Final Report

for the

Arkansas Commercial Truck Safety and Education Program (ACTSEP)

Prioritizing Solutions for Truck Parking: ParkSIM User Manual

By

Sarah Vavrik Hernandez
Department of Civil Engineering

Sarah G. Nurre
Department of Industrial Engineering

Marjan Asadinia, Research Assistant
Taslima Akter, Research Assistant
Amin Asadi, Research Assistant
Sharif Mahmud, Research Assistant
Annabelle LaCrue, Research Assistant

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UNIVERSITY OF
ARKANSAS

Disclaimer:

This report represents the views of the authors, who are responsible for the factual accuracy of the information presented herein. The views expressed here do not necessarily reflect the views of the Arkansas Department of Transportation (ARDOT).

The model presented in this document, ParkSIM, is a tool to estimate truck parking demand based on assumed usage patterns, facility capacities, and driver behavior. The results of ParkSIM do not necessarily reflect observed truck parking usage patterns.

Table of Contents

List of Tables

List of Figures

Overview

Finding safe and available truck parking is consistently ranked among the critical issues facing the trucking industry. This report presents an agent-based simulation and optimization approach called ParkSIM to model truck movements and driver behaviors to determine feasible locations for truck parking facility capacity expansions across a state. The simulation model considers daily and cumulative Hours of Service (HOS) regulations set by the Federal Motor Carrier Safety Administration (FMCSA). Observed historical truck movement GPS data is used to generate agent profiles that capture truck origins, necessary stops, destinations, and historical parking behaviors. The simulation allows estimation of parking facility utilization over time by identifying where, when, and how long truck drivers rest. Facility utilization patterns are then fed into a maximal coverage capacitated multiple facility location optimization model to deduce parking expansion locations given budgetary restrictions. The simulation and optimization approach is combined in a user adaptable decision support tool called ParkSIM.

The ParkSIM model was applied to 168 existing and 42 proposed candidate sites. Under budgets of $1M to $11M, ParkSIM recommends adding capacity to between 5 and 35 existing parking facilities in increments of two to 28 parking spaces. This distributed capacity expansion solution would address up to 88% of unmet demand for truck parking.   Above a budget of $11M, ParkSIM recommends building new facilities in West Memphis, Searcy, and Blytheville, in addition to various capacity expansions at existing facilities. Each new facility is recommended to have 20 parking spaces. Costs for expansion and new builds were derived from ARDOT and proprietary construction cost databases and potential new facility locations were found in the Arkansas Economic Development Commission (AEDC) database. Overall, the ParkSIM tool allows decision makers to evaluate current and future truck parking conditions with the ability it investigate anticipated changes to HOS, parking capacity, and parking demand.

Introduction

Truck drivers and the trucking industry consistently report concerns of driver safety due to the lack of available and safe truck parking in the US. More than 75% of drivers struggle to find safe and available parking, which is exacerbated during nighttime hours when longer rest breaks are typically taken, with 90% of drivers reporting safety concerns attributed to parking shortages (FHWA 2015). Parking shortages force drivers to either park illegally on ramps and shoulders or violate HOS rules by driving past the allotted hours to search for safe and legal parking. With the recent mandate for Electronic Logging Devices to track HOS requirements, drivers have seen escalating demand for parking during peak hours (ATRI 2016).

A solution to alleviate truck parking shortages is to add capacity to existing parking facilities and/or build new parking facilities. Due to limited budgets, state transportation agencies must prioritize infrastructure capacity expansion projects and thus tend to invest in the most overcrowded parking facilities which can be the most expensive projects. However, this approach ignores the inherent

interconnectedness of truck parking behaviors and usage patterns. To make more informed investment decisions with larger impacts, agencies need data on when and how facilities are used and to what degree those investments may impact overall parking shortages and usage. Therefore, in this report, an agent-based simulation and optimization approach was developed to serve as a policy and decision support tool to guide strategic investment in statewide truck parking infrastructure.

Model Architecture

ParkSIM is designed as an agent-based simulation and optimization tool (**Figure 1**). The approach is divided into two sequential steps: simulation and optimization. Briefly, the simulation models driver movements and parking demand patterns and estimates hourly parking facility usage under a given set of HOS rules and facility locations and capacities. The optimization then identifies where to expand existing facilities or establish new facilities given input budgets.

Simulation
- NetLogo GIS Interface
- Calibrated with truck GPS data
- Models truck drive and rest behaviors
- Drivers modeled as risk takers or risk averse to allow flexible parking decisions.
- Determines parking facility usage rates by time of day and day of week

Optimization
- R solver enabled and integrated in NetLogo user interface
- Considers user-specified total budget
- References unique facility upgrade and new facility construction costs
- Determines recommendations for parking capacity improvement projects

Figure 1. ParkSIM Model Framework

Agent-based modeling and simulation (ABMS) is a powerful technique to model complex systems composed of interacting, autonomous "agents". An agent can be defined as an independent component (e.g., individual) that can follow decision rules and adapt their behavior based on changes in their environment. The primary characteristics of an agent is that it can make independent decisions. In complex problems, local information is available to an agent, systems are decentralized, and agents typically interact with a subset of other agents (agent's neighbors). In short, ABMS is a way of modeling complex problems and can provide important insight into the dynamics of the real-world systems.

There are several ABMS tools available such as Mason, Repast, StarLogo, and NetlLogo. The research team selected NetLogo as an agent-based simulator due to usability, ease of learning, need for sophisticated capabilities to connect to databases, graphical user interfaces, and GIS integration. NetLogo is a programmable modeling environment for simulating natural and social phenomena. Moreover, it is particularly well suited for modeling complex systems developing over time. This makes it possible to explore the connection between the micro-level behavior of individuals and the macro-level patterns that emerge from their interaction.

In the agent-based simulation, the main agents are trucks and parking facilities, each is assigned a set of static and dynamic attributes. Truck agent behaviors, including decisions on when, where, and for how long to drive and/or rest are derived from HOS rules. The problem focuses on long-haul trucking operations (multi-state, multi-day) as these are the drivers who seek overnight parking. Thus, truck agents are assigned a seven-day driving profile that was derived from real, observed historical truck GPS data. Then, truck agents navigate from a preassigned origin to a preassigned destination, making decisions to rest (choose an off-duty status) or continue to drive or work (choose an on-duty status) based on HOS adherence behavior. Once a truck agent is generated, the remaining driving and rest decisions are derived from their assigned historical profiles and historical data fit to distributions representing, by time of day and location, how long drivers drive and rest. Two types of truck agents were programmed to account for HOS adherence: risk-takers and risk-averse. Characteristics such as how soon to start looking for parking relative to upcoming duty-status changes or what type of parking to seek (legal in a facility, on a ramp) are tied to risk.

Parking agents are characterized by their capacity and location (static) and utilization (dynamic). When a parking facility reaches capacity (overcapacity), risk-taking drivers may park on nearby ramps or roads while risk-averse drivers will continue to seek legal parking at a downstream facility. Parking facility agents are initialized with non-zero usage based on historical truck GPS data.

The simulation allows a user to input percentage of risk-averse drivers, HOS daily driving hour limits, and locations and capacities of existing and future facilities. Thus, along with the GIS interface to show truck movements and facility usage, the simulation is flexible to serve as a policy and decision support tool.

Following the simulation, an optimization model proposes a cost-effective capacity expansion solution under a specified budget, e.g., a list of parking locations, their proposed type (amenity considerations like fuel, showers, etc.), and amount of added capacity. Specifically, the location model uses as input the overcapacity estimates from the simulation and candidate facilities (existing and new facilities) with different costs and service levels (no service, partial service with fuel and restrooms, and full service with food, restrooms, and fuel). The facility costs used in the optimization model were generated from construction cost estimates published by ARDOT and in RSMeans, a proprietary construction cost database. The total cost of a facility is based on unit costs of site clearing, paving, building infrastructure, and amenities such as fuel stations, lighting, restrooms, showers, etc.. Each new facility cost is calculated at three service levels and depends on the size of the lot.

The locations of new facilities are based on a search of commercial properties listed in the Arkansas Economic Development Commission (AEDC) database. Selected properties met the criteria for zoning, lot size, and proximity to the interstate. The optimization model then determines where to establish new parking capacity and assigns the overcapacity estimates to these newly established locations if they reside within a given search radius (i.e., driving distance) to maximize the percentage assigned.

ParkSIM Manual

The purpose of developing the ParkSIM model interface is to offer a user-friendly tool to track truck parking facility usage, note locations and degree of overcrowding, and enable decision makers to prioritize high impact, cost-effective truck parking improvements. The broader impact of the ParkSIM tool is to improve safety of commercial trucking and goods movement in Arkansas.

This report provides a detailed description of the ParkSIM operating interface with step-by-step instructions on how to operate the interface. With the help of this interface, users can adjust HOS criteria (daily driving hours), total investment budget, average highway speed, and assumed percentage of risk-taking behaviors (e.g., how often drivers may choose to park on ramps or shoulders). The tunable parameters allow the user to estimate parking demand under different scenarios that reflect changes to HOS policy, compliance, and parking capacity. Additionally, the input files that specify the locations and capacity of truck stops and rest areas (existing and new) can be changed by the user. In this way, ParkSIM serves as a decision support tool.

ParkSIM outputs a set of recommendations for parking facility investments under a user specified budget. The recommendations describe how much unmet demand (overcapacity) can be met by the providing additional capacity at existing parking facilities and at new facilities. The results detail the number of parking spaces to be added at each facility and how much the improvements will cost per facility. Lastly, the results state which overcrowded facilities benefit from improvements. Users can download the simulation result files to view more detailed statistics on (a) truck parking facility usage by time of day and day of week and (b) truck driving and rest patterns including HOS and parking violations.

The simulation model can be run for up to two weeks with time increments of 10 minutes. On a computer running Windows 10 with 16GB of RAM and an Intel Core i7-8750H processor, a two-week simulation scenario and optimization run takes approximately 14.5 hours.

Summary of Model Results

The model was applied to the state of Arkansas. The simulation model uses historical truck GPS data to define truck agent profiles of weekly driving histories and parking facility usage initialization. The road network used in the study was gathered from the Arkansas Statewide Travel Demand Model. Existing parking facility locations were gathered from the Arkansas Department of Transportation (ARDOT)

overnight truck parking study. New facility locations were selected based on commercial property databases that fit the criteria for appropriate zoning, proximity to highways, and size of parcel.

Reasonableness checks of the parking usage pattern results by the time of day, day of week, and location show agreement with direct observations of overnight parking usage patterns gathered by the ARDOT (See *Appendix F: Overnight Observation Comparisons*). Further, rates of HOS violations and illegal parking also show agreement with national statistics reported by FMCSA and the National Highway Transportation Safety Administration (NHTSA). The GIS-enabled interface allows the model to be implemented as an effective decision support tool.

The following two sections describe the results of repeated runs of ParkSIM under the following user-specified parameters and inputs:

1. HOS daily driving limit of 11 hours, e.g., current HOS regulation.
2. Assumed highway speed limit of 70 mph.
3. Percent of risk-taking drivers was 20%.
4. Budget of $1M to $16Million.
5. 168 existing facilities.
6. 42 possible new facility locations.

Existing Truck Parking Facility Usage Patterns

In total there are 168 existing parking facilities accounting for 6,887 truck parking spaces (total capacity), and 42 new facilities with maximum possible capacity of 3,160. Facility expansion costs for no service facilities range from $800,000 to $1.1 million depending on size of the facility. The full-service facilities cost ranges from $11M to $14M.

Applying ParkSIM under the above-mentioned criteria shows that overcrowding (more than 100% use of capacity) occurs at 23 of the 168 facilities in Arkansas with many significant overcrowding issues along the interstates (**Figure 2**). On average, across all facilities, usage is approximately 48% of total capacity. Although this seemingly shows provision of adequate capacity, overcrowding at key facilities is observed.
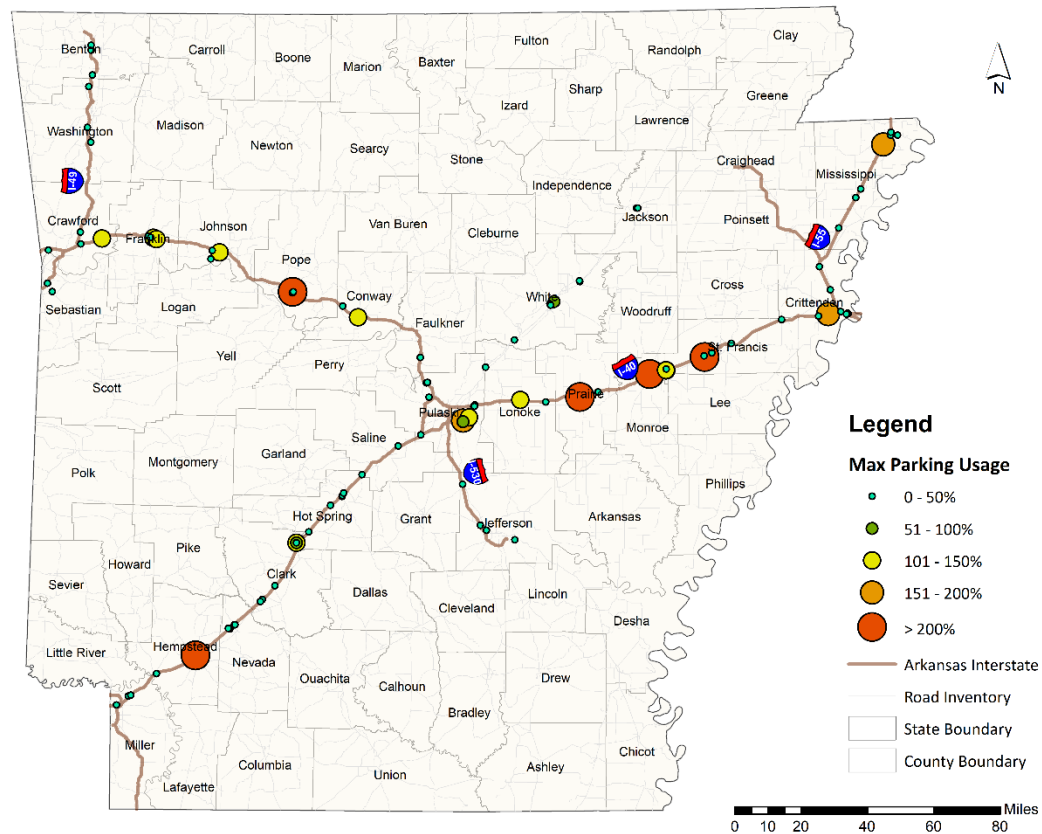
Figure 2. ParkSIM Estimate of Parking Overcrowding in Arkansas

Recommended Parking Facility Capacity Improvements

ParkSIM was applied to the 168 existing and 42 new facilities in Arkansas. The simulation was run with the abovementioned settings. The optimization model was applied using budgets of $1M to $16M with increments of $1M to gather recommendations for what facilities to build and/or expand and how many parking spaces to add at each facility.

