THE UNIVERSITY OF TEXAS AT AUSTIN
CENTER FOR TRANSPORTATION RESEARCH

PRODUCTS 0-6850-P1 and P2
TxDOT PROJECT NUMBER 0-6850

Corridor-Based Planning Tool for Transportation of Wind Turbine Components: Manual Guide (P1)

Workshop Presentation (P2)

Chandra R. Bhat
Sebastian Astroza
Priyadarshan Patil
Zhanmin Zhang

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http://library.ctr.utexas.edu/ctr-publications/0-6850-P1P2.pdf

0-6850-P1

CORRIDOR-BASED PLANNING TOOL FOR TRANSPORTATION OF WIND TURBINE COMPONENTS: MANUAL GUIDE

Chandra R. Bhat
Sebastian Astroza
Priyadarshan Patil
Zhanmin Zhang

TxDOT Project 0-6850: Texas Transportation Planning for Future Renewable Energy Projects

MARCH 2016; PUBLISHED MARCH 2017

Performing Organization: Center for Transportation Research The University of Texas at Austin 1616 Guadalupe, Suite 4.202 Austin, Texas 78701	**Sponsoring Organization:** Texas Department of Transportation Research and Technology Implementation Office P.O. Box 5080 Austin, Texas 78763-5080
Performed in cooperation with the Texas Department of Transportation and the Federal Highway Administration.	

Contents

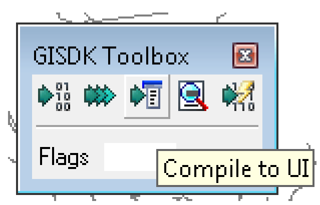
The accompanying CD/DVD contains 0-6850-P1, a stand-alone planning tool that can be used to propose a route plan for wind turbine components passing along Texas routes. Following are the instructions.

The CD/DVD contains a TransCAD batch file (Batch1.rsc), four datasets (Bridgeshort.zip, PMIS.rar, SAM_V3 Model.zip, and VertClearance.zip), the compiled TransCAD network (Final Map.rar), and the complete user's guide. The user should copy the folder "WTC_TOOL" and paste it in C:\. The four separate datasets were provided in addition to the already created network in case TxDOT would like to modify the network in the future. Detailed instructions on how to replicate the data creation process are provided in the appendix of this guide. However, the final dataset is the only map the user should open.

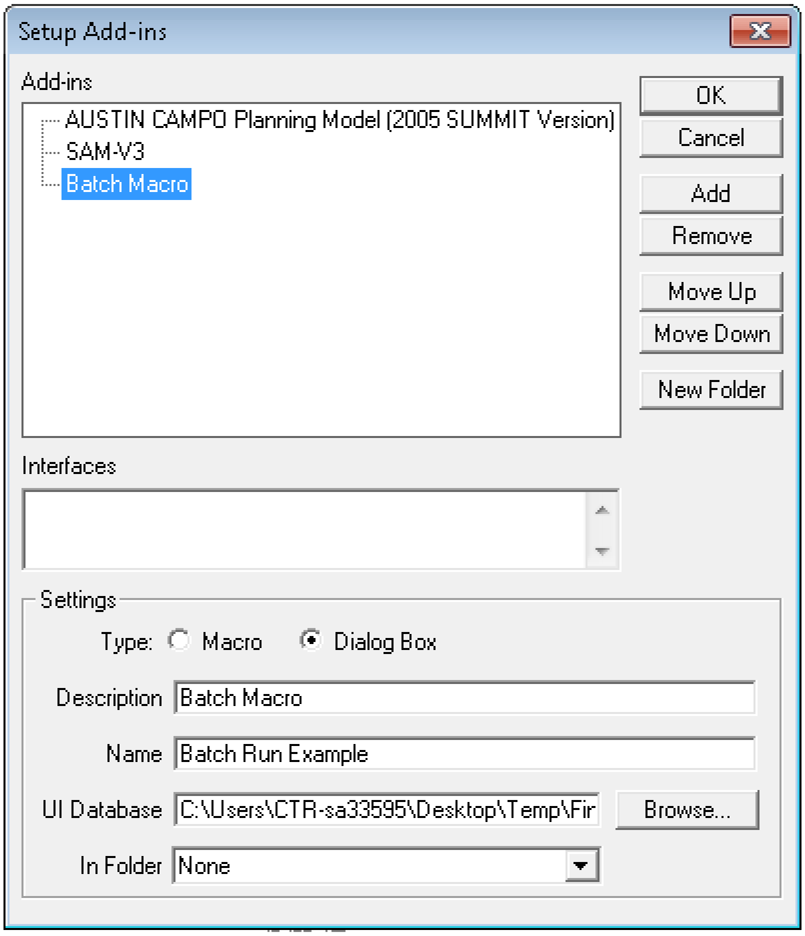
Using the tool requires only two steps: open the map in TransCAD (Final Map.cdf) and enter some basic inputs regarding the truck, load, and start/end points. The tool will generate the shortest route based on those inputs. However, the user should compile the batch file first.

Compiling the batch file

In order to compile the batch file, the user should go to the *'Tools'* menu and open the *'GIS Developer's Kit'*. Then the user should click in the first icon, *'Compile to UI'*, and select the file Batch1.rsc and the UI database ui1.dbd. A "compilation successful" message should appear after a few seconds.

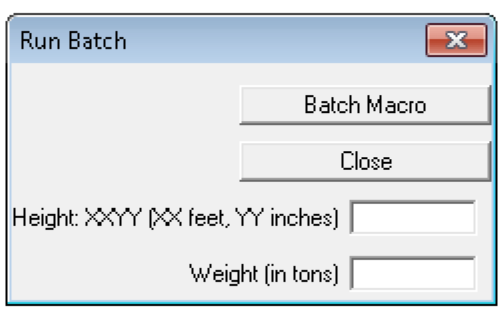


Once the batch file is compiled, the user needs to include an add-in in the TransCAD tools menu. In order to do that, the user should go to the *'Tools'* menu and open the *'Setup add-ins'* dialog box. The user should *'Add'* a dialog box with description "Batch Macro", name "Batch Run Example" and using the UI database included in the CD/DVD (ui1.dbd).



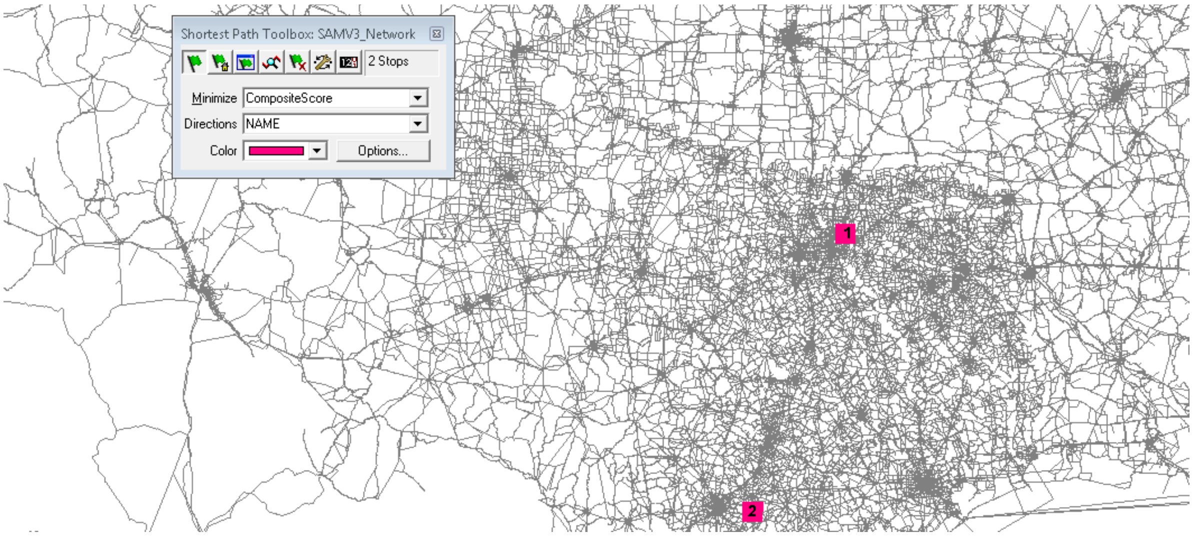
Running the add-in

In order to run the add-in, the user should go to the *'Tools'* menu and open the *'Batch Macro'*. A small dialog box will appear.

