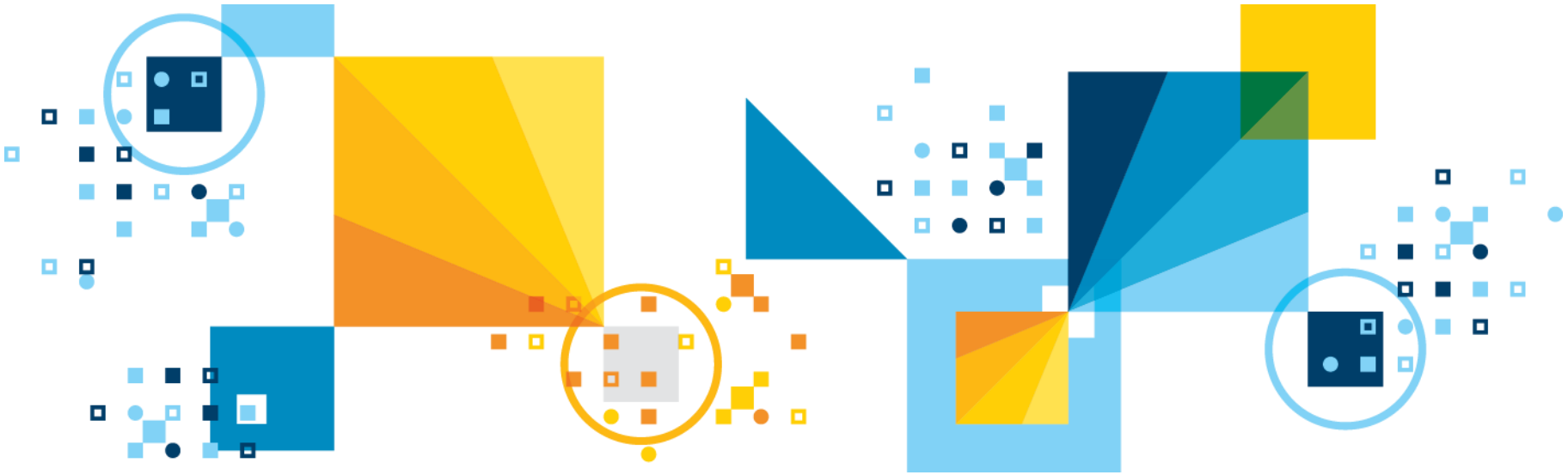
Results of two studies on the average impact of a 1% improvement in different variables on operating profit

	McKinsey(1992)	A. T. Kearney (2000)
Price management	11.1%	8.2%
Variable cost	7.8%	5.1%
Sales volume	3.3%	3.0%
Fixed cost	2.3%	2.0%

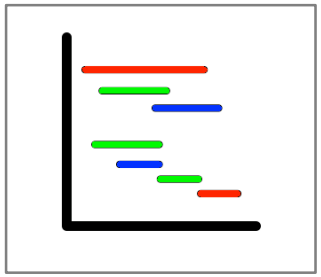
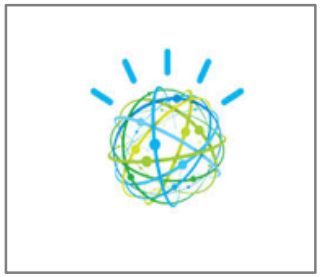
A Harvard Business Review article noted that some retailers are achieving "***gains in gross margins in the range of 5-15%***" **from the use of optimization based assortment and pricing optimization systems**.

Source: Pricing and Revenue Optimization, Robert L. Phillips (Stanford, CA,: Stanford Business Books, 2005)

Decision Optimization
aka
Prescriptive Analytics



Prescriptive Analytics within the Analytics Portfolio

	DESCRIPTIVE	PREDICTIVE	PRESCRIPTIVE	COGNITIVE
Technology				
Need	*What is happening in my business today?*	*What will happen in the future?*	*What should I do about it?*	*Have you considered?*
Outcome	Discover Report Analyze	Forecast Correlate Anticipate	Recommend Decide Assign	Understand Reason Learn

What is Prescriptive Analytics?

- **Manage resource efficiency, utilization and allocation**
- **Resources can be a number of things, in different industries**

Resources	Industries
Capital	Financial
People	Industrial, Public, Comms, Distribution, Financial
Equipment	Industrial, Comms
Facilities	Distribution, Industrial
Vehicles	Distribution
Material/Product	Distribution, Industrial

- **Keywords to look out for:**
  - Minimize and maximize
  - How many, how much, which, when, where
  - Decide, choose, plan, schedule, assign, route, source, maintain, locate, trade-off

The Science of Better Decisions

What to build, where and when?

How to best allocate aircrafts and crews?

Inventory cost vs. customer satisfaction

Optimization helps businesses:

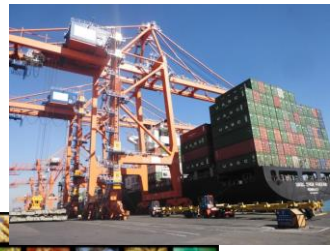
- create the best possible plans
- explore alternatives and understand trade-off
- respond to changes in business operations

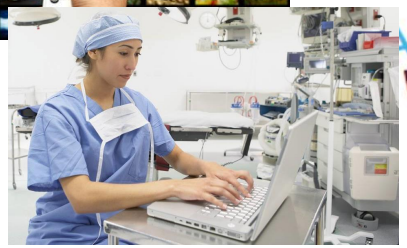
Risk vs. potential reward

Schedule jobs, sequence, machines and people

How to best allocate price and promotions?

IBM Decision Optimization (DO)





IBM Decision Optimization

What is inside ?

“CPLEX” and “Constraint Programming (CP)” advanced mathematical optimization algorithm/solver

CPLEX inside several industry software vendors

Airline reservation systems

AMADEUS

Sabre

Supply Chain, Manufacturing

flexis jda.

FuturMaster
Deliver Business Performance

Logistics

Geoconcept
THE GEOPTIMIZATION COMPANY

navis

Odyssey

Telecom Network

atesio

Revenue Management - Transportation

ExPretio

Workforce

KRONOS

Finance

bondIT

fiserv.

CLARIFI
lifelong financial literacy

Energy & Utilities

PCI
ENERGY IN FOCUS.

SIEMENS

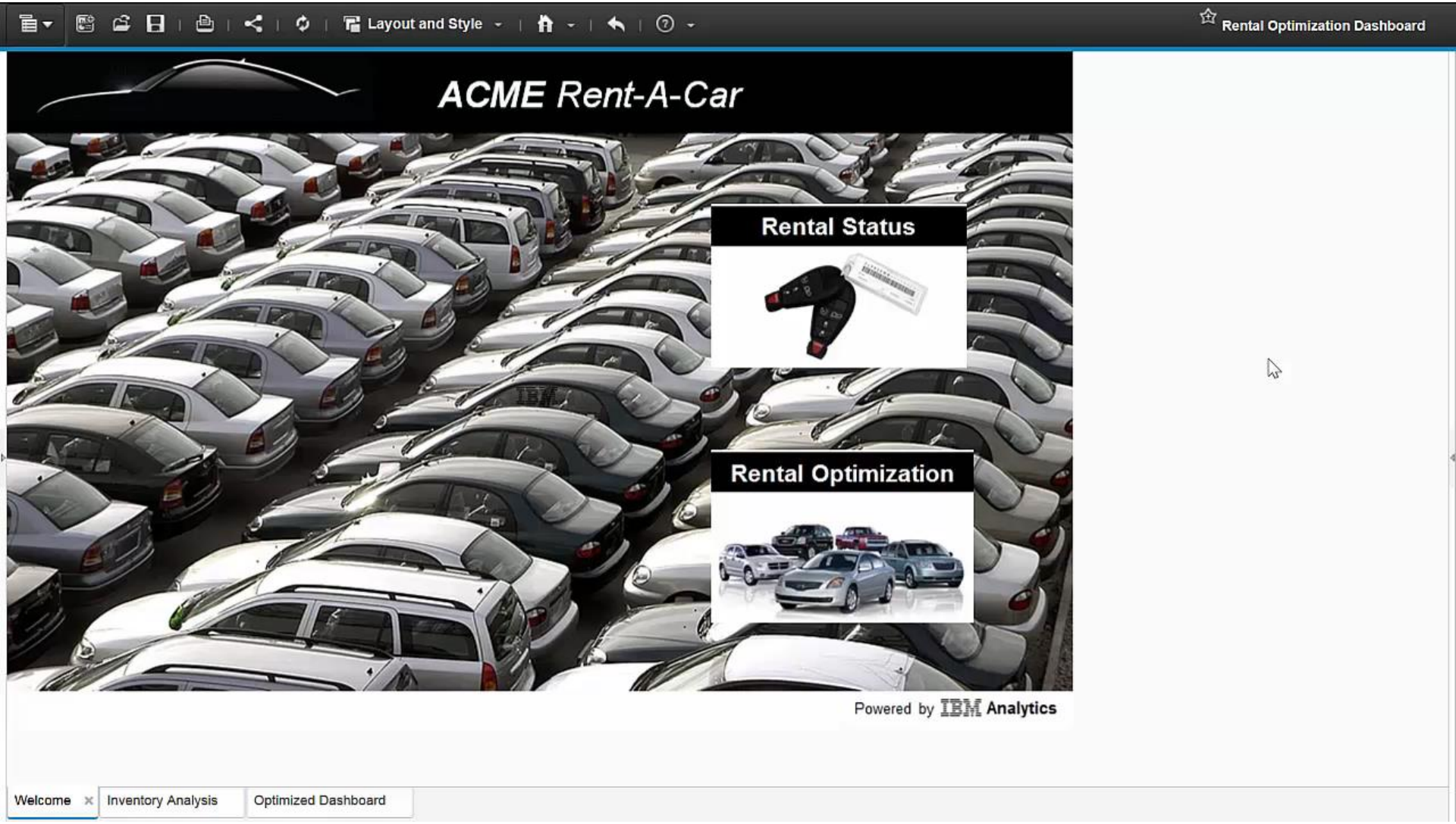
Healthcare

ACCURAY
Precise, innovative tumor treatments™

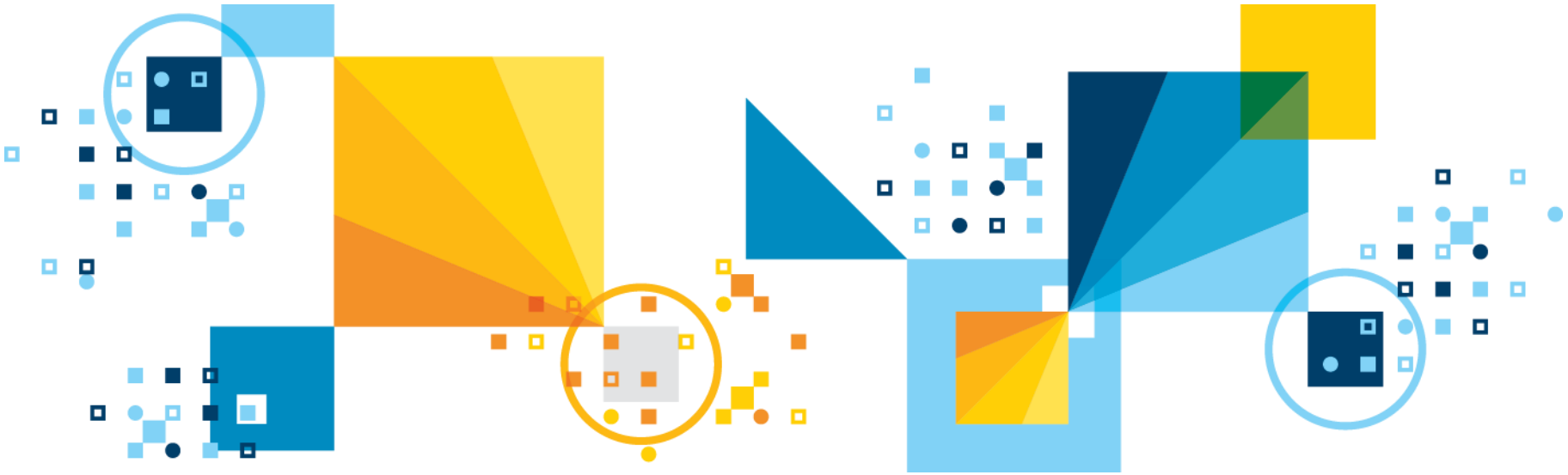
What is inside ?

"CPLEX" and "Constraint Programming (CP)" advanced mathematical optimization algorithm/solver

Example: Rental Car Repositioning



Industry use cases



Sales & Operations Planning

- **Business needs:**
  - Efficiently allocate production capacity to market demand
  - Make difficult supply-demand trade-offs
- **Typical Challenges:**
  - Lacks agility (planning 3 months in advance)
  - Continuous manual re-adjustments of plan
  - Lack of collaboration among planners at different levels

Typical S&OP Process

Prescriptive Analytics S&OP Solution

- **Automated breakdown from high-level goals to low-level assignments**
- **Optimized balancing of conflicting goals and constraints**
- **Common planning cockpit for all involved planners**

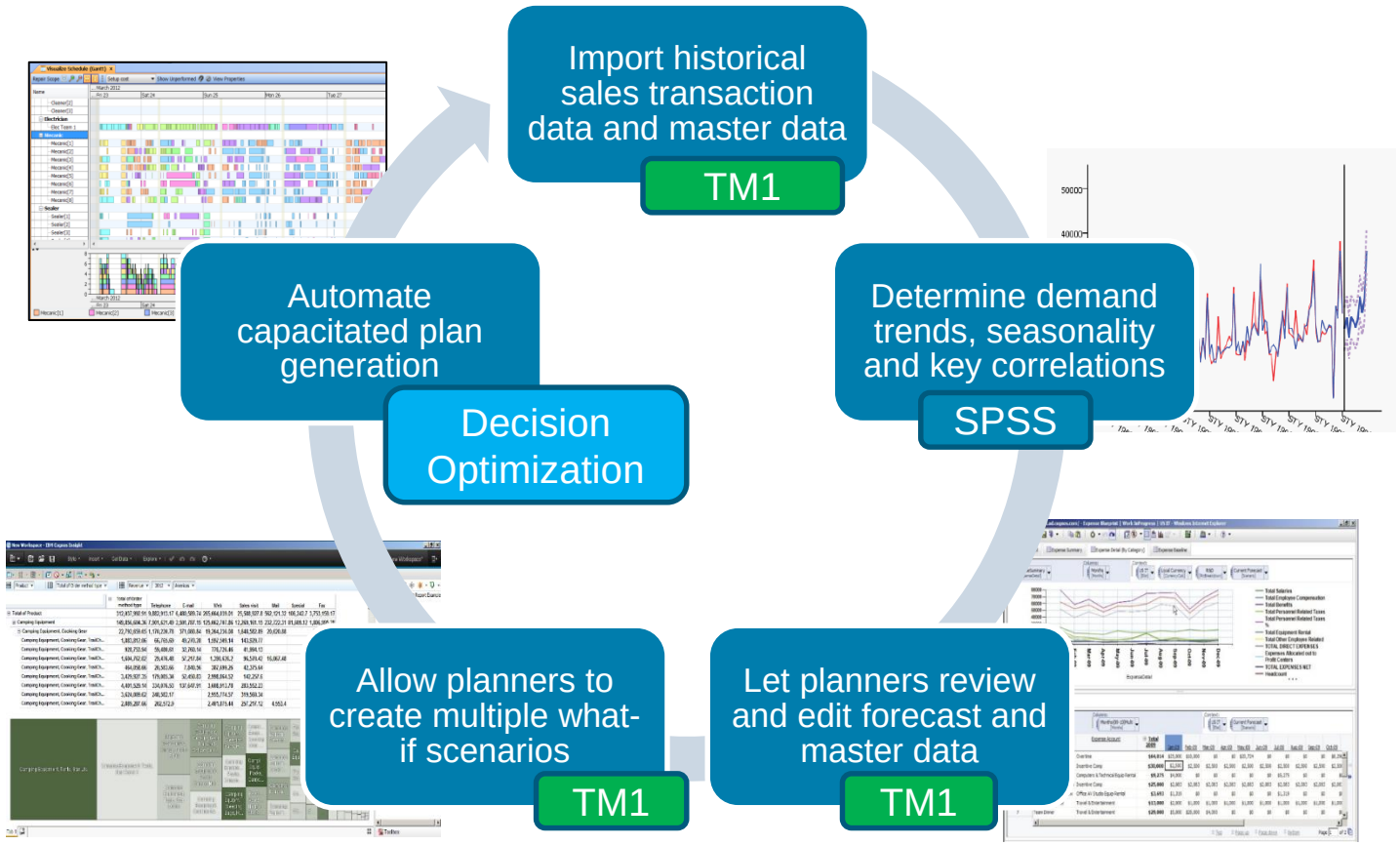
Typical Business Benefits:

75%
Reduction in planning figures that have to be filled in manually

50%
fewer planning shifts throughout the planning process

Minutes
to create new plans down from one month

Decision Optimization in end-to-end IBM Analytics Example: Advanced S&OP Lifecycle



JLG adopts IBM Decision Optimization to fast track production planning

Challenges:

- Production plans based on 24 month regional (spread across the globe) forecasts
- Plants across the globe with varying production capabilities, capacities and costs
- Very time and labor intensive excel based production plan rebalancing
- 3-5 person planning team would take10 days/month to get one feasible plan, which may not even be optimum.

