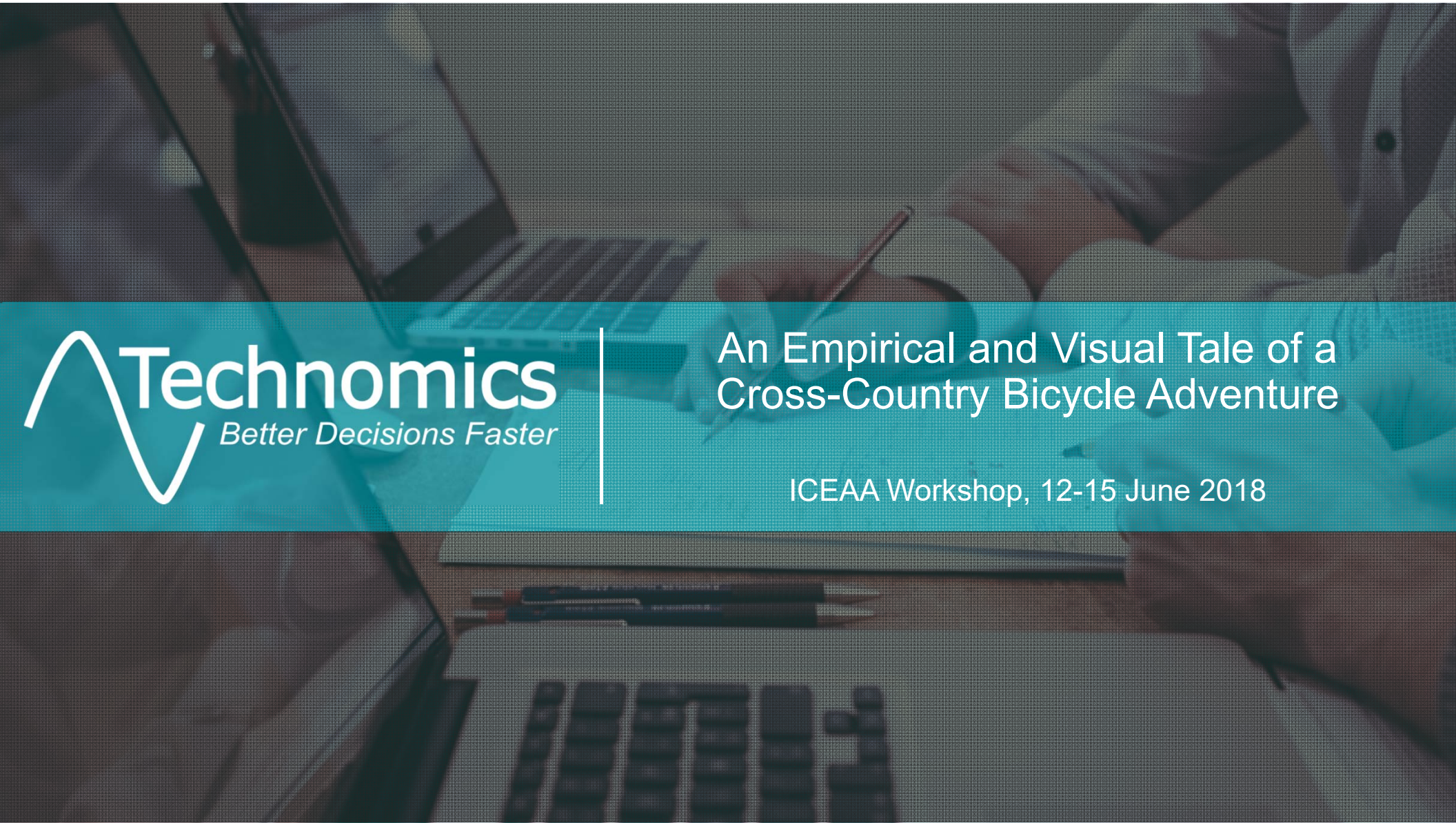

Technomics

Better Decisions Faster

An Empirical and Visual Tale of a Cross-Country Bicycle Adventure

ICEAA Workshop, 12-15 June 2018

Meet the Authors

Rick Collins
Technical Director

Rick Collins is responsible for ensuring the technical excellence of Technomics products and services. Rick has over 37 years of government and private sector cost analysis experience, including 17+ years at Technomics President/CEO, 11+ years in leadership positions at the Naval Center for Cost Analysis and 9 years at SAIC. His contributions to the cost analysis profession have been recognized via the Department of Navy *Superior Civilian Service Award* and the ICEAA *National Estimator/Analyst of the Year Award for Management.* Rick has B.A. (Wake Forest) and M.A. (Virginia Tech) degrees in Economics.