Overall, the results show that with budgets less than $11 million, the model recommends adding incremental capacity (7-28 spaces each) at existing parking facilities, including public and private facilities. A budget over $11M allows for the addition of <u>new facilities</u>, specifically at the following locations:

1. West Memphis on I-40 near Bolling Lane (facility number CS14378, see Appendix A), 20 spaces
2. Searcy on Benton Ave./HWY 267 (CS1244), 20 spaces
3. Blytheville on I-55 and US HWY 61 (CS2252), 20 spaces

Detailed results show that until the budget exceeds $11M, no new facilities are recommended (**Table 1**). Instead, the model recommends adding capacity to existing facilities. For example, with a budget of

$1M, the model recommends adding capacity to five existing parking facilities to provide an additional 26 parking spaces. Under this recommendation, only 9.4% of the trucks looking for but unable to find legal parking are accommodated by the expanded facilities, e.g., referred to as the average percent of met demand. As the budget increases to $11M, capacity expansions are recommended at 35 facilities for a total of 268 additional parking spaces. This solution accommodates 88.1% of the trucks looking for but unable to find legal parking.

Under each budget amount, the set of facilities at which to add parking spaces (capacity) and new facilities to build differs (**Table 2**). The number of additional spaces to add to existing facilities ranges from two spaces to 50 spaces, with a median of five spaces. Several locations are consistently recommended for expansion, e.g., locations that are recommended across multiple budget amounts. For example, with a budget of $1M, the following capacity expansions are recommended:

1. White River Rest Area on I-40 at Exit 199 near Carlisle (114), 2 additional spaces
2. West Memphis Welcome Area on I-55 at Exit 278 (481), 2 additional spaces
3. Fast Market (Citgo) on I-55 at Exit 14 near Marion (AR051), 10 additional spaces
4. Colt's Quick Draw (Mobile) on US HWY 65 (1/2-mile S of AR HWY 25 Junction) in Greenbriar (AR901), 4 additional spaces
5. Bald Knob Travel Center on US HWY 67/167 at Exit 55 (AR917), 8 additional spaces

Of the five above listed expansions, the site near Marion is recommended for expansion in under all budget solutions. The other four sites appear in at least 14 of the 16 budget levels. This suggests these sites are critical for accommodating parking overcrowding across the state.

Table 1. Parking capacity recommendations for different budgets

Available Budget	Number of new facilities to be built	Number of existing facilities to add capacity	Number of added parking spaces	Average met demand (%)
$1 M	0	5	26	9.4
$2 M	0	7	52	18.7
$3 M	0	9	77	27.7
$4 M	0	12	102	36.7
$5 M	0	16	127	45.7
$6 M	0	20	152	54.7
$7 M	0	22	176	63.3
$8 M	0	27	198	70.9
$9 M	0	26	221	79.5
$10 M	0	31	244	86.7
$11 M	0	35	268	88.1

Table 2. Recommendations for capacity additions at existing facilities

Facility Name (ID)	Capacity Added (spaces)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Texarkana Welcome Center onI-30 Exit 7 Eastbound Parking (13)	7											✓			✓	✓	✓
Marion City Rest Area onI-40 Exit 274 Westbound Parking (45)	5							✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
White River Rest Area onI-40 Exit 199 Westbound Parking (114)	2	✓	✓	✓		✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓
Ozark Rest Area Westbound onI-40 Exit 36 Westbound Parking (139)	3				✓		✓	✓	✓	✓	✓	✓	✓		✓		
West Memphis Welcome Area onI-55 Exit 278 Southbound Parking (481)	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
JJ's Truck Stop onI-30 Exit 106 (Military Rd) (AR019)	50															✓	
65 - 81 Truck Stop (Citgo) on US 65-425 (3 mi S) & AR 81 (AR029)	10											✓		✓	✓		✓
Fast Market #36 (Citgo) onI-55 Exit 14 (CR 4 E) (AR051)	10	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Filling Station (Citgo) on US 65 & 800 N Bryant (AR057)	15											✓	✓		✓		✓
Sumac Mart (Valero) on4374 AR 7 S (AR062)	2		✓				✓	✓	✓	✓	✓		✓	✓			
Exit 44 Quick Mart onI-30 Exit 44 (US 371 S) (AR206)	24		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Pilot Travel Center #430 onI-40 Exit 84 (AR 331 S) (AR208)	28							✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Pit Stop (Shell) on AR 7 (3/4 mi S of US 278) (AR604)	12											✓					
Sweet Pea #401 onI-40 Exit 221 (AR 78 N) (AR616)	24					✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Missile Mart #08 (Mobil) on4050 US 167 N (AR727)	4											✓	✓				✓
Camp I-30 Truck Stop onI-30 Exit 2 (Loop 245 S) (AR777)	6											✓	✓	✓			
Jordan's Kwik Stop #6 (66) onI-30 Exit 78 (AR 7 N) (AR790)	2									✓	✓	✓	✓	✓			
Tiger Mart #102 (Exxon) on US 167 S & AR 14 (AR797)	3						✓	✓	✓	✓	✓		✓	✓			
Mapco Express #3154 onI-40 Exit 221 (AR 78 S) (AR806)	8									✓	✓	✓	✓	✓	✓	✓	✓
Gasoline Alley on US 65 & AR 9 (5 mi S of Clinton) (AR807)	1		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Powell's One Stop on5452 US 62 W & AR 103 S (AR822)	3																
Love's Travel Stop #271 onI-40 Exit 37 (US 219) (AR833)	4					✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Snappy Mart #23 (Exxon) onI-55 Exit 21 (AR 42 W) (AR839)	2				✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Family Stop #3 (66) on US 71 S (AR847)	2								✓				✓	✓	✓	✓	✓

ParkSIM User Manual

Facility (ID)	Capacity Added (spaces)	Available Budget (million $)															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Gas N Go (Valero) on US 62 W (AR848)	4														✓		✓
Gas Mart on2115 US 79 N (AR861)	3														✓		
Conoco 1 Stop on AR 1 Bypass & AR 1 Business (AR862)	3				✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Shell Truck Stop onI-55 Exit 48 (AR 140 E) (AR865)	8								✓		✓	✓	✓	✓	✓	✓	✓
Love's Travel Stop #275 onI-40 Exit 233 (AR 261 N) (AR868)	20									✓	✓	✓	✓	✓	✓	✓	✓
Snappy Mart # 7 (Exxon) on US 67-167 Exit 55 (US 167 N) (AR869)	6					✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Exxon Travel Center on US 67-167 Exit 16 B (AR 5) (AR870)	10				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Magnolia Travel Center (Valero) on10 US 82 W & US 371 (AR871)	10																✓
Exit 57 Auto/Truck Express (Shell) onI-40 Exit 57 (AR900)	7						✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Colt's Quick Draw (Mobil) on1075 US 65 N (1/2 mi S of AR 25 jct) (AR901)	4	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓
Hermitage Shell on149 US 63 Bypass (AR904)	5												✓			✓	
Cash's Travel Plaza (Citgo) on607 US 65 (1.5 mi N of US 165) (AR906)	7												✓				
Tobo's 66 onI-49 Exit 58 (CR 26) (AR908)	10				✓		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
Newport Truck Plaza (Exxon) on US 67 & AR 18 W (AR912)	10			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Corner Store #1796 (Valero) on I-440 Exit 5 (Fourche Dam Pike S) (AR914)	4								✓	✓	✓	✓	✓	✓	✓	✓	✓
Missile Mart #10 (Mobil) on3700 US 82 W (AR915)	5														✓		
Bald Knob Travel Center (66) on US 67-167 Exit 55 (US 167 N) (AR917)	8	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
8 Mile Store on US 64 E & AR 36 N (AR923)	1					✓		✓		✓	✓	✓		✓	✓	✓	
Big Red (Valero) on AR 5 & AR 16 (W junction) (AR927)	1								✓		✓	✓		✓	✓		
Corner Store #1789 (Valero) onI-30 Exit 98 B (US 270 N) (AR928)	5						✓	✓	✓	✓	✓	✓	✓	✓			✓
West 66 Food Mart (Valero) on1939 AR 66 W (AR938)	3												✓		✓	✓	
Stop N By #17 (Exxon) onI-55 Exit 63 (US 61 N) (AR941)	2					✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Red Mule Mart on1706 US 62-412 (AR943)	3												✓			✓	✓
Love's Travel Stop #607 on US 63 Exit 40 (AR952)	16			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Chapter 1: Getting Started with the Interface

Chapter 1 instructs the user on how to download and install ParkSIM including the programming tool, NetLogo, and access and operate the ParkSIM GIS-Interface.

1.1 What is ParkSIM?

ParkSIM is the integrated simulation and optimization model to determine where and how much capacity to add to existing and new truck parking facilities. ParkSIM is programmed using NetLogo. NetLogo is an open-source agent-based modeling tool developed by the Center for Connected Learning and Computer-Based Modeling at Northwestern University. NetLogo can be run on multiple-platforms (Mac, Windows, Linux, etc.) and is fully programmable.

The user of ParkSIM does not have to have any programming experience, only the ability to install software and libraries as directed in this manual. The following details are provided solely for documentation purposes. NetLogo allows programming of mobile agents and stationary agents. Mobile agents move around the environment, e.g., a truck; while static agents do not move, e.g., a parking facility. Both have static and dynamic attributes. Static attributes do not change over time, e.g., parking facility capacity, location, and name. Dynamic attributes change over time and are updated with each temporal progression of the simulation, e.g., location of a truck, hourly usage rate of a parking facility, duty status of truck.   NetLogo uses its own programming language called Logo which is similar to Scala and Java that allows the developer to program agents, build an interface, and import/export data. For ParkSIM, NetLogo version 6.1.1 was used.

Within the NetLogo interface, the display features line, bar, and scatter plots, sliders for simulation speed of display, labels, and map areas. NetLogo comes with Application Programming Interface (API) capabilities. These allow NetLogo to be embedded in other scripts or applications. Lastly, other programming tools and languages such as R can be called from the NetLogo script. R is used for the optimization model development.

1.2 Downloading NetLogo

1.2.1 System Requirements

ParkSIM was designed to run on most current computers. For Windows operating systems, ParkSIM runs on Windows 10, Windows 8, Windows 7 and Vista. For Mac, Mac OS X 10.8.3 or newer is required. Run time will vary with different computer configurations. For development and testing, ParkSIM was run with Windows 10 on a Dell laptop computer with 16GB of RAM and an Intel Core i7-8750H processor. With this configuration the simulation of two-weeks of truck movements completes in approximately 14 hours. The optimization model computes in approximately 0.5 hours.

1.2.2 Version Guides

There are 13 versions of NetLogo available starting with NetLogo 1.3.1 and currently at NetLogo 6.1.1. When downloading ParkSIM, the latest version of NetLogo (6.1.1) needs to also be downloaded following the instructions in the next sections.

1.2.3 Download NetLogo on macOS and Windows

To download NetLogo, visit https://ccl.northwestern.edu/netlogo/download.shtml. A webpage with a NetLogo download link will pop-up. Select the latest version of NetLogo (6.1.1). The system by default selects the most recent version, which is NetLogo 6.1.1 as of September 2020. To complete the download the user needs to enter their name, organization, and email address. This is to support usage statistics for the open-source software. Next, a selection menu will list available operating system download options **(Figure 3)**.
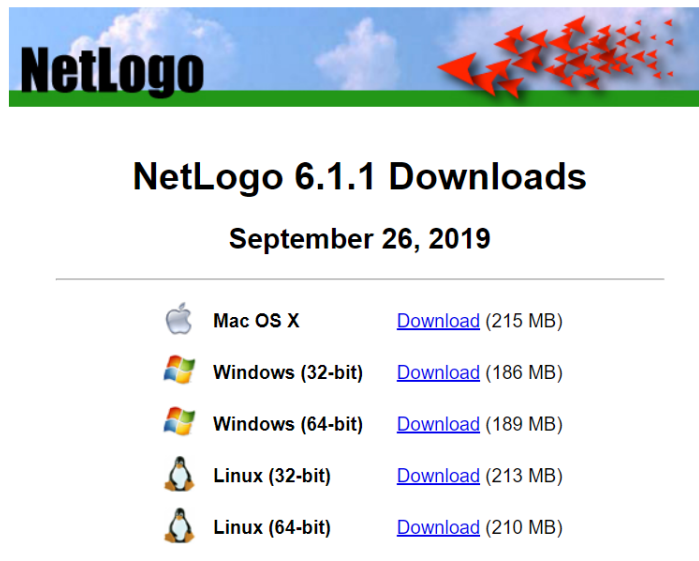
Figure 3. NetLogo Download Page for Various Computer Operating Systems

For Windows Users

Click on the link next to Windows (32-bit) or Windows (64-bit), depending on the user's computer operating system. The installation file, ***NetLogo-6.1.1-XX.msi***, will be downloaded. Here XX is the bit size: 32-bit or 64-bit.

For Mac Users

The installation file, ***NetLogo-6.1.1.dmg***, will be downloaded.

1.3 NetLogo Installation

This part of the manual describes how to install the downloaded NetLogo software on your computer.

