Current and Future CUBE Development for the next Generation

TPB TRAVEL FORECASTING SUBCOMMITTEE (March 2020)

Bentley®
Advancing Infrastructure

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COVID-19: Working From Home

https://communities.bentley.com/products/citilabs-cube/w/citilabs-wiki/47477/working-from-home-with-cube

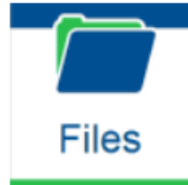"We are excited to become a part of Bentley Systems. Our customers and partners will have a fantastic opportunity to *fully integrate the planning, design, and operation* of multi-modal transportation systems."

- Michael Clarke, President and CEO
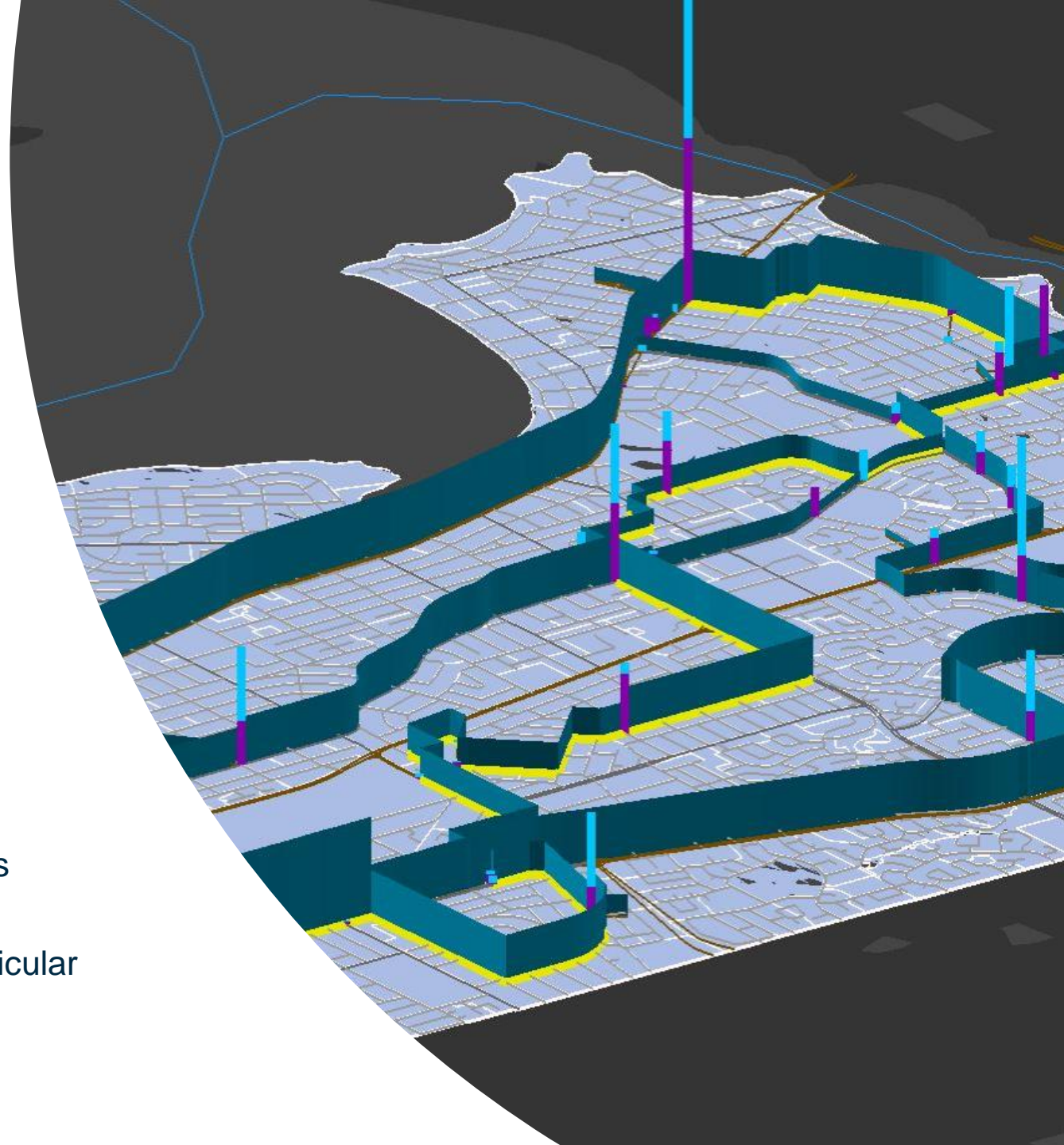**Citilabs**

Citilabs Acquisition by Bentley Systems

- Officially Bentley as of 8th October 2019
- CUBE and Streetlytics product names remain (Sugar branded under CUBE)
- Admin systems switched over 1st January 2020
- Citilabs staff fully integrated into Digital Cities division. Some with new titles/roles:

  - Michael Clarke (former CEO), *Senior Director, Mobility Analytics*
  - Austen Duffy (former CTO), *Research & Development, Mobility Analytics*
  - Ahmed Mohideen, *Director of CUBE Support*
  - Alex Fox, *Product Manager Streetlytics*
  - Oliver Charlesworth, *Product Manager CUBE*
  - Katie Brinson, *Account Manager*
  - Bill Allen, *Senior Project Manager, Mobility Analytics*
  - Chris Simons, *Senior Project Manager, Mobility Analytics*
  - Vipul Modi, *Senior Technical Support Engineer, Mobility Analytics*
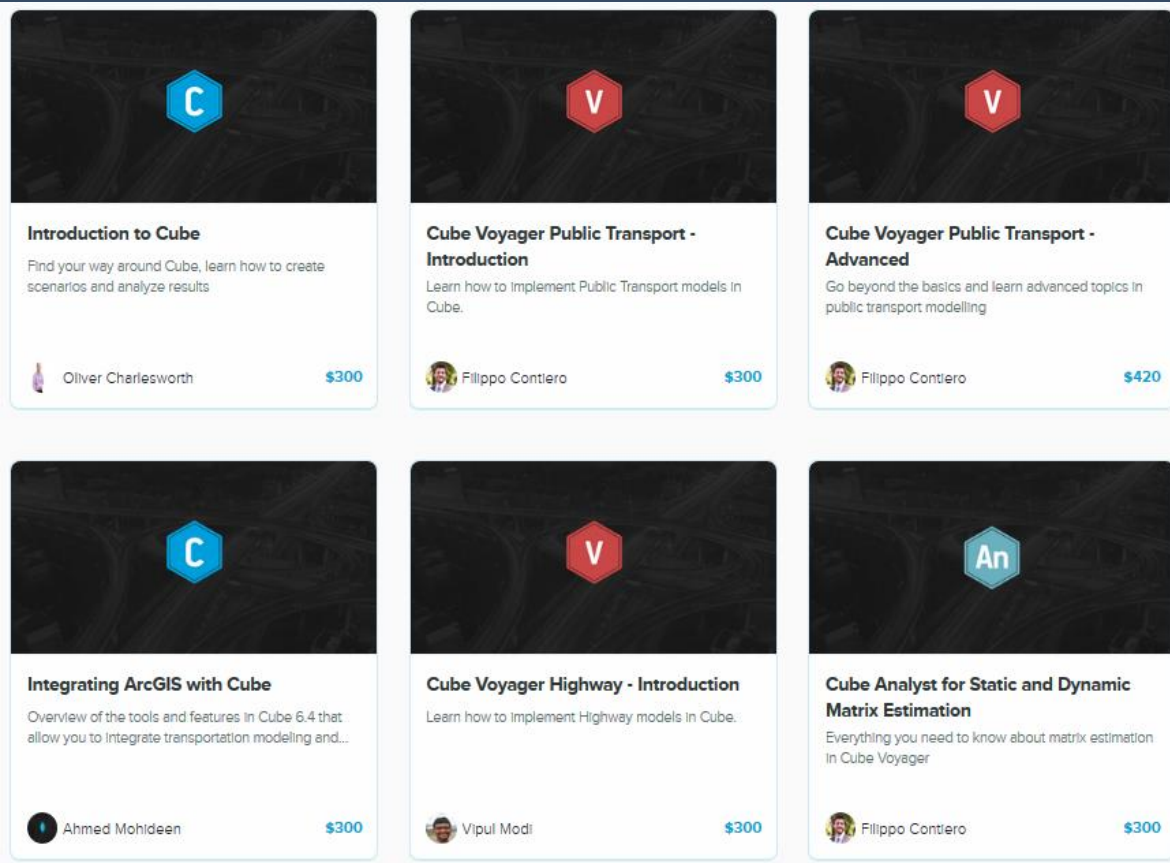
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Cube 6: PT, Updates and Releases

Transit:
PT Overview

- Model all aspects of public transportation
- Flexible headway and time-table based modeling
- Enumerate a set of potential routes for each OD pair
- Evaluate the routes based on several factors
  - Out-of-vehicle and in-vehicle travel times
  - Mode preferences
  - Transfer penalties
  - Fares
- Vary your public transportation using Crowding effects
  - Transit travel times
  - Probability of being able to board a line at a particular stop

COVID-19:
Working From Home

http://citilabs.teachable.com/courses

Introduction to Cube
Find your way around Cube, learn how to create scenarios and analyze results

Oliver Charlesworth — $300

Cube Voyager Public Transport - Introduction
Learn how to implement Public Transport models in Cube.