Maggie Dozier
Senior Associate

Maggie Dozier is a Senior Associate with Technomics, Inc. She has three years cost analysis experience. She is currently providing cost estimating and proposal evaluation services to Naval Sea Systems Command (NAVSEA) Program Executive Officer (PEO) Integrated Warfare System (IWS) 3.0 (Surface Ship Weapons Programs) and previously provided cost estimating services to PEO IWS 8.0 (Frigate Combat Management System Program). She graduated from Virginia Tech with a B.S. in Industrial Engineering and a minor in Statistics.

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Meet the Authors

Paul Hardin
Subject Matter Expert

Paul Hardin is a Subject Matter Expert with Technomics, Inc. Previous employment includes the OSD Cost Assessment and Program Evaluation and the Naval Center for Cost Analysis. Over the past 26 years Paul has led numerous independent cost estimating efforts, cost research initiatives, policy improvement initiatives and cost modeling and data visual analysis development efforts. Paul holds degrees from Georgia Tech and Virginia Tech.

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Associate

Orly Olbum is an Associate with Technomics, Inc. She has one year cost analysis experience and is currently performing data acquisition and database management for the Air Force Cost Analysis Agency (AFCAA), as well as supporting Space and Naval Warfare Systems Command (SPAWAR) 1.6. She graduated from Penn State with a BS in Statistics.

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Presentation Objective

- Chronicle the ride and describe post-ride analysis of a time-series data compiled daily during the trip.
- The narrative and pictures that characterize the journey are designed to not only educate but also inspire readers to get on a bike and experience the ‘power’ of cycling, including but not limited to the smile it will undoubtedly generate.
- The analysis, which likewise represents a journey, is intended to be an educational example of how to use techniques such as influence diagrams and constrained optimization to understand and model how a wide array of parameters may have impacted average riding speed.

Riding a bike …

- … feels good
- … is energizing & liberating
- … is a great way to see, hear, smell and more generally experience virtually any place -- big cities, small towns, bike trails, country roads, national parks, wilderness areas, etc.
- …makes you smile

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The Questions

- Why are you doing this?
- Where are you headed today?
- Where's your buddy?
- Where did you start and where are you headed?
- What do you eat?
- How much weight are you carrying?
- Where are you staying tonight?
- You want another beer?
- How many miles are you riding per day?
- How long have you been on the road?
- Have you had any close calls?
- How many flats have you had?
- Have you done other rides like this?
- You want me to refill your water bottles?
- Would you do this again?
- What's been the favorite part of the ride?
- Why are you going this way?
- How long did it take you to climb that hill?
- Have you seen other cyclists?
- Are you retired?
- Do you have a gun?
- What are you doing for nutrition?
- Are you in good shape?
- Are you tired?
- Are you crazy?
- Are you THE guy who's riding across the country?
- Would you like to join us for breakfast?
- Would you like to speak at the historical preservation society meeting tonight?
- How old are you?
- Are you a teacher?
- Did you play that song on the jukebox?