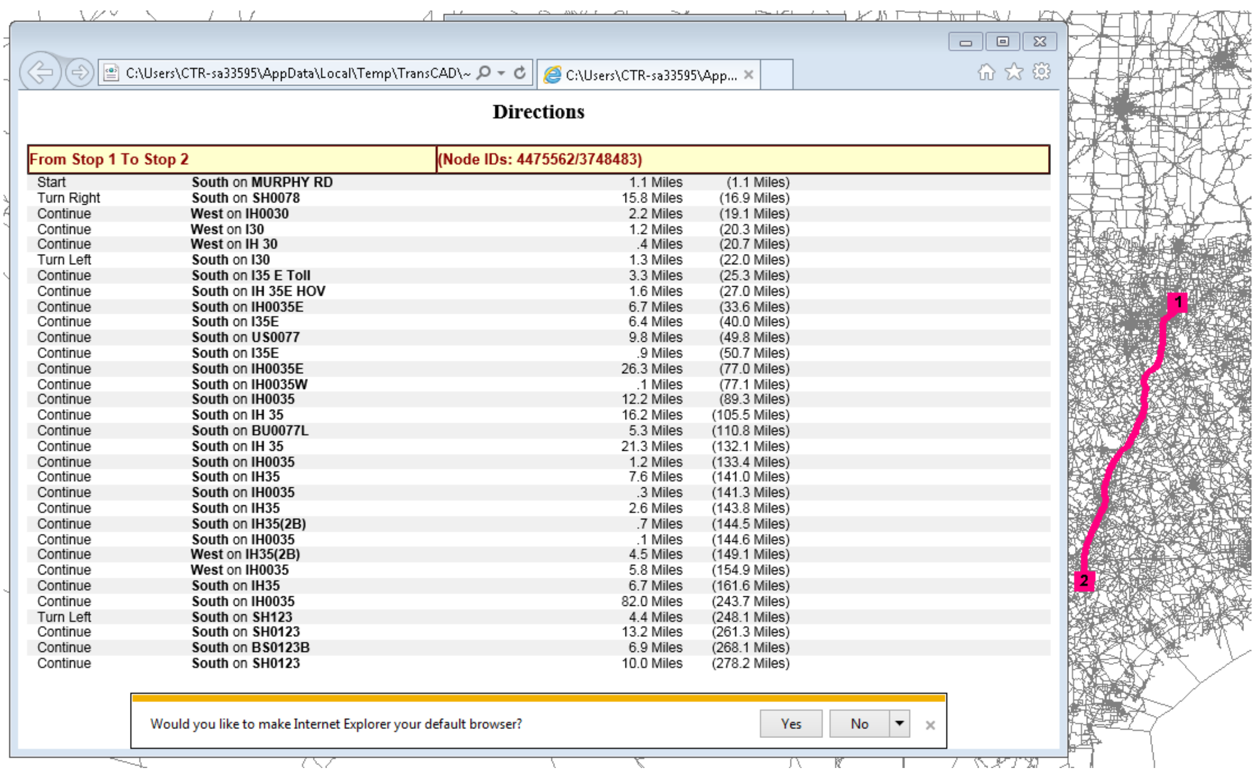


The user should input the Height of their truck (this is a four-digit code, with first two showing feet and next two showing inches, e.g., a clearance of 12 feet and 5 inches will have 1205 as the attribute) and also the weight of the load and truck (in tons). Finally, the user should press the "Batch Macro" button and TransCAD will automatically select only the links of the network in which the truck meets the load and vertical clearance limitations. The user should see a “Batch routine terminated successfully” message after a few seconds.

Now the user can go to the *‘Networks/Paths’* menu and run the shortest path toolbox.



At this point, the user inputs origin and destination (or multiple points, as multiple stops are allowed) and the routine will find the shortest path, creating a list of instructions in a .txt file and an accompanying map.



From Stop 1 To Stop 2	(Node IDs: 4475562/3748483)		
Start	South on MURPHY RD	1.1 Miles	(1.1 Miles)
Turn Right	South on SH0078	15.8 Miles	(16.9 Miles)
Continue	West on IH0030	2.2 Miles	(19.1 Miles)
Continue	West on I30	1.2 Miles	(20.3 Miles)
Continue	West on IH 30	.4 Miles	(20.7 Miles)
Turn Left	South on I30	1.3 Miles	(22.0 Miles)
Continue	South on I35 E Toll	3.3 Miles	(25.3 Miles)
Continue	South on IH 35E HOV	1.6 Miles	(27.0 Miles)
Continue	South on IH0035E	6.7 Miles	(33.6 Miles)
Continue	South on I35E	6.4 Miles	(40.0 Miles)
Continue	South on US0077	9.8 Miles	(49.8 Miles)
Continue	South on I35E	.9 Miles	(50.7 Miles)
Continue	South on IH0035E	26.3 Miles	(77.0 Miles)
Continue	South on IH0035W	.1 Miles	(77.1 Miles)
Continue	South on IH0035	12.2 Miles	(89.3 Miles)
Continue	South on IH 35	16.2 Miles	(105.5 Miles)
Continue	South on BU0077L	5.3 Miles	(110.8 Miles)
Continue	South on IH 35	21.3 Miles	(132.1 Miles)
Continue	South on IH0035	1.2 Miles	(133.4 Miles)
Continue	South on IH35	7.6 Miles	(141.0 Miles)
Continue	South on IH0035	.3 Miles	(141.3 Miles)
Continue	South on IH35	2.6 Miles	(143.8 Miles)
Continue	South on IH35(2B)	.7 Miles	(144.5 Miles)
Continue	South on IH0035	.1 Miles	(144.6 Miles)
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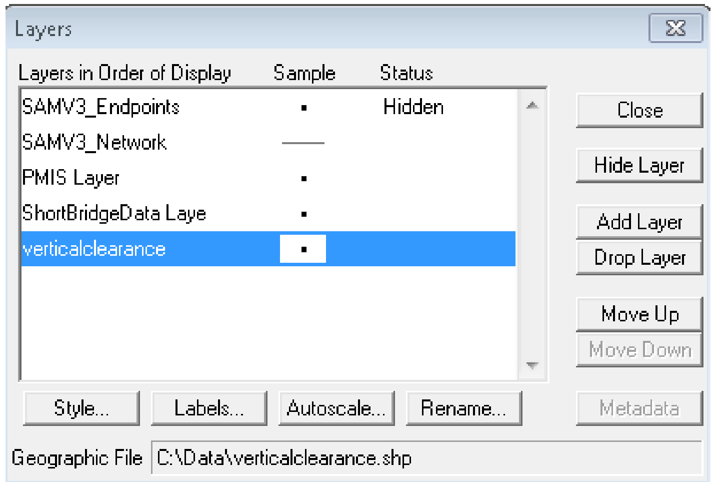
Turn Left	South on SH123	4.4 Miles	(248.1 Miles)
Continue	South on SH0123	13.2 Miles	(261.3 Miles)
Continue	South on BS0123B	6.9 Miles	(268.1 Miles)
Continue	South on SH0123	10.0 Miles	(278.2 Miles)

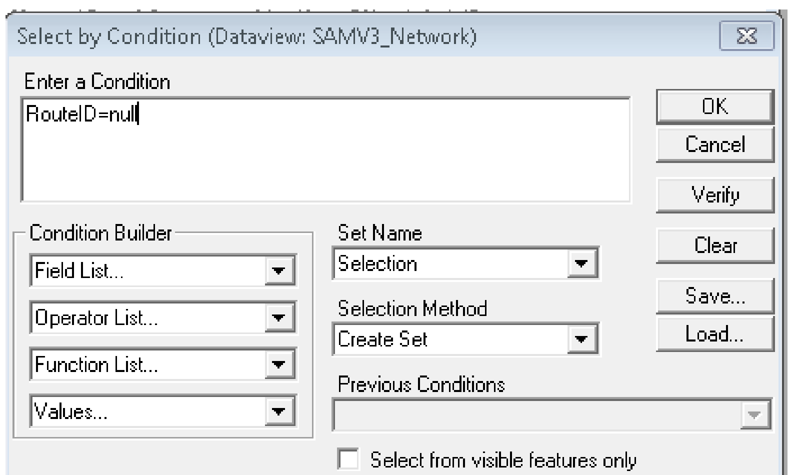
Appendix A: Data creation process

The operations we perform to create the dataset are as follows:

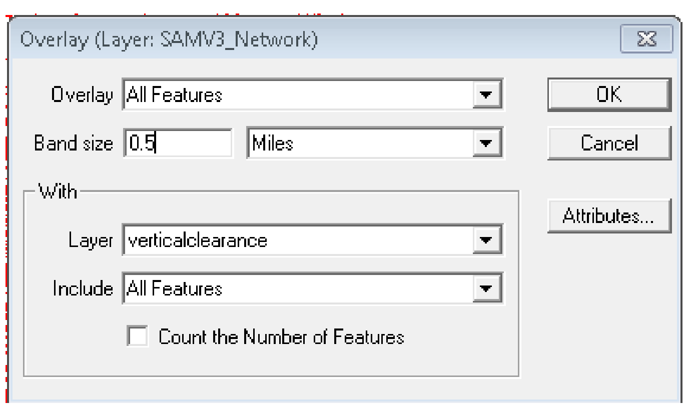
1) Read the Texas road network from the SAM Dataset and add the other three layers (bridges, vertical clearance and pavement condition).