1.3.1 Install NetLogo on Windows

First, open the downloaded NetLogo installation file and click Next (**Figure 4**). Next, select where to install NetLogo. If there is no preferred choice, keep the default destination folder. If there is a preference, click Change and a new window will pop-up. Click on the Look in the drop-down to find and select a destination folder. Click Ok after changing the destination folder then click Next. Next, when the *Ready to Install* dialog box appears, click Install (**Figure 5**). When the installation completes and the *Completed* dialogue box appears, click Finished (**Figure 6**).
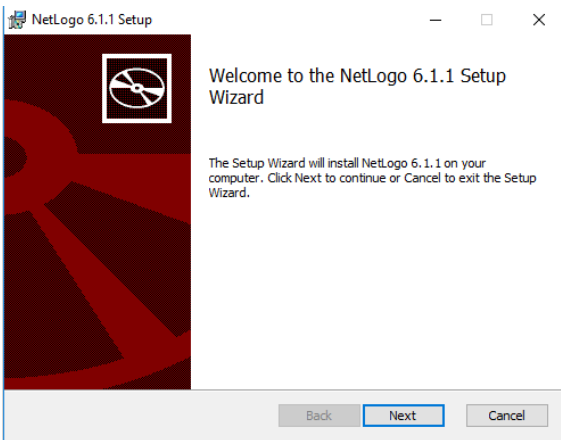
Figure 4. NetLogo Setup Wizard
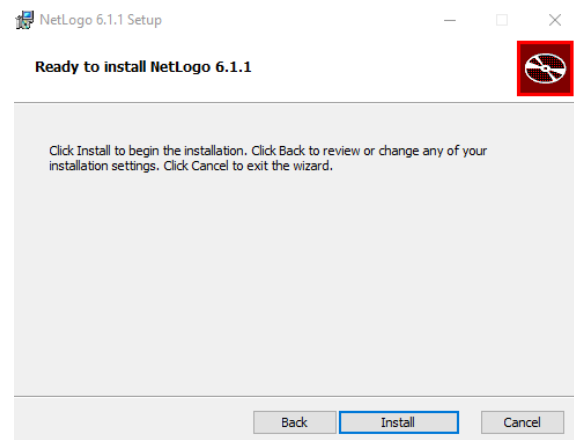
Figure 5. NetLogo Installation
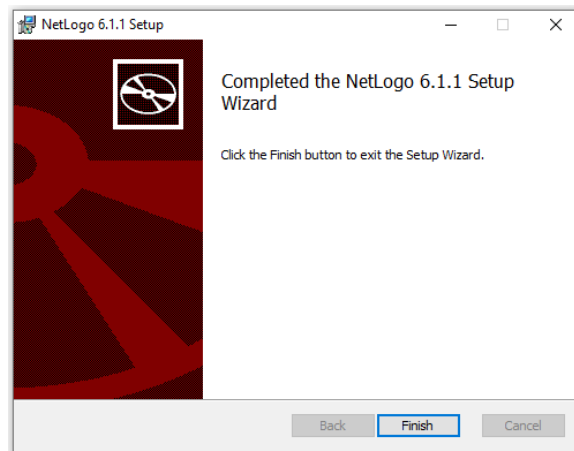
Figure 6. Exiting NetLogo Setup Wizard

1.3.2 Install NetLogo on MacOS

First, find the downloaded NetLgo-6.1.1.dmg file folder. Then, open the folder named NetLogo 6.1.1. Next, select all the files in the folder (**Figure 7**) by using keyboard shortcut "command" + "A". Now copy the files using "Command" + "C". Then go to the application folder and paste the copied files from the

ParkSIM User Manual

previous step using the keyboard shortcut "Command" + "V" (**Figure 8**). Finally, to access NetLogo, open the NetLogo 6.1.1.app file from the NetLogo 6.1.1 folder (**Figure 9**).
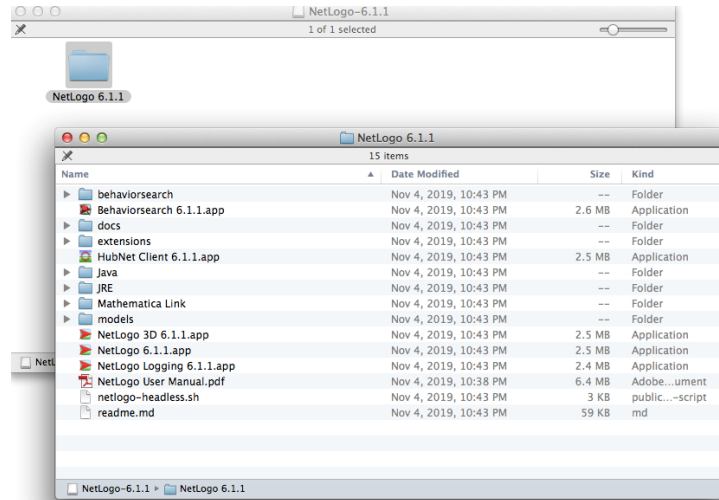
Figure 7. Accessing NetLogo Installation Files
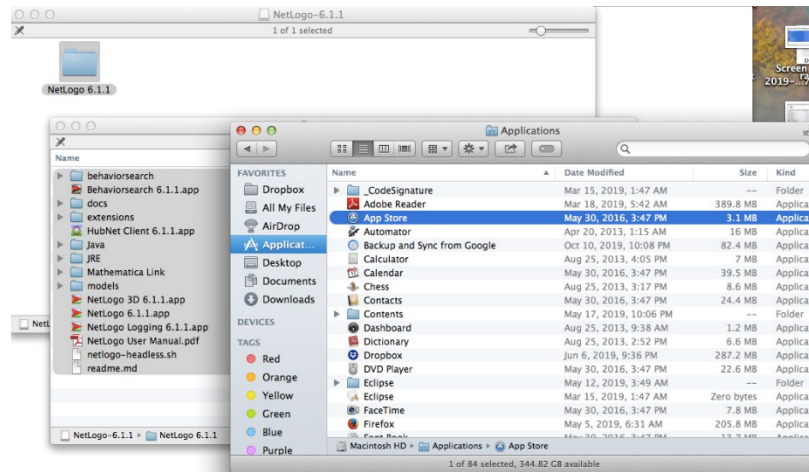
Figure 8. Copying NetLogo Installation
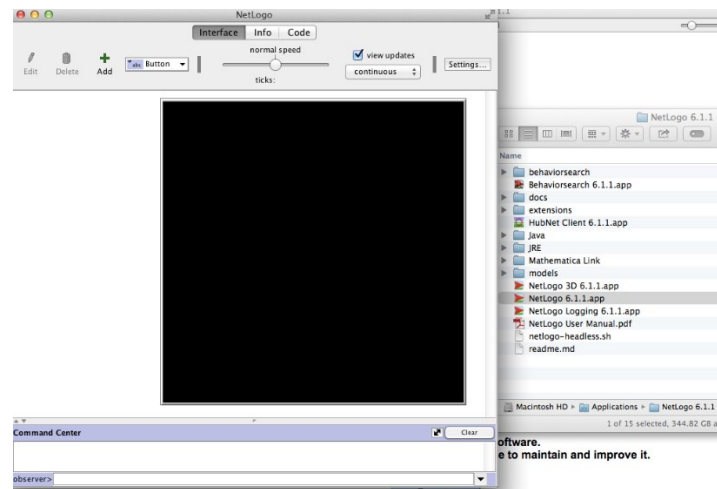
Figure 9. Accessing the NetLogo Interface

1.3.3 Configure the R Extension

ParkSIM requires the R Extension to run and calculate the final output of the model. R is an open-source computational tool. To use the R Extension, R version 3 or later must be installed on the computer. This simulation was written and tested using R version 4.0.2 (64-bit) for Windows. To install R, go to: https://cloud.r-project.org/.

First, open the downloaded installation file, select a language, and click OK. Read the license agreement and click Next. Select where the R file should be installed and click Next. The file does not have to be in the same location as NetLogo or ParkSIM. In the next window, choose which components of the software to install. It is recommended to keep each box on this screen checked. For Windows, confirm that the box next to the computer's operating system is checked. Then click Next. Next, select No when asked about custom options, then click Next. Finally, when asked what additional tasks the installer should perform, keep the default boxes checked, then click Next. The program is now installed.

Once you have installed R, the program can be opened by clicking the desktop icon (**Figure 10**), if you chose to create one during installation, or by typing "RGui" in the computer's search bar. Once opened, two packages will need to be installed: *rJava* and *JavaGD*. These packages allow R to communicate with NetLogo. This can be achieved by copying and pasting the following line into the console (**Figure 11**):

install.packages(c("rJava", "JavaGD"))

The R GUI will ask to pick a server to use for installation. The user should keep the default and click OK. The packages will now be installed. Click Yes for any dialog boxes that appear during installation.

Figure 10. R Desktop Logo
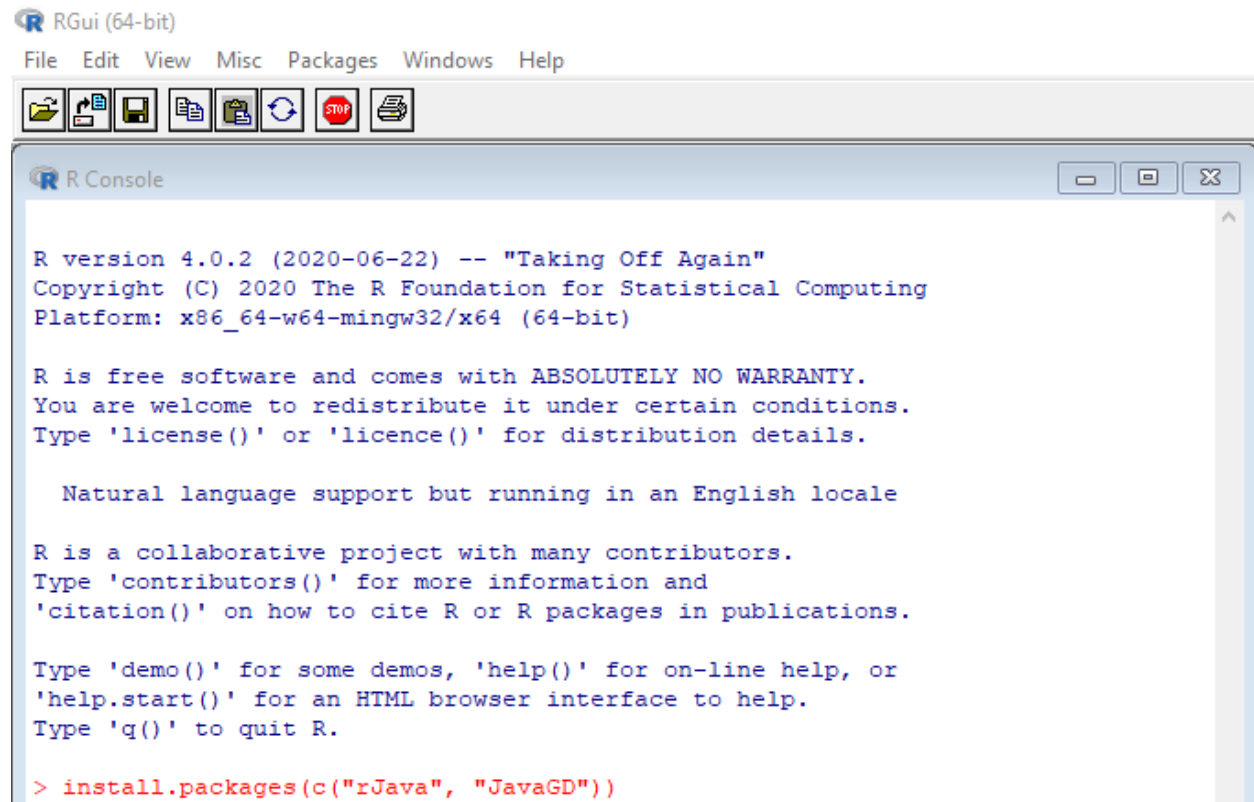
Figure 11. R GUI Package Installation

For Mac Users

At this point, users on Mac OS should be able to start and run the ParkSIM program. If any errors are received when attempting to setup or run ParkSIM, further configuration of the R extension may be required. Read the **Troubleshooting** below for tips on how to accomplish this, or visit the NetLogo website at https://ccl.northwestern.edu/netlogo/docs/r.html. Scroll to the heading labeled "Configuring the R extension" for further assistance.

For Windows Users

Windows requires an additional step to finalize the installation of the R extension. Users on Windows computers must add a variable to your system's PATH. First, open the *System Properties* window by typing Environment Variable into your computer's search bar (**Figure 12**). In the window that opens, click the button in the lower right labeled, "Environment variables…" (**Figure 13**).
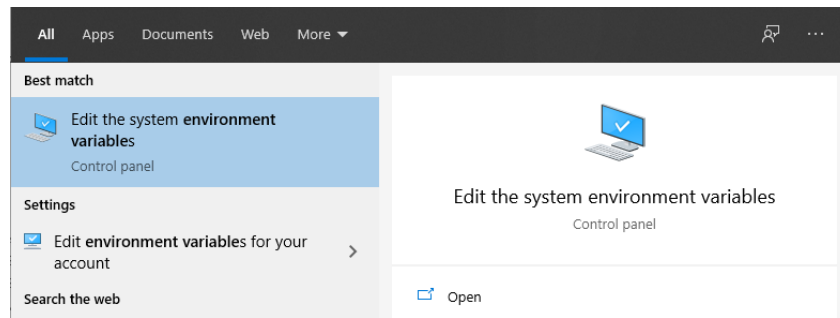
Figure 12. Editing System Variables to Configure R for Windows
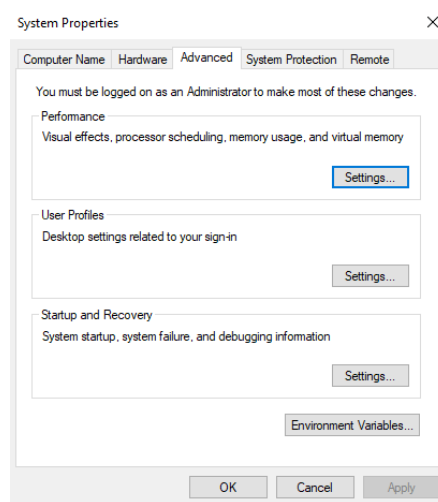
Figure 13. Setting Environmental Variables in Windows

Next, click on the variable labeled "Path" in the lower box (**Figure 14**) and then click the "Edit" button below that panel. Then, click the "New" button on the right side of the next window, and type one of the following locations into the new line (**Figure 15**). For users with 32-bit NetLogo installed, use "C:\Program Files\R\R-<version>\bin\i386\" and replace <version> with the version of R installed on your computer. For users with 64-bit NetLogo installed, use "C:\Program Files\R\R-<version>\bin\x64\" and replace <version> with the version of R installed on your computer.