The Northern Tier (NT) Route

The NT Route

Landscape*

- *"The route lets you warm up for about 100 miles before any prolonged climbing begins.* ***There are four major passes in the first 300 miles, and Sherman Pass is the highest at 5,575 feet.*** *The terrain then becomes rolling, the route following river valleys until you reach Glacier National Park. Logan Pass, on Going-to-the-Sun Road, is the last major climb in the Rocky Mountains. There's a series of roller-coaster hills heading into Canada.*

- *Once you get about 20 miles east of the Rockies, you're truly in Big Sky country with moderately flat plains. The plains roll out through Montana and occasionally become hilly in western North Dakota, and then the route flattens out in eastern North Dakota and Minnesota.*

- *In Wisconsin and Iowa the terrain is continuously rolling.* ***Ask any Iowan if Iowa is flat, they will respond with a "No," especially in the northeastern part of the state.***

- ***From the Mississippi River at Muscatine, Iowa to Palmyra, New York, the route is virtually flat****. Illinois has some gently rolling prairie and is treeless except in towns.* *The trees increase in Indiana. East of Cleveland, Ohio, the route climbs to a low ridge for a few miles and then descends back to the lake shore until Buffalo, New York. From Buffalo to Palmyra, the route experiences only slight elevation changes at the locks along the Erie Canal.*

- ***The mountains in New York, Vermont, and New Hampshire extend north and south, and the route travels east-west so the remainder of the route has a lot a variety — flat sections along river valleys and several challenging climbs****. The Kancamagus Pass at 2,855 feet is the highest point on the eastern end of the Northern Tier Route.*

- *This route is best ridden in late spring to mid-fall.* ***Due to heavy snow falls, State Route 20/North Cascades Highway in North Cascades National Park is usually closed mid-November to mid-April*** *though the park remains open with limited access.* ***Going-to-the-Sun Road in Glacier National Park is usually closed until early to mid-June*** *and has limited hours for cyclists which is noted on the map."*

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* As described by Adventure Cycling Association

The NT Route

Sleep, Food & Other Services*

- *"Services are generally good along this route. There is a 73-mile stretch of limited services between Cardston, Alberta, and Cut Bank, Montana.* ***There are also some sporadic spots lacking services in central Montana, but nothing is farther apart than a day's ride.***

- *The people of the towns across the plains of Montana and North Dakota are super generous and genuine. Camping in town parks is not uncommon.* ***Only a few bike shops exist between Whitefish, Montana, and Fargo, North Dakota.***

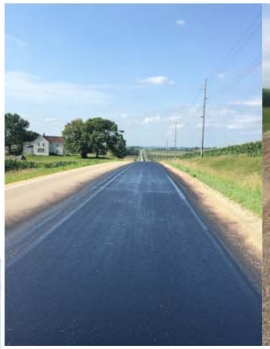
- ***In the Midwest, townsfolk are friendly.*** *Campgrounds are reasonably plentiful, but there are a few gaps, and advanced planning is needed if you are camping.* ***Some campgrounds will charge a cyclist traveling by himself less if they have hiker/biker sites, but often they will charge the price of a regular tent or RV site****, and that can easily be $10-$40/night (higher in the east).*

- *The maps list churches that have opened their doors to cyclists, but they aren't all that closely spaced.* ***If you're friendly and ask around, you can often get yourself invited to camp in a yard.***

- *Our routes sometimes go through national forests (more so in the west) and you are allowed to camp anywhere on national forest land as long as you "pack it in, pack it out."* ***Many city parks are free to camp in.*** *You may also wish to sign up with Warmshowers, a reciprocal hospitality site for bicycle travelers, for other overnight options."*

The ‘Roads’

- “Road Closed – Detour” = “shit” & “no way, no how”



- Rumble strips – friend & foe

- Tar & chip (aka chipseal) – loud & bumpy

- Multi-use trails – flat, slow & mellow

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What's Crossing the 'Roads'?

- Snowmobiles
- Moose
- Bighorn sheep
- Turtles
- Saw precisely none of these, but experienced a dead beaver, several dead snakes & many dead birds on the shoulder