Filippo Contiero — $300

Cube Voyager Public Transport - Advanced
Go beyond the basics and learn advanced topics in public transport modelling

Filippo Contiero — $420

Integrating ArcGIS with Cube
Overview of the tools and features in Cube 6.4 that allow you to integrate transportation modeling and...

Ahmed Mohideen — $300

Cube Voyager Highway - Introduction
Learn how to implement Highway models in Cube.

Vipul Modi — $300

Cube Analyst for Static and Dynamic Matrix Estimation
Everything you need to know about matrix estimation in Cube Voyager

Filippo Contiero — $300

Contact me for free PT course coupons:
Oliver.Charlesworth@Bentley.com

Transit: PT Process

Step 1 - PT Network Development
- – Definition of the Transit Network (Speed, cost model)
- – Definition/Generation of the Non-Transit Legs

Step 2 - Enumerates "Acceptable" Discrete Routes
- – Finds least cost route
- – Enumerates all other routes within defined limits
- – For every OD pair (RTE file)

Step 3 - Evaluates Routes and Performs Analysis
- – Decisions on access and assignment to individual lines through a series of logit choice models
- – Route evaluation through a hierarchical logit choice model

Step 4 - Loading / Assignment of Trips
- – Loading trip matrix with calculated percentages
- – Iterative process if using Crowding

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Transit: PT Fares

- Different fare systems can be modelled for the same PT Network

- Complex fare systems can be modelled by userclass (demand by ticket type)

  – **FREE** – No cost incurred

  – **FLAT** – One fixed cost per use

  – **DISTANCE** – Possible boarding cost + unit cost per distance or cost look-up table

  – **FROMTO** – Fare zone matrix based on the start/end zones

  – **COUNT** – Counts number of fare zones crossed

  – **ACCUMULATE** – Each fare zone has a fare and when crossed adds to cost

  – **HILOW** – Zone based, fare result of the highest and lowest zone number crossed

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Transit: PT Crowding

- Iteration by iteration outputs

- Iteration by iteration statistics

- Stopping criteria

- Utilization > 100%

- Iterative smoothing

- Incremental loading
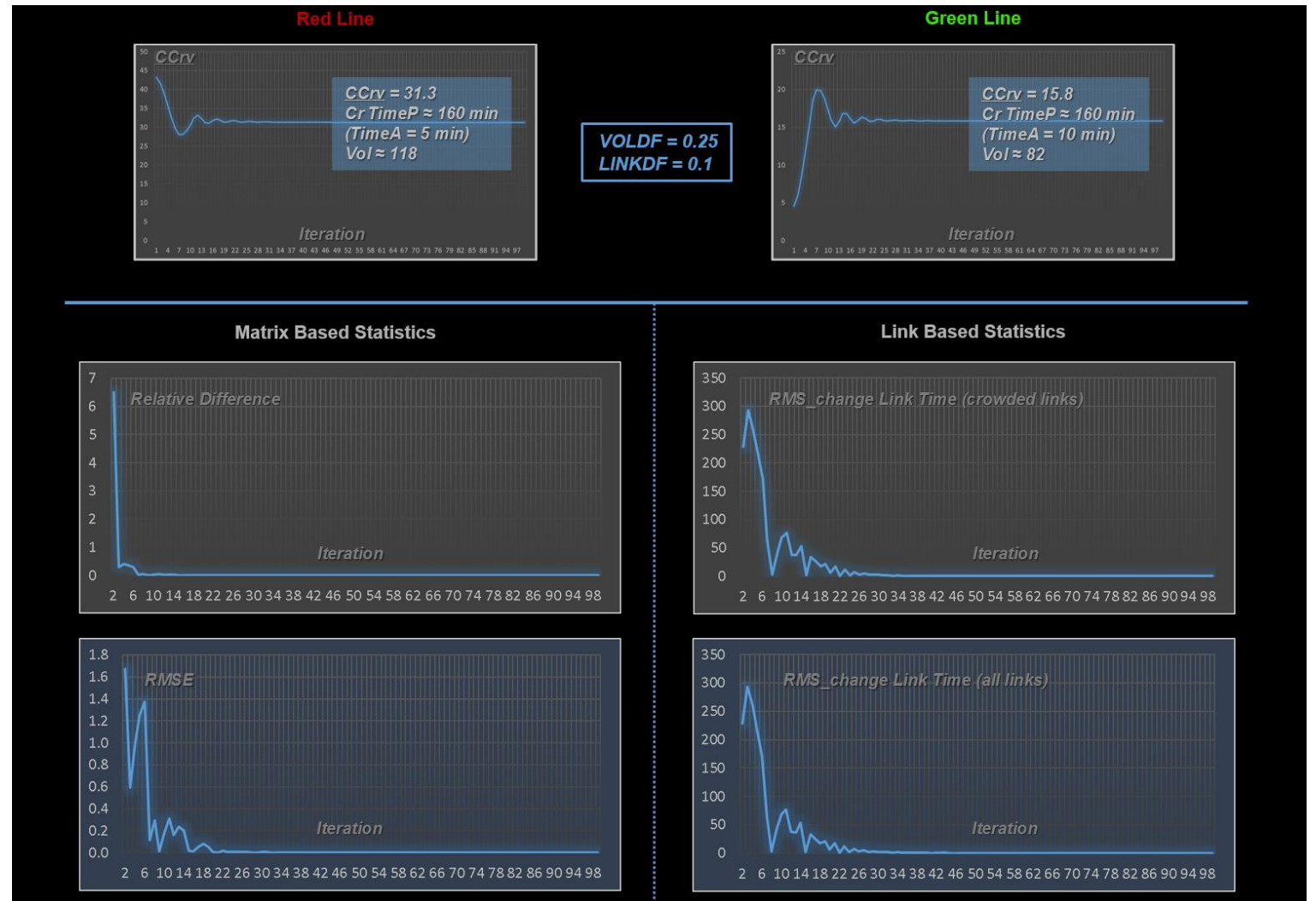
http://www.citilabs.com/citilabs_blog/cube-voyager-public-transport-crowding/

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Transit: TPB Version 2.5 (with PT)

Route Enumeration	SPREADFUNC	SPREADFACT	SPREADCONST	MAXFERS	RUN-TIME
BESTPATH	-	-	-	5	00:10:00
Multi-Routing	1	1.01	1	5	00:11:07
	1	1.01	1	4	00:09:47
	1	1.05	1	4	00:15:31
	1	1.05	1	5	00:18:17
	1	1.10	1	4	00:38.17
	1	1.10	1	5	01:11:23
	1	1.15	1	4	02:32:33
	1	1.15	1	5	06:32:00
	1	1.25	60	5	>7hrs

Spread function 1 =

Explore routes with a generalised cost up to the maximum of 'Best path x Spread factor' and 'Best path + Spread Constant'

Spread function 2 =

Explore routes with a generalised cost up to

'Best path x Spread factor + Spread constant'

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Highway: TPB Version 2.5

- **MULTITHREAD (from v6.4.5)**
  - Sub-keyword used with **COMBINE=EQUI**. This keyword enables distributing the Adjust phase across multiple threads.

- **DEC=F2 (from v6.4.5)**
  - DEC Specifies the accuracy of the link value on which the paths are to be built. Default value is F (floating). Accepted DEC values are: 0, 1, 2, 3, 4, F, F2 which represent 0, 1, 2, 3, 4 decimal places, floating point and optimized floating point, respectively. Using lower accuracy will speed up the assignment process considerably, especially for larger networks.