ParkSIM User Manual
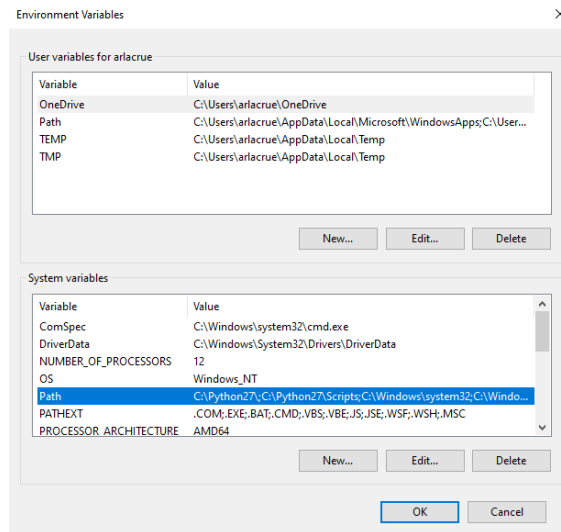
Figure 14. Selecting the Path Variable in Windows
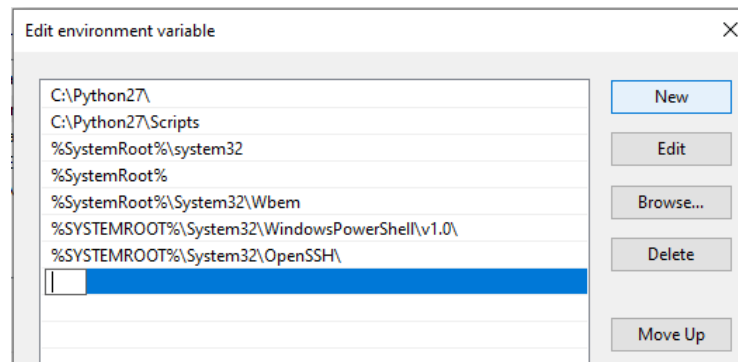
Figure 15. Inserting the Path variable for R Installation
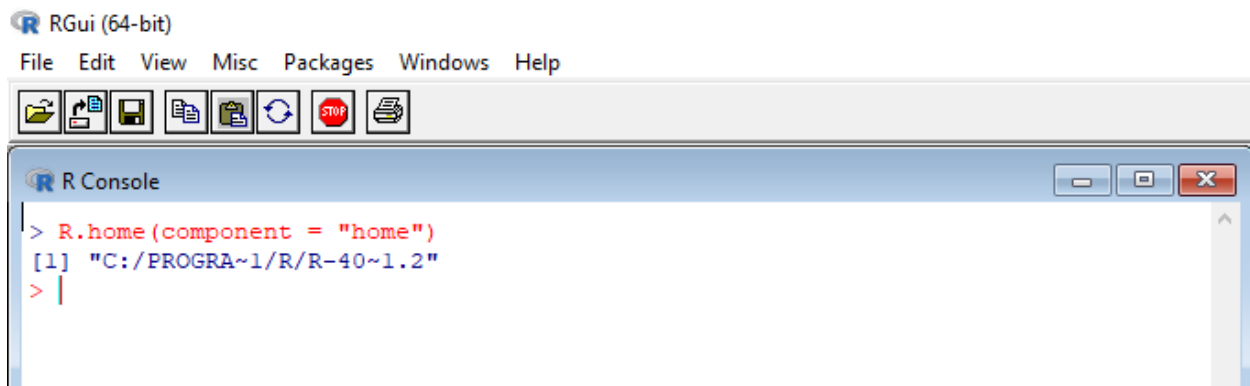
Click "OK" to return to the previous window. Finally, click the "New" button located underneath the lower panel. In the window that opens, set a location for a variable called R_HOME. Type "R_HOME" into the field labeled "Variable Name" (**Figure 16**).
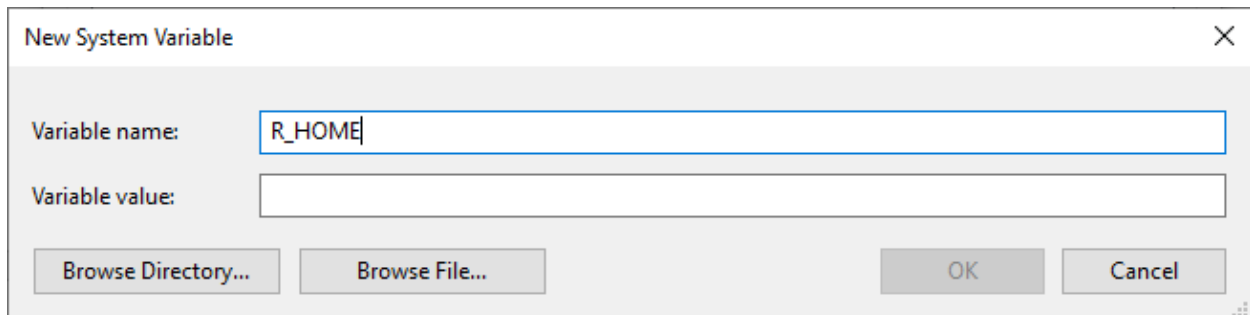
Figure 16. New System Variable for R Integration

To find the location of this variable, navigate back to the R program used previously to install packages for the R extension and type the following line into the console: "R.home(component = "home")". Hit

"Enter" on your keyboard and the result that appears will be the location used to create the variable R_HOME on your PATH (**Figure 17**). Navigate back to the system variable window from before and type this result into the field labeled "Variable value," then click OK. Click OK to close the Environment variables window and OK again to close the System Properties window. If you have already opened NetLogo, you will need to close and restart the program for these changes to take effect.

Figure 17. Finding the R File Path on Windows

Troubleshooting Your R Extension

At this point, the R extension for NetLogo should be installed correctly. Any further errors that arise may require further configuration of a file called "user.properties." Please visit https://ccl.northwestern.edu/netlogo/docs/r.html and go down to Troubleshooting to find common errors and ways to fix them.

1.4 NetLogo User Interface

To open the NetLogo software, go to the Start menu (windows icon in Windows and apple icon in Mac OS X), type in NetLogo 6.1.1, and click on the NetLogo icon . The NetLogo interface will show up (**Figure 18**).

ParkSIM User Manual
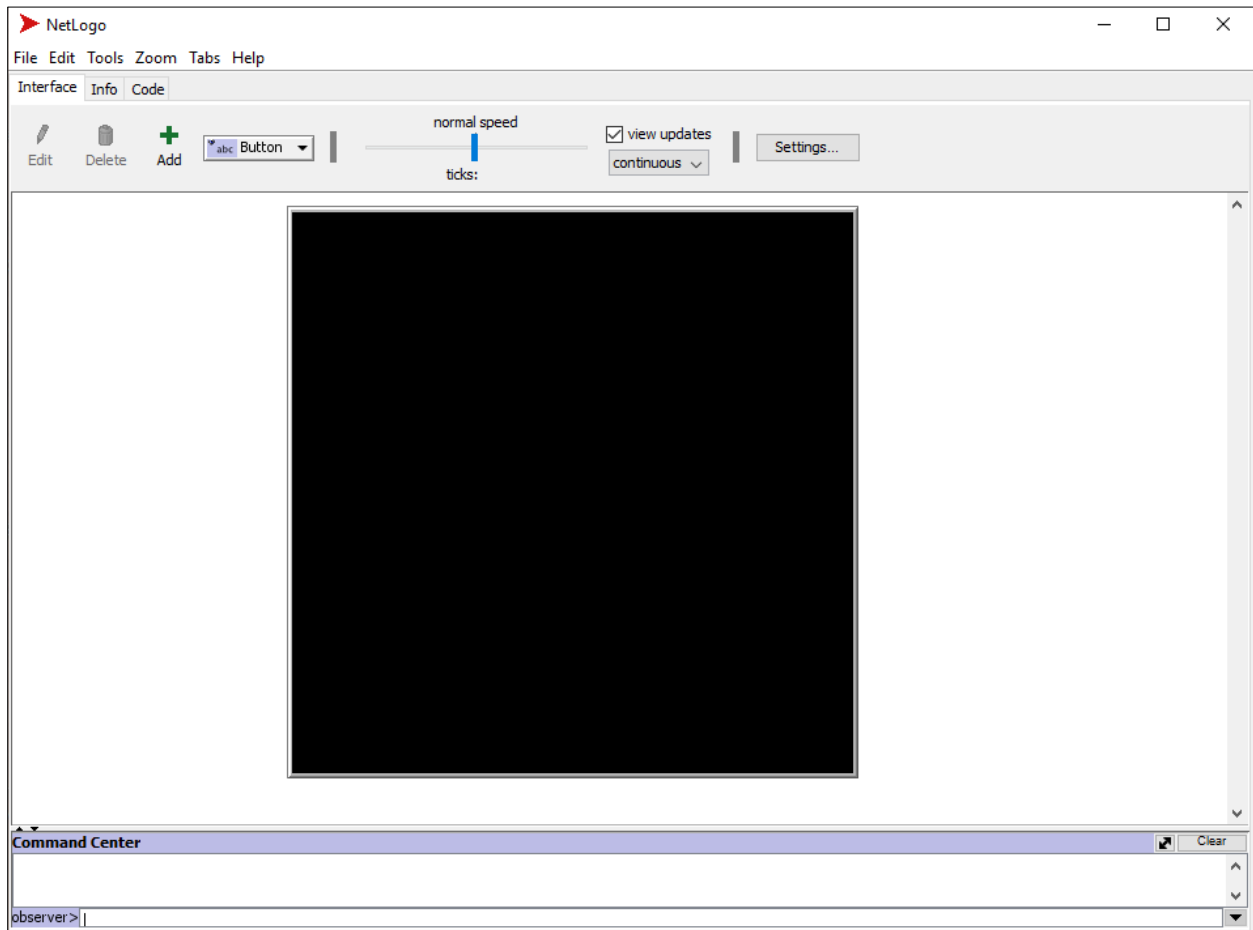
Figure 18. NetLogo User Interface

1.4.1 Menus

On Windows, the menu bar is located at the top of the NetLogo window. **Table 3** summarizes the menu options available within the menu bar. It is unlikely that the ParkSIM user will need to access most menu items, but the list is provided here for general reference.

Table 3. NetLogo menu options

Menu	Options	Purpose
File	New	Creates a new model
	Open	Opens a NetLogo model saved on your computer
	Models Library	A collection of example models
	Recent Files	Re-opens any recently opened model in NetLogo
	Save	Save the current NetLogo model
	Save As	Save the current model with a different file name and path
	Upload to Modeling Commons	Uploads the model to Modelling Commons
	Save As NetLogo Web...	Saves a web page, in HTML format, containing NetLogo web running your model
	Export World...	Saves all variables, the current state of all turtles and patches, the drawing, the plots, the output area and the random state information to a file.
	Export Plot...	Saves the data in a plot to a file
	Export All Plots...	Saves the data in all the plots to a file
	Export View...	Save an image of the current view (2D or 3D) to a file (in PNG format)
	Export Interface...	Save an image of the current interface tab (in PNG format)
	Export Output...	Save the contents of the output area or the output section of the command center to a file
	Export Code...	Save the model's code to an HTML file, preserving colors.
	Import World...	Load a file that was saved by Export World.
	Import Patch Colors...	Load an image into the patches
	Import Patch Colors RGB...	Load an image into the patches using RGB colors
	Print...	Sends the contents of the currently showing tab to your printer.
	Quit	Exits NetLogo. On a Mac, this item is on the NetLogo menu instead
Edit	Undo	Undo the last editing you performed
	Redo	Redo the last editing you performed
	Cut	Cuts out or removes the selected text and temporarily saves it to the clipboard
	Copy	Copies the selected text
	Paste	Places the clipboard text where the cursor is currently located
	Delete	Deletes selected text
	Select All	Selects all the text in the active window
	Find...	Finds a word or sequences of characters within the info or Code tabs
	Find Next	Find the next occurrence of the word or sequence you last used Find with
	Comment/Uncomment	Used in the code tab to change to add or remove semicolons from code
	Shift Left/Shift Right	Used in the Code tab to change the indentation level of code
	Format	Used in the Code tab to correct the indentation of the currently selected code
	Snap to Grid	When enabled new widgets stay on a 5-pixel grid so it is easier to line them up
Zoom	Larger	Increase the overall screen size of the model. Useful on large monitors or when using a projector in front of a group
	Normal Size	Reset the screen size of the model to the normal size.
	Smaller	Decrease the overall screen size of the model.

ParkSIM User Manual

1.4.2 Tabs

At the top of NetLogo's main window are three tabs labeled "Interface", "Info", and "Code" (**Figure 19**). Only one tab at a time can be visible, but the user can switch between them by clicking on the tabs at the top of the window. The tab "Interface" shows the maps and other graphical devices, "Info" gives information about the model, and "Code" gives the source codes for the model.
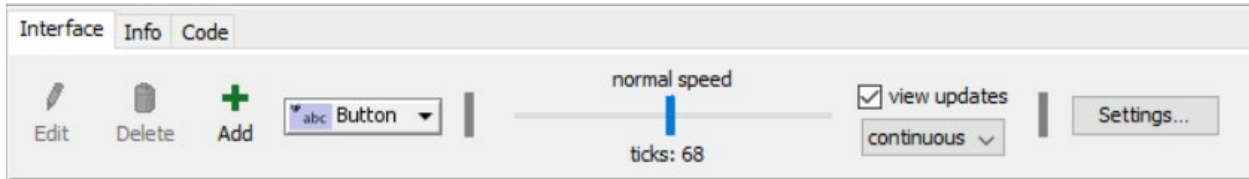
Figure 19. NetLogo tabs

1.5 ParkSIM Interface

1.5.1 Accessing the interface

The ParkSIM files can be downloaded from wordpressua.uark.edu/sarahvh/research. The folder "ParkSIM" contains the model file along with required data input files. The full list of input files included in the installation folder are provided in *Appendix E: Model Files.*

To access the interface, open the folder "ParkSIM" and find the NetLogo Model file ParkSIM.nlogo. Next, open the ParkSIM model by right-clicking on the NetLogo file, then going down to "Open with", and selecting NetLogo 6.1.1 in the options (**Figure 20**). Another way to open the ParkSIM model is to first open the NetLogo software interface, then click File, go down to Open and find the ParkSIM.nlogo file from your computer.