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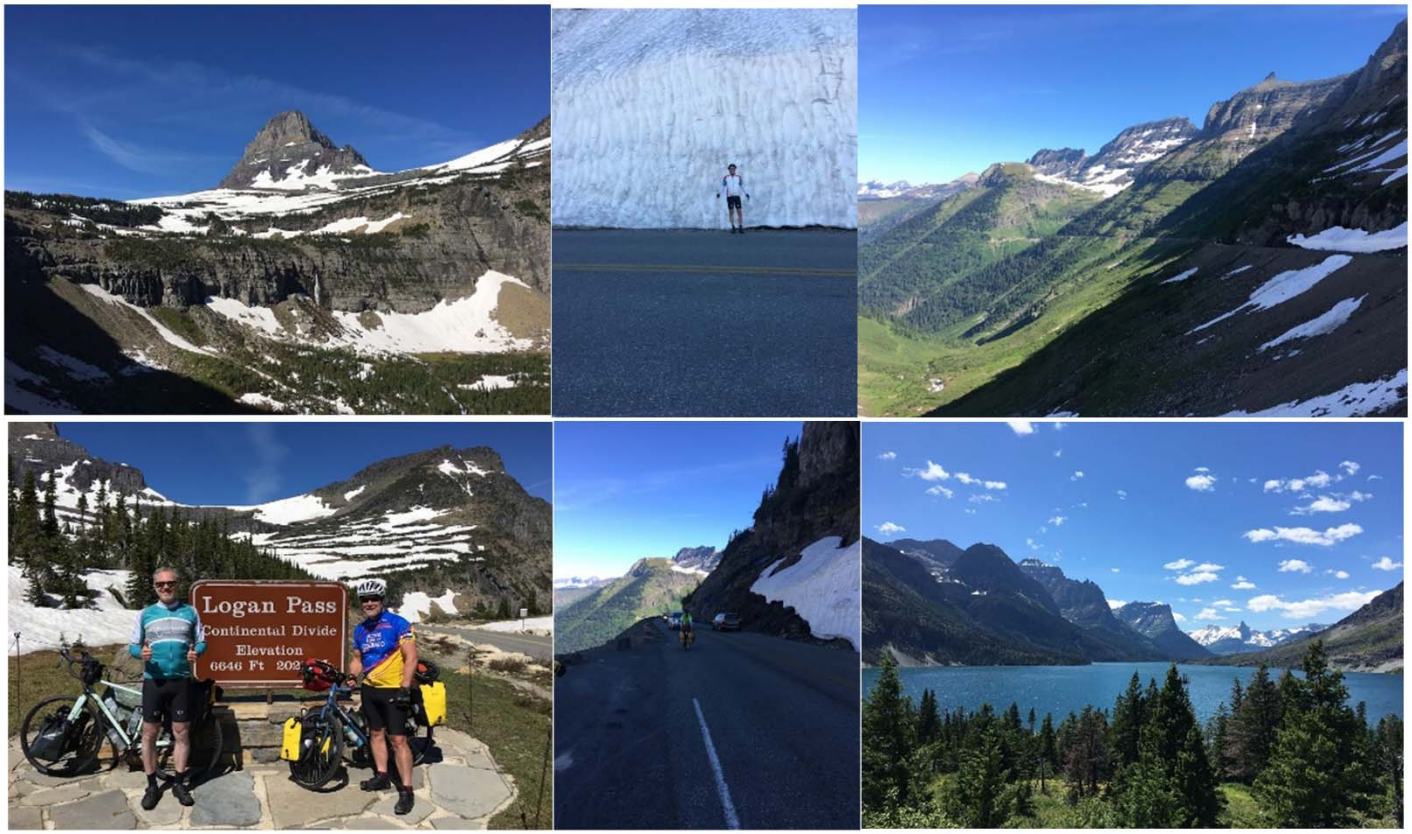
Going to the Sun Road (Glacier NP, Montana)

- 15 mile climb requiring ~2.5 hours
- 3,000 foot elevation gain to Logan Pass at 6,646 feet
- Average gradient of the last 10 miles is 5.7%
- L'Alpe d'Huez in Tour de France climbs roughly 3,770 feet in 9.4 miles, has average gradient of 7.6% and reaches 6,068 feet



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The Lodging

- 50/50 split between camping & ‘cheap’ motels
- Camping in campgrounds, RV parks, city parks & other areas
- Small town motels served their purpose -- bed and shower

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Cyclist-Only Lodging

- Alice's Attic (Morrill, MN)
- Adventure Cyclist's Bunkhouse (Dalbo, MN)
- Iroquois Village Hall (Iroquois, IL)
- Monroeville Community Center (Monroeville, IN)
- Great spots with friendly hospitality