MAXITERS = 50 9 PATHLOADS	Original Script	DEC=F2	Change
BiConjugate	67 mins	55 mins	-18%
BiConjugate + 4 Cluster	19 mins	16 mins	-16%
Frank-Wolf	69 mins	54 mins	-22%
Frank-Wolf + 4 Cluster	19 mins	16 mins	-16%

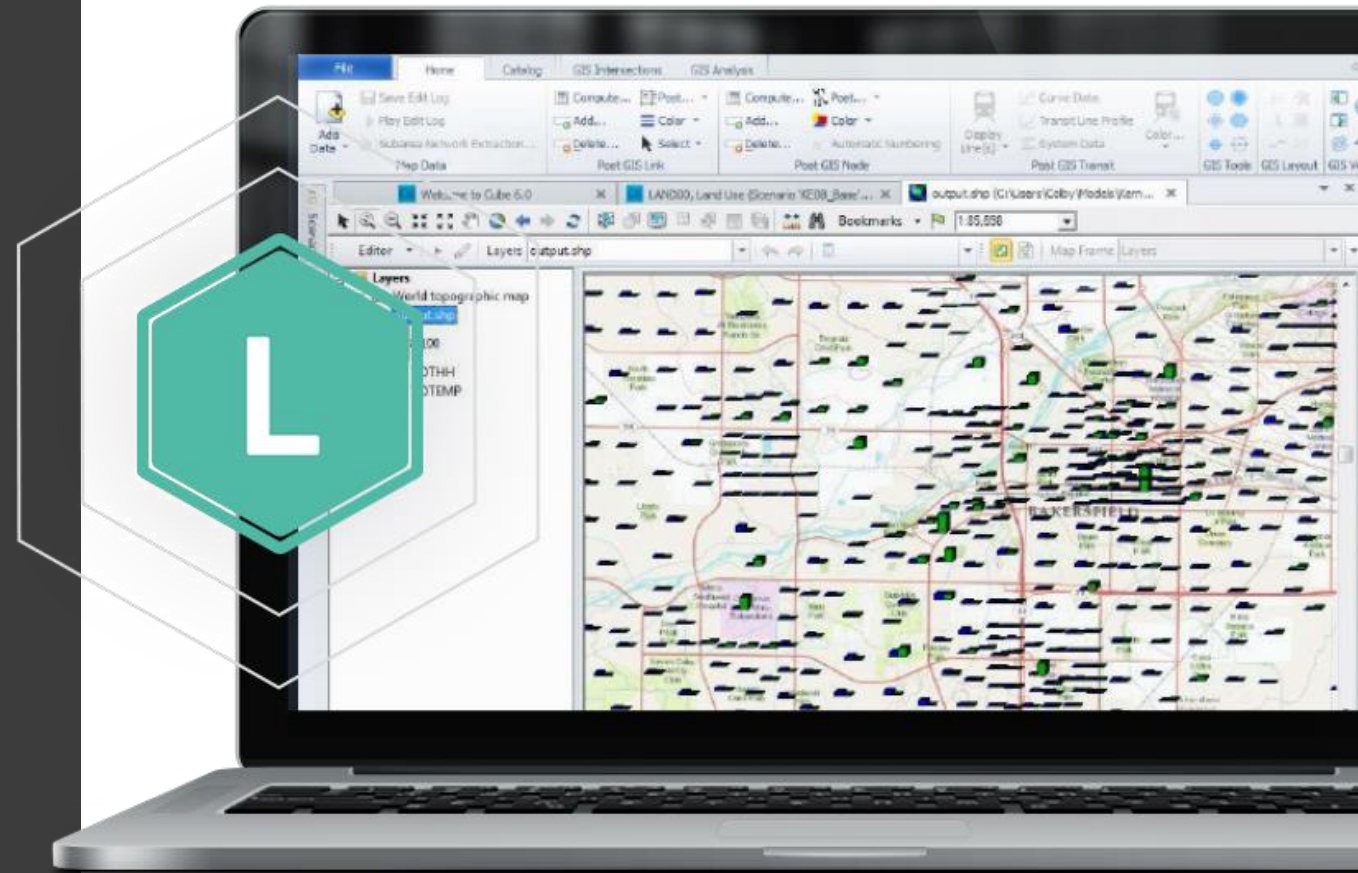Bentley®

Next Release: Cube 6.5
(April 2020)

Cube Land Update

- 64-bit version
- Better reporting & error syntax
- Clearer input file definition

ArcGIS 10.7

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Future Releases: CUBE 6.X

Some CUBE 7 features

CUBE 7 conversion tools

ArcGIS updates

General updates

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Cube 7: Next Generation

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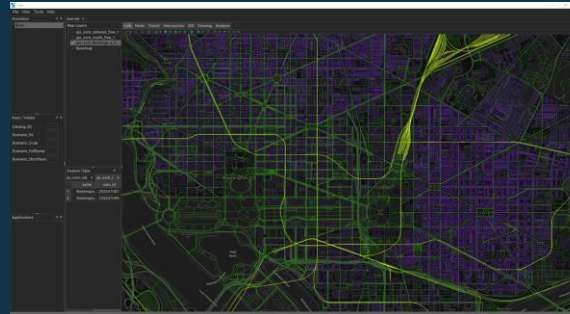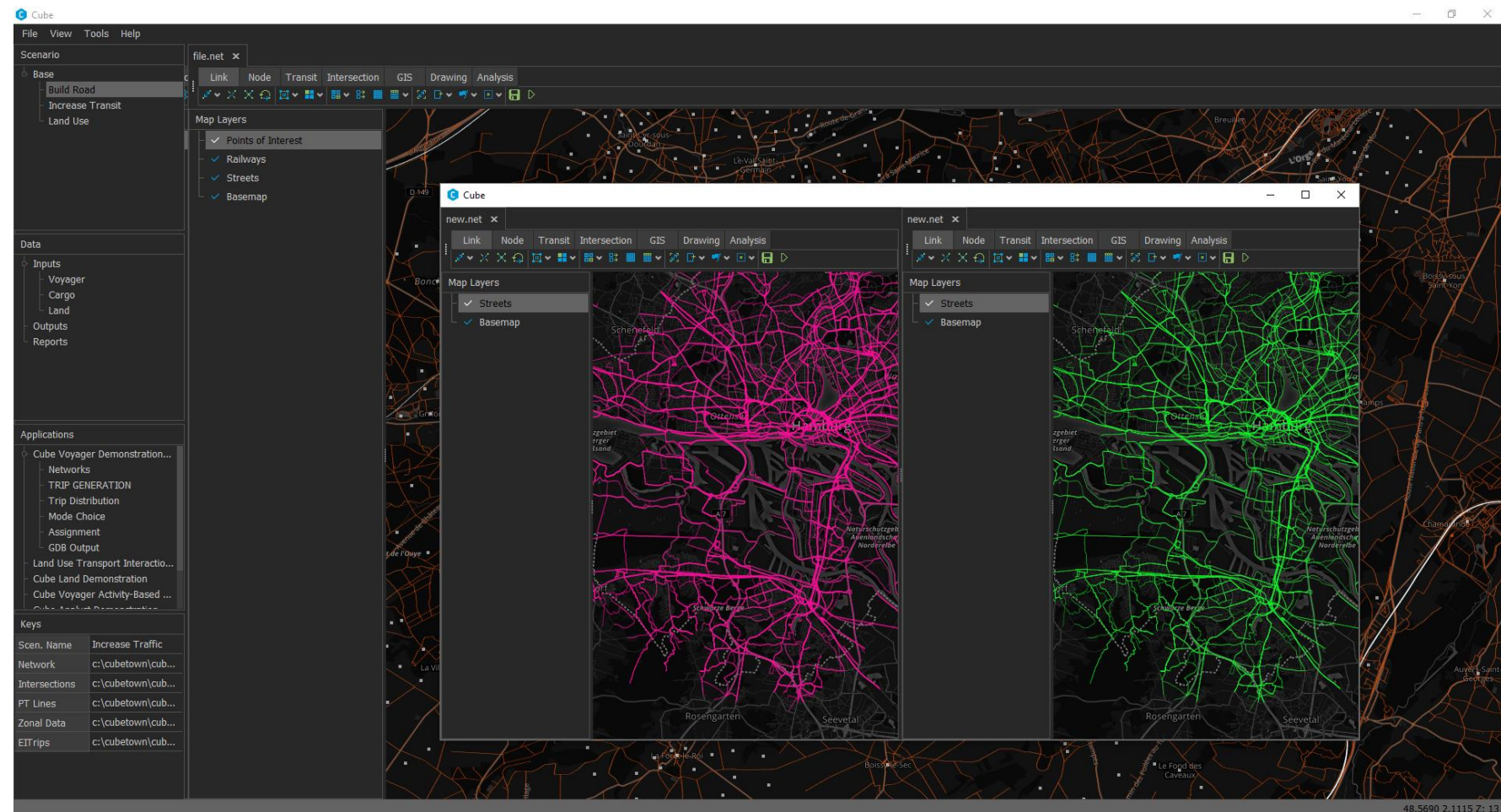
CUBE 7

Beta release in 2020

- Focus on big data handling and speed
- New Interface
- New GIS Network Editor
- Voyager Improvements
- Major Updates to Application Manager & Task Monitor
- Cube Cluster overhaul
- Foundation for new mobility systems (TNCs, CAVs...)
- Further enhancements and direct support for ABMs

CUBE 7: New Network Editor and Spatial Analysis

- High performance visualizations with support for huge datasets

- A single interface and window for .NET Networks and GIS data

- Native support for a wide variety of modern GIS data sources, Esri, OpenGIS Simple Features or SQL/MM, such as Spatialite, PostGIS, Oracle, Microsoft SQL Server, and more!