JLG Industries, Inc., an Oshkosh Corporation company, is world's leading designer and manufacturer of industrial access equipment.

Variable	# of Data Points
Assembly Lines	35
Active Models	x 220
Forecast Groups	x 10
Periods (months)	x 24
TOTAL INTERSECTIONS	**1.8M**

Business Benefits:

Manual effort reduced from 10 days to 3 days / month
~ $70K yearly savings

Accurate supplier forecast. Reduced expediting and shortages
~ $250K yearly savings

More accurate financial analysis of projected spend and budgets
~ $20K yearly savings

JLG integrates advanced analytics (IBM Decision Optimization) with their Planning Analytics for production planning

Optimization re-balances production plan within minutes instead of days when demand changes. Planners can also use it to account for unforeseen events as well as scheduled maintenance downtime.

Continental Tires Optimizes manufacturing of 10,000 products across 20 plants worldwide

Key Challenges:

- Manufacturing process of each tire variety needs around 100 steps and different combination of materials, some with long lead times
- 20 plants vary is size and equipment
- **1000 new products every year**
- Efficiency of production landscape is a key determiner of its commercial success.

Continental Tires is a major global tire manufacturer, generating annual revenues of around EUR9.8 billion and employing around 47,500 people. It produces more that 10,000 different types of tires.

Business benefits:

30% reduction
in planning activities

30 times
More What-If scenarios evaluated.

Predict and Prevent bottlenecks
Resulting higher revenues and profit

Optimization based Future Allocation and Capacity Tracking (FACT)

Determine which products to produce at which locations while considering logistics and several other constraints

WestRock uses Decision Optimization based solution for optimizing its internal supply chain to meet internal and external demand

Key Challenges:

- Inventory stock outs at box plants
- High production and freight costs
- Inability to quickly react during unplanned events such as machine going down
- Inability to have visibility to trim situation and transportation planning more than a week out
- Disjointed production planning, supply planning and transportation planning

WestRock

WestRock is one of the largest paper and packaging manufacturing company with $15 billion annual revenue, 42000 employees in 30 countries. It's Supply Chain Network comprises of 80 box plants and 14 paper mills spread all across United States.

Business benefits:

3% improvement

in box plant service levels measured as % of SKUs without stock outs

13 weeks out

visibility to trim needs of production batches and transportation needs by mode

Rapid replanning for unplanned events

Less than a day to replan and reschedule the entire network

Optimization based demand sourcing, production planning & scheduling, transportation planning

Determine which demand to source to which mill; create optimized batches for production that minimizes production and transportation cost while meeting customer service levels

Marriott takes revenue management to next level by adopting optimization driven dynamic pricing

Opportunity:

- Develop a yield management application to plan room and service allocation levels and pricing at Marriott hotels worldwide
- Dynamically Price
  - Room Rates
  - Banquet/Meeting Space
  - Spa Services
  - Food & Beverage e.g.

Marriott International, Inc. is an American multinational diversified hospitality company that manages and franchises a broad portfolio of hotels, has more than 5700 properties in over 110 countries. Revenue over US $14.4 B.

Business benefits:
US$ 500 M / year
in revenue increase

Competitive Advantage

"As a result, no competitor has anything close to the solution Consolidated Inventory / Total Yield provides. The system puts the right information in *employees' hands so they can deliver* on the expectations of group customers and close the right business for the *hotel." said Bruce* Hoffmeister, Global CIO.

Marriott adopts IBM Decision Optimization based Yield Management for the lodging industry

Dynamically determine optimal pricing based on capacity constraints, fluctuating demand, variable price elasticity and changing supply to increase revenue.

Workforce Planning and Scheduling: Tactical/Operational Optimization

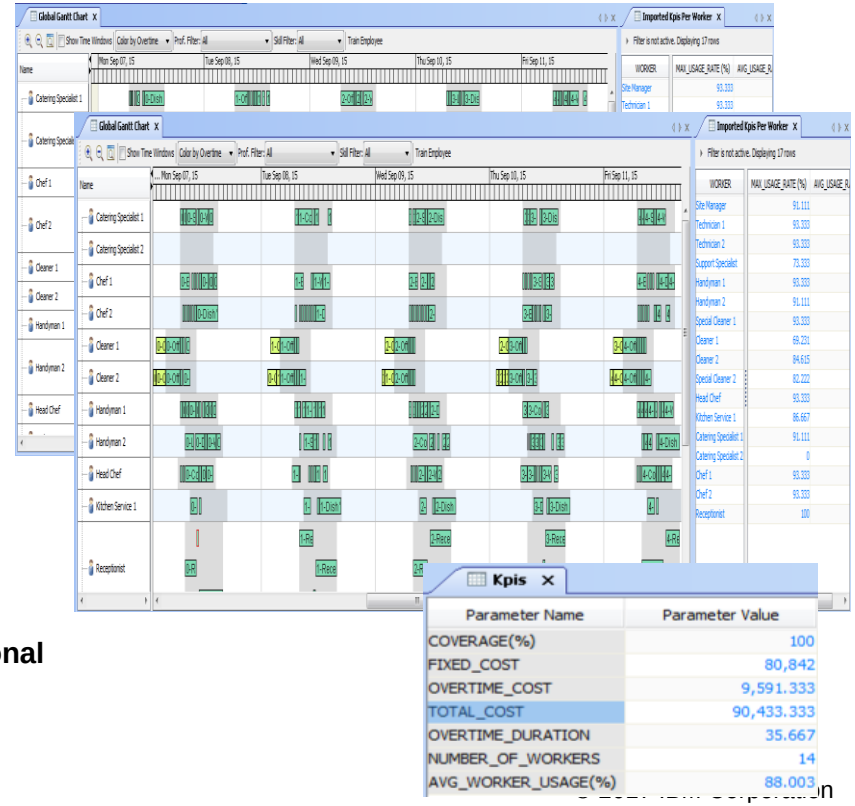
- Over capacitated workforce drive higher costs
- Under capacitated workforce drives higher cost due to
  - Overtime needed to meet SLA's
  - Penalties for under achieved SLA's

1. Workforce sizing : 5% savings
2. Select Cross skilling options: 10% savings
3. Optimize Service Level Agreements: 7% savings
4. Optimize Shift Designs

Tactical

5. Share workforce / Scheduling

Operational



Nurse scheduling for University Hospital in the UK

Challenge

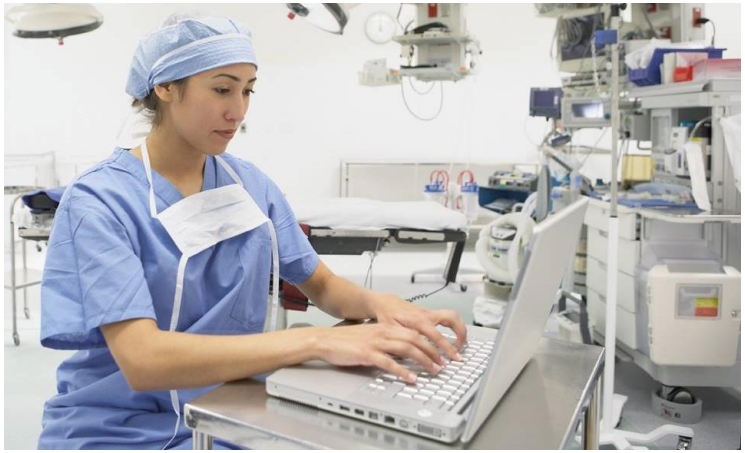
- **The hospital needed a solution that could equitably allocate work shifts, while helping to ensure there are enough nurses with the right skills to meet the needs of the patients.**

Solution

- IBM® ILOG CPLEX, serves as the mathematical solver in handling the complex calculations used to generate schedules and provides the optimum schedule considering all constraints as possible in real time.

Benefits/ROI

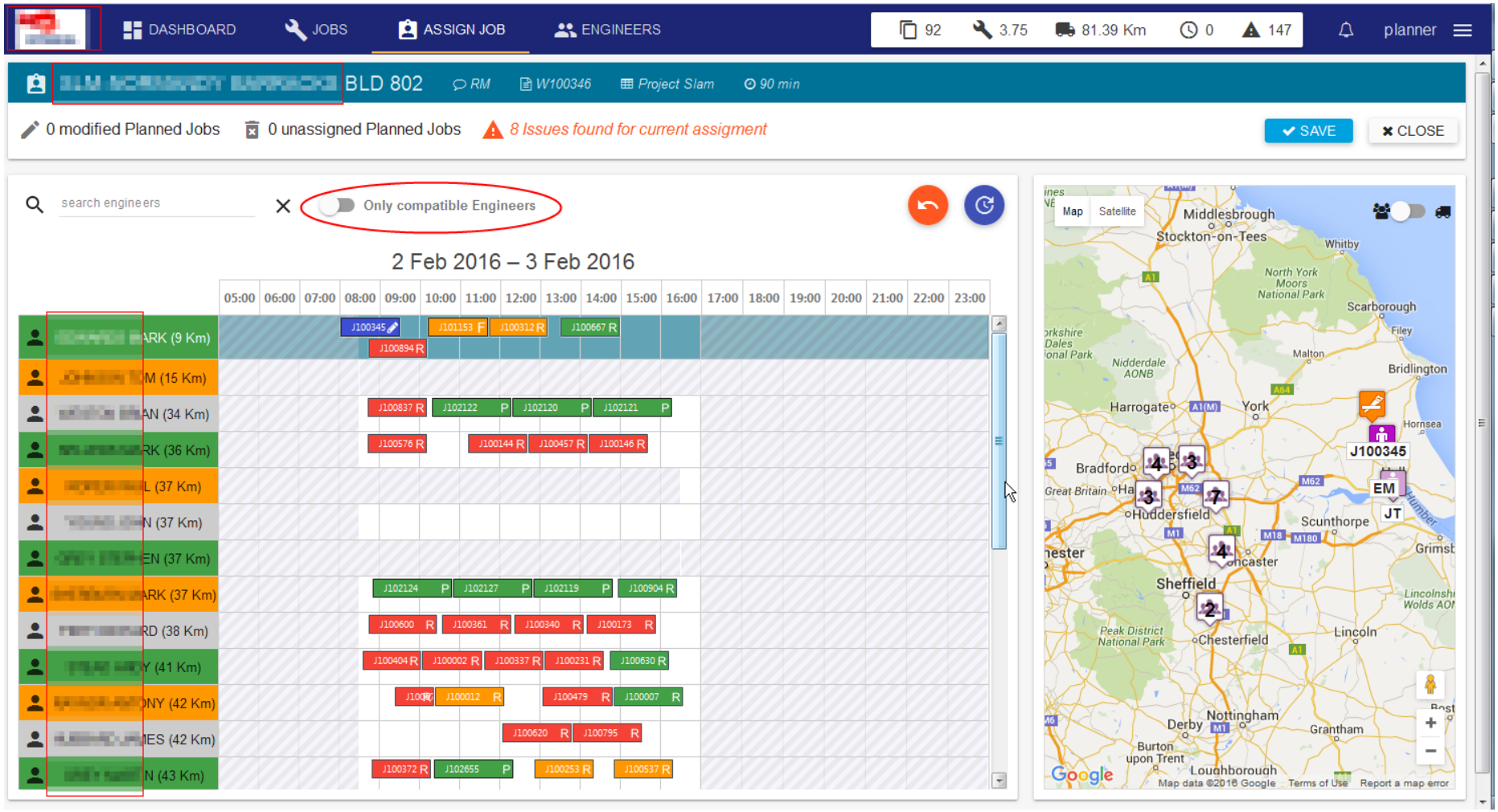
- Reduced labor cost by approximately **£1.2m per year**
- Improved plan accuracy and efficiency
- Generates new schedules in minutes
- Flexible solution addresses the business complexity of high number of conditions and constraints



Customer Profile

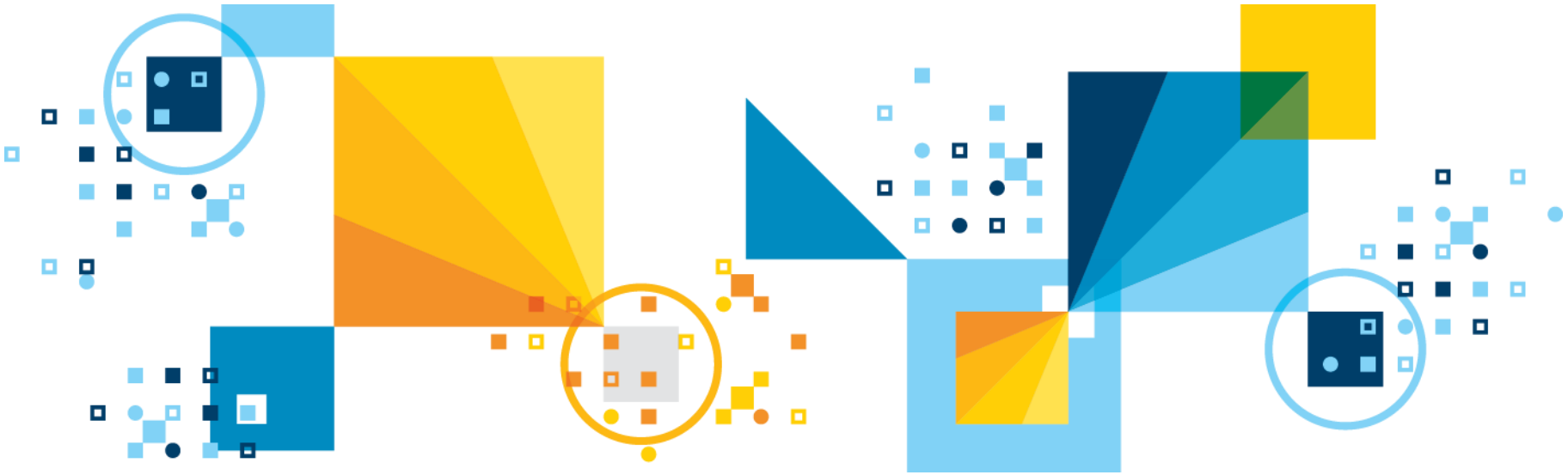
This university hospital provides general hospital services and specialist care in obstetrics and neonatology, fetal medicine and neuro-rehabilitation.