ParkSIM User Manual
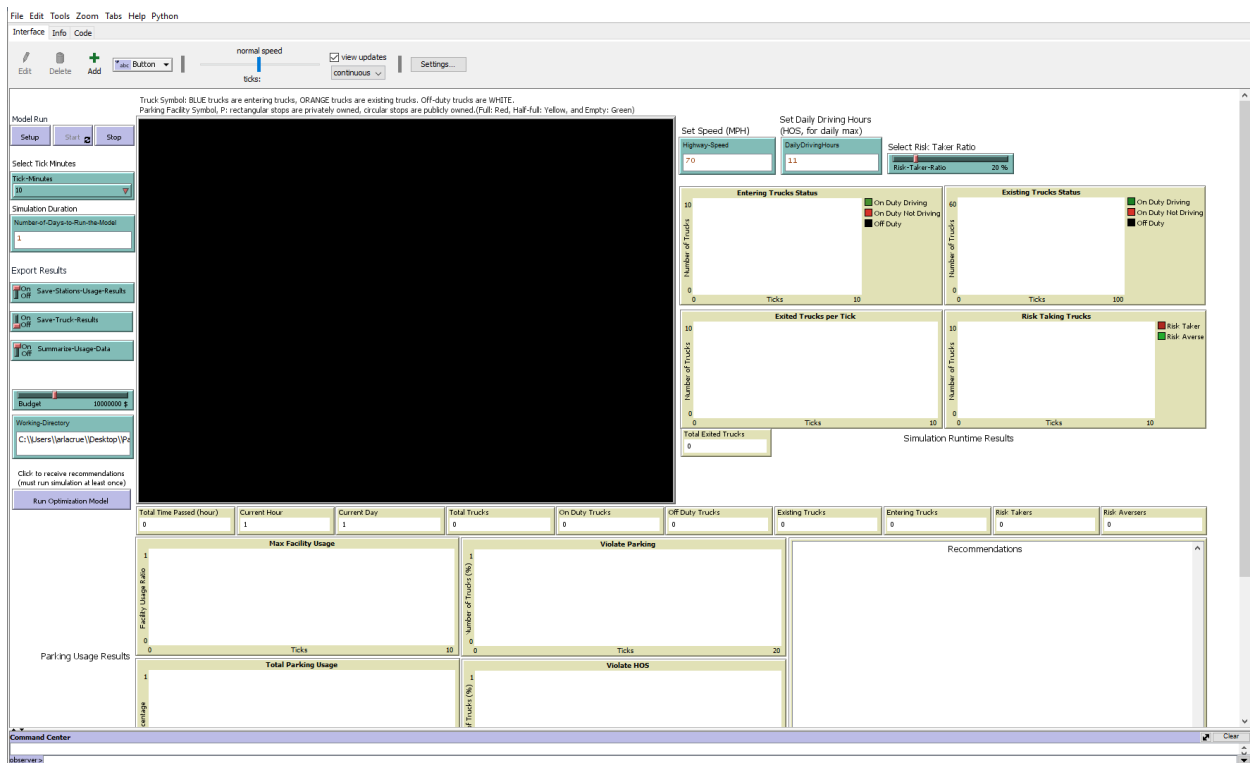
Figure 20. ParkSIM Model Interface

1.5.2 Toolbox and Graphics

This section describes the purpose and use of the tools included in the ParkSIM model.

Model Run

The Model Run tool has three components: Setup, Start, and Stop.

Setup

The Setup button helps setting up the agents (agents are collection of autonomous decision-making entities such as truck drivers) before the simulation can be run.

Start
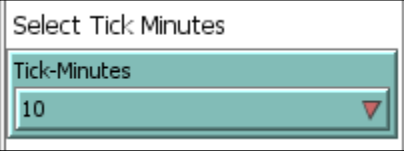
The Start button initiates the simulation; when pressed, trucks begin to move through the network.

Stop

The user can stop the simulation at any point hitting the Stop button.

Select Tick Minutes

The *tick* is a discrete unit of time that passes between iterations of a simulation. The user can select a preferred number of ticks using this tool. This feature lets the user select 1, 10, 20, 30, or 60 minutes as ticks.

ParkSIM User Manual
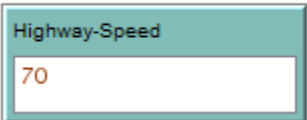
Set Speed

The *Set Speed* interface allows the user to change the assumed speed of trucks in the simulation. By default, the speed of trucks has been set to 70 mph.

Select Risk Taker Ratio

The *Select Risk Taker Ratio* feature allows the user to specify the percent of risk-taking drivers. Risk-takers are those drivers who may park on nearby ramps or roads while risk averse drivers will continue to seek legal parking at a downstream facility. The user can select the percentage of drivers to be risk-takers using a slider. For example, a 20% risk taker ratio means that 20 out of every 100 drivers are classified as risk-takers. This is meant to allow the user to consider varied levels of driver compliance with HOS and parking laws.
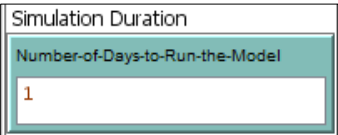
Simulation Duration

The *Simulation Duration* feature allows the user to select the duration of the simulation. The simulation can be run up to 14 days. Note that the higher the number of days the longer it will take for the simulation to complete. A 14-day period is suggested to allow for variation in parking behaviors by day of week.

Set Daily Driving Hours

The user can set the maximum driving hours for truck drivers with the *Set Daily Driving Hours* feature. This corresponds to the FMCSA's daily driving limit currently set to 11 hours. The ParkSIM model already incorporates other HOS regulations including the weekly cumulative driving and rest hour limits, e.g., the 70-hour rule, as well as the required 30-minute (short break) and 10+ hour (long break) rules.

The ParkSIM model does not include the sleeper berth provisions for breaking the long break into two and eight hour segments.
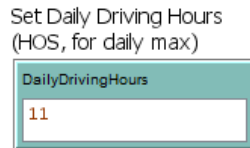
Set Budget

The *Set Budget* feature lets the user input a budget to be distributed to parking facility capacity expansion projects and is used within the optimization model. The slider can be changed from $0 to $30 million. The model will generate results showing possible capacity improvements that meet the input budget. If the overcrowded facilities can be accommodated with capacity expansions that cost less than the budget, the model will recommend which facilities to expand or build and indicate the percentage of demand at overcrowded facilities that can be accommodate by the expanded or new facilities.

Export Results

The *Export Results* section allows the user to export the results from the simulations (**Figure 21**). There are three types of results as described below.
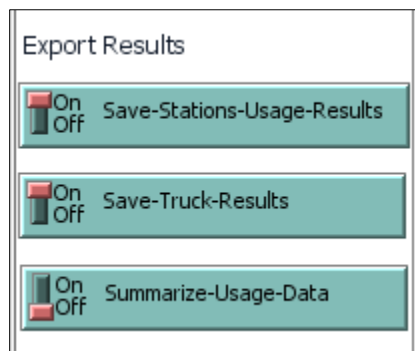
Figure 21. Tools for Exporting Results

Save Stations' Usage Results

The *Save Stations Usage Results* toggle button lets the user choose to export the results from the simulation in a .csv file format. This includes the hourly and daily usage status for each of the parking facilities included in the model.

Save Truck Results

The *Save Truck Results* button lets the user choose to export truck movement results from the simulation as a .csv file. This file includes the daily and weekly rest and drive hours for each truck in the simulation.

Summarize Usage Data

The *Summarize Usage Data* button lets the user choose to run the optimization model when the simulation completes to determine where parking facility capacity expansions can be made. The results will show in the interface and are based on the hourly usage statistics from the simulation for each parking facility.

Time and Feature Count

The *Time and Feature Count* features provide updates regarding the total time elapsed, the current hour and day of the simulation, and different types of trucks while the simulation is running (**Figure 22**). See Section 3.2 for further details on these tools.

Total Time Passed (hour)	Current Hour	Current Day
0	1	1
Total Trucks	On Duty Trucks	Off Duty Trucks
0	0	0
Existing Trucks	Entering Trucks	Risk Takers
0	0	0
Risk Aversers		
0		

Figure 22. Time and Feature Count Tools

Simulation Runtime Results

This segment of the interface graphically shows simulation runtime results for duty status of entering and existing trucks and count of the exited trucks, risk takers, and risk averse drivers (**Figure 23**). Each truck in the simulation is assigned a duty status as either on-duty driving, on-duty not driving, and off-duty. On-duty driving corresponds to driving activities. On-duty not driving corresponds to labor associated with loading, unloading, paperwork, etc. Off-duty corresponds to rest breaks. Risk takers are the trucks that have a higher probability of parking illegally and/or violating HOS rules. Risk averse are the trucks that comply with parking laws and HOS rules

When the simulation begins, these graphs will start as blanks, but as the simulation model is setup and run, these figures will be updated with results from the simulation. See Section 3.1 for further details on these graphical features.
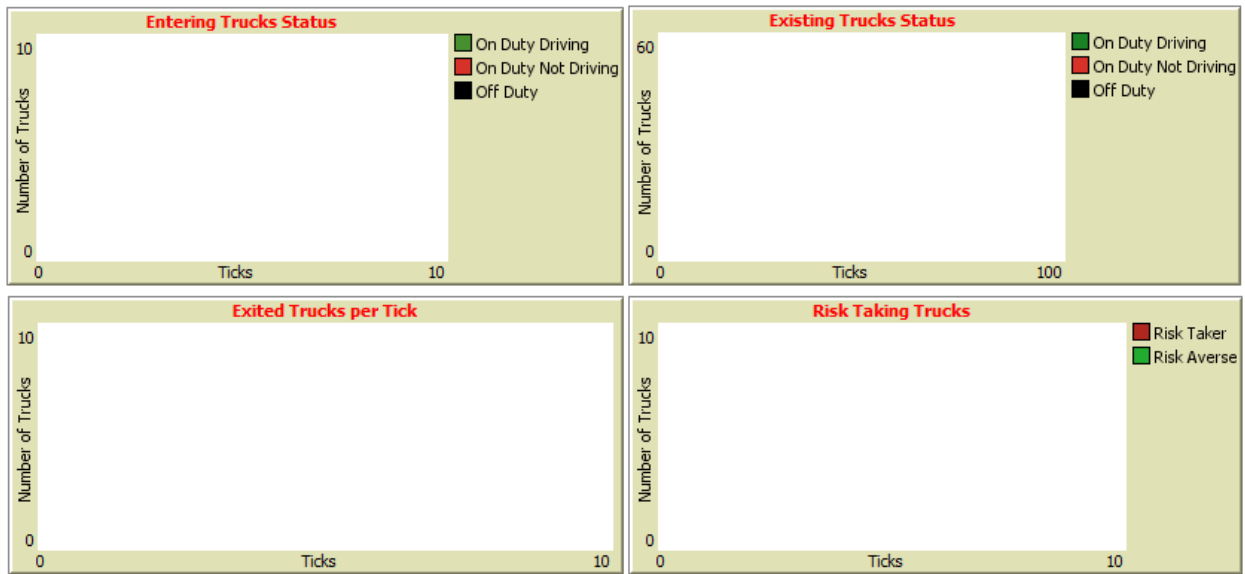
Figure 23. Figures for Simulation Runtime Results

Parking Usage Results

These graphical features continuously update the average facility usage, HOS, and parking violations as the simulation runs (**Figure 24**). These graphs will start as blanks, but as the model is setup and run, these figures will be updated with results from the simulation. Please see Sections 3.1.5, 3.1.6, and 3.1.7 for further details on these graphical features.
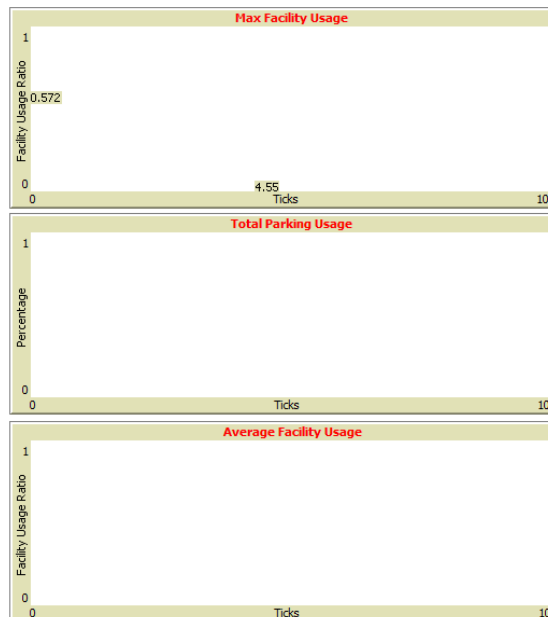
Figure 24. Graphical features for parking usage

ParkSIM User Manual

Parking and HOS Violations

The figure labeled *Violate Parking* updates with the share of trucks that violate parking in each tick (**Figure 25**). The figure labeled *Violate HOS* updates with the share of trucks that violate HOS in each tick. Please see Section 3.1.7 and 3.1.8 for examples with data.

Figure 25. Violate Parking and Violate HOS Graphs

Run Optimization Model

Once the simulation run is complete, the user can click on the *Run Optimization* button to get recommendations of where capacity improvements projects can potentially take place. This button only activates if the simulation has completed.   If a user runs the simulation but wants to test a different budget, they may update the budget and hit the Run Optimization Model button to determine a new set of parking facility capacity expansion locations, without the need to re-run the simulation.
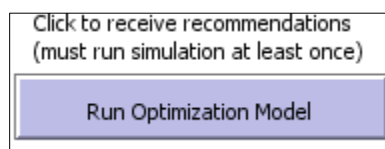
Recommendations

After running the simulation and then running the optimization model, the *Recommendation* box will be populated with text describing which of the candidate facilities should be built to address overcrowding issues estimated during the simulation.

Chapter 2: Building and Running the Model

Chapter 2 guides the user on how to setup and run the ParkSIM model.