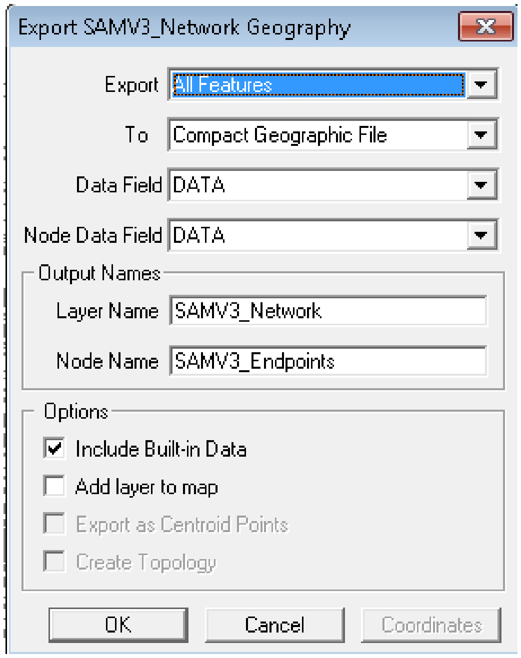
2) Select only road links from the network (exclude rail and air).



3) Overlay the vertical clearance shapefile on the data with a band size of 0.5 miles.



4) Export this overlay map and save it.



5) On this overlaid map, overlay the bridge data with a band size of 0.05 miles (this data is fairly accurate, geographically).

6) Export and save this overlay map.

7) Open this saved map and overlay the pavement data with a band size of 0.05 miles.

8) Export and save this final map.

9) Open the dataview of the map, and delete the columns we are not using.

10) Use the vertical clearance data fields along with the bridge over/under data fields to add an attribute of maximum vertical clearance to all the links. (This is a four-digit code, with first two showing feet and next two showing inches, e.g., a clearance of 12 feet and 5 inches will have 1205 as the attribute).

11) Use the bridge data to fill in the maximum load capacity of certain links (in tons).

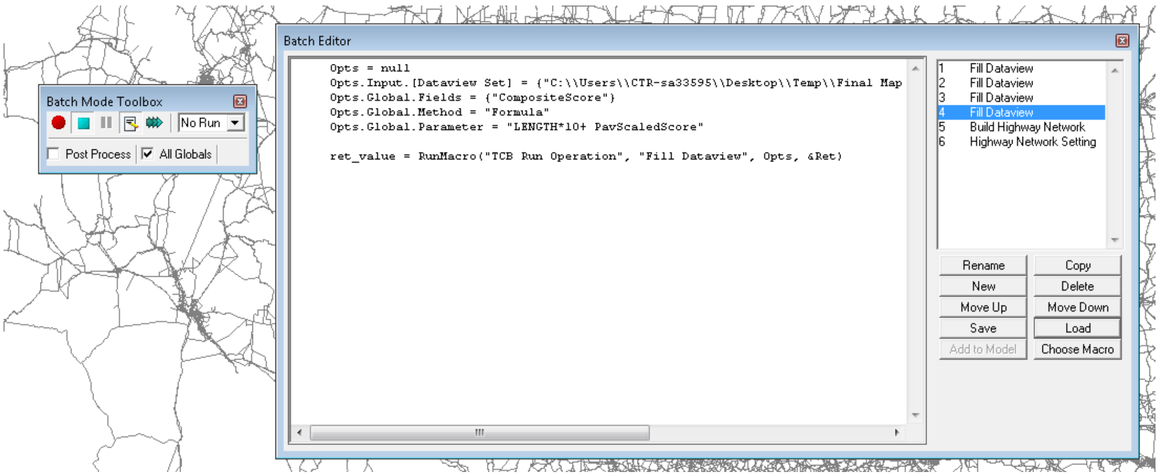
12) From the pavement data, assign a condition score to each road.

13) Export this dataset. This is our final dataset.

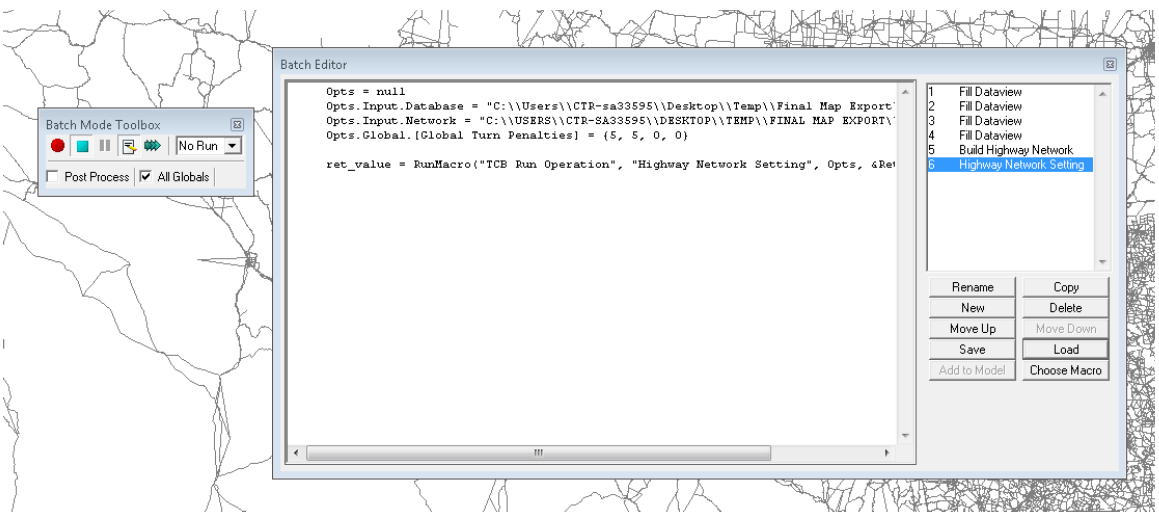
Appendix B: Modifying the optimization criteria

The user can modify the parameters of the optimization criteria using the Batch Mode Toolbox.

Item number 4 contains the formula with the weights of the travel distance and the pavement score.



Item number 6 contains the left turn and right turn penalties.



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CENTER FOR TRANSPORTATION RESEARCH

0-6850-P2

WORKSHOP PRESENTATION

Research Supervisor:
Chandra Bhat

TxDOT Project 0-6850: Texas Transportation Planning for Future Renewable Energy Projects

AUGUST 2016; PUBLISHED MARCH 2017

Performing Organization:	**Sponsoring Organization:**
Center for Transportation Research The University of Texas at Austin 1616 Guadalupe, Suite 4.202 Austin, Texas 78701	Texas Department of Transportation Research and Technology Implementation Office P.O. Box 5080 Austin, Texas 78763-5080
Performed in cooperation with the Texas Department of Transportation and the Federal Highway Administration.	

Workshop Overview

This project produced a corridor-based planning tool for TxDOT's use in planning for future construction of wind farms and the transportation of wind turbine components. The research team organized a three-hour workshop to present the tool's predictive functionalities in these areas: (1) the most likely wind farm locations and their production capacities; (2) the nature and size of wind turbine components corresponding to the estimated production capacities of wind farms; (3) the routing paths for the wind turbine components; and (4) the truck movement patterns corresponding to the routing paths, as well as recommendations for investing in additional transportation infrastructure to facilitate the movement of wind turbine components. The workshop's PowerPoint presentation is provided here.

The workshop was held at the CTR offices on August 9, 2016, from 9:00 a.m. to noon. The research team presented the features and uses of the software and performed a detailed demonstration of the tool.

Most of the participants expressed positive feedback about the tool and indicated willingness to use the tool to improve their operations and predict the future needs of their riders. However, several comments and concerns were voiced during the workshop, which will be addressed by the research team. These comments and suggestions were incorporated into an updated version of the tool (provided to TxDOT as 0-6850-P1).

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CENTER FOR TRANSPORTATION RESEARCH

Texas Transportation Planning for Future Renewable Energy Projects

Workshop (August 9, 2016)

COLLABORATE. INNOVATE. EDUCATE.

Introduction

Background

- There is currently the **most wind power construction activity** in the history of the U.S. wind industry.

- The **majority of wind construction activity** continues to be focused within **Texas** (>8,000 MW).