Workforce Planning and Scheduling Optimization



Decision Optimization

How does it work ?

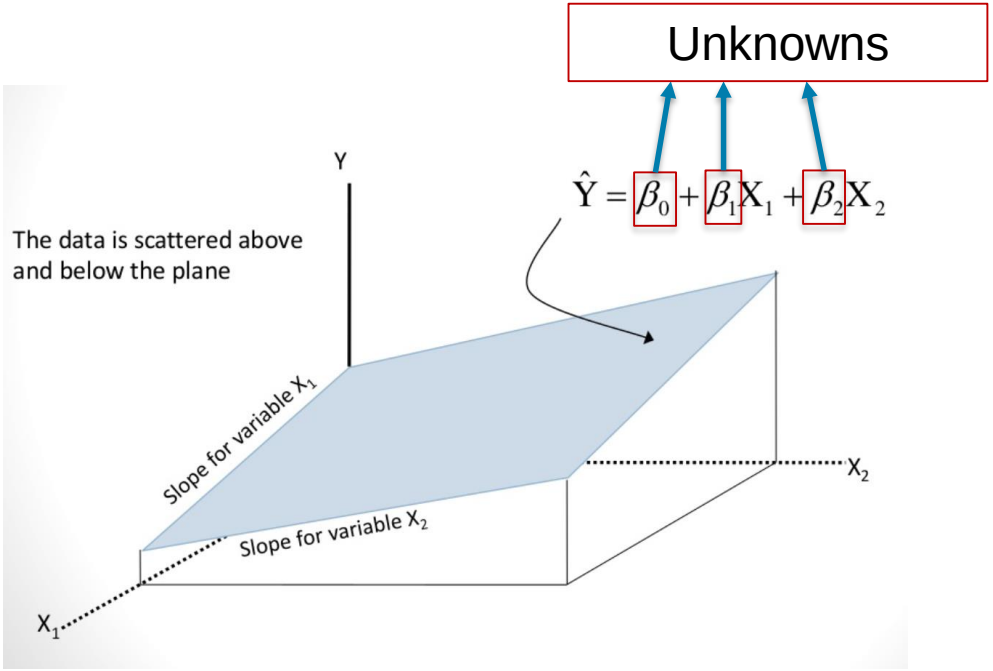


Predictive vs Prescriptive

Predictive model:

For given data, fit/find a model such as

- Regression
- Neural Network
- CHAID
- …
- …



Predictive vs Prescriptive

Optimization model:
Define business objectives and constraints, find decisions

Production Facility (PF)	PF1	PF2	PF3
# Units to Produce ?	U1	U2	U3
Production Cost / Unit	100	150	80
Production Capacity	500	350	300

DATA

Total Demand = 1100

Optimization Model

Decision Variables:

Objective Function
Minimize Total Cost

Total Cost =
100xU1 + 150x U2 + 80xU3

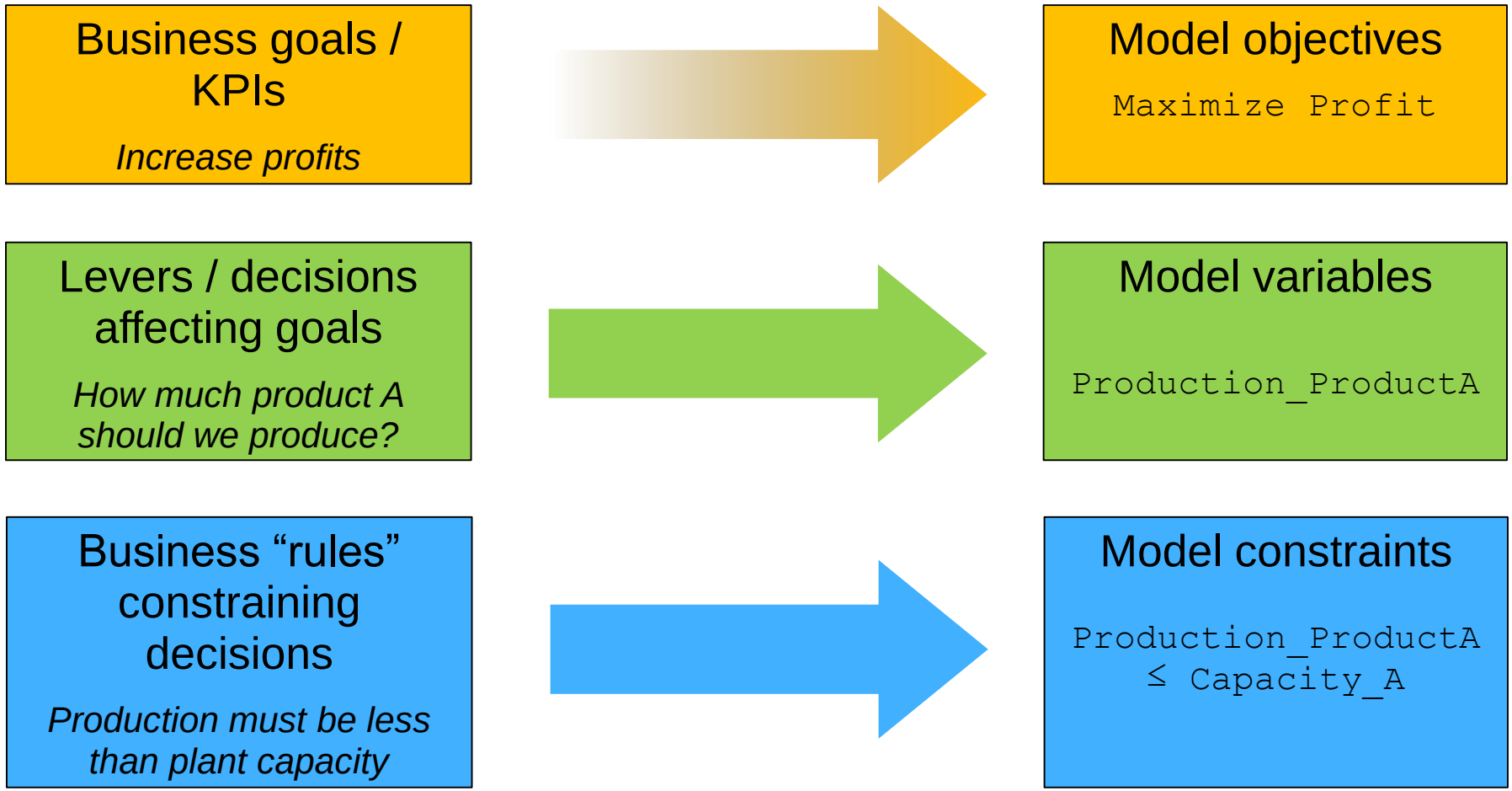
Unknowns / Decision Variables

Constraints:
U1 <= 500 ; U2 <=350 ; U3 <=300

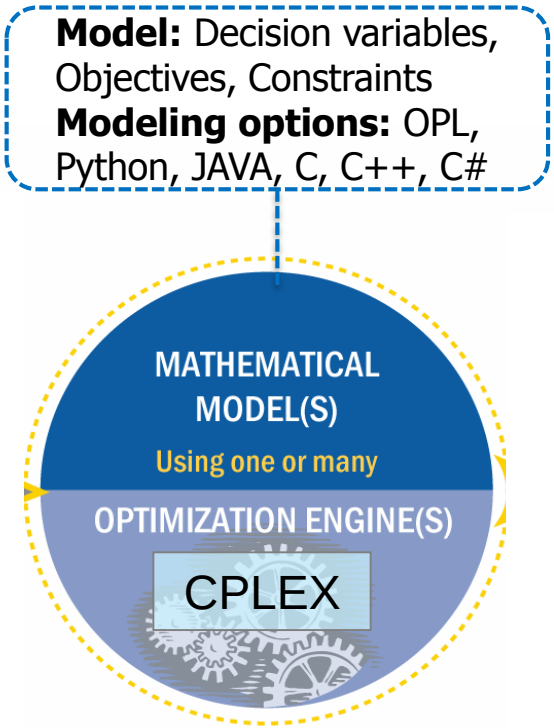
U1 + U2 + U3 ==1100

What is an optimization model?

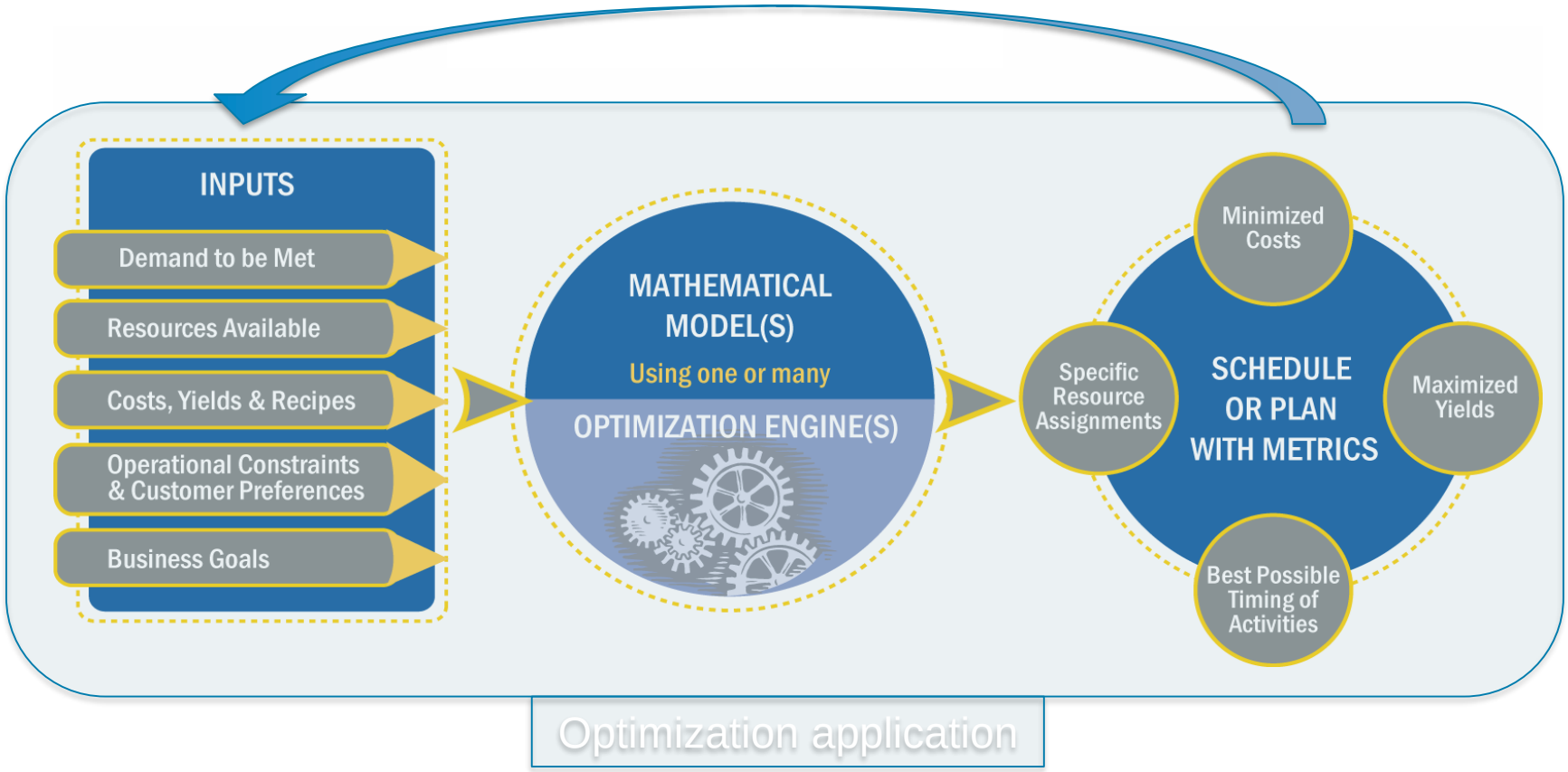
A translation of your business problem into math



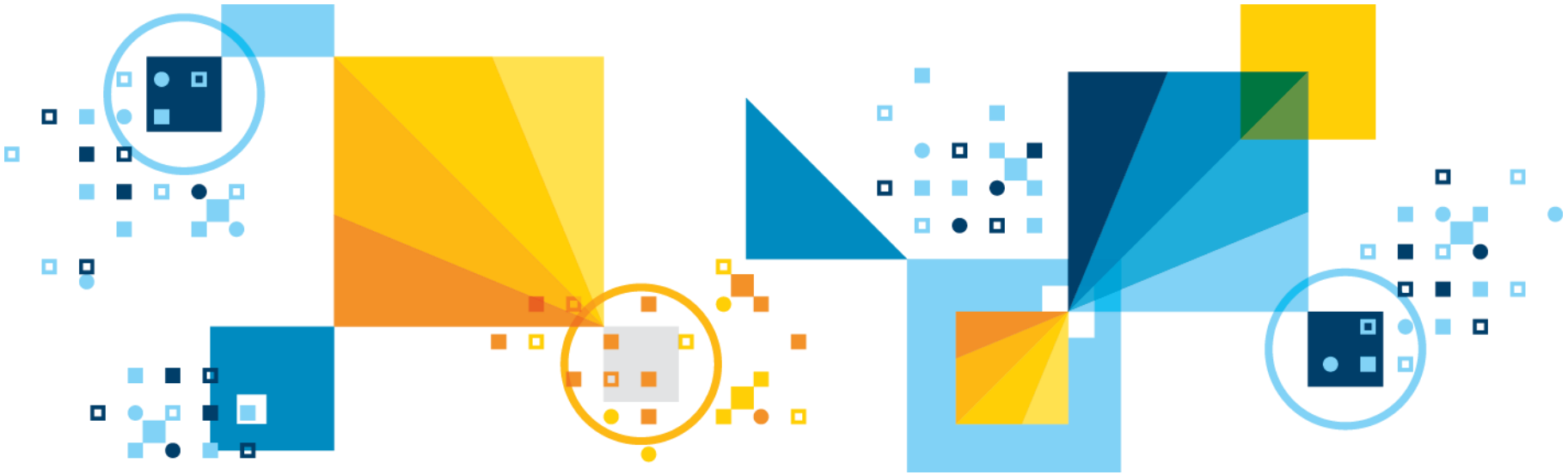
Application building and use



Prescriptive Analytics – How does it work?