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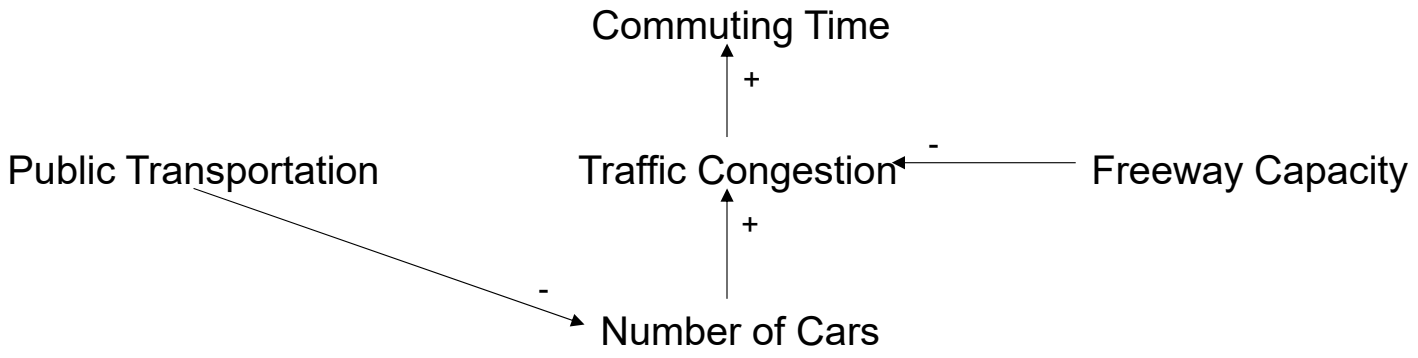
The Analysis
Overview

- Objective -- understand the system behavior associated with the ride

- Approach
  1. Develop a representation of the system using influence diagramming techniques
     - Determine an objective measure within the system (i.e., average speed)
     - Identify variables and hypothesize their expected influences on each other
  2. Collect and organize relevant historical data for each variable
  3. Formulate a quantifiable model (i.e., equation structure) to test
  4. Determine the influence of each variable using constrained optimization (i.e., Excel Solver)
  5. Assess and compare the results for type and degree of influence to our hypothesis
     - Do they make sense?
  6. As necessary, revisit/re-think the hypothesis based on additional contextual information provided by the rider

The Analysis
Influence Diagram (Definition)

- Influence Diagrams originated as part of System Dynamics (SD) in the 1950s
  - SD is a methodology and mathematical modeling technique to frame, understand, and discuss complex issues and problems
  - IDs depict the relationship among system variables
- Influence of one variable on another identified with an arrow (or a double arrow if the two variables influence each other)
- Relationship of the influence is identified with a (+) or (-) sign based on:
  - + means a direct relationship (i.e., increase $\xrightarrow{+}$ increase or decrease $\xrightarrow{+}$ decrease)
  - - means an inverse relationship (i.e., increase $\xrightarrow{-}$ decrease or decrease $\xrightarrow{-}$ increase)