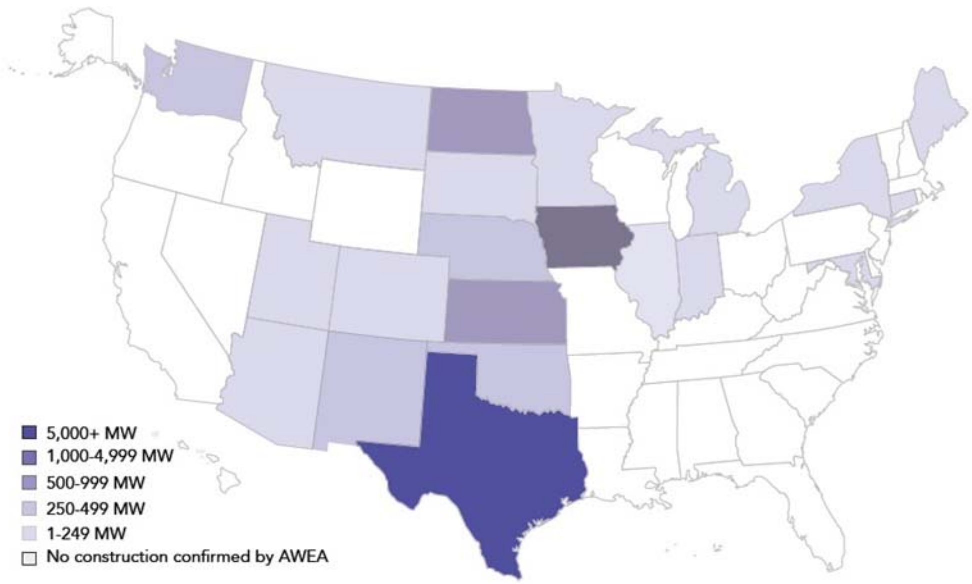

Figure: Map of wind power capacity under construction
Source: U.S. Wind Industry First Quarter 2014 Marker Report (AWEA)

Background

- Texas's **success in installed wind power capacity** is attributed to:
  - Renewable Portfolio Standard (RPS),
  - competitive prices,
  - available federal tax incentives,
  - abundance of capturable wind capacity,
  - plan for the installation of transmission lines, and
  - postage-stamp system for the transmission cost.
- This **exponential growth** of wind energy production **is a challenge** for the roadway system.

Background (cont.)

- The construction of wind farms **requires transport of wind turbine components** that create increased loads on rural roads and bridges.

- Rural roads and bridges are typically not designed for such loads.

- **Greater burden** on transportation **infrastructure in Texas**.

Background (cont.)

- Bridges, tunnels, tightly bending roads, signals, roadside signs, and markings are **navigation challenges for the trucks** carrying extra-large oversize/overweight (OS/OW) loads.
- Drivers of **OS/OW loads cannot take the most direct route** because of **highway impediments** (e.g.: sharp turning radii or insufficient vertical clearance).
- Wind turbine components are considered **"super loads"** → **transporting them requires close cooperation** between manufacturers, shippers, state transport officials, and port authorities.

Background (cont.)

- Moving **one wind turbine takes eight to ten trucks**, mostly **specialized trailers**, and requires **OS/OW permits**.

- **OS/OW loads can damage infrastructure**, creating safety concerns and the need for **expensive repairs**.

Background (cont.)

- Due to transportation cost, **manufacturing plants** will be located **close to wind farm locations**.

- Many **international manufacturers ship** their components **to major Texas Gulf ports** (e.g. Houston and Corpus Christi), where the components begin journeys to remote wind farm sites.

Background (cont.)

- Wind turbine components also enter the state through land in either East or West Texas.

- Many domestic manufacturers also **use the Texas road system as a throughway for cross-country traffic**.

- In summary, **preparing the Texas transportation network for future wind farm installations is essential.**

Objective

- Create a methodology and a corresponding **operational planning tool** that can be used to:
  - propose **route plans** for wind turbine components passing along Texas routes and
  - develop **recommendations** for **planning construction** of new wind farms as well as road maintenance strategies.
- With a well-designed plan for transporting wind turbine components,
  - truck drivers can use easier and more direct routes,
  - wind energy developers can reduce costs,
  - state authorities can reduce investment in road maintenance and repair, and
  - the entire state and country can stand to gain from the use of this promising renewable energy source.

Contributions

- **The methodology and associated tool** provide a number of highly valued services that further **optimize wind turbine transport.**

- Previous tools focus on tour planning given an origin/destination pair → **operational tools** that provide the **best route solely in terms of distance**.

- Our methodology and tool **contribute in two ways.**

Contributions (cont.)

- **Our tool improves upon route planning not only in terms of distance, but also considering the number of turns and pavement damage.**

- **Making a turn is a challenge** when transporting turbine blades and tower sections (sometimes more than 100 feet long).

- Routes must be scouted by an advance driver looking for sharp turns and obstructions.

Contributions (cont.)

- The trucks are complex and **each turn means several minutes of delay.**

- The heavy loads of **wind turbine components cause significant road deterioration**,

  - **shortening** the original **life expectancy of pavement** and

  - forcing authorities to **invest in road repair** instead of in transportation infrastructure improvement.

Contributions (cont.)

- **Our methodology and related tool also go beyond route planning.**
- Multi-faceted planning system that can predict what transportation infrastructure will be needed based on predictions of wind energy growth.
- In the process of adding these predictive components, we also include **the capability for performing "what-if" analysis.**

"What-if" Analysis Examples

- Determine the **exact locations and types of road infrastructure improvements** that would most improve the **routing of wind turbine components**,
- identify **how the continually changing technology of wind turbines will impact transportation planning**,
- determine the **best locations** to install a **wind turbine manufacturing plant,**
- analyze **how the country's economic growth could influence wind energy production trends** and the related transportation of components,
- identify the **best location for new electric transmission lines** specific to wind power energy, and
- evaluate **what kind of improvements can be made to port-adjacent freight corridors** to optimize the path between the locations where wind turbine components are imported into and their inland destinations.

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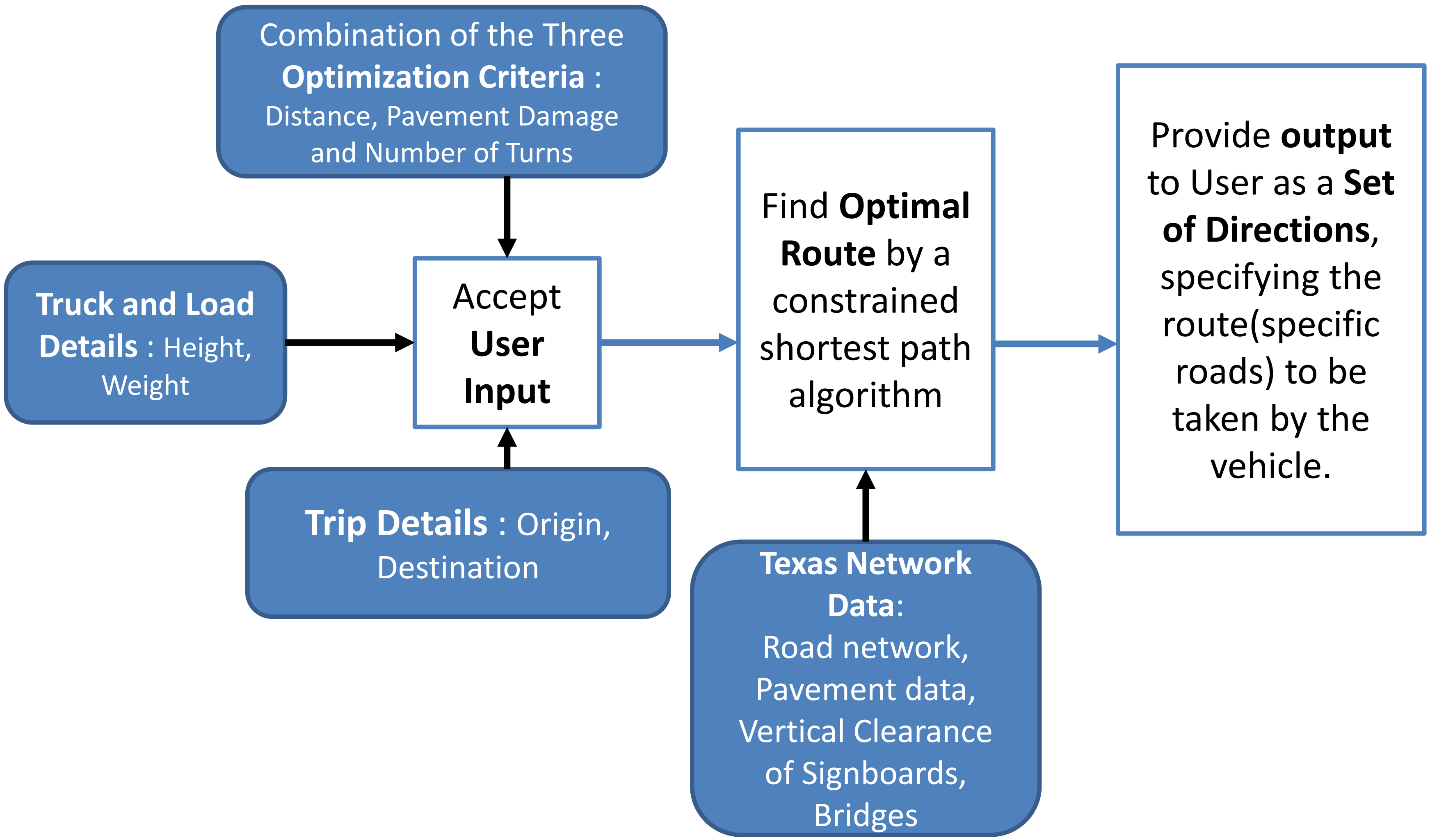
Methodology and Tool Development

Schematic of the Tool



Data Sources

- **Road network** – The road network was extracted from the Texas Statewide Analysis Model (SAM) Version 3.