Quick Product Review



IBM Decision Optimization (DO) - offering

CPLEX Solver On-Prem

- Solver + model development environment
- Various deployment options

Decision Optimization on Cloud (DOcplexCloud)

- CPLEX Solver on cloud
- Various APIs available to submit, monitor and manage remote solves

Decision Optimization Center (DOC)

- Platform offering for DO applications
- Client Server architecture of distributed applications with thick client, REST API, and scenario management

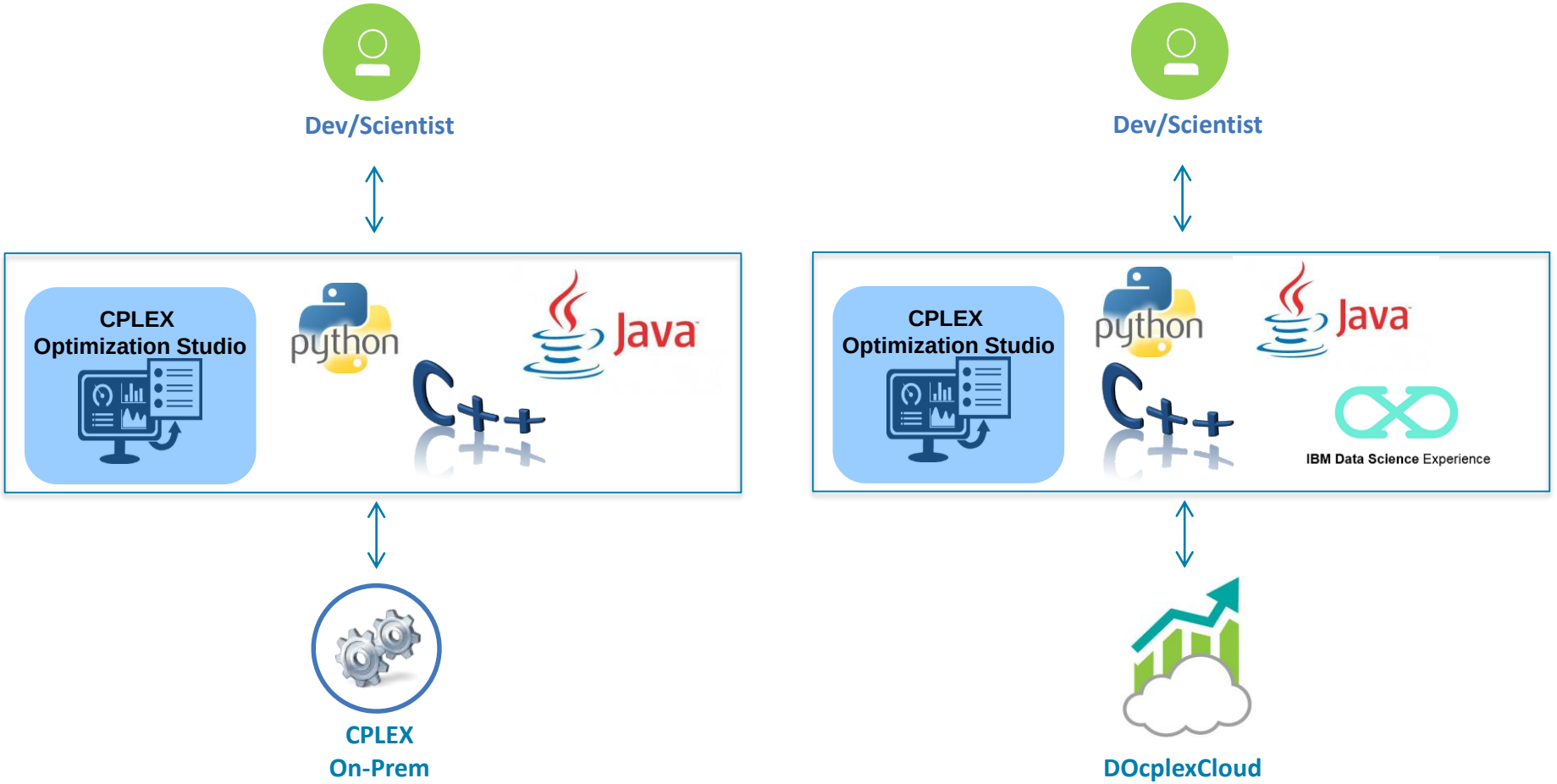
IBM Data Science Experience

- DO is one of the two key advanced analytics services in DSX
- Can be consumed from Notebooks, R-studio

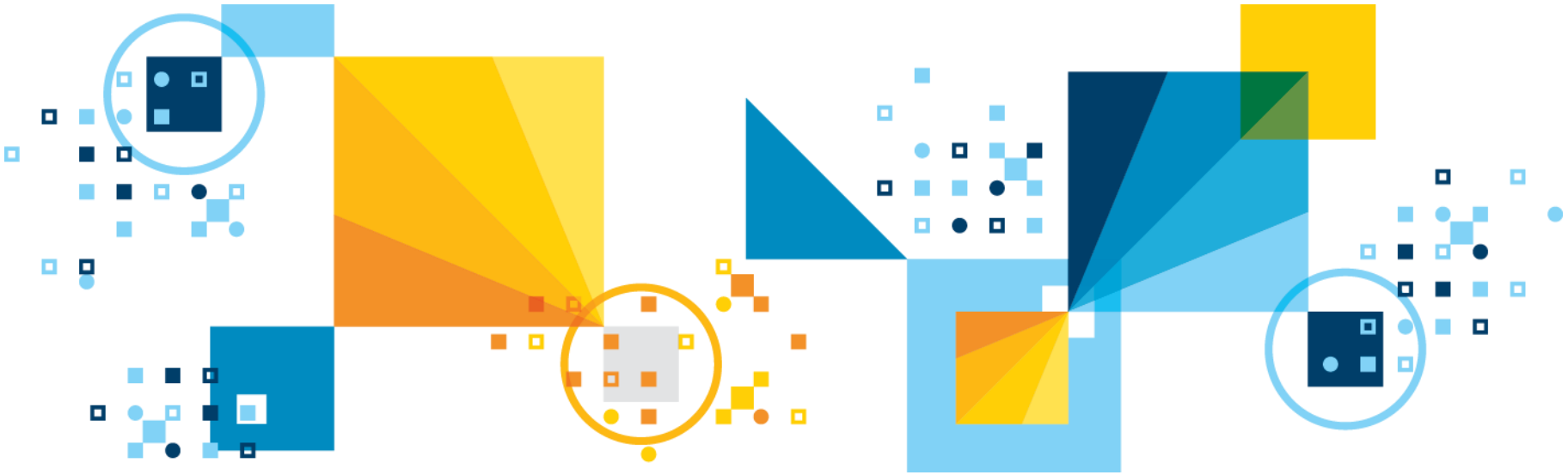
- DO Catalog service within IBM's cloud development and deployment platform
- APIs are available in REST, Java, Node.js, and Python.

- CPLEX node in SPSS Modeler 18.1
- Default includes limited Community Edition (CE) of CPLEX solver

CPLEX Development options



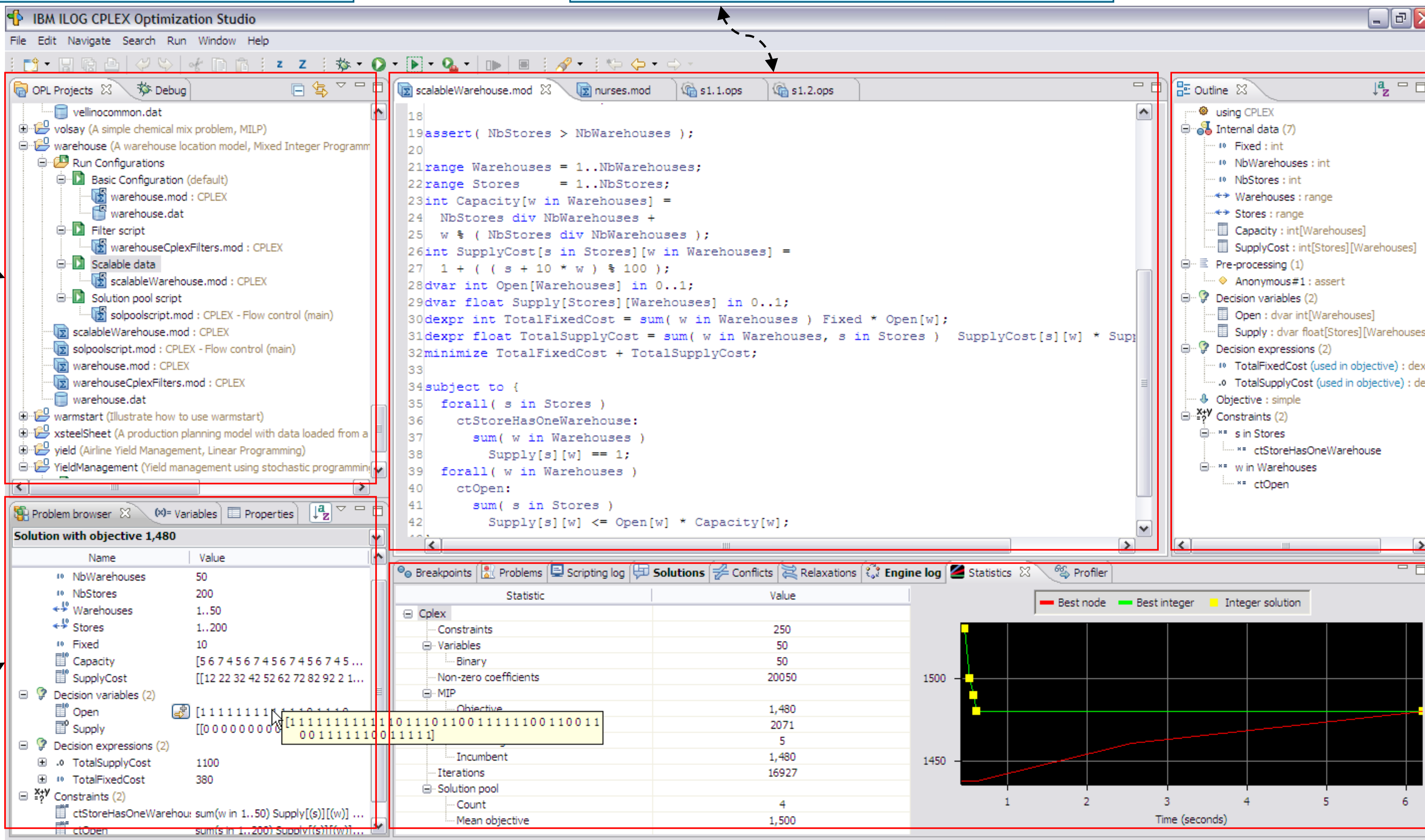
Product Details
CPLEX Optimization Studio (COS)



CPLEX Studio IDE – Model Development Tools

Project navigator

Model/script code editor



Problem browsers

Inspector/output tabs

Problem outline

An example of a model

scalableWarehouse.mod | blending.mod | gas.mod | vellinogenBin.mod | *warehouse.mod

```
14 int Capacity[Warehouses] = ...;
15 int SupplyCost[Stores][Warehouses] = ...;
16 dvar boolean Open[Warehouses];
17 dvar boolean Supply[Stores][Warehouses];
18
19 minimize
20   sum( w in Warehouses )
21     Fixed * Open[w] +
22   sum( w in Warehouses , s in Stores )
23     SupplyCost[s][w] * Supply[s][w];
24
25 subject to{
26   forall( s in Stores )
27     ctEachStoreHasOneWarehouse:
28       sum( w in  Warehouses )
29         Supply[s][w] == 1;
30   forall( w in Warehouses, s in Stores )
31     ctUseOpenWarehouses:
32       Supply[s][w] <= Open[w];
33   forall( w in Warehouses )
34     ctMaxUseOfWarehouse:
35       sum( s in Stores )
36         Supply[s][w] <= Capacity[w];
37 }
38
39 {int} Storesof[w in Warehouses] = { s | s in Stores : Supply[s][w] == 1 };
40 execute DISPLAY_RESULTS{
41   writeln("Open=",Open);
42   writeln("Storesof=",Storesof);
```