- Full support for true relational database management systems bringing concurrent use within Cube/multiple users.

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CUBE 7: New Network Editor and GIS Tool

- Support for multiple basemap sources, ArcGIS Online, Open Street Map data, Bing, etc

- Full support for WMS/WMTS

- Complex visualizations and animations to be added in early versions (GPS path animations, 2.5D desire line visualization, etc.)

- Greater flexibility and quicker implementation of future capabilities

- The user will be able to have themes and even tie basemaps to those themes (i.e. a dark basemap along with a dark menu theme, etc).

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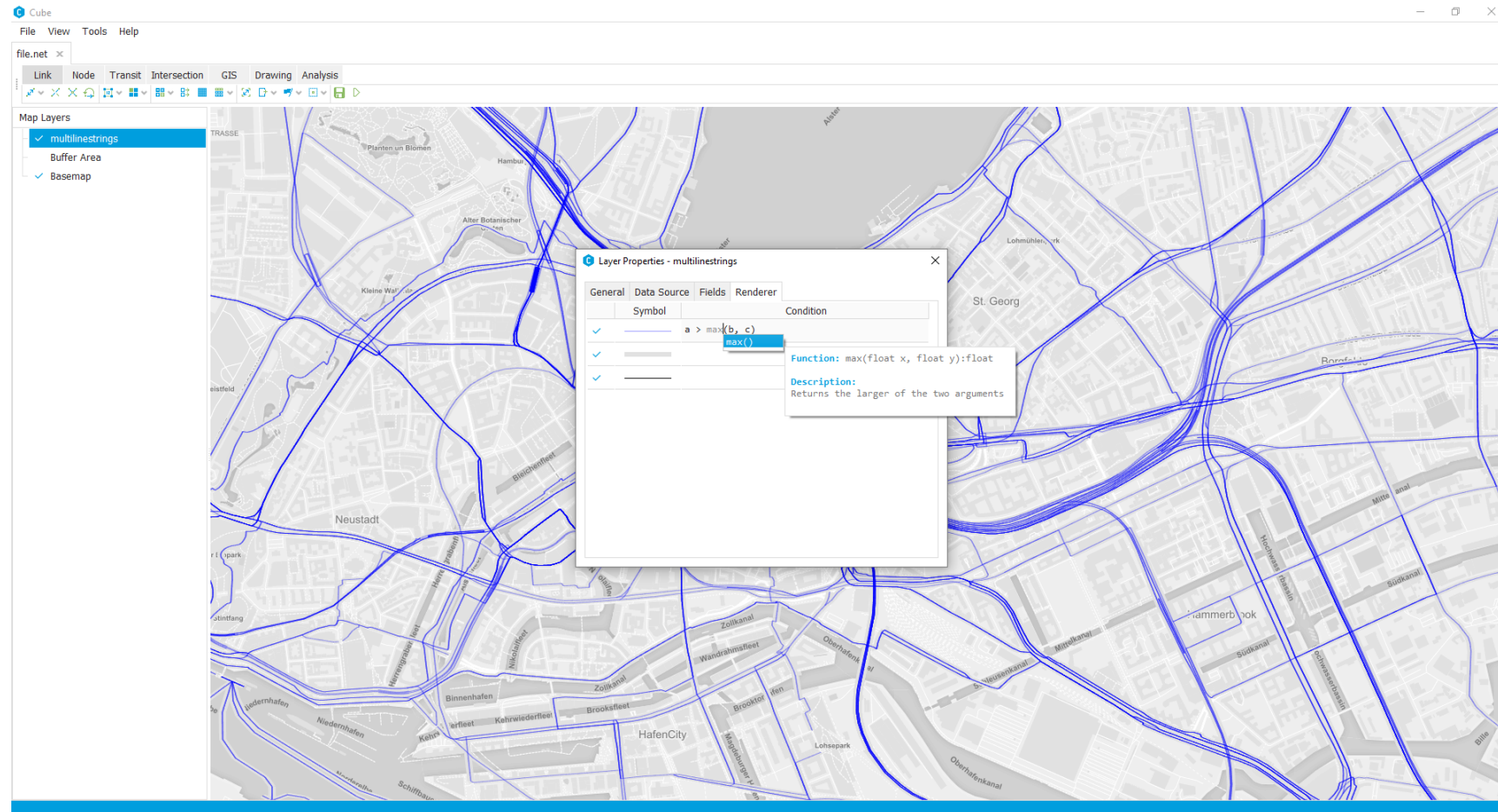
CUBE 7: Next Generation Interface
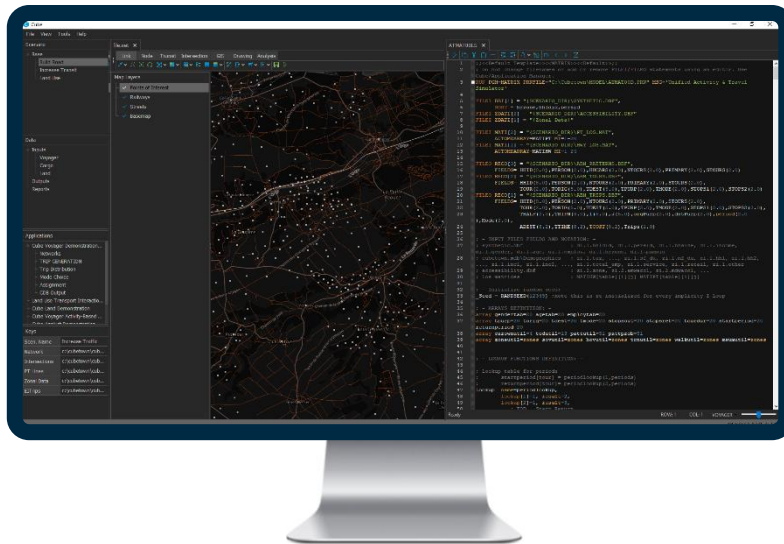
- Users can view multiple tabs at once.
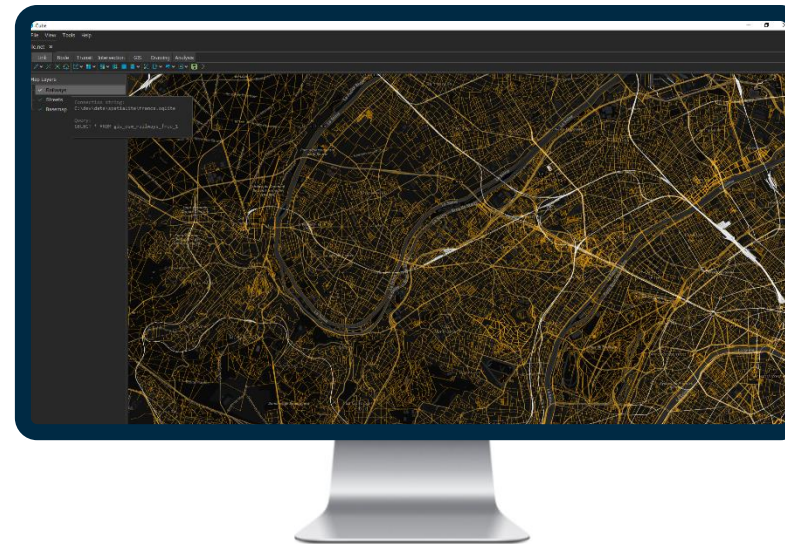
- Multiple windows can be opened simultaneously and dragged to different screens.