- **Bridge Data** –Available from TxDOT (Microsoft Access file sent on December 2015).

- **Vertical clearance of Signboard Data** –Available on TxDOT website.

- **Pavement data** – Available from Pavement Management Information System (PMIS) .

Routing Tool Function

- The **four datasets are combined by performing geographic analysis operations**.
- **Route network** data is the **base layer**.
- The **other data layers are geographically overlaid** and the attributes matched to the base roads matching a given spatial threshold.
- The bridge dataset establishes the height and weight limits on the bridges → preventing their inclusion in routes generated for trucks carrying loads in excess of those limits.
- The vertical clearance data also restrict the number of paths considered in the shortest path algorithm.
- The pavement data is used to allot a certain score to the pavement, based on its current known condition.

The Shortest Path Formula

- The default expression for the composite score corresponds to:

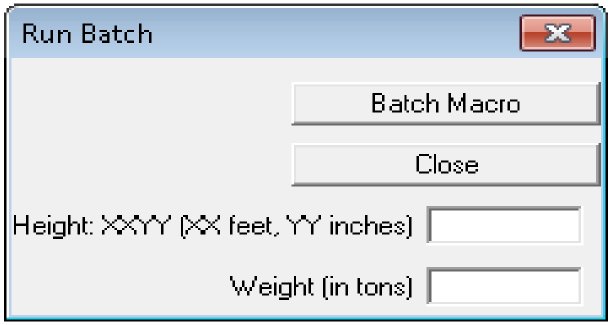
Composite Score (miles) = 0.9**Travel Distance in Miles* + 0.1**Pavement Condition* + 5**Number of turns*

- Pavement Condition=*Travel Distance* * (100 - *condition score*)/100

- Roads with pavements in better condition contribute to lower, more favorable composite scores.

Running the Batch File

- Run the add-in from the *'Tools'* menu

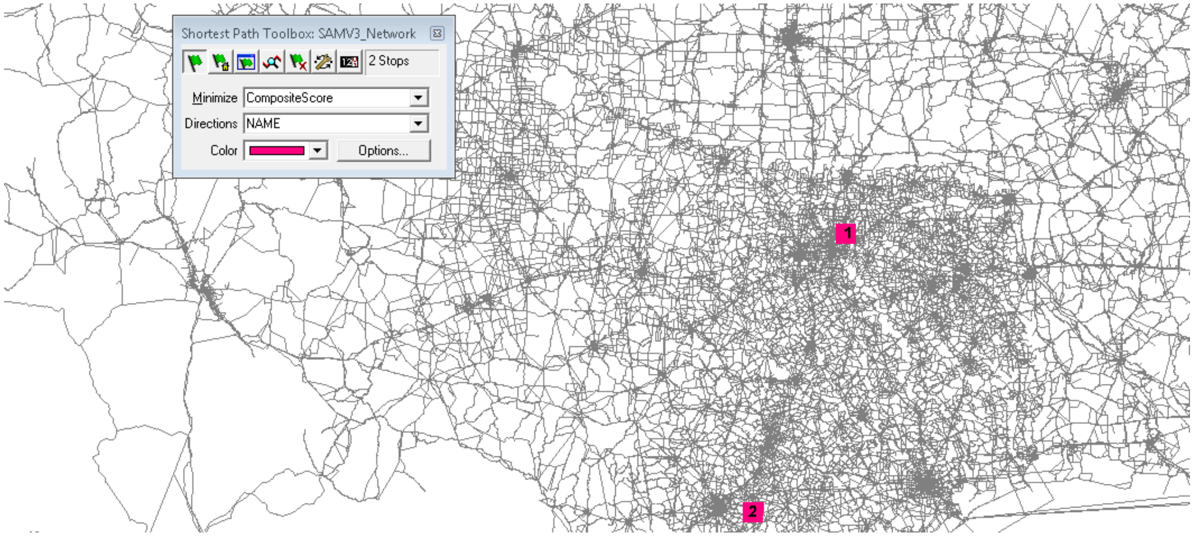


- Input Height and Weight.

- Press the *'Batch Macro'* button.

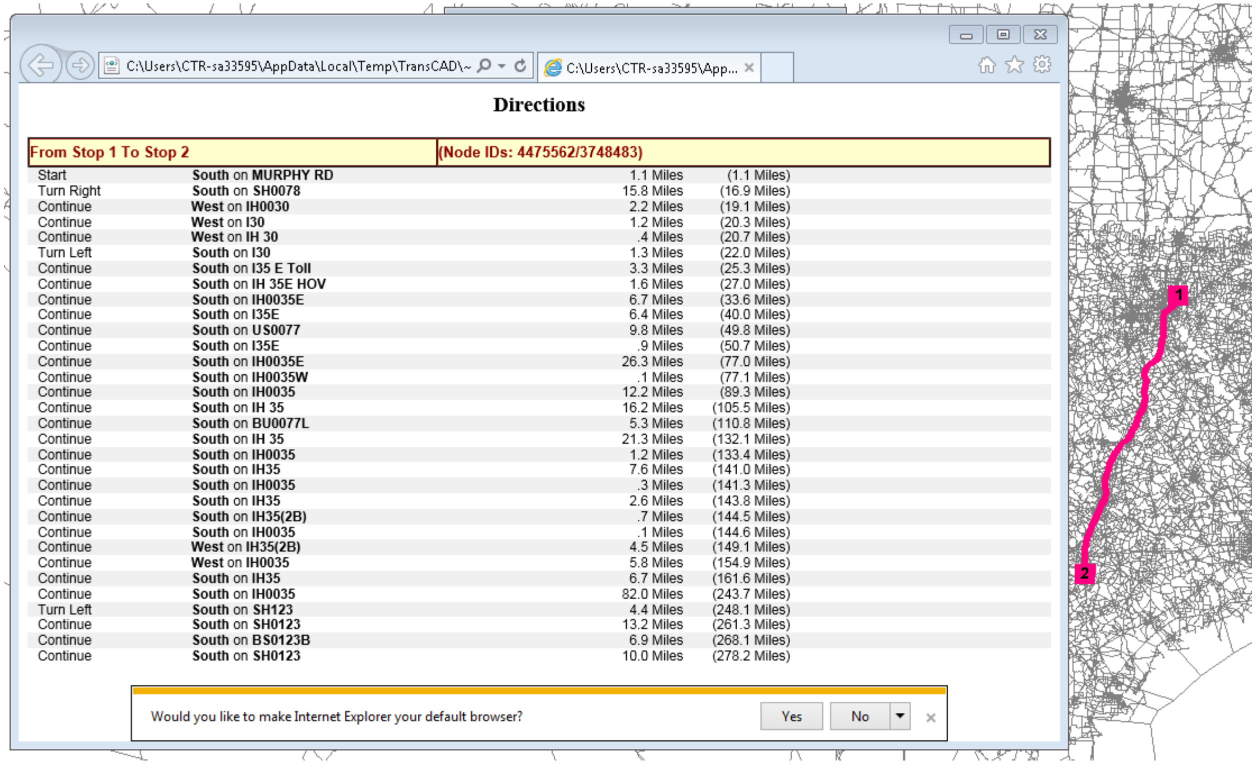
Computing the Shortest Path

- Open the shortest path toolbox from the *'Networks/Paths'* menu



Computing the Shortest Path

- ❑ Example of results:



Directions

From Stop 1 To Stop 2	(Node IDs: 4475562/3748483)		
Start	South on MURPHY RD	1.1 Miles	(1.1 Miles)
Turn Right	South on SH0078	15.8 Miles	(16.9 Miles)
Continue	West on IH0030	2.2 Miles	(19.1 Miles)
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Continue	South on IH0035W	.1 Miles	(77.1 Miles)
Continue	South on IH0035	12.2 Miles	(89.3 Miles)
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Continue	South on SH0123	10.0 Miles	(278.2 Miles)

Planning for the future

Planning for the future

- Our tool **can help to plan the future transportation of wind turbine components.**

- We **predict how much wind power energy will be installed** in the state each year from 2016 to 2025.