Data initialization

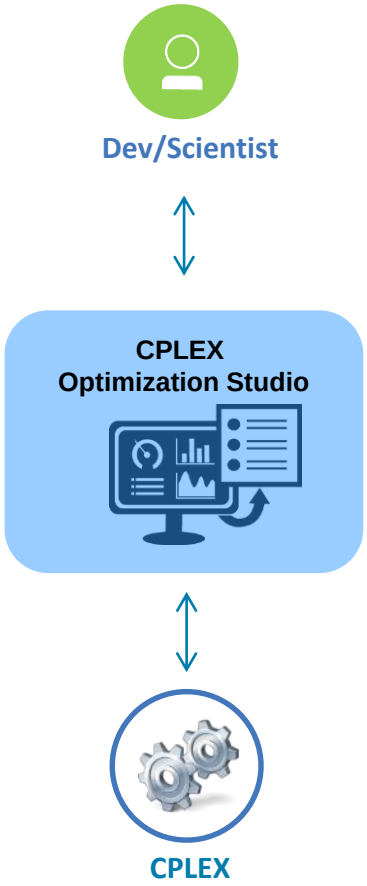
Decision Variables

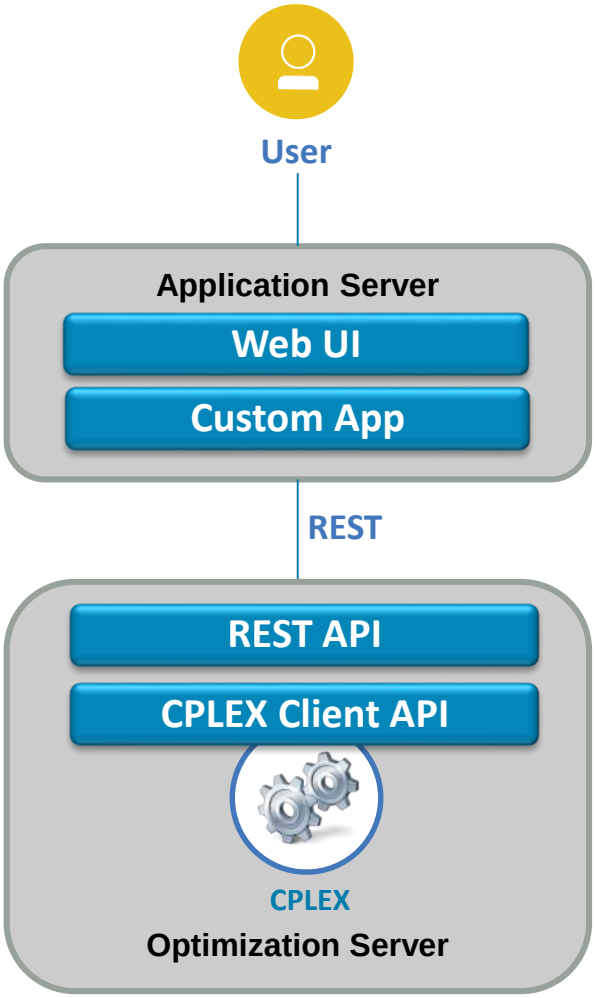
Objective Function

Constraints

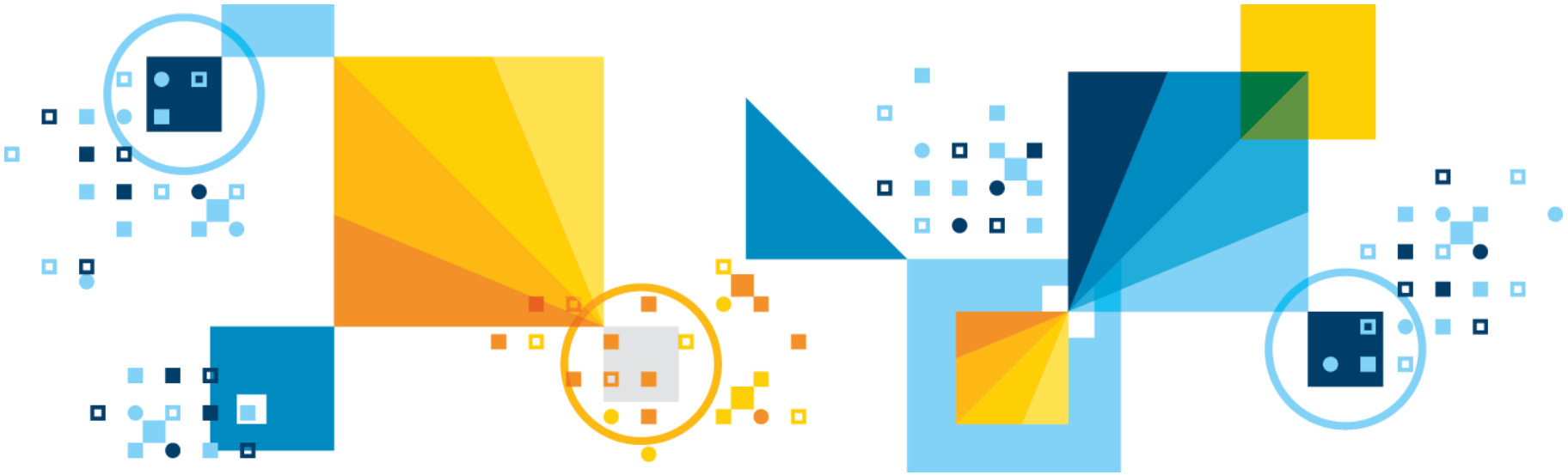
Post-processing

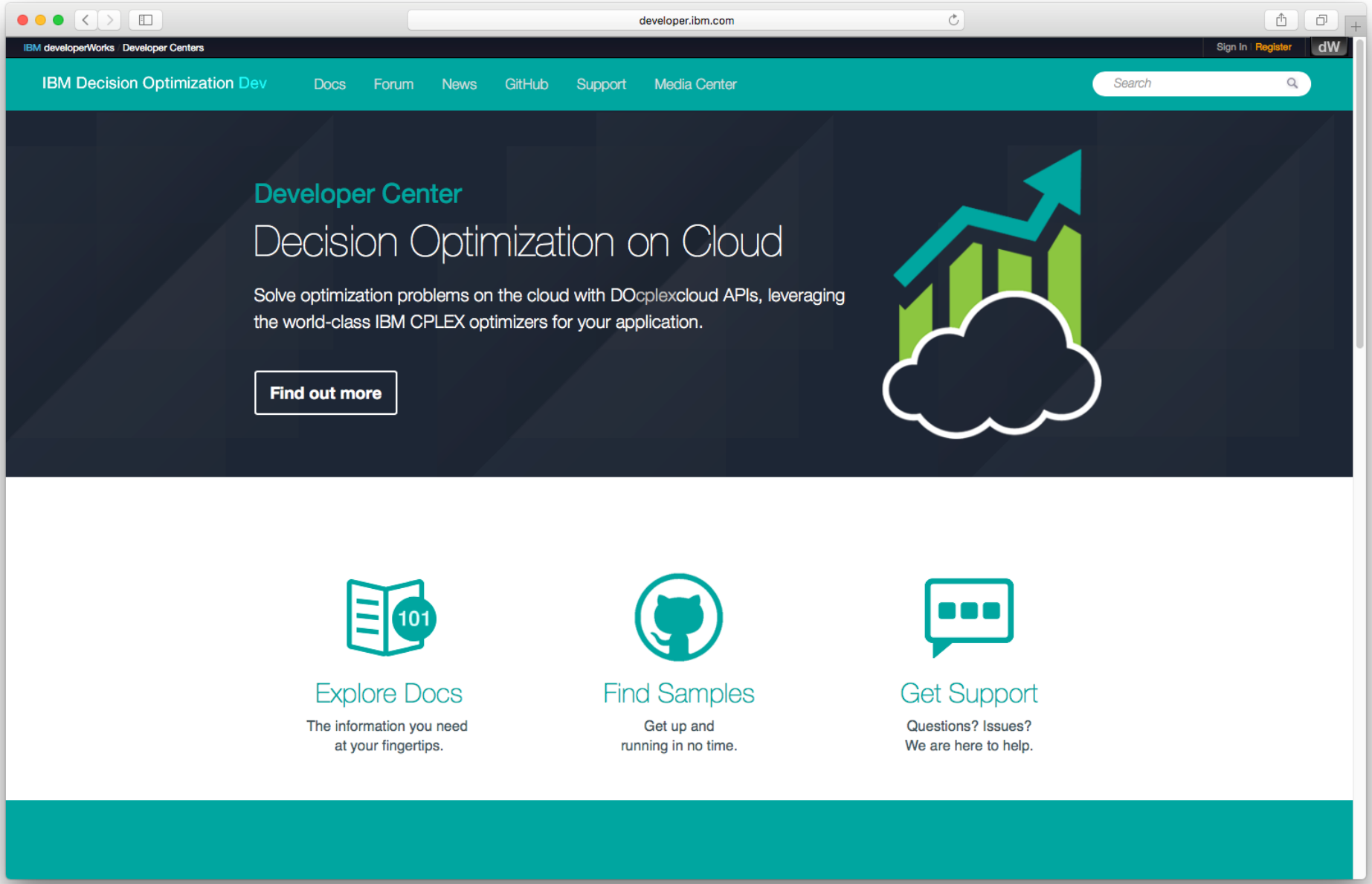
COS – Development and Deployment options





Product Details
Decision Optimization on Cloud (DOcplexcloud)





https://developer.ibm.com/docloud/

DOcplexCloud – Enabling Optimization Solutions

Understanding the Integration Principles

- Benefits:
  - Automate the execution of your optimization problems (OPL and CPLEX) without deploying and maintaining any of the optimization libraries
  - Free up application resources and get solutions asynchronously
  - Solve more demanding problems by using large configurations

Decision Optimization on Cloud (DOcplexCloud)

There are many ways to solve optimization problems with Decision Optimization on Cloud

api

You call a solver from your **Bluemix** application using a DOcplexcloud API.

api

You call a solver from your application using a DOcplexcloud API

You drop an optimization problem in the DropSolve Website.

You configure access in your optimization modeling tool

You have a **Bluemix account** and use the Decision Optimization for Bluemix service.

You subscribe
to a Decision Optimization on Cloud Pricing plan or Free Trial via the IBM Market place.

DO cloud solve: modeling and solve options

CPLEX Solver On-Prem

CPLEX

Modelling Options

- Optimization Programing Language (OPL)
- Python
- C, C++
- JAVA

Decision Optimization on Cloud (DOcplexCloud)

Modelling Options

- Python (full modelling API)
- Optimization Programing Language (OPL)
- JAVA concert – requires model export to .lp, or .sav file

API – to access/control

- JAVA
- Python
- REST
- Node.js
- R

Create the job

Initialize a new job and upload the associated model and data files.

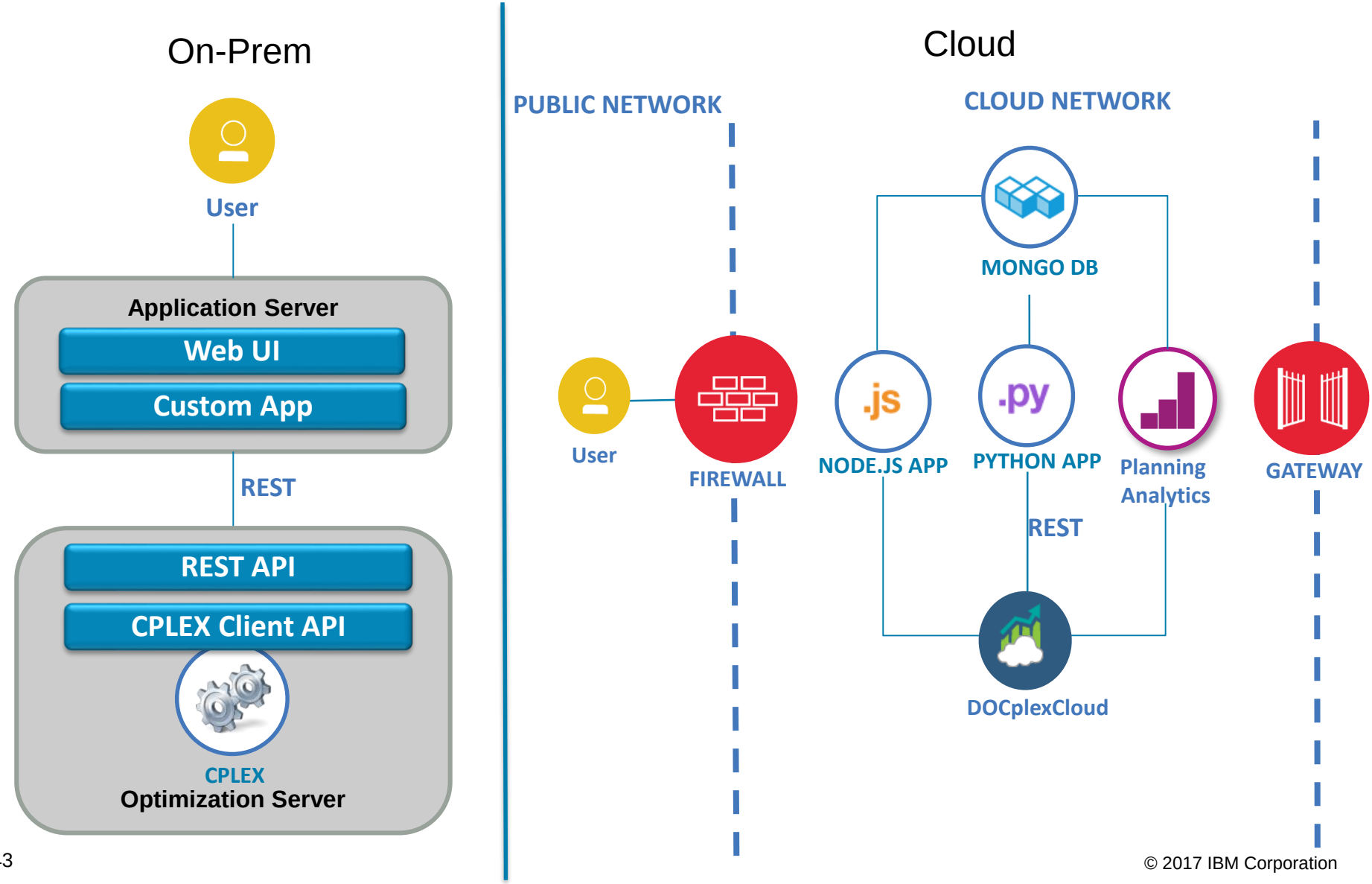
Submit the job

Submit the job to execute and monitor its status.

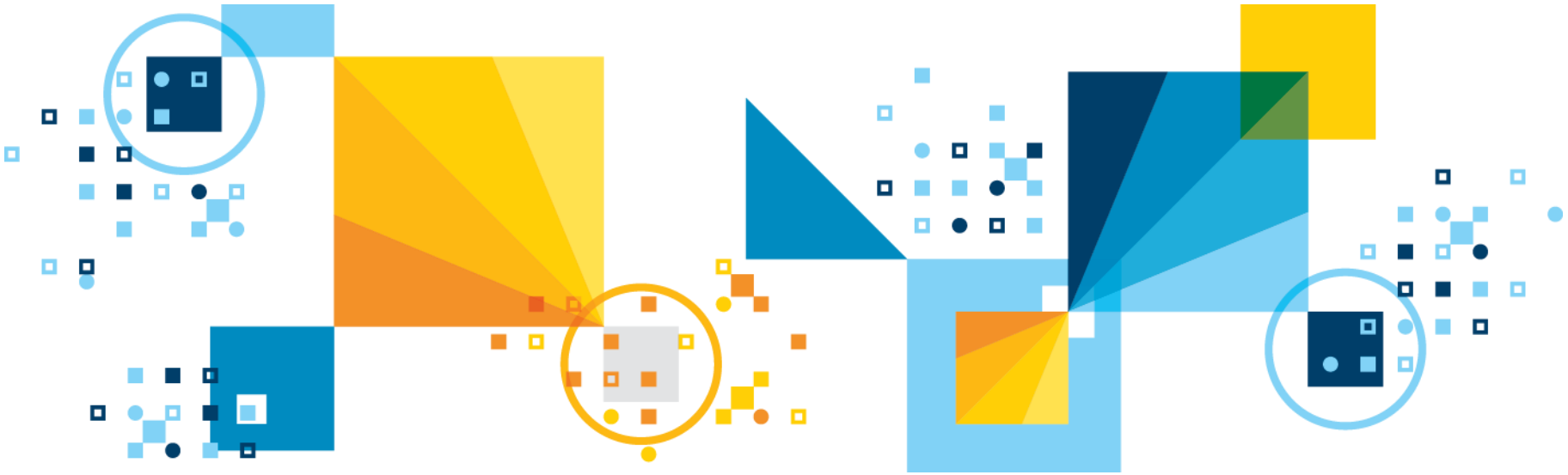
Get results

Access results and download them to your application.