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CUBE 7: Cluster

Cl

- Much greater usability and manageability
- Based on a robust client-server protocol system rather than file based inter-process communication
- Consolidated and centralized cluster node management
  - Compute resources (individual computers) registered into the system initially
  - Cluster runs able to be started from one central machine and managed within one interface (no longer will you have dozens of cluster voyager windows)
- Automatic determination of nodes to assign for a particular Multistep or Intrastep
- Ability to manage multiple Cube Cluster compute pools from one interface / client (i.e., multiple model runs could be started and monitored from one user interface even if each run is occurring on a different set of computers)
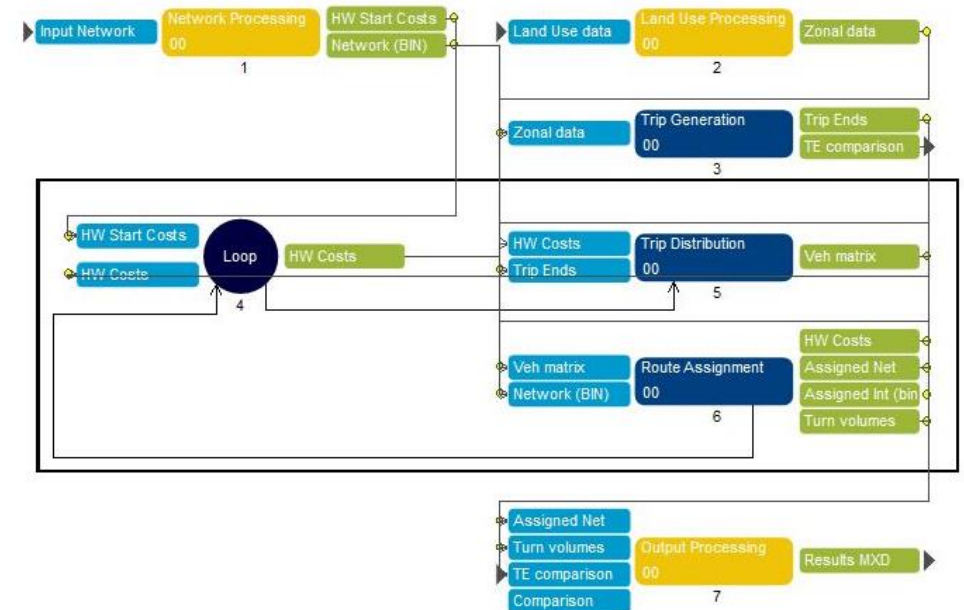
Voyager

V

- Native use of GIS formats and relational databases throughout the system (great for tour-based and activity-based modelling) – no conversion to Cube binary first!
- 32K zone limit increased to "virtually unlimited"
- Improved data formats and I/O performance and speed
- Full Unicode support throughout Cube 7; this will allow for seamless uses of international character sets for purposes of filenames, strings, comments, etc
- Further Speed Enhancements for Highway, PT and other Voyager modules

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CUBE 7: Application Manager

- Application Manager will have a new look and have more powerful visual capabilities such as:
  - Zooming / scaling,
  - Application navigation view
  - Hover over group displays preview of that group's flowchart
  - Ability to view the entire application group tree hierarchy and navigation
  - Edit history and undo / redo
- Users will have more control over model design e.g. how far up a group hierarchy that an input file may be "public"
- Model run mode; AM will allow running of an application and all of its subgroups in a read-only view that highlights the currently running program and various statistics about the current run (similar to Task Monitor but more detailed)

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CUBE 7: Version Control

- In Cube 7, we are committed to creating an experience that works very well with industry standard version control systems

- Full support for relative paths throughout Cube (Scenario Manager, Application Manager, Voyager, etc) and relative paths will be the default behaviour for file paths when possible, which will mean that no updates are needed when the root directory of a model is moved

- Updated configuration file formats, such as the catalog file, so that version control systems may easily track modifications to scenarios and keys

- Guidance on how best to use Cube with version control systems
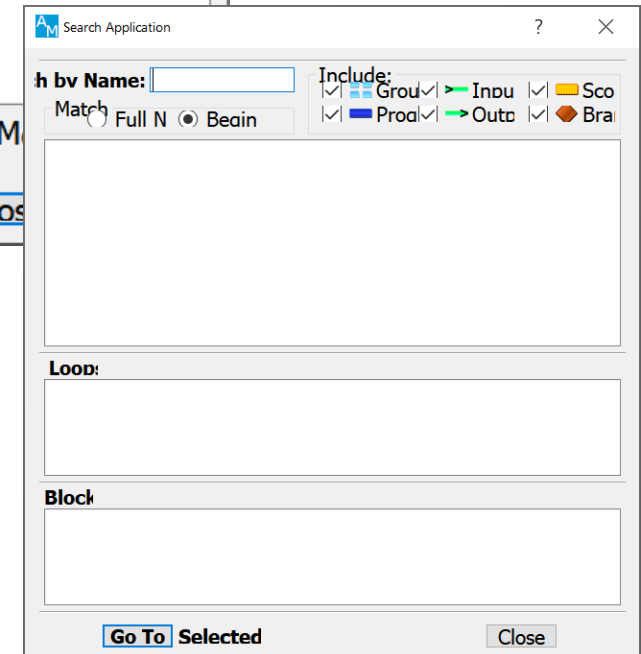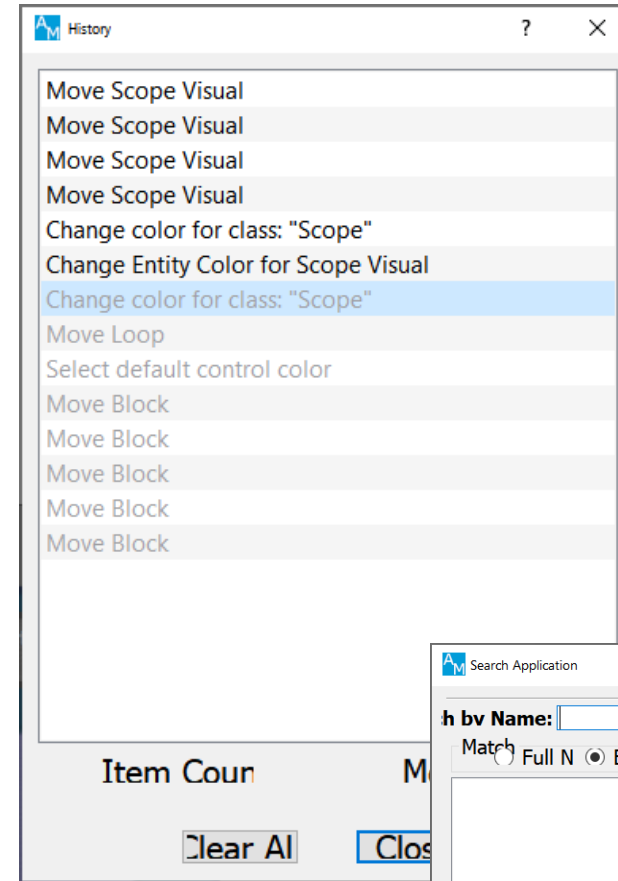
CUBE 7: Cube Py

- A next generation alternative model scripting system based on Voyager technology

- Utilizes Python, for an easy to learn and integrate experience

- Greatly enhanced flexibility in the assignment algorithm processes with more control over individual phases

- Powerful capabilities for manipulating matrices and networks

- Able to perform GIS analyses directly within CubePy

- Interoperate between popular Python libraries such as scipy and numpy , as well as other libraries callable from Python

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CUBE 7: Other Features

- GPS visualizing & processing Tools

- New database & matrix editors

- A powerful data format API for integration with various processes and workflows