- Then we use those predictions to:

  - **compute the number of turbines to be installed** and

  - **recommend the best way to transport them** over the state roadway network.

Prediction Method

1) **Texas** was **divided** into several **census block groups**.

2) For each zone, **information on several attributes** that may **impact the number of wind farms installed** per year was collected.
   - distance from the centroid of each zone to the nearest urban road,
   - distance from the centroid of each zone to the nearest primary electric transmission line,
   - wind power potential of each zone.

3) Based on information available online, **an estimate of the amount of wind power energy 'installed' each year** (from 1996 to 2015) in each zone was made.

4) One record was created in our estimation sample for each year and each zone and the **installed wind power energy was appended**, as well as the other zone characteristics.

5) **A regression model** was estimated using the records generated in the previous step.

6) The parameters estimated in Step 5 were used to **predict the amount of wind power energy that will be installed each year (from 2016 to 2025) in each zone.**

Data Sources

- Our base map is the **U.S. census shapefile with the 15,811 census block groups in Texas.**

- The 2013 US Geological Survey provides a **dataset identifying windmill locations across the U.S**

- 7,715 valid windmill locations available in Texas with their exact latitude and longitude.

- **Wind farms constructed in 2014 and 2015 were addressed separately:**
  - Available information about facility, county, and company name for the announced wind farms.
  - Search for any news articles or report pertaining to the proposed location of these wind farms.
  - Once there was some local information (e.g., 40 miles northeast of Amarillo), we used Google Maps to determine the latitude and longitude of that proposed facility.

Data Sources (cont.)

- The map with the **wind power potential in Texas, quantified in the form of wind power class (WPC) scores**, was obtained from the National Renewable Energy Laboratory.

- WPC is a way to **classify wind resources based on wind power density and wind speed.**

- A shapefile with **all the primary transmission lines in Texas** was created.

- As **transmission line locations have changed over time** we constructed two different transmission line maps: one for years preceding 2013 and another for 2013 and later.

Data Sources (cont.)

- We considered the **Competitive Renewable Energy Zones (CREZ)** already defined by (Public Utility Commission) PUC as **potential future location sites for wind farms.**

- PUC identified the top 25 wind regions based on wind capacity and **grouped them into four groups: North Texas, West Texas, Central Texas, and the Panhandle.**

- We digitized the CREZ map and **classified each of our zones into one of these four areas.**

Factors responsible for site selection and wind power energy generation

$$y_{q,t,t-1} = y_{q,t} - y_{qt-1} = Constant + \beta_{GDP} * GDP_{t,t-1} + \beta_{RPS} * RPS_t$$
$$+\beta_{DLines} * \left(DLines_{q,t} - DLines_{q,t-1}\right) + \sum_{i=1}^{4} \beta_{Zcat}^{i} * Zcat_q^i$$
$$+\beta_w * w_{q,t-1,t-2} + \beta_{wNC} * Zcat_q^{non\_CT} * w_{q,t-1,t-2}$$

Variable	Coeff.	t-stat
Constant	-4.331	-0.50*
$GDP_{t,t-1}$	0.958	2.82
$Dlines_{q,t}$-$Dlines_{q,t-1}$	-0.100	2.86
RPS_t	8.912	2.42
Dummy West Texas – Low WPC	-4.537	-2.65
Dummy West Texas – High WPC	-6.790	-2.57
Dummy North Texas	-0.461	-2.15
Dummy Panhandle	9.197	3.361
$w_{q,t-1,t-2}$	-0.227	-3.01
$w_{q,t-1,t-2}$ interacted with:		
Dummy non-Central Texas	0.055	1.85*
Adjusted R square	0.32	

Factors responsible for site selection and wind power energy generation

- **High Gross Domestic Product (GDP)** is related to **high consumption of energy.**
- **Wind farms** tend to be **located close to the electric transmission lines.**
- The introduction of the Senate Bill 20 of the **RPS in 2005 has had a positive impact on the amount of energy installed.**
- Of all the CREZs defined by PUC, **the zones located in West Texas will have fewer wind farms**.

Factors responsible for site selection and wind power energy generation

- **The Panhandle** will evidence the **highest amount of energy installed in the coming years.**
- Surprisingly, **a higher WCP is related to a smaller amount of wind power energy installed in West Texas.**
- West Texas area might be getting less popular for wind energy installations because the sites with high WPC in West Texas are already taken.
- Results suggest a type of **cyclical trend** in which a surge in wind farms in a zone in a certain year is followed by a decrease in the next year.
- This **cyclical trend is more pronounced for** the **Central Texas** category

Prediction of Wind Power Energy Installed

- **We applied our model to each zone year by year through 2025**.
  - We keep constant the zone characteristics.
  - We **vary** the percentage change of **GDP following the predictions available on the World Bank** website.
- The total **amount of wind energy installed is predicted to slightly increase with time.**

Prediction of Wind Power Energy Installed

Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Percentage of change of the U.S. GDP from previous year	3.28	2.97	2.76	2.64	2.56	2.50	2.47	2.45	2.42	2.40
Total wind power energy installed (MW)	5,660	6,954	8,330	9,610	10,882	12,355	13,424	14,893	16,462	18,030
Average wind power energy installed (MW)	55.0	72.8	73.5	105.1	107.7	132.3	132.9	145.4	166.9	180.5
Maximum wind power energy installed (MW)	650.8	759.0	801.5	891.6	932.0	1,023.5	1,119.1	1,175.8	1,227.3	1,287.7

Visualization of our Prediction

- A map indicating the **amount of energy installed** each year in each census block group: http://arcg.is/1OYv8c0
- A map with the **number of turbines installed :** http://arcg.is/1jUvRzW (Considering the most common wind turbine in Texas: capacity 1.5MW).
- A map of **percentage of land used for wind farms:** http://arcg.is/1OnpehS. (assuming that 1.5MW turbines use a space of 5 hectares).

Route Plan Development

- The **most common wind turbine installed in Texas has a capacity of 1.5 MW**, so we assume that future turbines will have that capacity.

- Transporting the 1.5MW turbine **requires eight trucks with the following dimensions** (in terms of height and load, including the corresponding wind turbine components):

1) height 16’4’’ and weight 116 tons,
2) height 16’4’’ and weight 100 tons,
3) height 14’6’’ and weight 64.4 tons,
4) height 17’4’’ and weight 56 tons,
5) height 14’2’’ and weight 45.5 tons,
6) height 14’6’’ and weight 109 tons,
7) height 14’6’’ and weight 39 tons, and
8) height 14’ and weight 42.5 tons.

Route Plan Development

- An estimated **17% of the wind turbines are transported by rail.**

- **15% of the total wind energy installed in Texas is also installed in neighboring states** (New Mexico, Oklahoma, Arkansas, and Louisiana) and the related components are transported across Texas roads.

- The **shipping points (route origins) and their respective share** are:

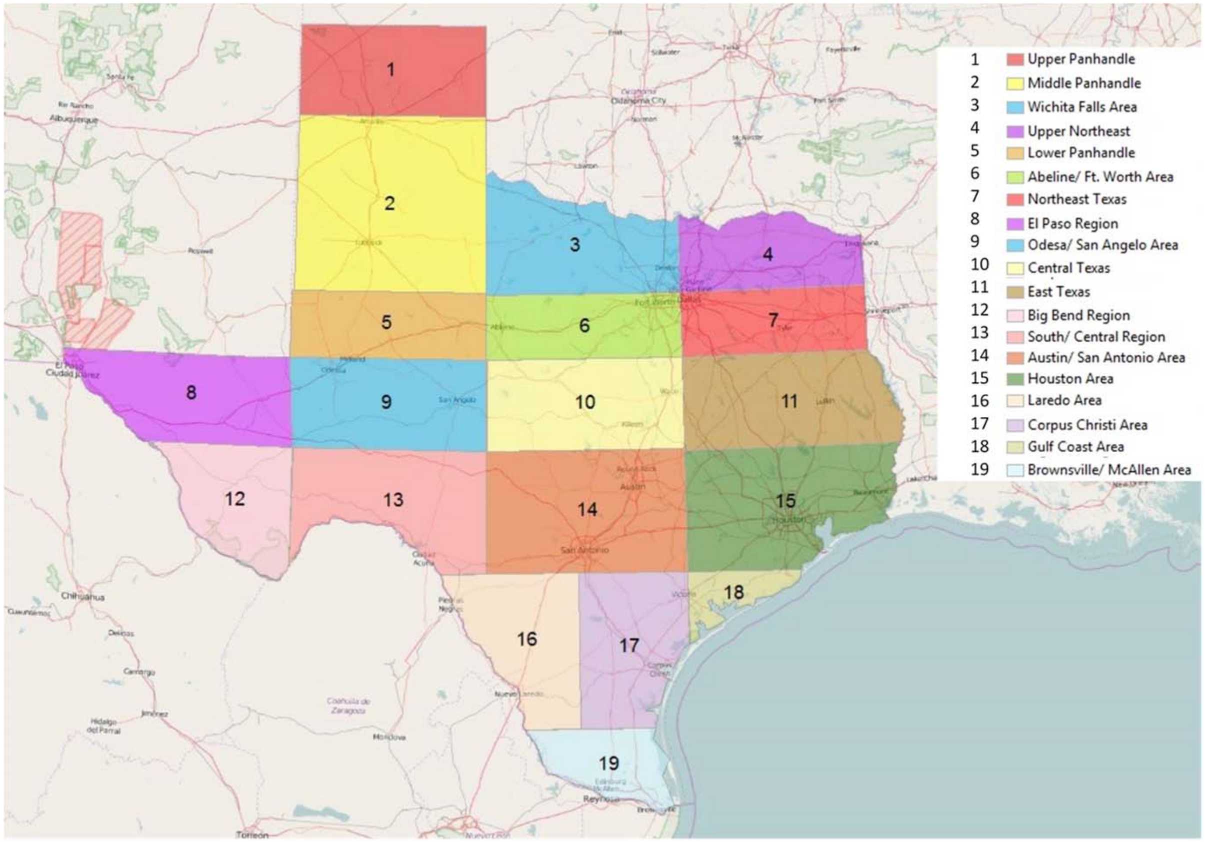
  - **Out of state:** Arkansas (1.9%), Louisiana (5.6%), New Mexico (13.0%), and Oklahoma (10.1%).

  - **Ports:** Houston (16.6%), Galveston (4.8%), Corpus Christi (14.4%), Freeport (12.1%), and Beaumont (2.7%).

  - **In-state production:** Coleman (14.4%) and Fort Worth (4.4%).

Route Plan Development

- **Sub-division of 19 smaller zones** based on **possible trip origins** and **possible trip destinations.**



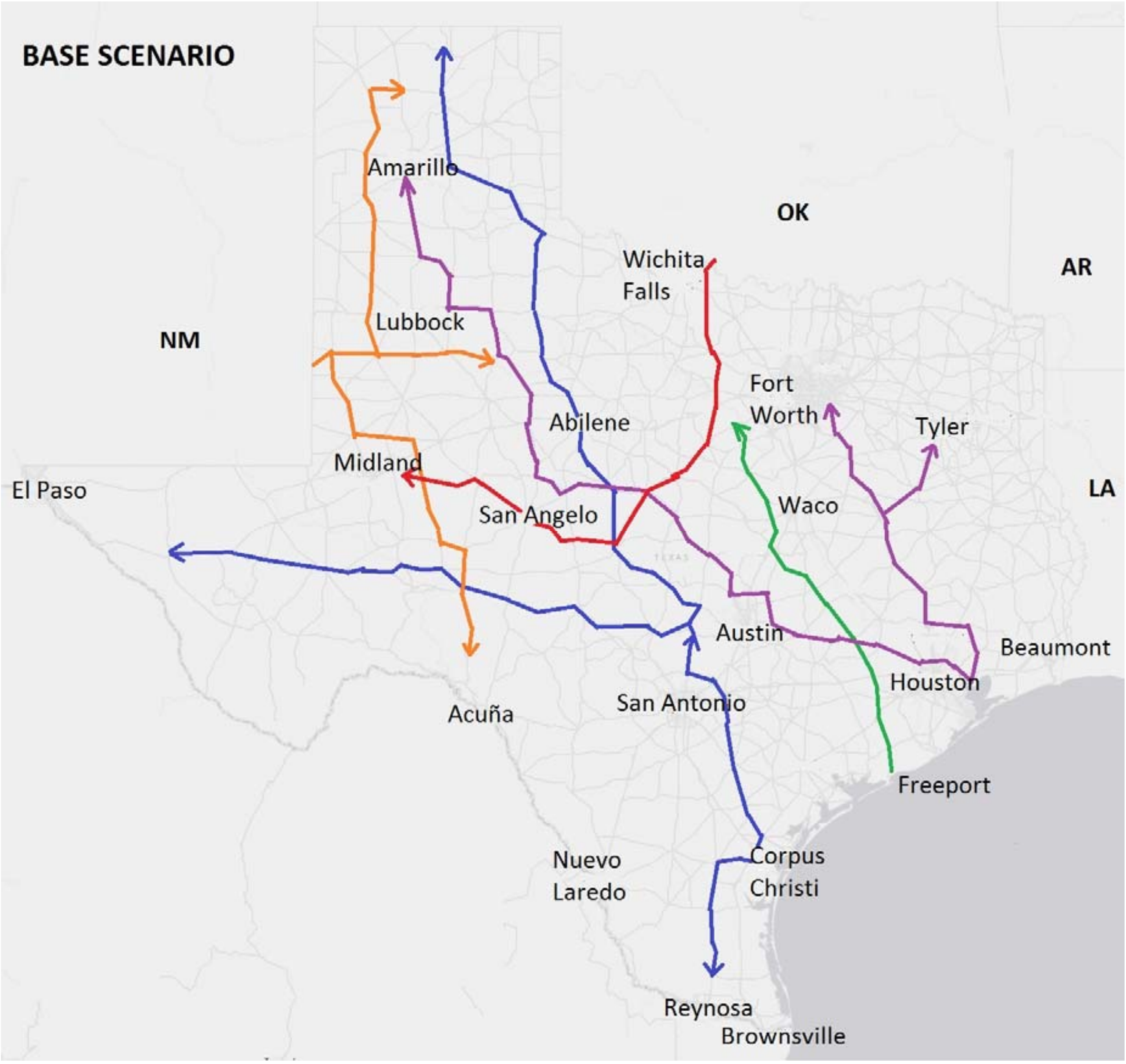
Route Plan Development (cont.)

- Using our tool, **we found the shortest path (in terms of our composite score) between each pair of zones** and then we loaded on those paths the necessary trucks to satisfy the demand.

- **We studied in detail each zone to identify the end and beginning of each path**, paying attention to shipping points and the nearby area of the potential wind farms.

- **We repeat this process for every year** from 2016 to 2025.

Route Plan


BASE SCENARIO
Amarillo
OK
Wichita
Falls
AR
NM
Lubbock
Fort
Worth
Tyler
Abilene
Midland
LA
El Paso
San Angelo
Waco
Austin
Beaumont
Houston
San Antonio
Acuña
Freeport
Nuevo
Laredo
Corpus
Christi
Reynosa
Brownsville

"What-if" Analysis

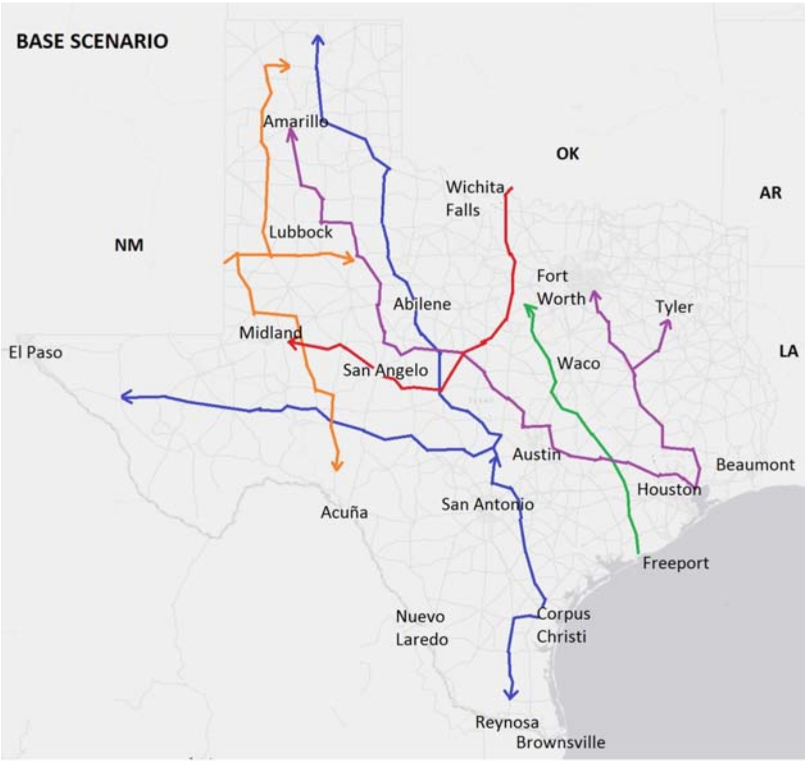
- **Scenario A:** we replicated the prediction process to create a scenario in which **three critical points are "relaxed"** (we changed the vertical clearance of three specific bridges from 16 feet to 17 feet).