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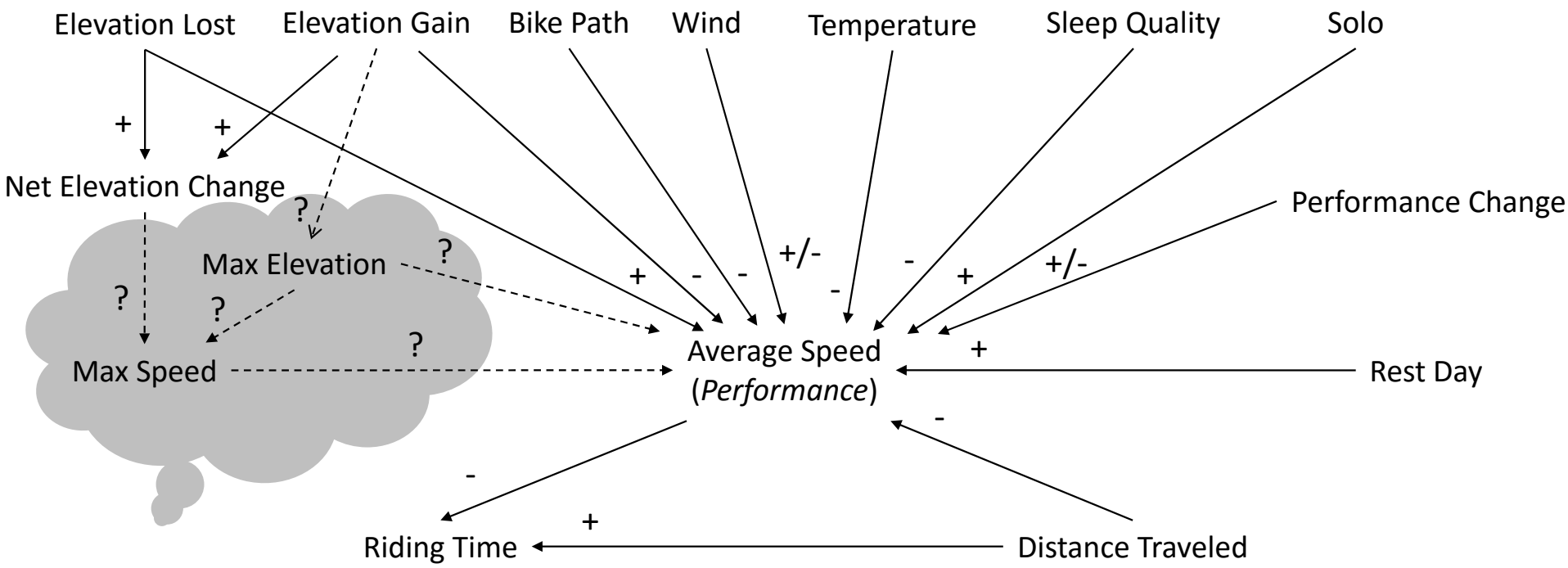
The Analysis

Influence Diagram (Initial Hypothesis)



The Analysis

Summary of Data Collected Real-time

- Four of the 14 states account for >50%
  - Washington
  - Montana
  - Minnesota
  - New York
- Daily highs
  - Distance: St. Mary, MT to Cut Bank, MT (79 mi)
  - Time: Brockport, NY to Sodus Point, NY (6 hr/ 10 min)
  - Elev gain: Rainy and Washington Pass, WA (6,411 ft)
- Daily lows
  - Distance: Wilton, IA to Muscatine, IA (15 mi)
  - Time: Wilton, IA to Muscatine, IA (1 hr/17 min)
  - Elev gain: Lockport, NY to Brockport, NY (36 ft)

Not shown – 1) Wisconsin (2 hr riding + 1 hr under tree waiting out thunderstorm)
2) Six rest days on days 8, 23, 24, 31, 40 & 63
3) Weather & other data also included in analysis

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The Analysis
Model Design

Flexible Structure allowing for linear, nonlinear or no effect

$$\text{Average Speed} = a * DT^{b} * EG^{c} * EL^{d} * HTA^{e} * CTA^{f} * TW^{g} * HW^{h} * CW^{i} *$$

$$j^{\text{Bike Path = 1, else 0}} * k^{\text{Camping = 1, else 0}} * l^{\text{Rest Day = 1, else 0}} * m^{\text{Solo = 1, else 0}} *$$

$$PCP^{n} * PCS^{o}$$

Dummy Variables

Performance Change over time

DT	Distance Traveled divided by average
EG	Elevation Gain divided by average
EL	Elevation Loss divided by average
HTA	Hotter than average temperature
CTA	Colder than average temperature
TW	Tailwind wind speed
HW	Headwind wind speed
CW	Crosswind wind speed
PCP	Performance Change with partner (day count)
PCS	Performance Change solo (day count)

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The Analysis
Constrained Optimization Tools

- Excel Solver
  - Searches for and finds the best solution that minimizes a user-defined error term (i.e., objective function)
  - Allows for any equation structure hypothesized to be modeled
  - Allows for all combinations of defined error terms to be easily tested
    - Testing different error terms (i.e., objective functions) is useful to better understand the quality of the results