2.1 Setting Up the Model

First, the user should click the Setup button in the model interface (**Figure 26**). The map, road network, and parking facility layers should start to populate. The network is complex, so this setup may take a few minutes. Wait until the "Setup" button returns to its original format (black text, purple background) similar to the next two buttons, i.e., Start and Stop, before proceeding to the next step.
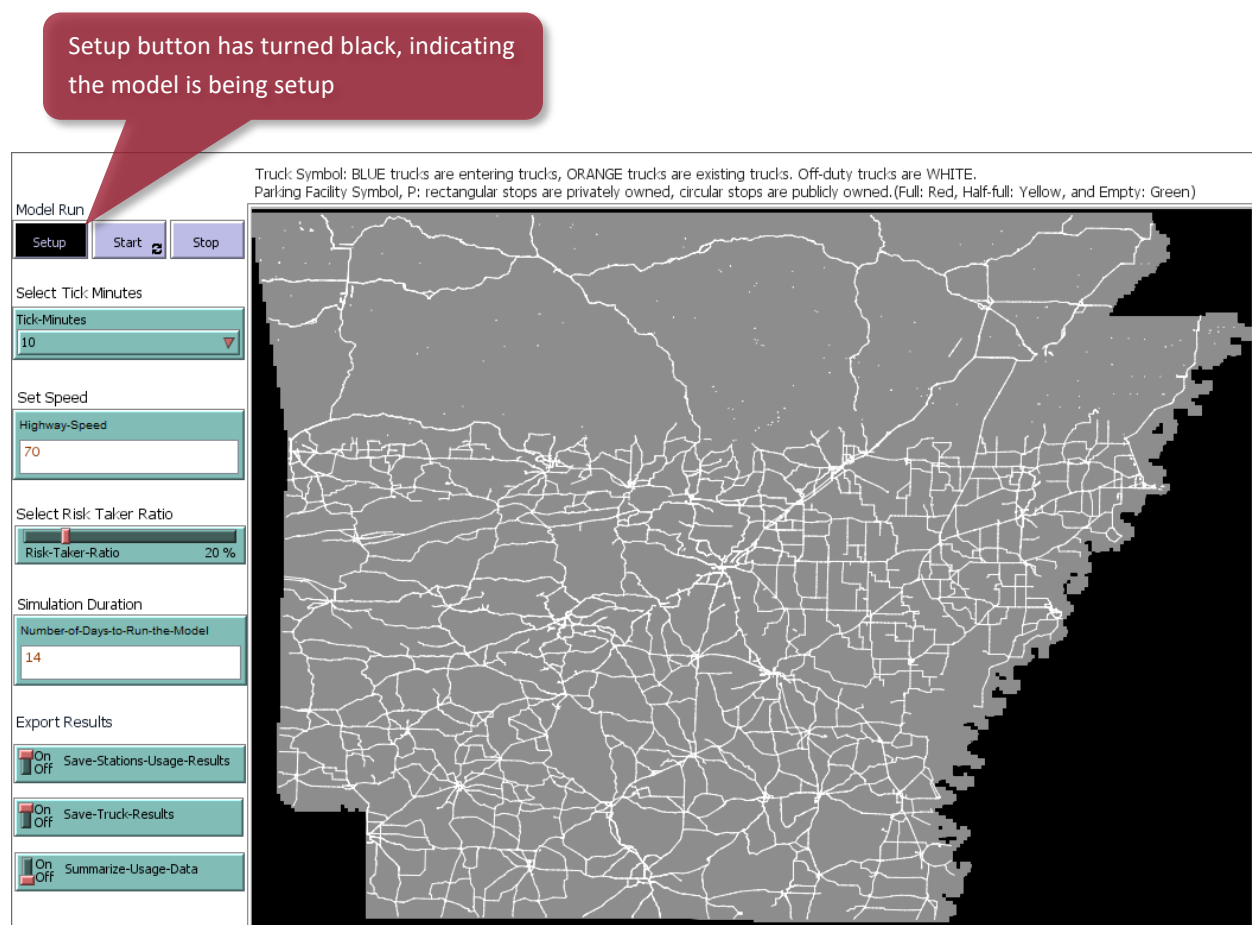
Figure 26. Setting up the ParkSIM Model Interface

Once setup is complete, trucks and parking facilities should appear (**Figure 27**). Existing trucks are represented by truck symbol with orange outline and parking facilities are depicted with a P-symbol framed by rectangular (private truck stops) and circular shapes (public rest stop). Existing trucks are those that are within the state driving or resting at the start of the simulation. During the

simulation, additional trucks will appear at the highways crossing the state borders. To further make sure the model is set up, look for an activated Start button with the title in black letters (previously grey).
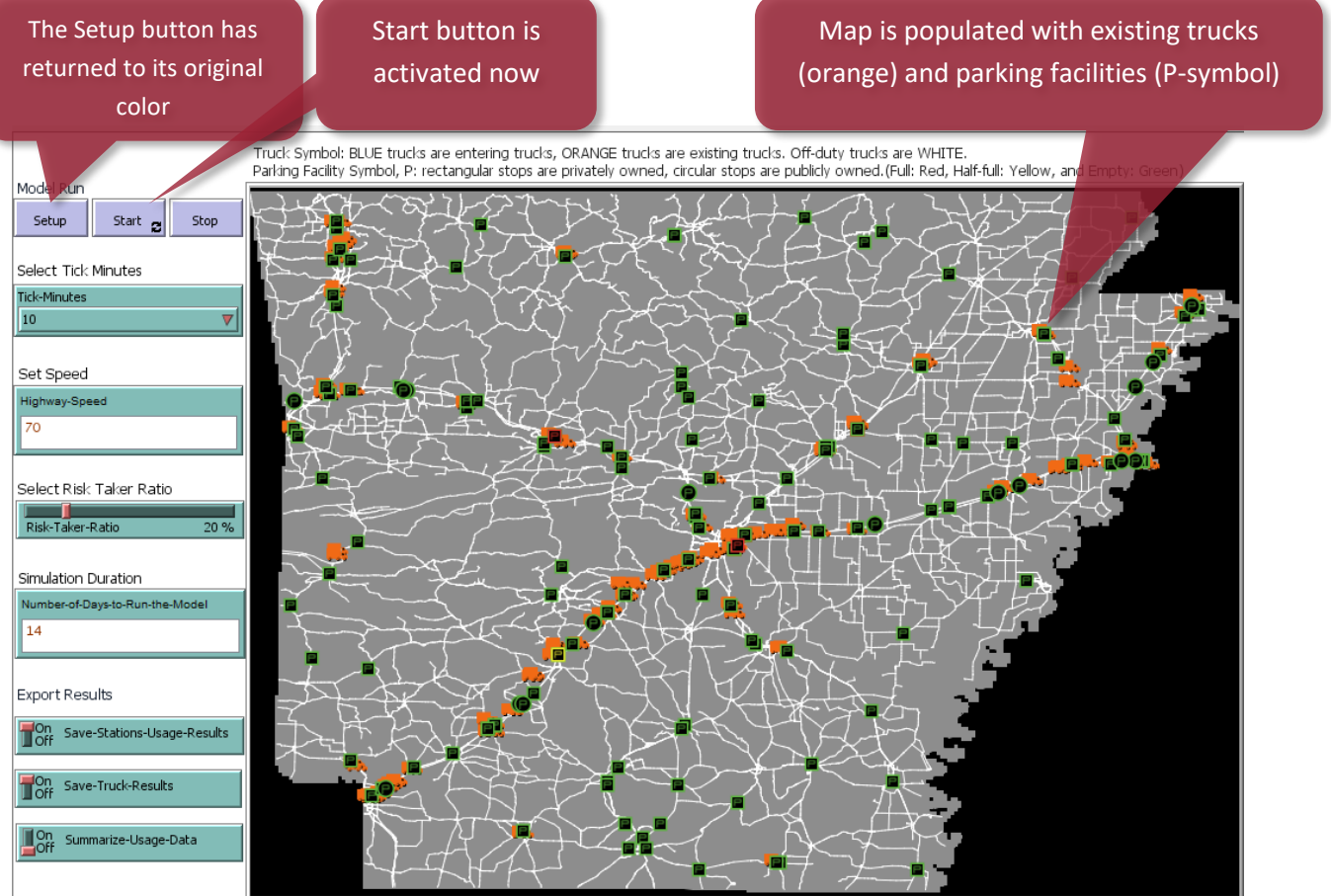
Figure 27. Starting the ParkSIM Model

2.2 Running the Model

To run the simulation after set-up, first click on the Start button (**Figure 28**). The button will turn to black and the refresh icon will turn green. The user will see trucks moving and parking facility colors changing depending on their usage. Blue trucks on the map are trucks that are *entering* Arkansas and orange trucks are the *existing* trucks within the state, e.g., those initialized by the model at set-up. Once the simulation starts, the parking facilities will be occupied with trucks and their colors will change depending on their capacity usage (**Figure 29**). If a parking facility is empty, then the facility icon will stay green. If the parking facility is half-full, i.e., 50% of capacity is utilized, then the facility will turn yellow. If it is full, i.e., all the parking spaces are utilized, the icon will turn red.
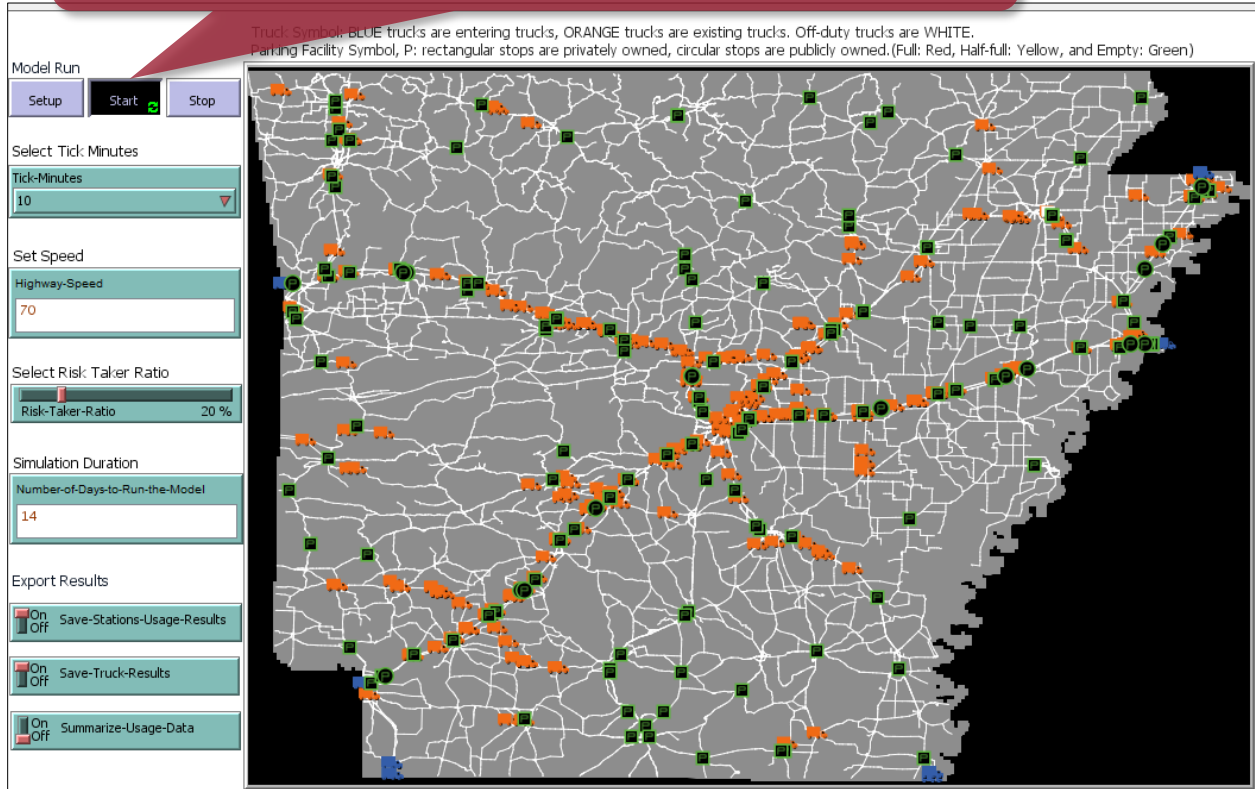
Figure 28. Running ParkSIM

ParkSIM User Manual
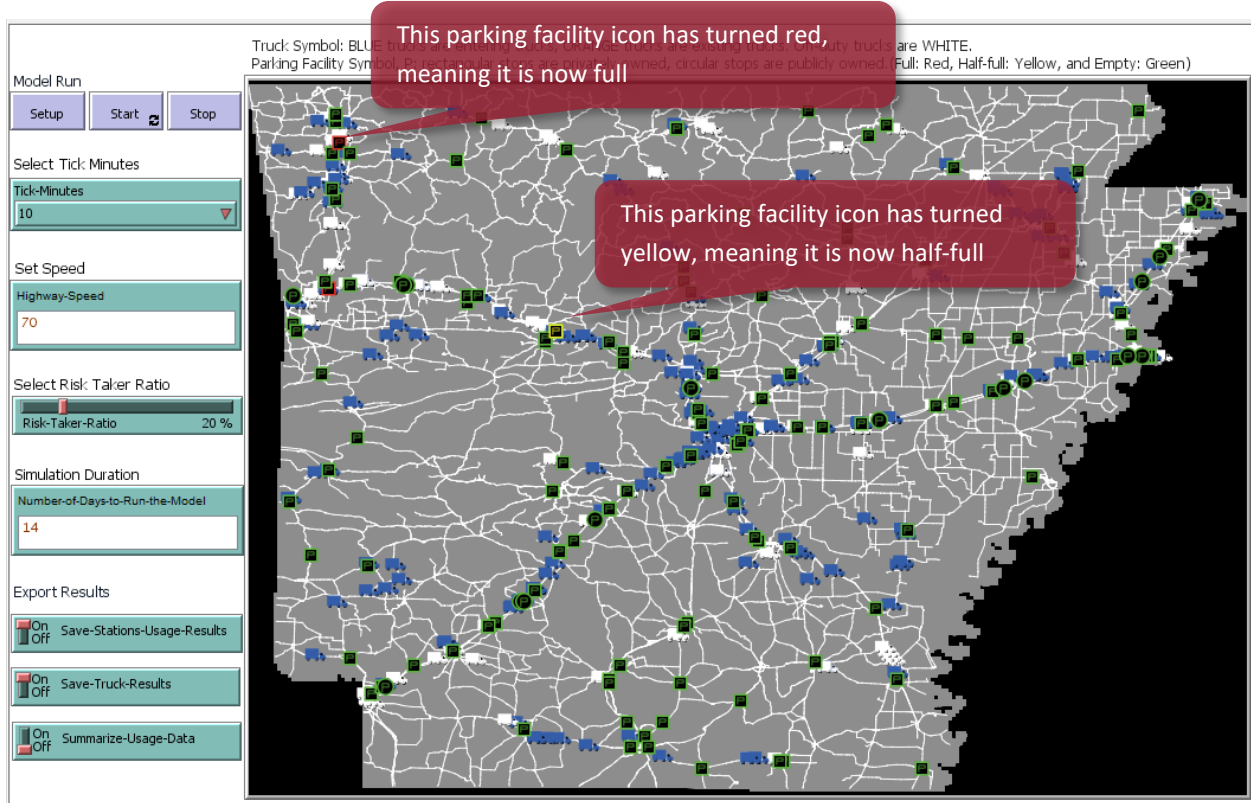
Figure 29. Simulated Truck Movement and Facility Usage Change

Chapter 3: ParkSIM Model

Chapter 3 documents the tools and visualizations within the ParkSIM model interface.

3.1 Simulation Runtime Results

This section describes the simulation's runtime results, i.e., information on trucks entering and exiting the state, their duty status, i.e., driving and rest status, and the number of drivers that are risk-takers versus risk-averse.

3.1.1 Entering Trucks Status

Recall, that the simulation initializes with trucks already resting and driving in the state and as the simulation progresses, new trucks are introduced crossing into the state and referred to as *Entering Trucks*. The duty statuses of *Entering Trucks* are: 1) on duty driving, 2) on duty not driving, and 3) off-duty. On-duty time includes time spent working and driving. On-duty time can be further divided into (i) on-duty driving, and (ii) on-duty not driving. On-duty driving time accounts for the time a driver is behind the wheel of a commercial motor vehicle in operation. On-duty not driving time accounts for the periods of time when a truck driver is on duty (e.g., loading and unloading), but not driving a commercial motor vehicle.