CPLEX Deployment – Basic architecture

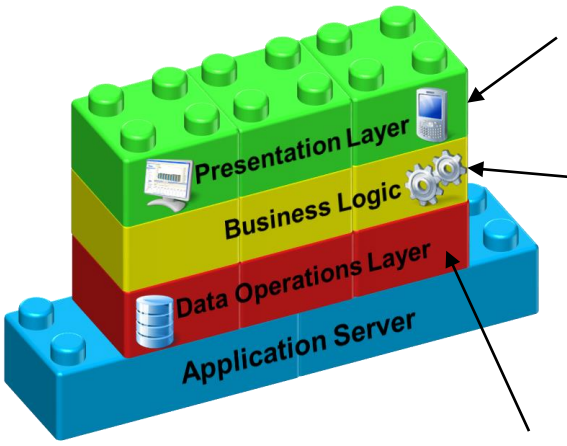


Product Details
Decision Optimization Center (DOC)



IBM Decision Optimization Center (DOC)

Framework: Software with prebuilt components



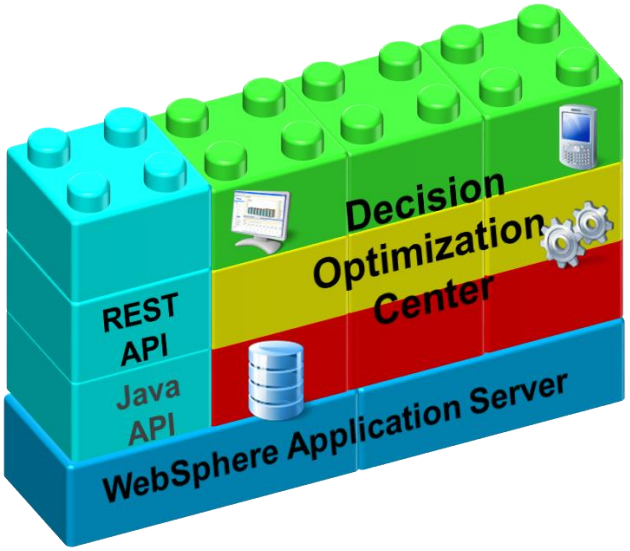
- Navigation
- Accessibility
- Visualization
- Portability

- Business rules
- Security & Access
- Configuration
- Services
- Integration

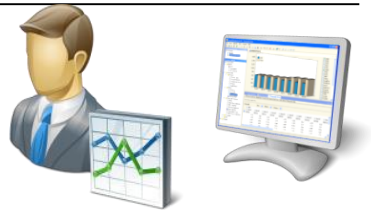
- Storage
- Model
- Relationships
- Referential Integrity

DOC: Framework for building Optimization applications

- Configurable Data and UI elements
- Custom UI option

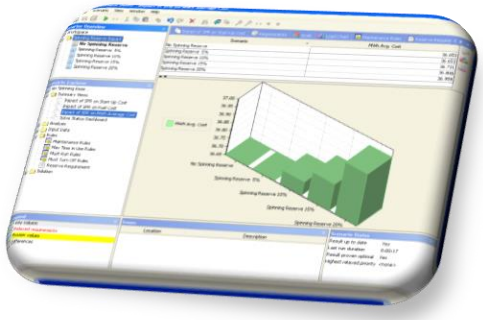


DOC Client

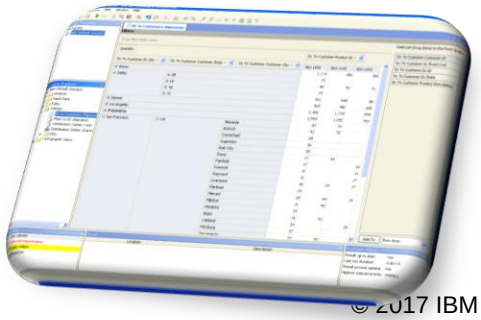


- **Windows native application**
- **Extensible through APIs and Hooks in Java**
- **Optional component**
  - can be replaced by Web Services architecture with REST API
- **Out-of-the-box:**
  - Prioritization of constraints
  - Weighing objectives
  - What-if analysis
  - Scenario management.
  - Multi-scenario comparison.
  - Tables and charts.

Graphs



Charts

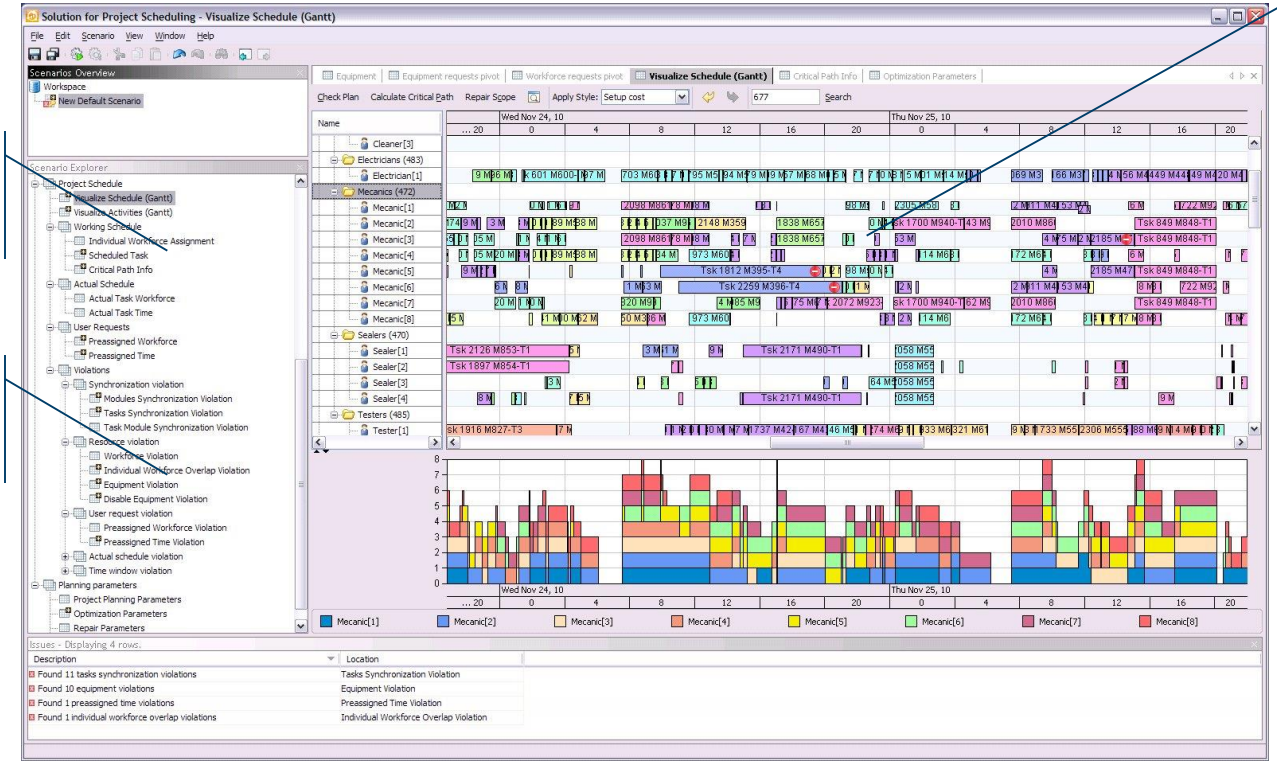


Pivot Tables

DOC for Complex Project Scheduling (CPS)

•Compare multiple scenarios
•Run What-If Analysis

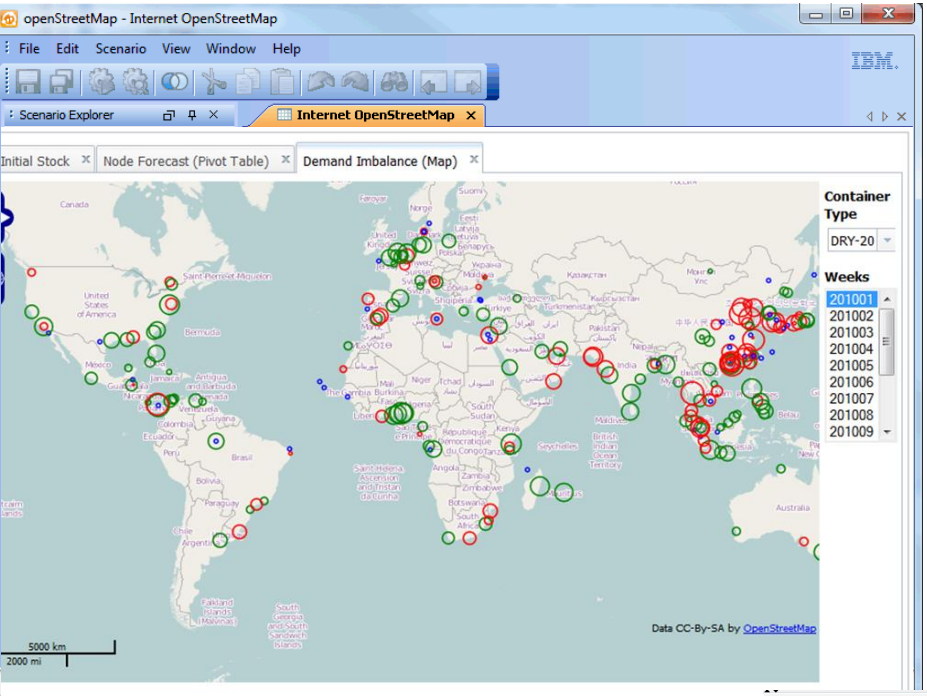
•Master Data:
Workers
Skills
Machines
Capacity
Zones
Time Periods
Etc.

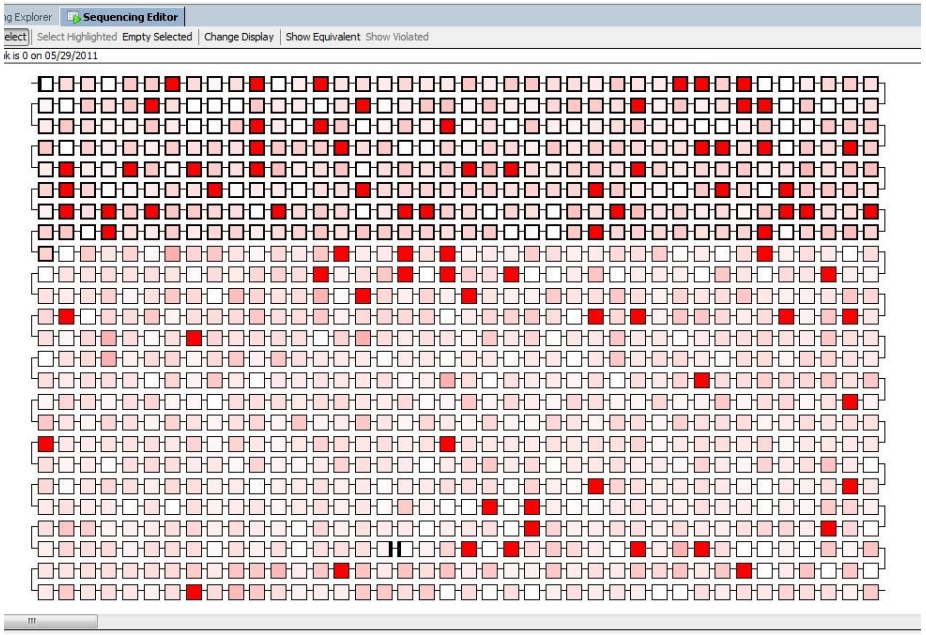


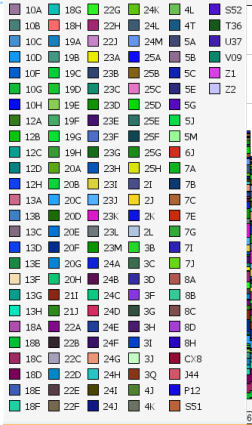
•Drag and Drop
•Dynamic Rescheduling
•Address constraint violations in real time

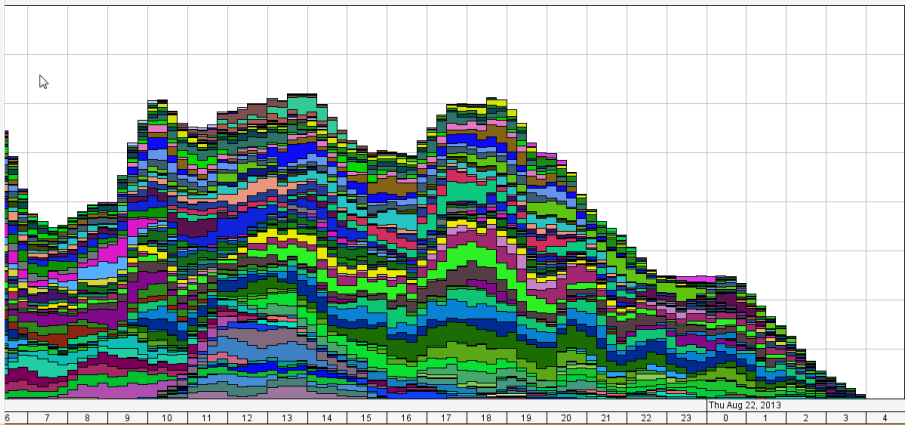
•Adapt to different quality measures for different industries
•Multi-Criteria Optimization and KPIs
•Performance and Scalability to manage hundreds of thousands of tasks