- Technomics-developed front-end
  - Enables efficient set-up/execution of analysis & improved understanding of results
  - Allows for multiple run settings -- a must for finding best solution to the more complex problems
    - Informs the user of the quality of the solutions and any need for additional search time/optimization runs
  - Employs customized visual & statistical output to better understand what is working (or not) & why
  - Enables more efficient inclusion/exclusion of specific variables (using a single equation) during the analysis process
    - Additional analyses that can be performed in a more efficient manner to arrive at a better solution

The Analysis
Results & Findings

Variable Name	Variable abbr.	Coeficient	Value	Parameter Range Min	Parameter Range Avg	Parameter Range Max	Data Range Influence on Speed	Outcome
Constant (i.e., average speed)	-	a	11	9	12	17	-	
Distance Traveled	DT	b	0.09	15	55	79	17%	*Not Expected*
Elevation Gain	EG	c	-0.11	36	1,364	6,411	-43%	Expected
Elevation Lost	EL	d	0.09	49	1,348	5,213	50%	Expected
Hotter than average	HTA	e	0.01	0	-	18, 98-80	3%	*Not Expected*
Colder than average	CTA	f	0.01	0	-	23, 80-57	3%	*Not Expected*
Tailwind Speed	TW	g	0.04	0	-	11	11%	Expected
Headwind Speed	HW	h	-0.04	0	-	11	-8%	Expected
Crosswind Speed	CW	i	-0.01	0	-	10	-3%	Expected
Bike Path	-	j	0.90	0	-	1	-10%	Expected
Camping	-	k	0.96	0	-	1	-4%	*Not Expected*
Rest Day	-	l	1.06	0	-	1	6%	Expected
Solo	-	m	1.20	0	-	1	20%	Expected
Performance Change with partner	PCP	n	0.04	1	-	50	19%	*Not Expected*
Performance Change solo	PCS	o	-0.02	1	-	17	-5%	Expected

- Next slide cites possible explanations regarding influences that we “did not expect”
- These led to an improved understanding of the system

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The Analysis

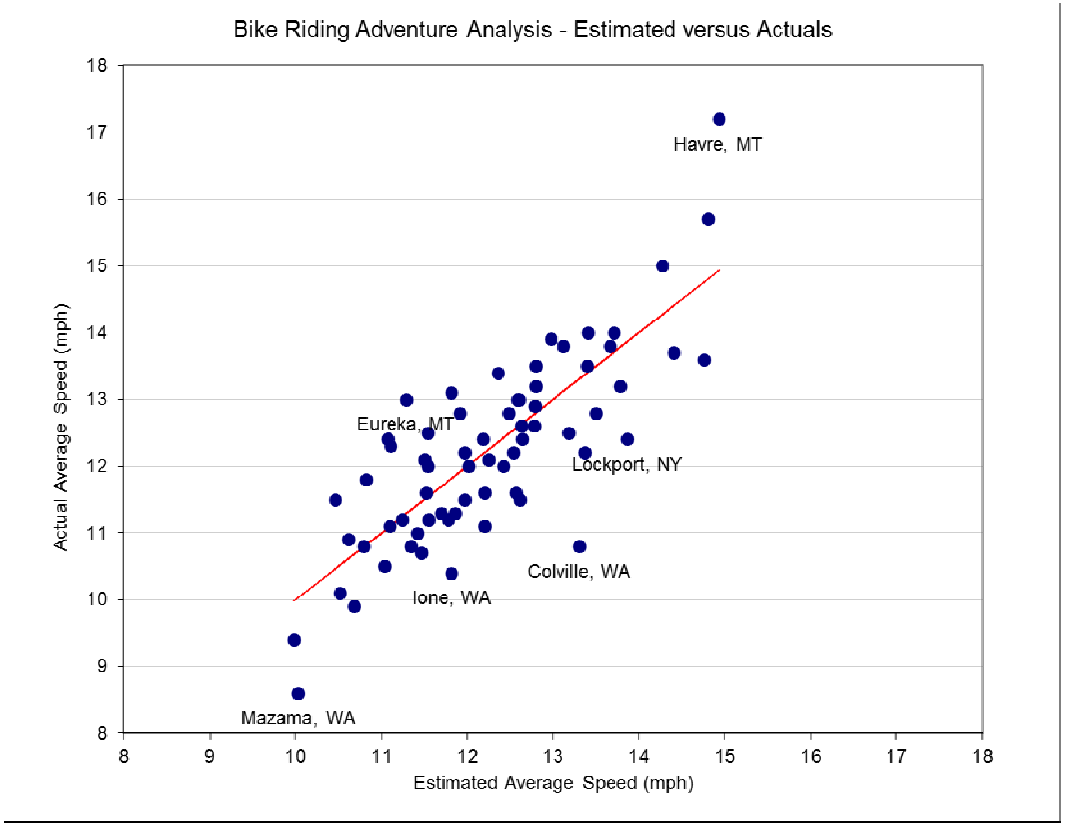
Rethinking Our Initial Hypothesis (Do the results make sense?)