- Multi-version installations

- Improved reports

- Faster select-link analysis

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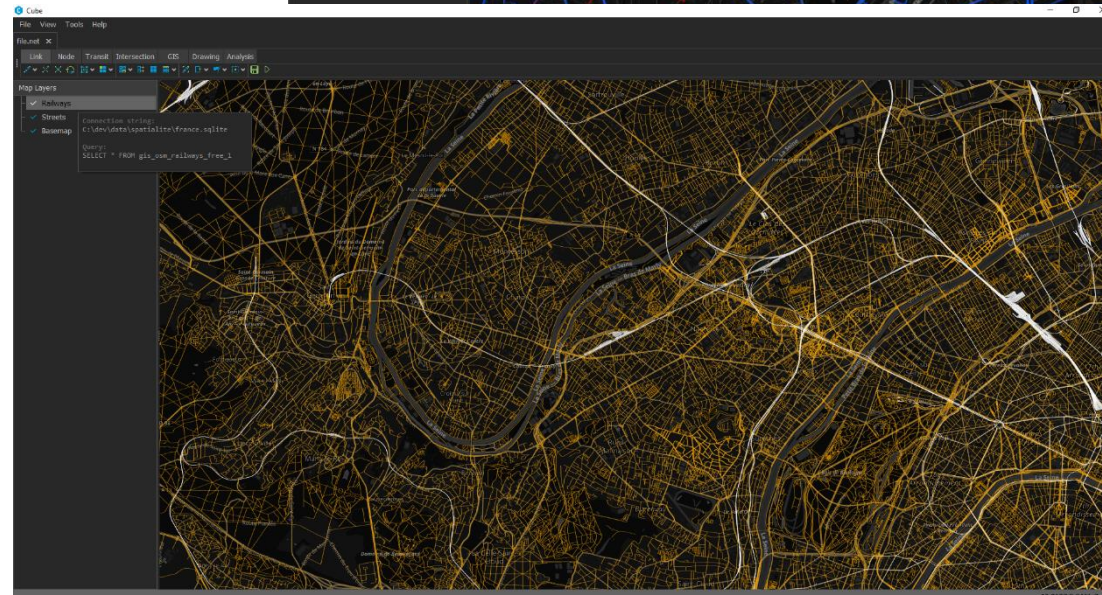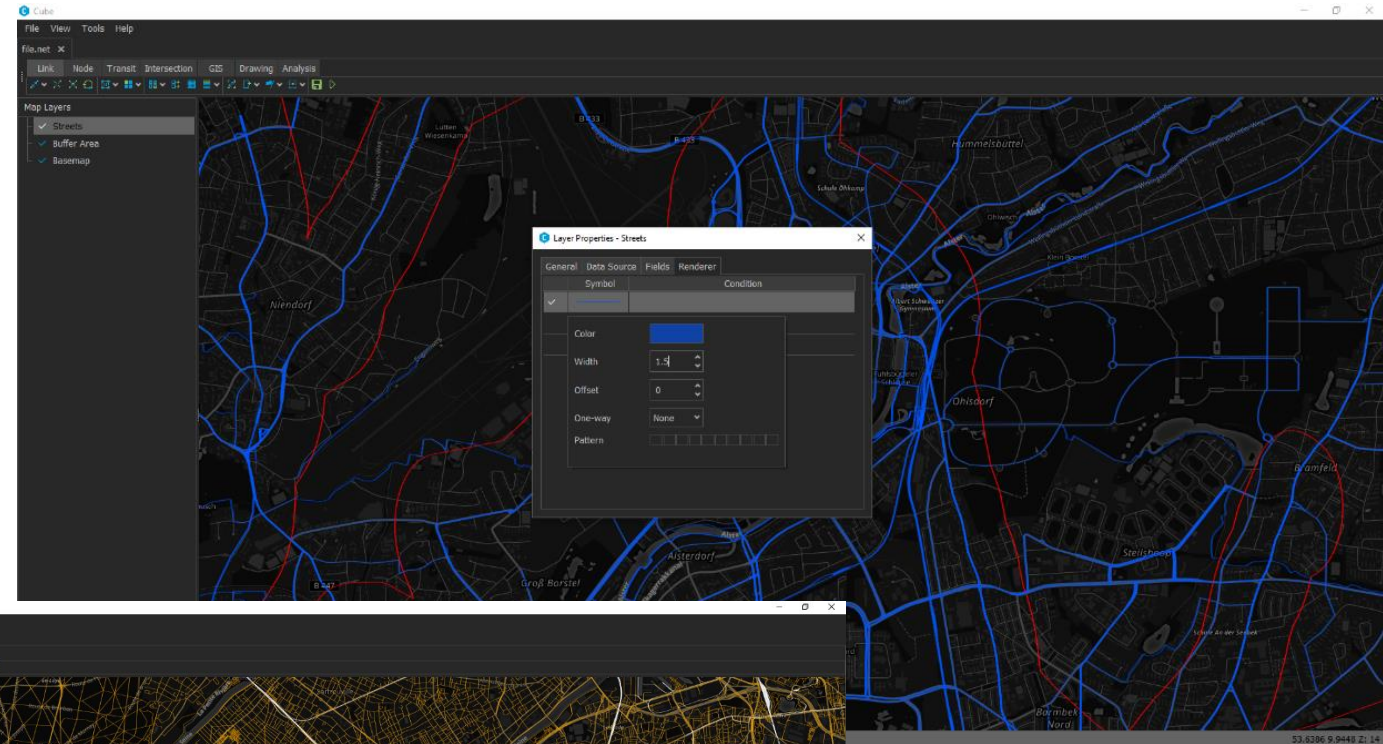
Cube 7: Research and Development

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Analyst Drive: GPU Computing in CUBE 7

- CUBE 7 will be the first version of Cube to make use of GPU co-processors for both Visualization and Computation.

- Current Analyst Drive GPU version slashes runtimes for large problems. A single class Chicago model time was reduced from over 7 hours on an Intel i7-8700 to under 12 minutes on an Nvidia RTX 2070.

- A Florida Statewide Model (circa 2012) AD test reduced runtimes from 5 hours 21 minutes to just 24 minutes, a 13X speedup

Class	nzA	nzX	nzb	CPU Gradient Time (s)	GPU Gradient Time (s)	Gradient Speed-up Factor	CPU Iteration Time (s)	GPU Iteration Time (s)	Iteration Speed-up Factor	Saving (s)
1	78026272	2363837	10818	32	0.3	**107**	63	1.6	**39**	**61.4**
2	166380269	1558394	10720	56	0.58	**97**	77	2.9	**27**	**74.1**
3	74617942	551040	10606	25	0.3	**83**	33	1.5	**22**	**31.5**
4	214592	17622	2821	0.35	0.04	**9**	0.4	0.3	**1**	**0.1**
5	4311412	57592	7964	1.4	0.06	**23**	1.8	0.38	**5**	**1.42**
6	43455642	3020901	10695	23	0.2	**115**	61	1.1	**55**	**59.9**
7	30690138	2035163	10700	16	0.16	**100**	41	0.9	**46**	**40.1**
8	112736160	3034003	10829	45	0.41	**110**	85	2.12	**40**	**82.88**
9	30563354	630061	10238	11	0.17	**65**	17.5	0.9	**19**	**16.6**

Florida Statewide Model – CPU vs GPU AD runs. nzA=non-zero route choice matrix entries, nzX= non-zero OD matrix entries, nzb=total counts with non-zero initial volume. Gradient computation is entirely done on GPU and is the most computationally significant piece of each iteration.

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Trip Distribution: TRIPDIST
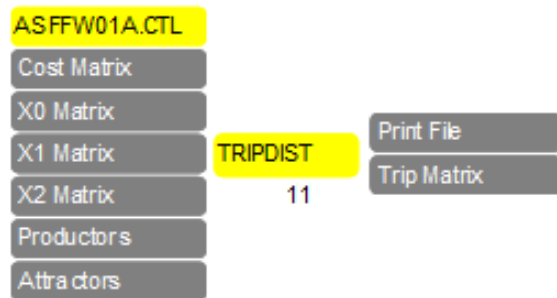
TRIPDIST is a specialized Distribution program that solves the HBW gravity model using gamma impedance function (Distribution module example 3 on page 685 of the Cube Voyager documentation).
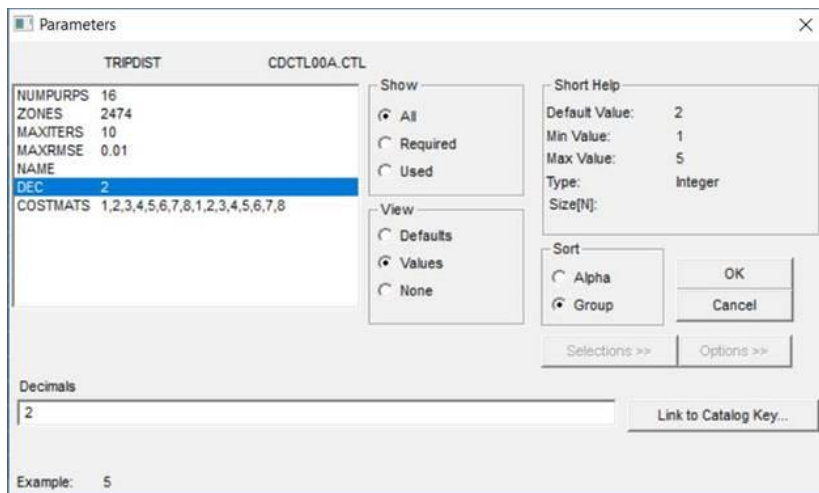
TRIPDIST achieves 20x speedup over the scripted distribution used in the Abu Dhabi STEAM model.
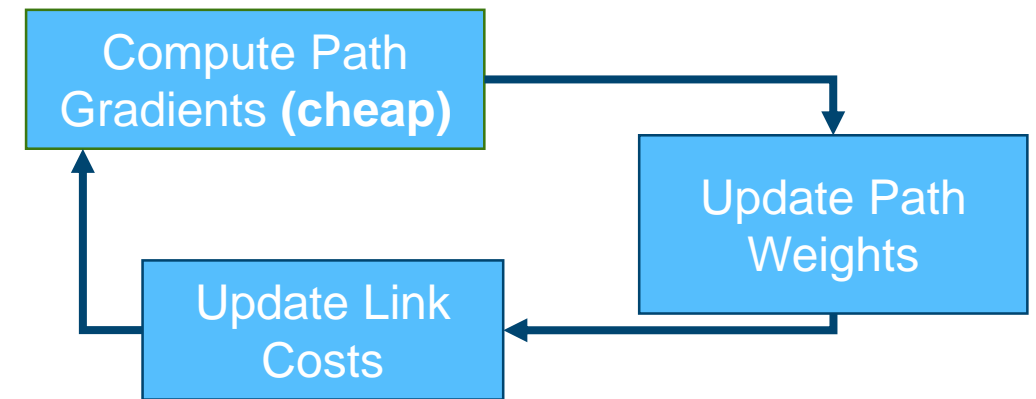
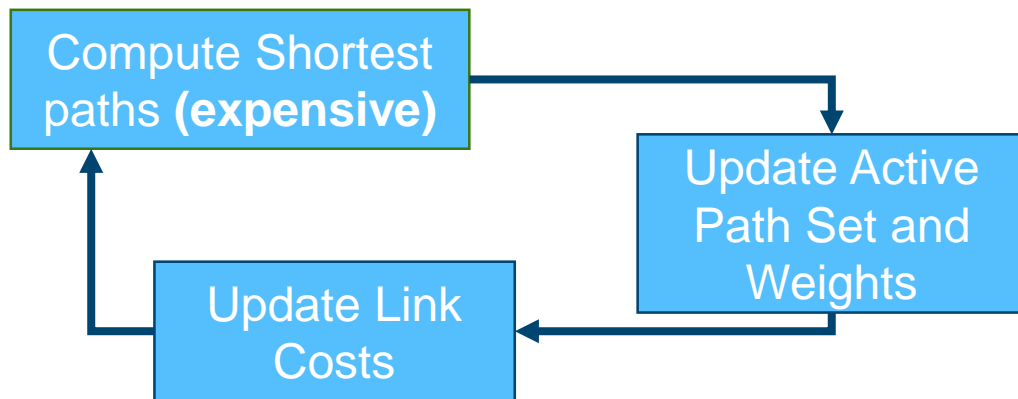Bentley®