DOC Custom Data Visualizations

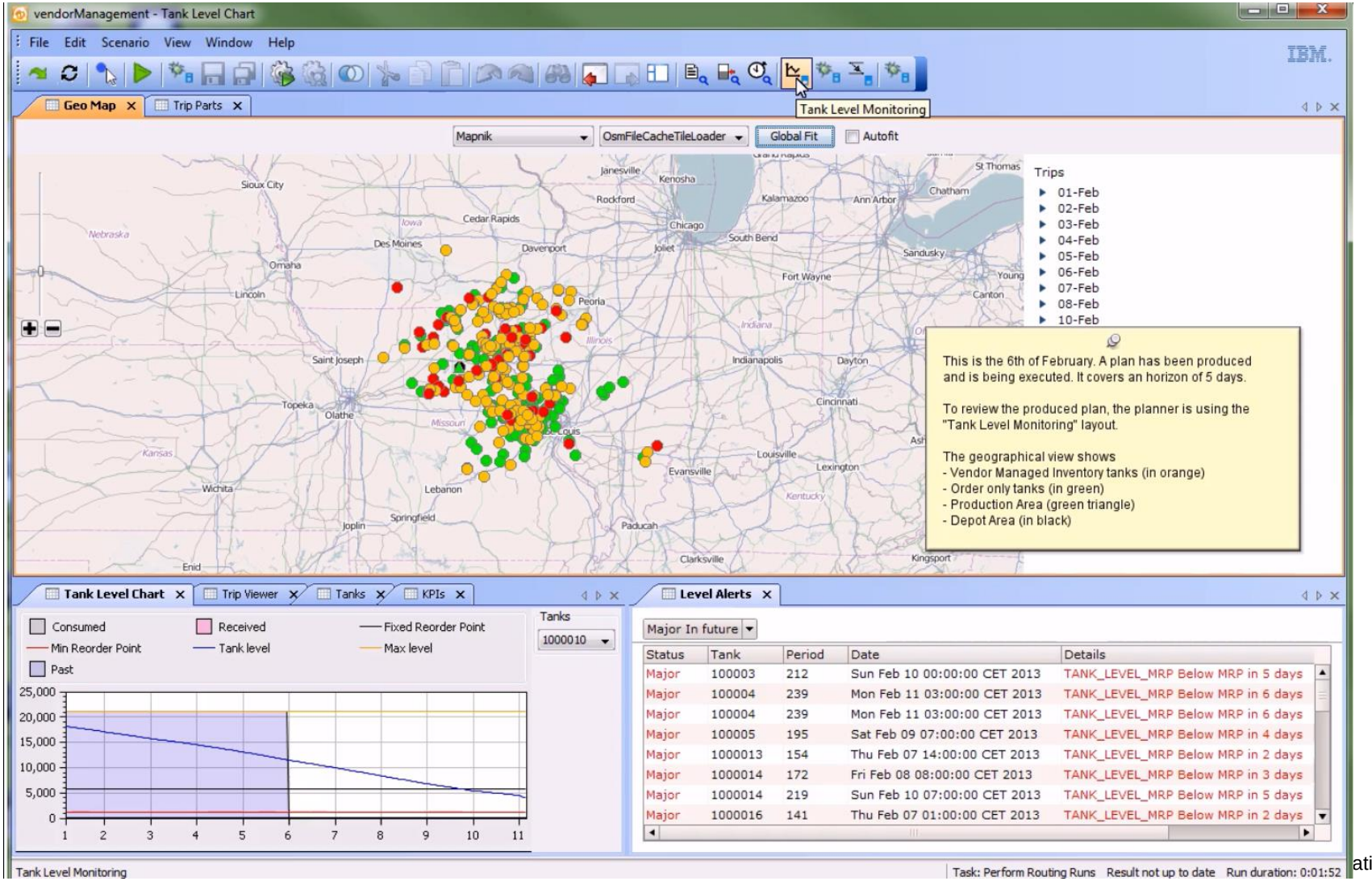




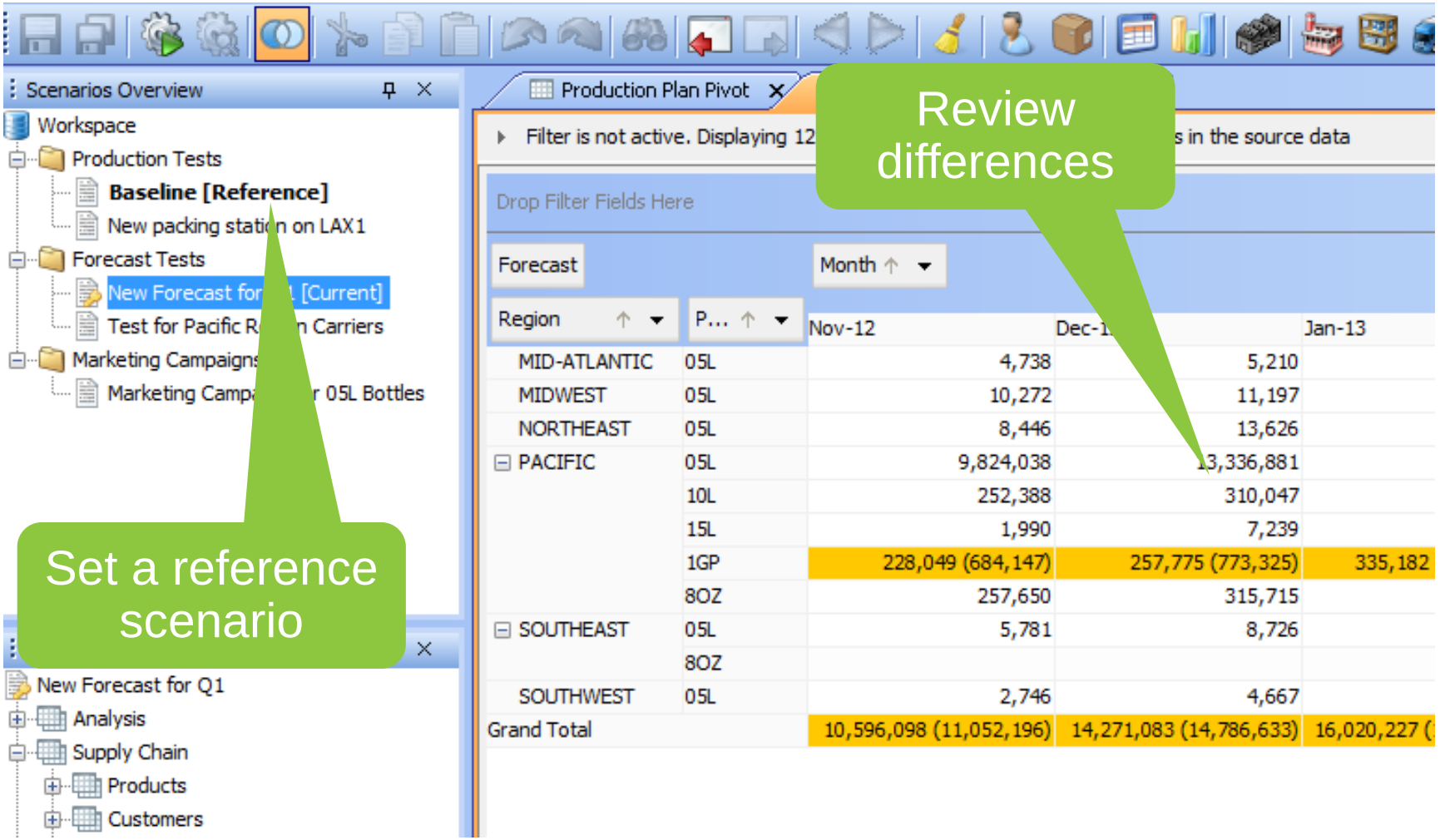




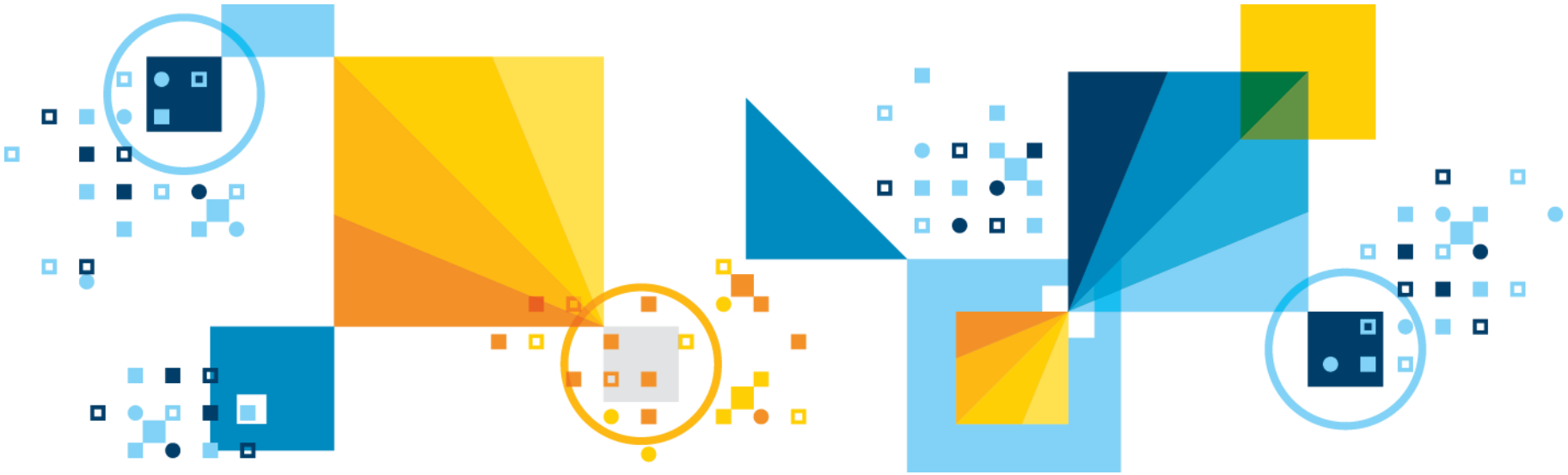
DOC Application example
Vehicle Routing with map view



DOC Application Example
Explaining The Results: Scenario Comparison

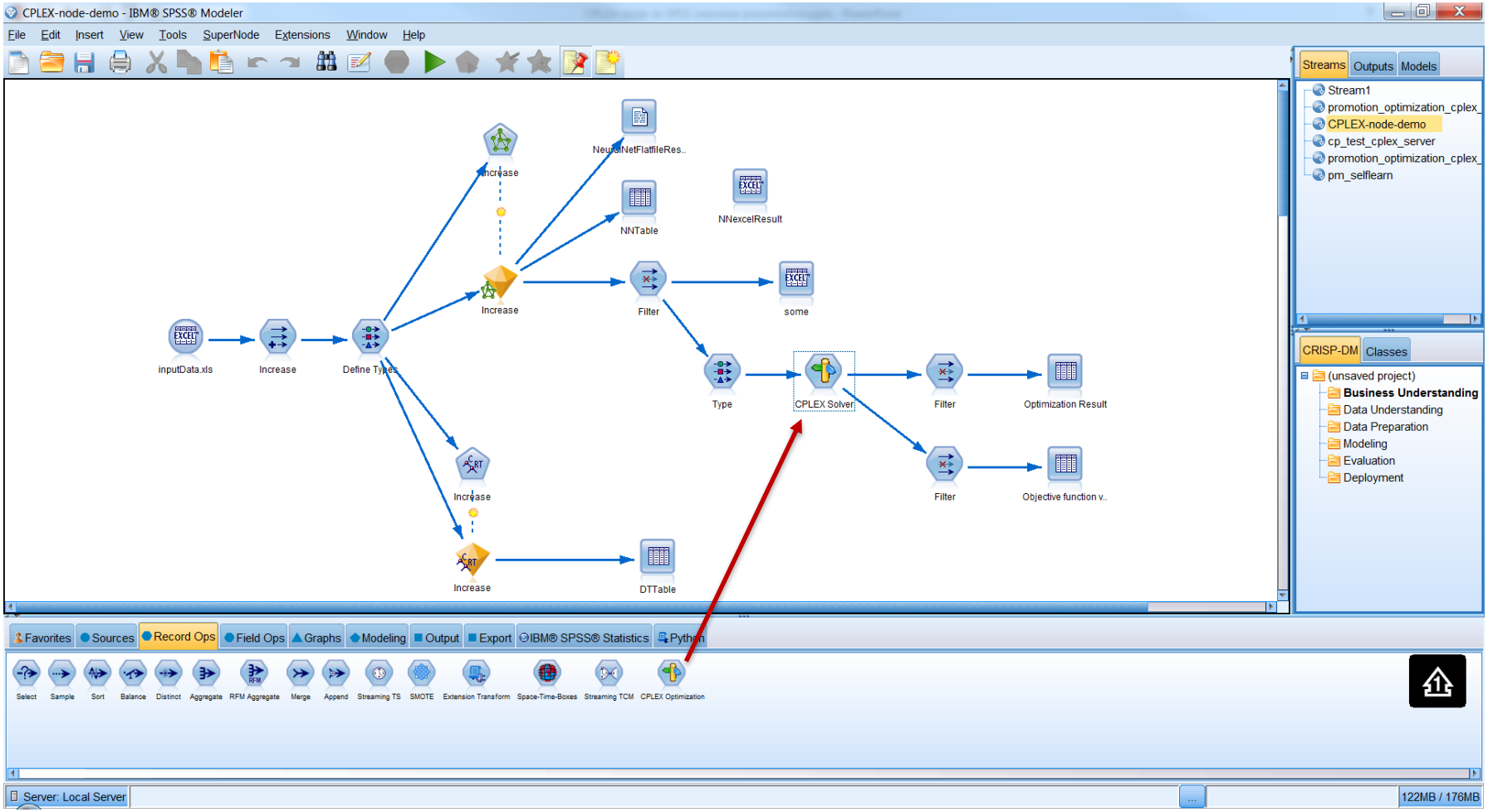


CPLEX node in SPSS



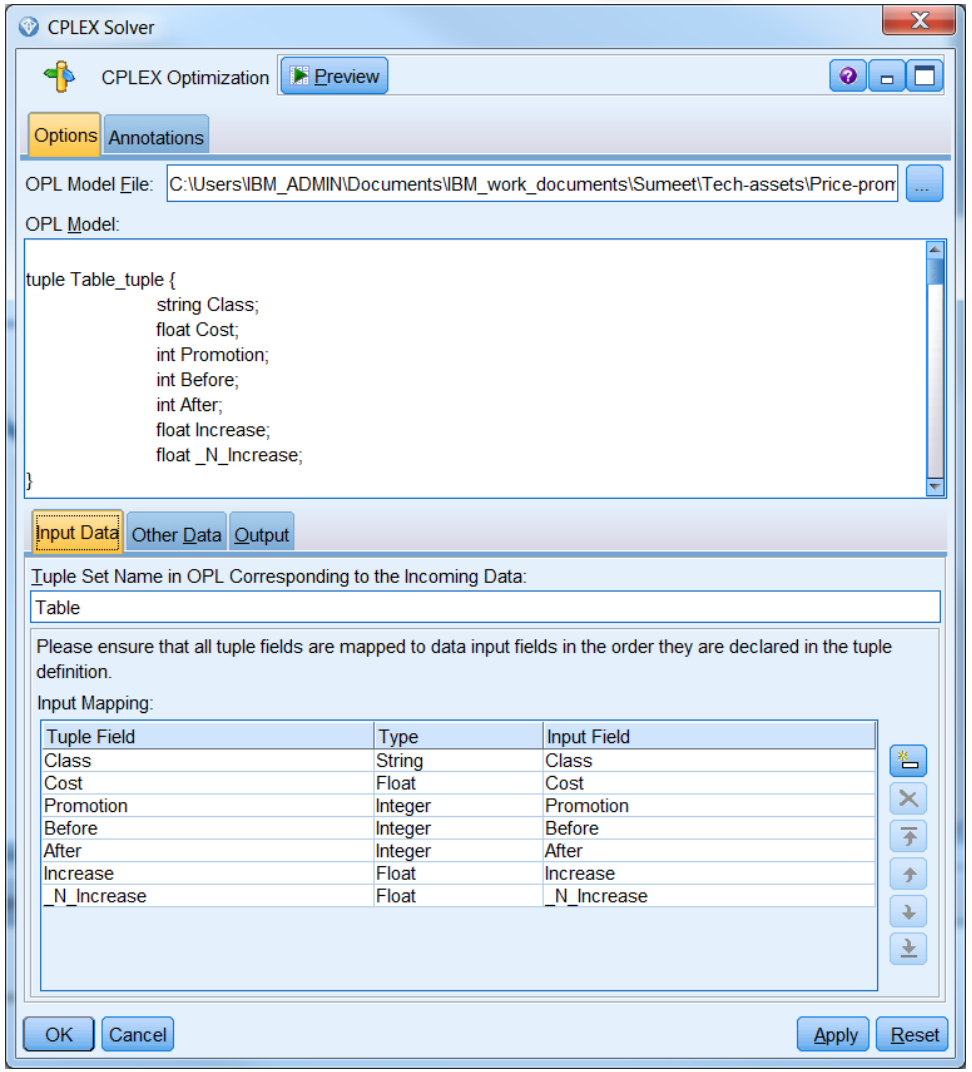
CPLEX node in SPSS - Overview

- **Modeler 18.1 comes packaged with CPLEX Community edition (model limited to 1000 variables, 1000 constraints)**

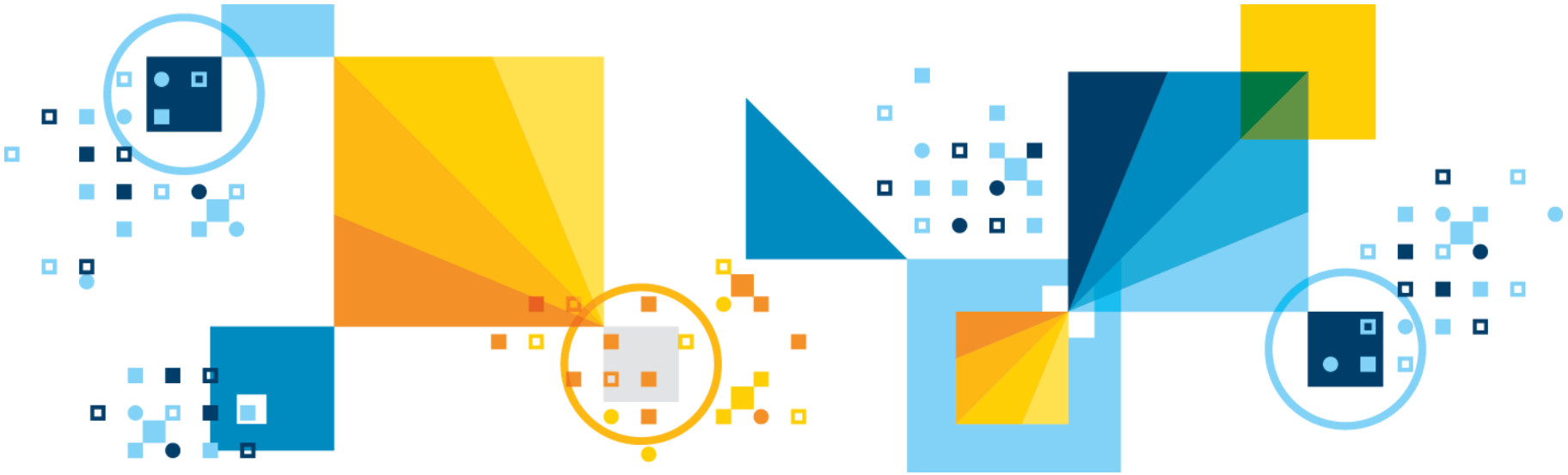


CPLEX node in SPSS - Overview

- **Run Optimization Programing Language (OPL) models**
- **Run OPL script**
- **Input Data:**
  - Input data to OPL model Tuple
  - Additional data option
- **Output Data:**
  - Objective function value
  - Decision Variable values