The status of the *Entering Trucks* is reported in the graph on the right of the main map (**Figure 30**). The horizontal axis is the tick (*tick* is a discrete unit of time that passes between iterations of a simulation). One tick may represent 1, 10, 20, 30, or 60 minutes depending upon what the user selected for *Select Tick Minutes* before setting up and running the simulation. The vertical axis represents the number of trucks that have a particular duty status.

The duty status graph will show cyclical patterns. The number of truck drivers who are on duty driving is lower during the overnight period, higher during midday periods, and again lowers during the evening period. When the number of on-duty drivers are high, the number of off-duty drivers is low, as there is a constant number of trucks that exist at any time tick.
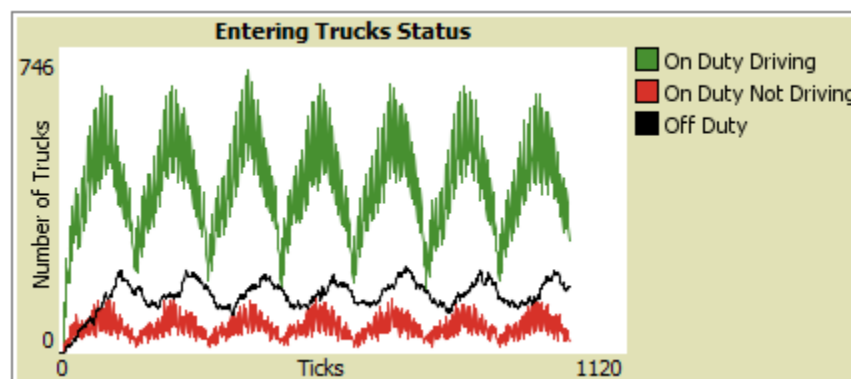
Figure 30. Duty Status of Entering Trucks Over Time

3.1.2 Existing Trucks Status

The *Existing Trucks Status* graph shows the duty status of trucks that were initialized during the simulation set up (Figure 32). These trucks are referred to as *Existing Trucks* and can be initialized in three driving modes.
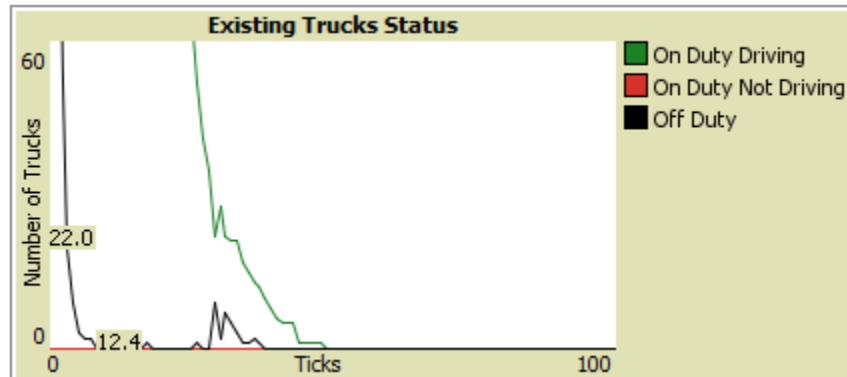
Figure 31. Duty Status of Existing Trucks Over Time

3.1.3 Exited Trucks Per Tick

The *Exited Trucks* graph depicts the number of trucks that exited the state during the runtime of the simulation (Figure 32). A truck exits the state on its route to its destination. Once a truck exits the state it is no longer part of the simulation. Again, the graph will depict a cyclical pattern as truck flows by time of day are diurnal.
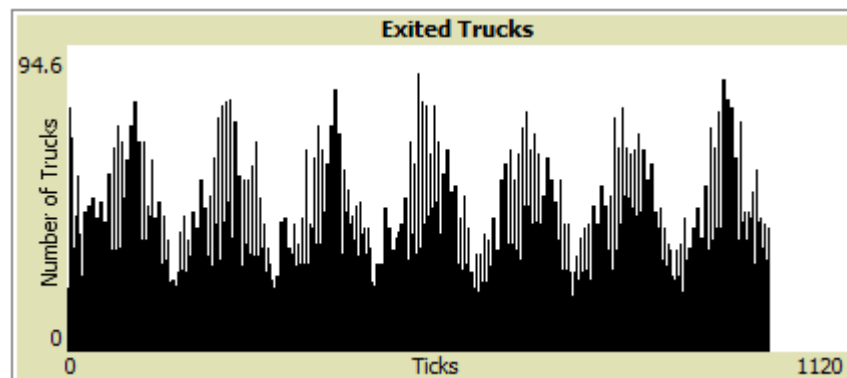
Figure 32. Number of Exited Trucks Over Time

3.1.4 Risk Taking Trucks

The *Risk Taking Trucks* graph depicts the number of risk-takers and risk-averse drivers during the runtime of the simulation (**Figure 33**). All trucks are marked as risk-taking or risk-averse. The percent of risk-averse drivers is set by the user. The graph shows the total count of risk-taking and risk-averse drivers with on-duty status which totals to the total number of drivers in the simulation. The graph

should show a cyclical pattern. The number of both risk-taking and risk-averse drivers are higher during midday periods when there is high number of drivers who are on-duty driving. The numbers of risk-taking and risk-averse drivers start to decrease in the evening when drivers start to take off-duty breaks at the parking facilities.
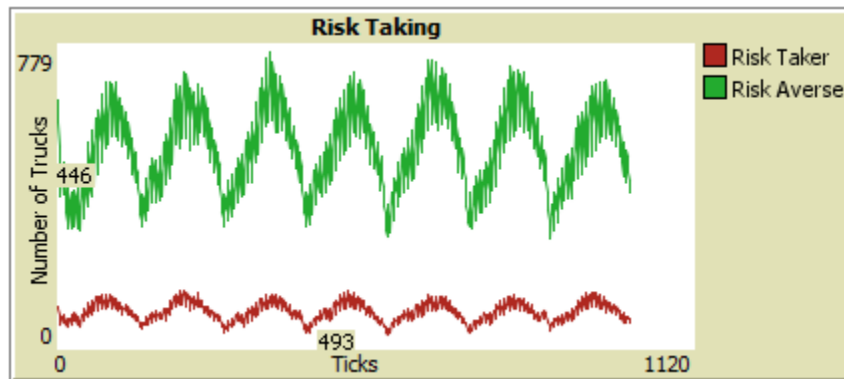
Figure 33. Number of Risk Taker and Risk Averse Drivers Over Time

3.1.5 Max Facility Usage

The *Max Facility Usage* graph shows the usage ratio of the station with the highest usage ratio during the tick (**Figure 34**). The usage ratio is calculated by dividing the current number of trucks parked at the facility by the capacity of the facility. A ratio above 1.0 indicates that more trucks are parked at a facility than the number of available spaces. This means trucks are parked along the interstate ramps leading to the facility or along the road near the facility.
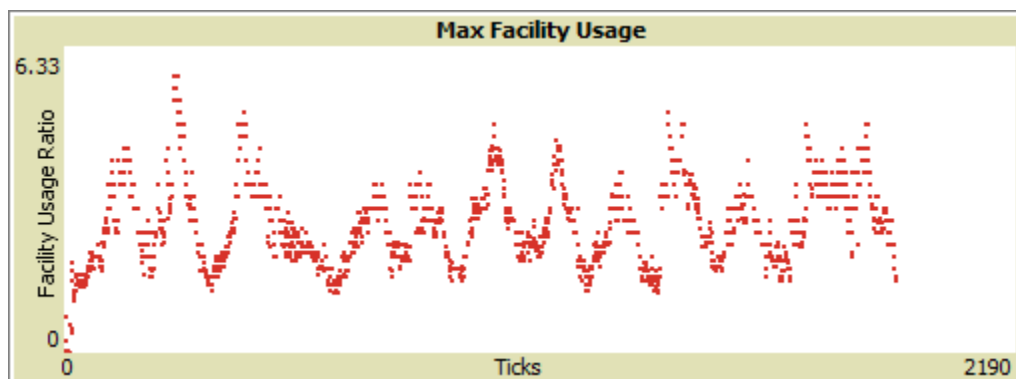
Figure 34. Maximum Facility Usage Over Time

3.1.6 Total Parking Usage

The *Total Parking Usage* graph shows how many parking spaces out of the total number available are currently occupied as a percent (**Figure 35**). The graph is cyclical depicting the diurnal patterns of parking demand at night. Note, this graph differs from the *Maximum Usage* graph in that it is the total of all facilities.
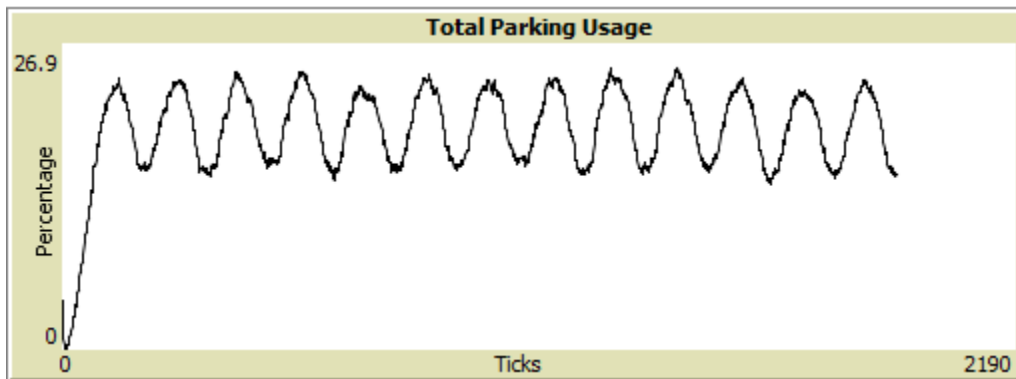
Figure 35. Total Parking Usage Over Time

3.1.7 Average Facility Usage

The *Average Facility Usage* graph shows the average facility usage ratio for all parking facilities (**Figure 36**). The facility usage ratio is the ratio between the number of parked trucks in a facility and the capacity of that facility. The average facility usage tends to appear stable throughout the period as it is the average of all facilities, some of which are underused and others are overcrowded.
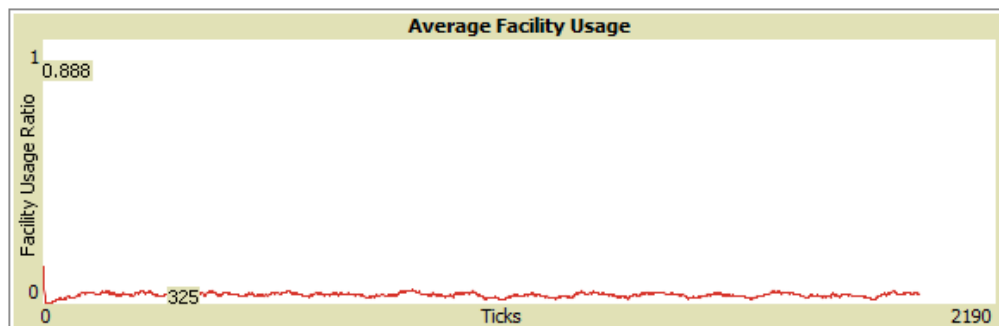
Figure 36. Average Facility Usage Over Time

3.1.8 Violate Parking

The *Violate Parking* graph shows the number of trucks that parked in undesignated locations during the simulation (**Figure 37**). This occurs when a parking facility is overcapacity and the driver decides to park on a nearby road or ramp rather than searching for legal parking and possibly violating their HOS requirements.

ParkSIM User Manual
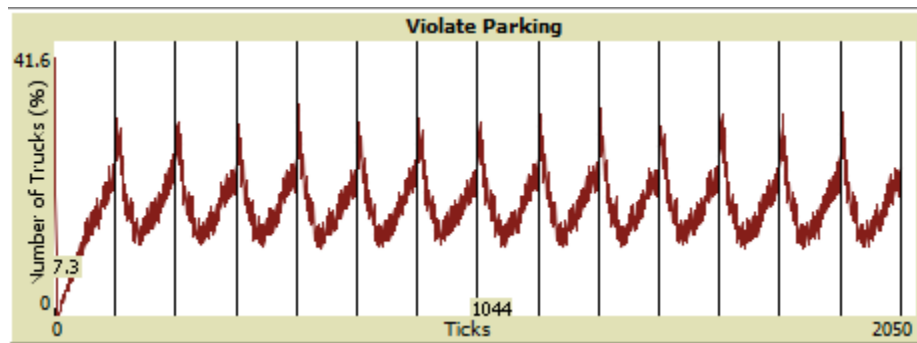
Figure 37. Parking Violation Over Time

3.1.9 Violate HOS

The *Violate HOS* graph shows the number of trucks that violated HOS regulations during the simulation (**Figure 38**). This occurs when a driver searches for available and legal parking and as a result drives past their daily or weekly driving limits.
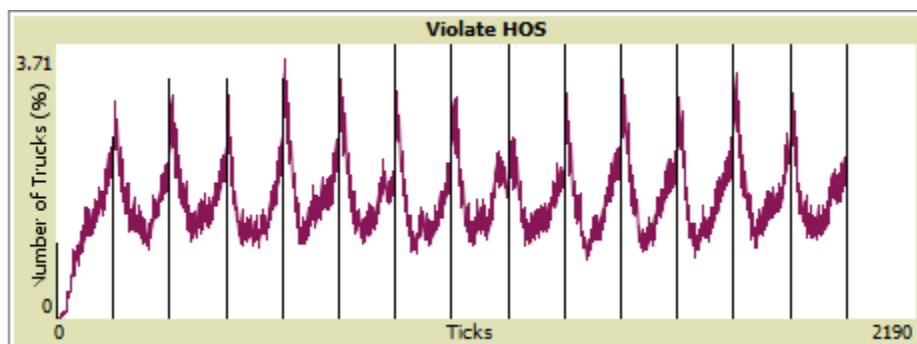
Figure 38. HOS Violation Over Time

3.2 Time and Feature Count

3.2.1 Total Time Passed (hour)

The *Total Time Passed* feature shows the current runtime of the simulation in total hours.

3.2.2 Current Hour

The *Current Hour* feature shows the hour of the current simulation day. Thus, the *current hour* count will be reset to 1 once a day of simulation runtime is complete.

ParkSIM User Manual

3.2.3 Current Day

The *Current Day* feature shows the current day of the simulation at any point in time. For instance, the graphic below says the current day is '7', which means the simulation at that point is on the 7th day since it started to run.