Highway: FASTPATH

FASTPATH = Fast Path Based Static Traffic Assignment

FASTPATH is a new assignment program that is a hybrid between a link based and a path based method.

| Uses a link based method in the early iterations to produce an active path set. | → | Switch to use a gradient descent method over the active path set |

Compute Shortest paths **(expensive)**

Update Active Path Set and Weights

Update Link Costs

Compute Path Gradients **(cheap)**

Update Path Weights

Update Link Costs

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Highway: FASTPATH

FASTPATH = Fast Path Based Static Traffic Assignment

- Specialized version, will have capability for users to code their own cost functions.

- Will have GPU run options

- After many link based iterations, paths barely change or just get repeated.

- User has choice on maximum number of paths to include in active path set for each OD pair (equivalent to number of link based iterations)

- Link based iterations use volume averaging and Frank-Wolfe class methods (FW, CFW, BiCFW)

- Faster runtimes when the number of link based iterations is less than the total number of iterations (Gradient based iterations significantly faster than link based ones)

- Possesses benefits of Gradient based methods such as faster and smoother RGAP convergence.

- Future incorporation with FASTLANE (more on this in later slide)
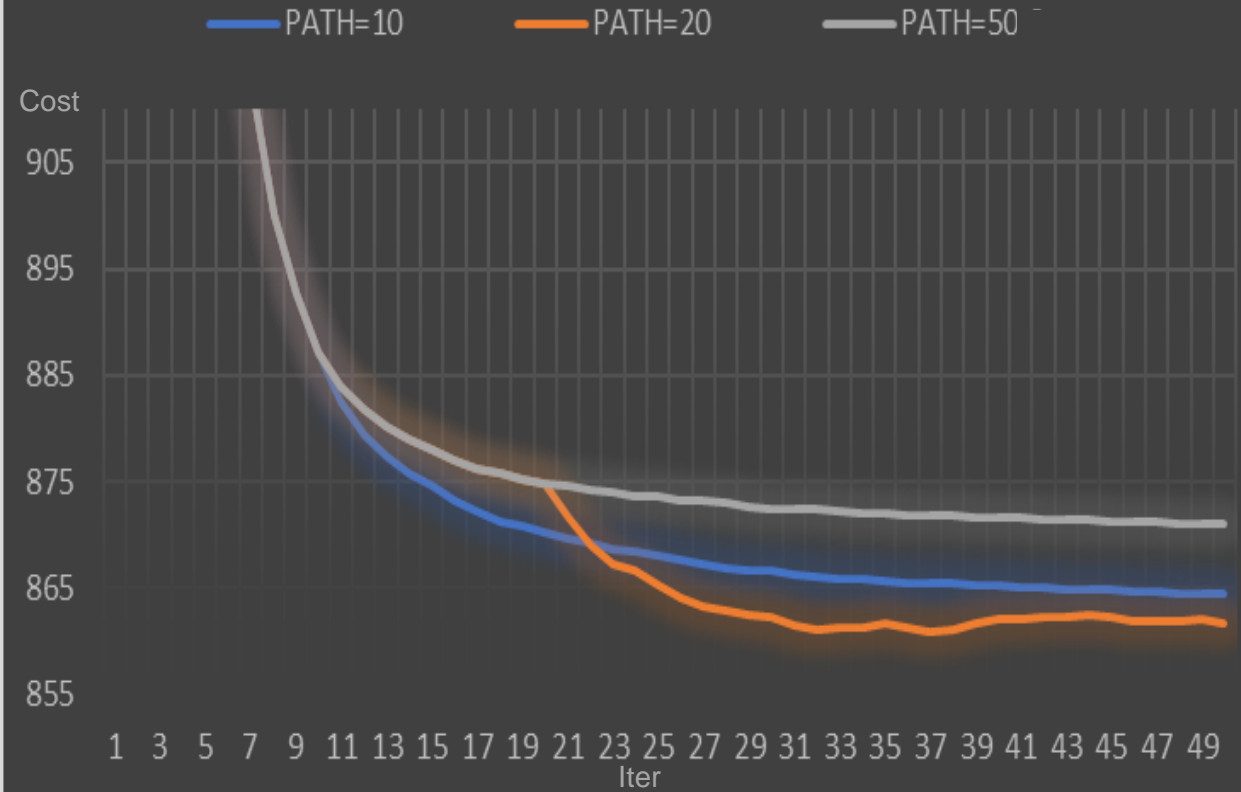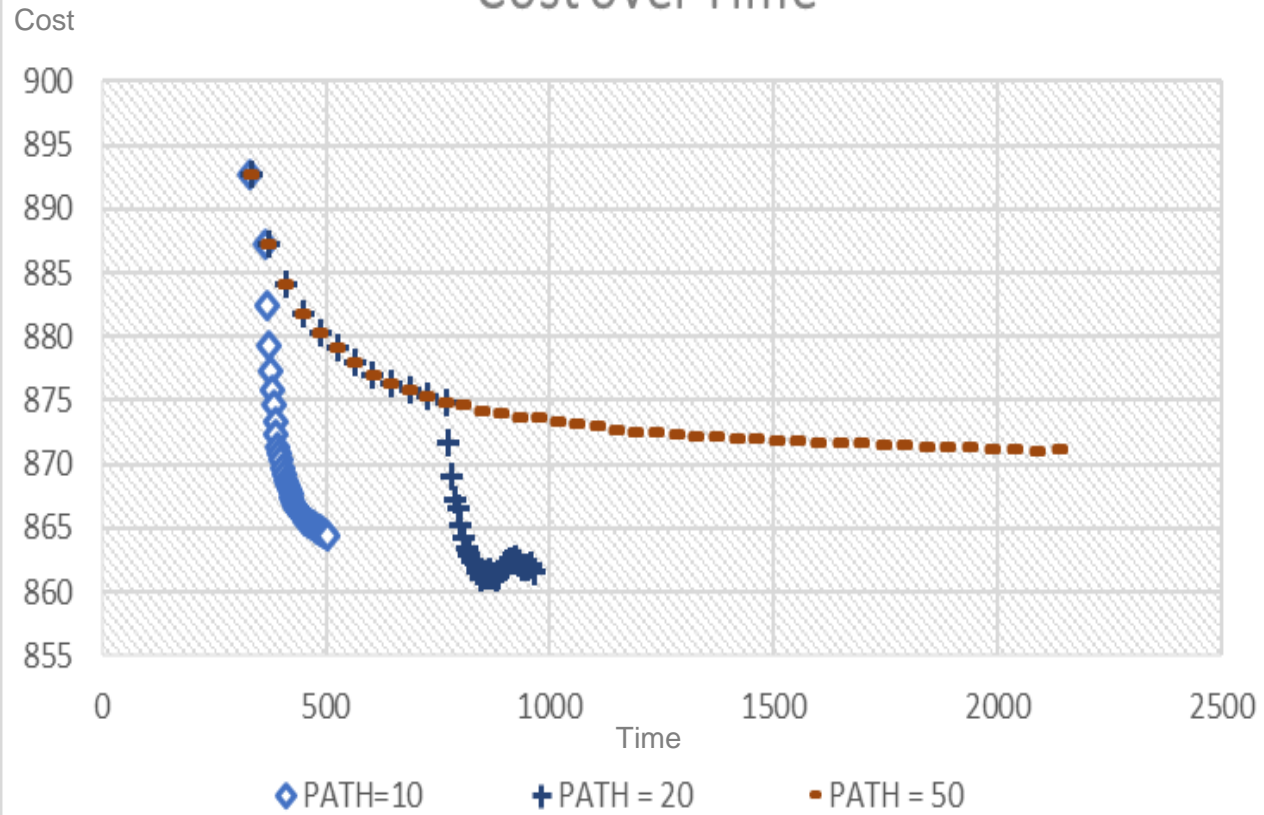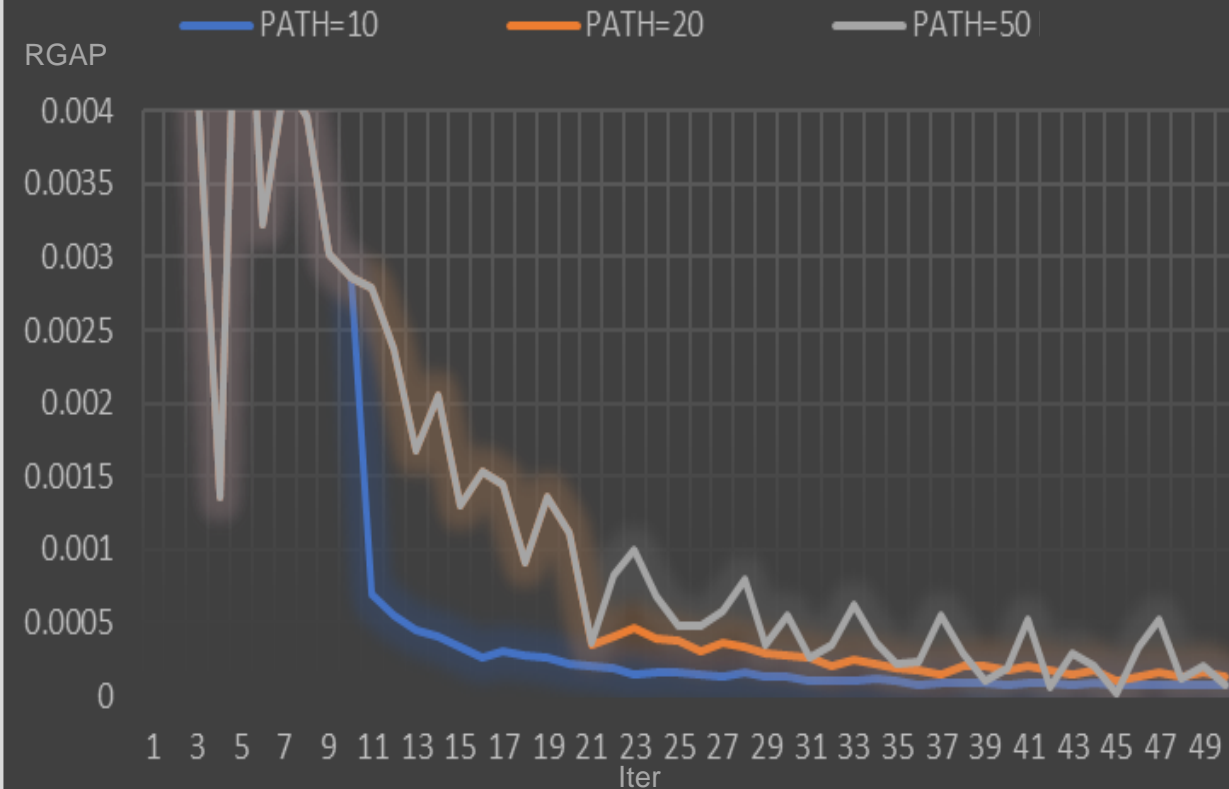
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FASTPATH
Chicago Regional Academic Model Analysis