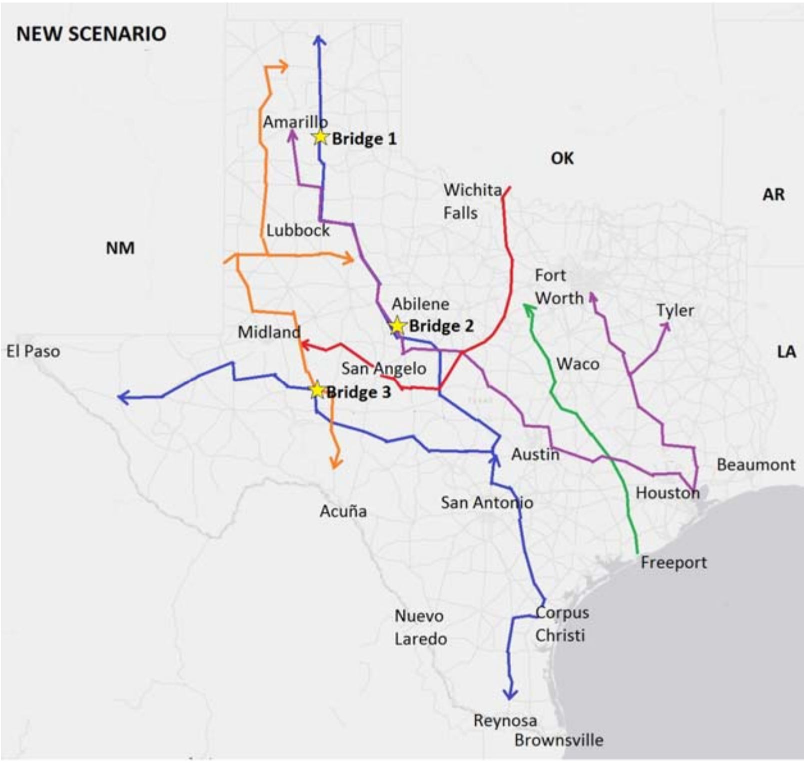
- **The total composite score is 23% lower** than the total composite score of the base scenario.

- **An investment in upgrading those three bridges can lead to a significant saving** in terms of distance traveled, number of turns, and pavement damage

- Those are key elements that **all the stakeholders involved** (manufacturers, shippers, public authorities, and the general public) **would like to minimize.**

Scenario A Results





23% CS

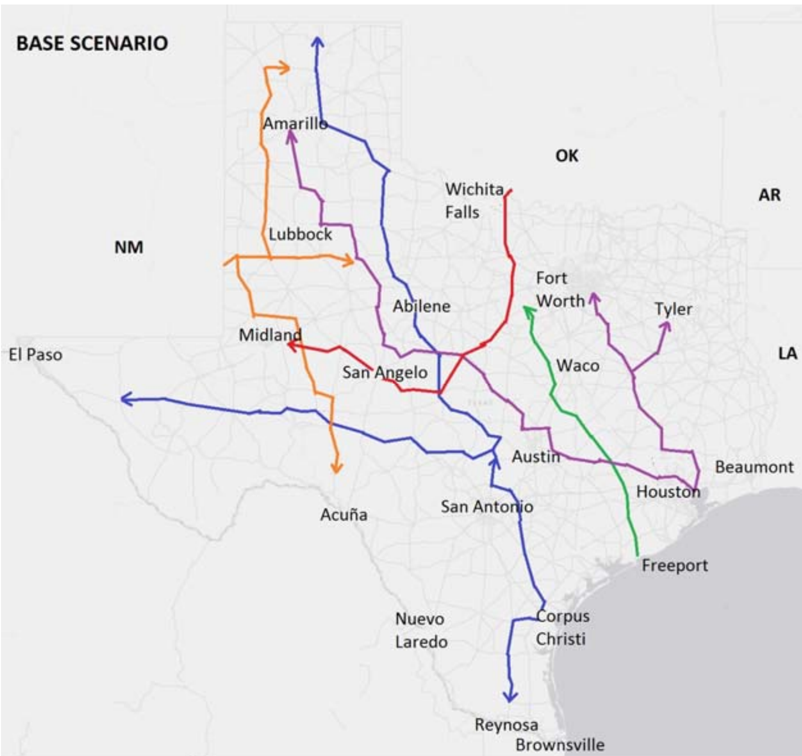
"What-if" Analysis

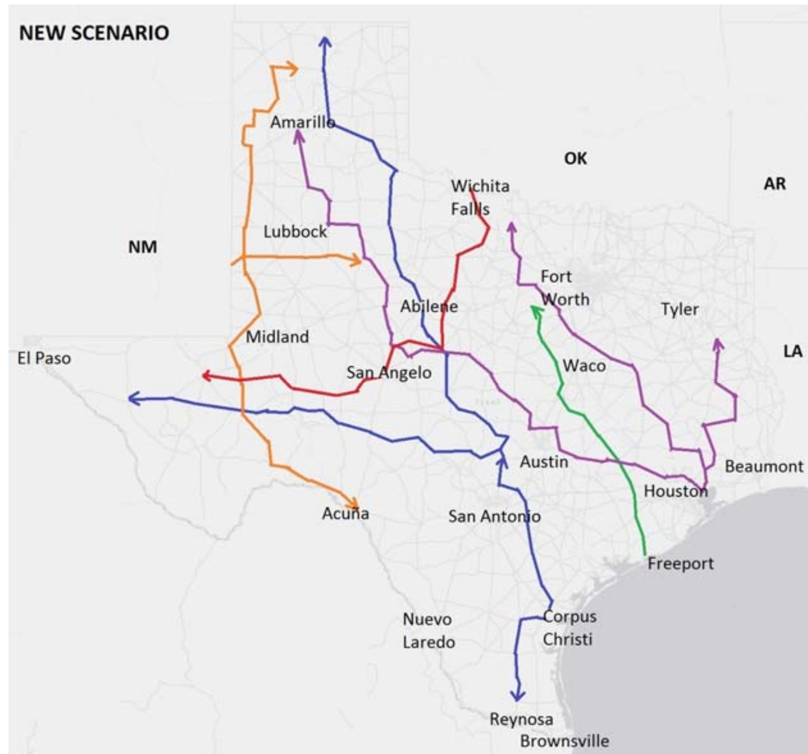
- **Scenario B:** We follow the predictions of several studies that have proposed even **bigger turbines in the future.**

- We replicated the prediction process **with the size of the turbine (and the associated trucks) 10% bigger than our original assumption** for the years 2020 to 2025

- **The total composite score is 15% higher** than the total composite score of the base scenario.

Scenario B Results





15%
CS

Conclusions

- **Texas** will doubtless see a **significant increase in renewable energy production facilities.**

- **The transport of wind turbine components creates increased loads** on rural roads and bridges, which are typically not designed for such loads.

- Repairing and upgrading the roadway network presents **challenges for TxDOT**, which must **operate under budget constraints**.

- We propose a **plan for mitigating the impacts of wind energy projects on roads**, while **facilitating the development of these projects** in and around Texas.

Conclusions (cont.)

- We created **a methodology and an associated operational planning tool** that can be used to:
  - **propose optimal route plans for wind turbine components** transported on Texas routes and
  - **develop recommendations for planning construction of new wind farms** as well as generating maintenance and upgrade strategies for the roads.

- **We predicted the amount of energy installed in Texas from 2016 to 2025** and we used that prediction to **create a plan for the routes**.

- The tool creates a route by **optimizing the travel distance, number of turns, and potential pavement damage**, **while checking restrictions** due to bridge clearances, postings, and pavement conditions.

Conclusions (cont.)

- Our methodology and associated tool have the capability of performing **"what-if" analysis.**

- The best routes are found for our base scenario, which we then compared with another possible scenario, generating recommendations and analyzing possible trends in the wind energy production industry.

- Our methodology can be used to

  - **test different changes on the Texas roads infrastructure** and their effect on the transportation of wind turbine components.

  - **test how the Texas transportation infrastructure could handle changes in the wind energy production industry**, such as new technology turbines with new dimensions.

THE UNIVERSITY OF TEXAS AT AUSTIN
CENTER FOR TRANSPORTATION RESEARCH

Questions?