- Distance Traveled
  - Assumed riding a longer distance in a day would be tiring and result in a decreased average speed for longer rides
  - But …
- Hotter or Colder than average temperature
  - Assumed extreme temperatures would have a decreasing effect on average speed
  - But …
- Sleep Quality
  - Assumed camping the night before might result in better sleep and a faster pace due to his partner's snoring in the motel room
  - But …
- Performance Change
  - Assumed every additional day of riding would result in a wearing down of the body and a resulting decrease in average speed over time
  - But …

The Analysis

Estimated versus Actual Plot of Results

- Used throughout the analysis process to identify outliers, gather more information & re-think our initial hypothesis as needed



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The Analysis
Closing Observations

- Influence diagramming -- powerful technique for understanding complexity of problem prior to generating analytical solution
- Constrained optimization via Excel Solver-- extremely useful approach, but not without criticism relative to Log Ordinary Least Squares via R
  - Poorly understood predictive capabilities – Does the model tell us anything about future rides?
  - Lack of model diagnostics – How do we know the model is good?
  - Lack of reproducibility – How easy is it for someone else to replicate the model?
  - Multicollinearity – Do any of the independent variables correlate to others?
- Access to the data source (Rick) was unique & invaluable to the analysis
  - Enabled authoritative answers to questions that helped us re-think why something behaved as hypothesized or not
  - In contrast to situation typically facing cost analysts (i.e., no access to an engineer/expert who lived the project & can explain why cost behaved as it did)

The End

- What was the best aspect of the trip?
- Great physical and mental test, but lots of smiling in 74 days
- "I'm 68 & never been to a doctor in my life because my daily training regimen is five raw eggs, no water, no aspirin, red meat only and 15 beers." (retired farmer in Muscatine, IA)

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Backup

The Analysis

Rethinking Our Initial Hypothesis (Do the results make sense?)

- Distance Traveled
  - Assumed riding a longer distance in a day would be tiring and result in a decreased average speed for longer rides
    - Rick would ride ahead and stop and rest on longer rides (many times) to wait for his partner. This periodic rest pattern resulted in him having more energy than riding continually on shorter ride days. On shorter ride days he would stay with his partner longer and spend more time riding at his partner's pace.
    - If we were modeling the training experience of a competitive cyclist then maybe we should see the influence we hypothesized
- Hotter or Colder than average temperature
  - Assumed extreme temperatures would have a decreasing effect on average speed
    - Only a very few days were really hot or cold and they were during the portion of the trip when Rick had a partner
    - Possibly on those days Rick (and more so his partner) pushed harder to complete the day's ride due to the temperature?
    - With more extreme temperature data points and a competitive training experience we might see what we hypothesized
- Sleep Quality
  - Assumed camping the night before might result in better sleep and a faster pace due to his partner's snoring in the motel room
    - Maybe so to some degree but camping required finding the location, setting up, taking down and possibly an overall reduced level of rest due to the quantity of sleep vice quality
- Performance Change
  - Assumed every additional day of riding would result in a wearing down of the body and a resulting decrease in average speed over time
    - Rick's partner was not in the best shape at the beginning of the trip and actually improved in performance over time
    - During the last part of the trip, when Rick was riding solo, Rick did show some degree of a decrease in performance
    - But he was also in a more focused "enjoyment mode" during these last days wanting to fully take in his last days of this wonderful experience and accomplishment