- 1790 zones, 39018 links.
- PATH is size of active path set (=number link based volume averaging iterations)
- Time in seconds

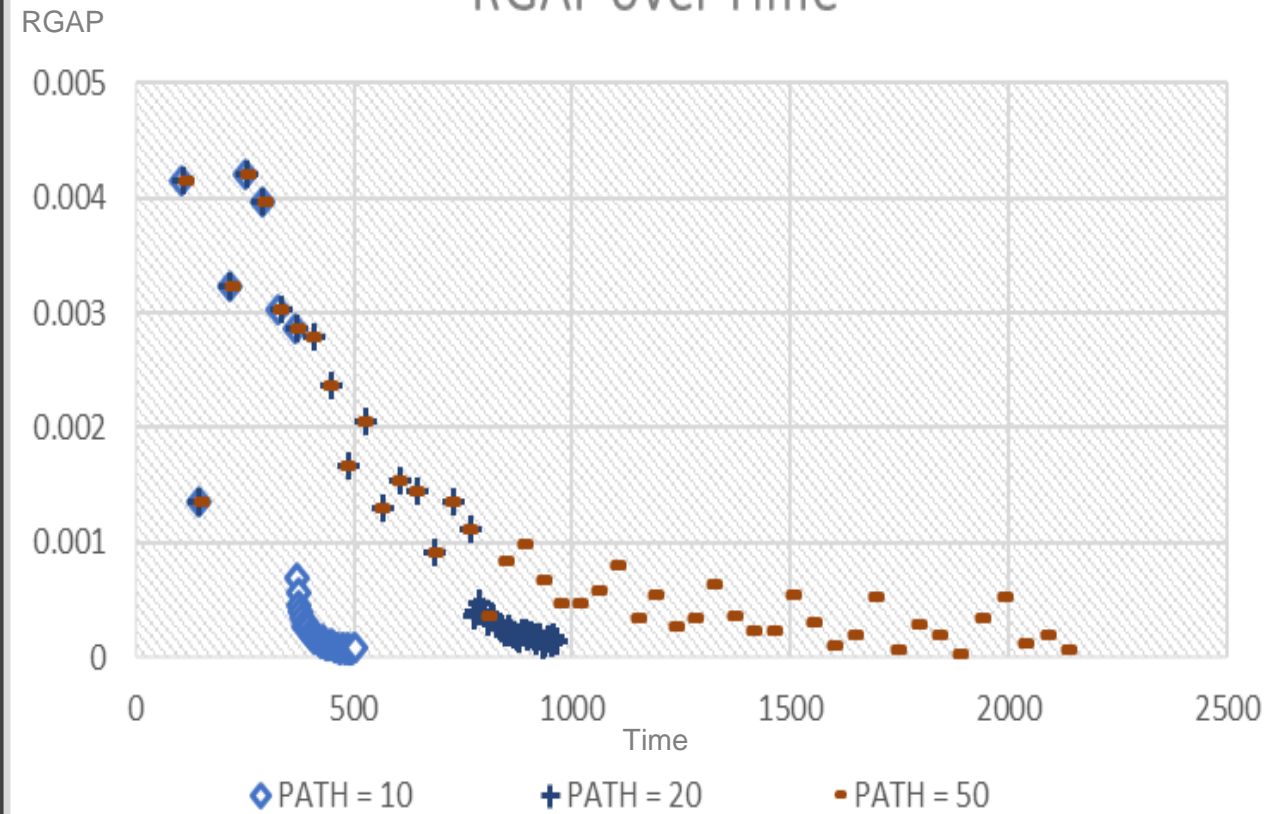Bentley®

FASTPATH

Chicago Regional Academic Model Analysis

- 1790 zones, 39018 links.
- PATH is size of active path set (=number link based volume averaging iterations)
- Time in seconds

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Highway: FASTLANE

FASTLANE = Fast Lane-Based Dynamic Traffic Assignment

- We are developing a next generation DTA software package

- Mesoscopic, lane-based, heavy mathematics

- Will run on GPUs to provide "real-time" capability

- A team of computational mathematicians will build the initial prototype Summer 2020

- Will incorporate with FASTPATH and maintain conservation of volume across a link subset of the larger network simulation

- Provide flexibility to scale down to the micro space

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Transit: Fast, Flexible, Easy

R&D focus project looking at Public Transport

- Development of a prototype for a PT methodology founded in mathematics and which is suitable to parallelization.

- Headline Considerations:
  - Computational speed is a <u>major</u> focus
  - Multi-modal assignments including built-in park-and-ride elements
  - Suitable for tour-based and trip-based approaches
  - GTFS importer/exporter and editor
  - Smart card/big-data compatibility for calibration/validation
  - Flexibility of reporting

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Thank you

oliver.charlesworth@bentley.com