DO in DSX



IBM Data Science Experience (DSX)

Community

- Find tutorials and datasets
- Connect with Data Scientists
- Ask questions
- Read articles and papers
- Fork and share projects

Open Source

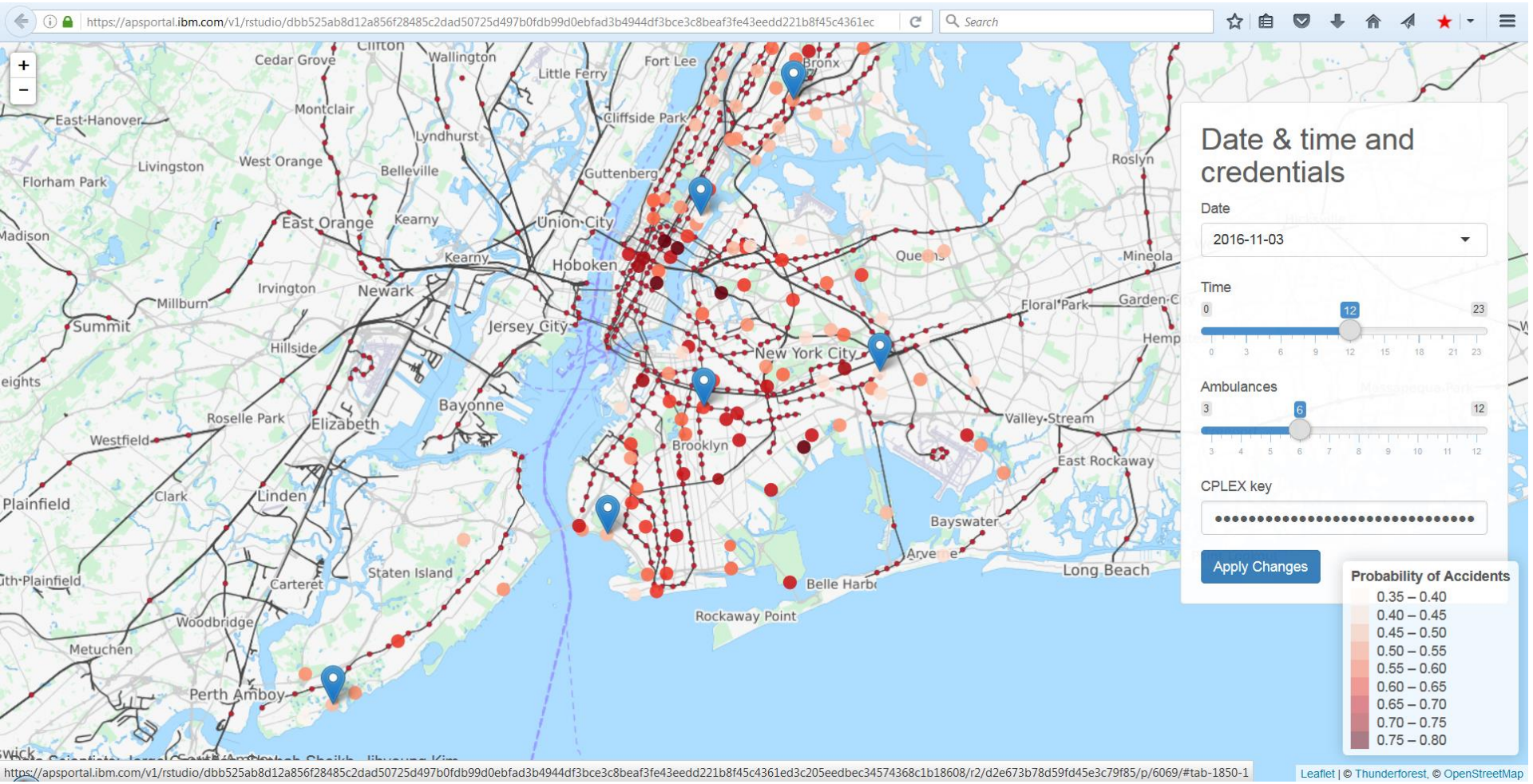
- Code in Scala/Python/R/SQL
- Jupyter Notebooks
- RStudio IDE and Shiny
- Spark ML
- Your favorite libraries

IBM Added Value

- IBM Machine Learning
- SPSS Modeler Canvas
- Prescriptive Analytics – Decision Optimization (CPLEX)
- Projects and Version Control
- Managed Spark Service

Powered by IBM Watson Data Platform

Positioning ambulances based on accident predictions



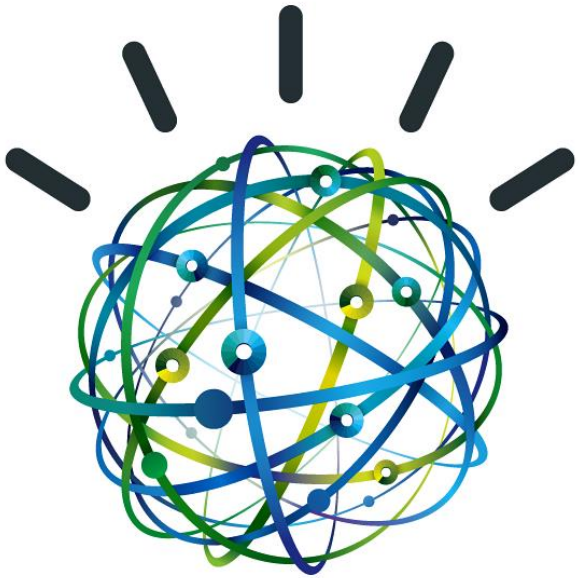
Summary: What Can Optimization Do?

Optimization helps businesses make complex decisions and trade-offs about limited resources:

- **Drive business process using high level KPIs**
  - Compliance with business policies and regulations
  - Free up planners and operations managers so that they can leverage their expertise across a wider set of challenges
- **Better Decisions Faster**
  - Automatically evaluate millions of choices
  - Trade off value against limited resources
- **Explore more scenarios and alternatives**
  - Understand trade-offs and sensitivities to various changes
  - Gain insights into input data
  - View results in new ways

THANK YOU !!

Questions ?



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Backup

Prescriptive Analytics: History & Brand Names

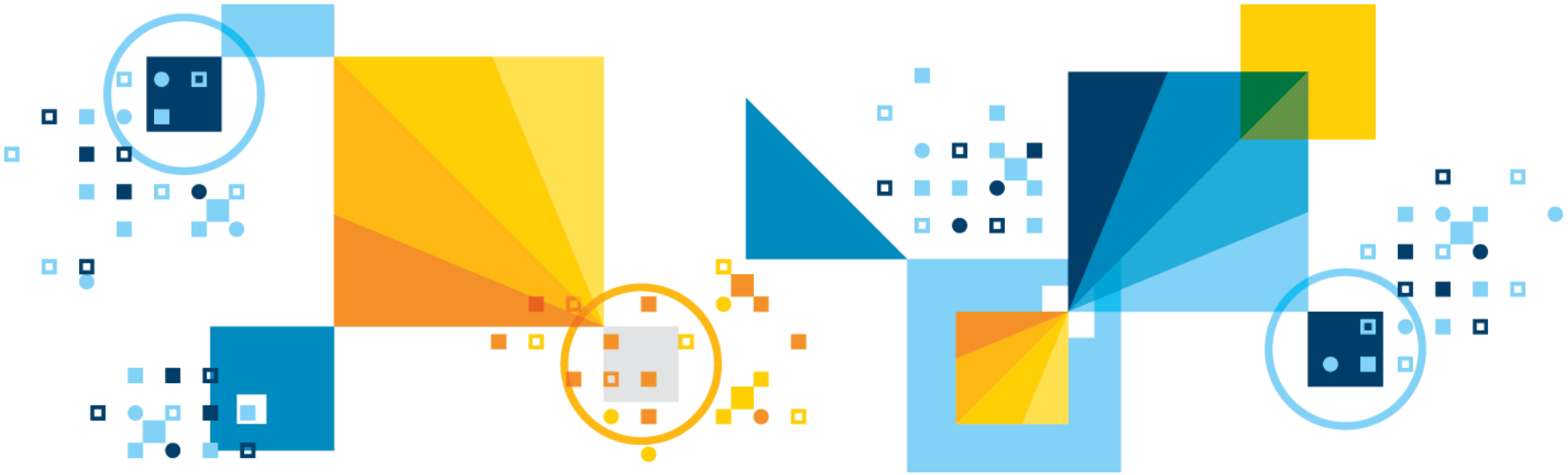
- **CPLEX**
  - Acquired by ILOG in 1997

- **ILOG**
  - Acquired by IBM in 2009 (founded in 1987)

- **IBM Decision Optimization**
  - Part of IBM Analytics in 2015

- **IBM Decision Optimization Product Names**
  - IBM CPLEX Optimization Studio (COS)
  - IBM Decision Optimization Center (DOC)
  - IBM Decision Optimization on Cloud (Docplexcloud)

Applications / Use cases

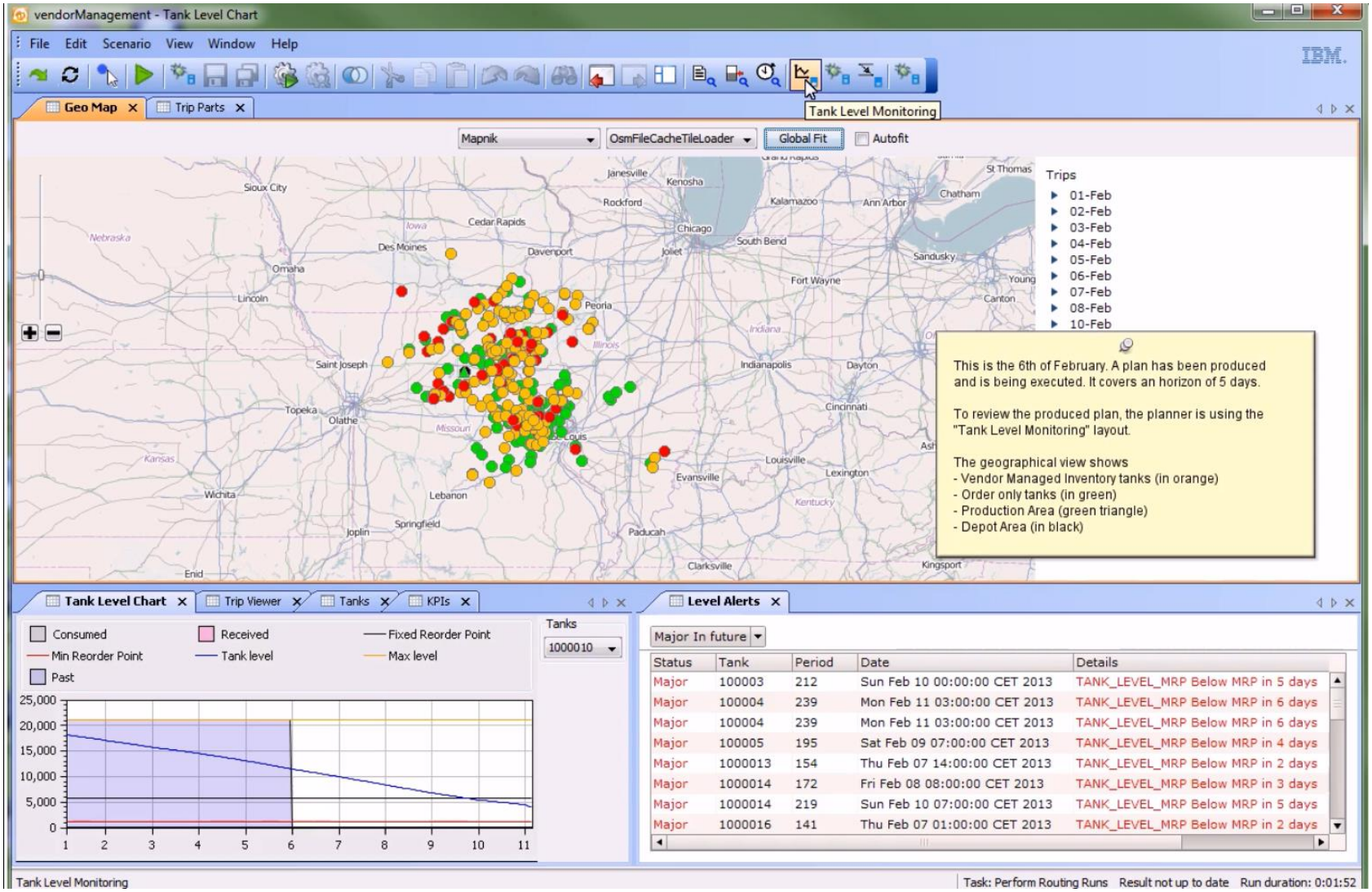


Re-allocation of Paramedic Units (City of Ottawa)

- Paramedic units re-allocation to different posts for maintaining coverage while minimizing travel times; overtime and taking into account human factors like meal-breaks
  - Minimize max-travel time
  - Minimize number of moves
  - Minimize travel times to individual posts (higher priority posts getting more preference)
  - Minimize re-routings

- Constraints
  - Tactical units cannot be positioned at Low Density (population) posts
  - Certain units having preference at higher priority posts
  - Low Density units preference to be assigned to their base post
  - Human factor constraints around eating periods
  - Incentivize relocation of an unit from mobile post (if there for too long)

Vehicle Routing Replenishment Optimization demo



Nissan UK drives down costs with production planning and scheduling optimization

Key Challenges:

- Production of a new model for the European market was awarded.
- Meeting production requirements within very tight deadline without disrupting the production for existing models.
- To deliver this third model, the plant had to increase output efficiency, making optimal use of existing facilities which in time required tighter and more accurate planning.

NISSAN

Innovation that excites

Business benefits:

30% throughput
increase without an investment in a new production line

85%
Schedule adherence after the new solution went into production (up from 3%)

Minutes
To create new plans down from days with the old process

Nissan UK

Production of a 3rd car model alongside the previous 2 models on the same 2 production lines.

IBM Software: IBM CPLEX Optimization Studio

Produces around 334,000 cars each year at its plant in northern England. The plant is recognized as the most efficient in Europe and the eleventh most efficient in the world.
- 2001

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