Current Day

7

3.2.4 Total Trucks

The *Total Trucks* feature updates the total individual trucks involved in the simulation. This number is cumulative over the period of the simulation.

Total Trucks

444

3.2.5 On-Duty Trucks

The *On-Duty Trucks* feature shows the number of truck drivers who are on-duty at any point in the simulation.

On Duty Trucks

253

3.2.6 Existing Trucks

The *Existing Trucks* feature provides the number of existing trucks that were present within the state boundary at the time the simulation was initialized.

Existing Trucks

0

3.2.7 Off-Duty Trucks

The *Off-Duty Trucks* feature provides information about the number of off-duty trucks in the simulation at any point in time.

Off Duty Trucks

162

3.2.8 Entering Trucks

The *Entering Trucks* feature provides the number of trucks entering the state boundary at any point of time during the run of the simulation.

Entering Trucks

12

3.2.9 Current Hour Entering Trucks

The *Current Hour Entering Trucks* feature provides the number of trucks entering the state over the duration of the *current hour* of the simulation.

Current Hour Entering Trucks

12

3.2.10 Risk Takers and Risk Averse

The *Risk Takers* and *Risk Averse* features give the number of truck drivers who are classified as "risk-takers" and "risk-averse", respectively.

Risk Takers

64

Risk Aversers

380

Chapter 4: Model Outputs

Chapter 4 shows the user how to retrieve simulation runtime data and export them in usable formats. Raw and summarized data are provided.

4.1 Exporting Formatted Results

4.1.1 Export Figures

The user can copy any figure from the interface to insert into external software like Microsoft Word. To accomplish this, right click on the figure followed by left click on the Copy Image (**Figure 39**).
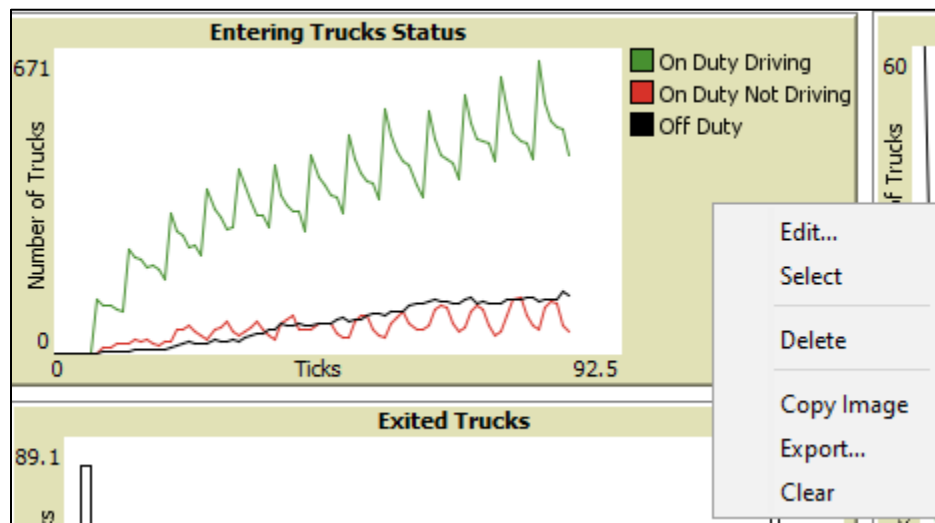
Figure 39. Exporting Figures from the Interface

4.1.2 Export Tables

To export parking facility usage results in .csv file format, click on the Save-Stations-Usage-Results button when setting up the simulation. The file named stationresults.csv will be saved to the computer in the same location the ParkSIM software was saved. The files can be opened in Microsoft Excel or other text editing programs. Similarly, hitting the Save-Truck-Results button saves the file called truckresultsweek1.csv which stores data on duty status (rest and drive hours) for each truck driver involved in the simulation.
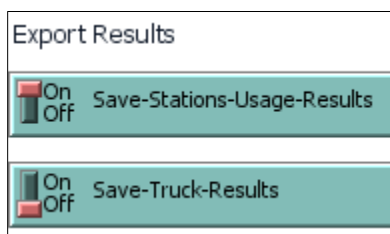
4.2 Interpretation of the Results

4.2.1 Final Map After Simulation

Once the simulation has finished running, it will contain populated figures and counters but the *Recommendations* section will not yet be populated. Once the optimization model is complete, the *Recommendations* section will contain text describing the recommended capacity expansions (**Figure 40**).
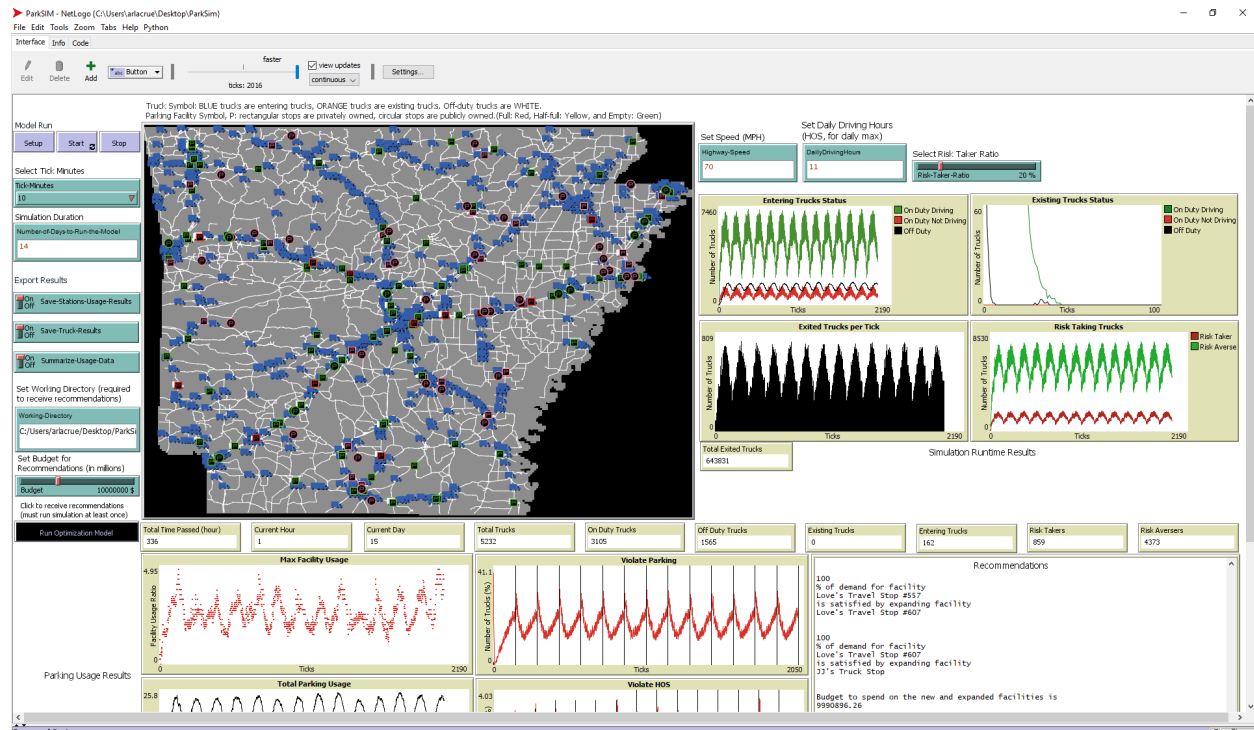
Figure 40. ParkSIM Interface After Simulation

4.2.2 Parking Usage Patterns

The exported stationresults.csv file contains a table of usage rates by tick for each parking facility (**Figure 41**). For each tick and for each parking facility, the file provides information on number of parked trucks, number of trucks violating parking near the facility, parking capacity, and a usage ratio (total of parked and violated trucks divided by the capacity). Trucks within 0.25-mile radius of the facility are considered to be trucks that violate parking at that facility.

A summary file of the stationresults.csv tables is also exported and it called Parking_hourly_results.csv. The summary file calculates the average capacity each hour for every station over the duration of the simulation. This file can be used to make time of day usage graphs.

ParkSIM User Manual

CurrentTick	Name	Parking ID	Number of Parked Trucks	Number of Violated Trucks	Parking Capacity	Ratio
1	Snappy Mart # 7 (Exxon)	AR869	0	0	30	0
1	I-40 Kwik Stop (Citgo)	AR610	0	0	10	0
1	West 66 Food Mart (Valero)	AR938	0	0	15	0
1	Exxon Auto/Truck Center #101	AR018	0	0	50	0
1	Truckomat	AR024	0	0	25	0
1	Newport Truck Plaza (Exxon)	AR912	0	0	50	0
1	Doublebee's (Conoco)	AR798	0	0	12	0
1	Morgan Valero #471	AR813	0	0	30	0
1	Exit 57 Auto/Truck Express (Shell)	AR900	0	0	35	0
1	White Oak Station #38 (Shell)	AR929	0	0	5	0
1	Pilot Travel Center #429	AR037	0	0	150	0
1	D J's Convenient Store	AR945	0	0	20	0
1	Texarkana Welcome Center	13	0	0	36	0
1	Hillbilly U-Pump	AR939	0	0	15	0
1	Love's Travel Stop #607	AR952	0	0	80	0
1	Tobo's 66	AR908	0	0	50	0
1	Missile Mart #08 (Mobil)	AR727	0	0	20	0

Figure 41. Snapshot of the Station Results

4.2.3 Driver Duty Status

The exported truckresultsweek1.csv file contains the driving and rest logs for each truck in the simulation (**Figure 42**). The table shows the duty status of each truck involved in the simulation for a week. Each value within square brackets in the columns "On Duty Driving", "On Duty Not Driving," and "Off Duty" represents hours spent by a particular driver on a particular day. For example, the attribute value [4.58 0 0 0 0 0 0] under the "On Duty Driving" column represents 4.58 hours of driving by that specific driver on day one of the simulation.

A	B	C	D	E
Truck ID	Truck Type	On Duty Driving	On Duty Not Driving	Off Duty
156043	existingtruck	[0.24 9.32 6.12 6.74 10.93 0 0]	[0.12 0.54 0.53 0.23 0.5 0 0]	[23.11 12.91 15.12 16.16 11.04 23.16 0]
156000	existingtruck	[0.1 6.33 4.69 0 0 0 0]	[0 0.97 0.32 0 0 0 0]	[22.08 15.5 18.43 0 0 0 0]
156123	existingtruck	[8.38 5.87 4.08 0 0 0 0]	[0.55 0.36 0.57 0 0 0 0]	[6.72 16.01 17.42 23.98 0 0 0]
156310	existingtruck	[9.84 6.77 6.8 8.85 7.85 6.4 0]	[0.1 1.52 0.3 0.55 0.32 2.51 0]	[5.19 10.05 15.35 13.58 14.86 13.82 23.98]
155856	existingtruck	[0.5 0 0 0 0 0 0]	[0.71 0 0 0 0 0 0]	[19 0 0 0 0 0 0]
155656	existingtruck	[0.5 0 0 0 0 0 0]	[0.71 0 0 0 0 0 0]	[19 0 0 0 0 0 0]
156005	existingtruck	[8.94 9.02 9.03 9.48 4.35 0 1.92]	[0.65 0.37 0.72 0.27 0.82 0 0.45]	[13.08 13.05 12.5 13.47 18.29 24 20.99]
155732	existingtruck	[4.71 2.25 8.35 9.67 8.47 9.02 6.89]	[0.93 0.42 2.57 0.41 0.76 0.08 4.24]	[17.86 20.63 11.81 12.35 13.29 13.28 11.36]
156258	existingtruck	[6.25 5.84 0 0 0 0 0]	[0.28 3.13 0 0 0 0 0]	[10.15 5.96 0 0 0 0 0]
156349	existingtruck	[7.07 5.23 2.54 0 5.67 0 0]	[0 0 0.07 0 0.21 0 0]	[8.16 16.82 20.94 24 16.49 0 0]
155639	existingtruck	[3.6 0 7.86 8.9 6.05 7.73 1.55]	[0.02 0 0.23 0.59 0.39 0.08 0.25]	[15 24 14.69 13.7 16.5 14.82 21.21]
156165	existingtruck	[8 5.93 4.61 4.89 7.92 7.63 2.2]	[0.74 0.49 0.35 0.19 0.33 0.08 0.25]	[11.78 16.11 17.03 17.62 15.18 15.6 9.05]
156177	existingtruck	[5.82 5.22 4.65 0 0 0 0]	[0.28 0.1 0.19 0 0 0 0]	[11.11 15.32 10.46 0 0 0 0]
155704	existingtruck	[6.49 6.87 6.35 0 0 0 0]	[1.11 0.77 0.24 0 0 0 0]	[11.67 15.5 15.26 0 0 0 0]
156314	existingtruck	[7.41 3.45 5.76 8.32 5.9 8.21 8.95]	[0.35 0 0.43 0.3 0.87 0.53 0.18]	[3.72 19.75 16.17 13.87 15.78 13.31 13.33]
155842	existingtruck	[9.31 0.73 0 0 0 0 0]	[0.82 1.67 0 0 0 0 0]	[11.75 21.25 24 0 0 0 0]
155879	existingtruck	[4.58 0 0 0 0 0 0]	[0.35 0 0 0 0 0 0]	[13.83 24 24 23.92 0 0 0]
156168	existingtruck	[6.55 4.93 7.55 5.94 7.86 6.75 0]	[0.33 0.72 0.25 0.83 0.85 0.5 0]	[8.81 16.36 15.1 14.14 13.68 13.5 0]
155746	existingtruck	[0 0 0 0 0 0 0]	[0.66 0 0 0 0 0 0]	[19.48 0 0 0 0 0 0]
156113	existingtruck	[7.7 1.84 9.63 2.98 0 0 0]	[5.05 1.1 1.87 1.38 0 0 0]	[0.75 20.18 10.58 19 24 24 24]

Figure 42. Snapshot of Duty Status Results from Week 1

4.2.4 Recommendations for Capacity Expansion of Parking Facilities

After completing the simulation, the parking facility usage rates are input to an optimization model to generate recommendations for parking facility capacity expansion based on a user-specified budget. Other inputs to the optimization model include locations of new facilities and costs of capacity expansion.   A full description of the model formulation and code is provided in *Appendix D: Optimization Model.*

Model Overview

From the simulation output, the usage rate for facilities operating overcapacity is used as input to the optimization model. First, the model considers any facility to be overcapacity if the usage ratio is above 1.0, e.g., more than 100% of its capacity is used. Second, the model identifies candidate facilities which could potentially serve the unmet demand at the existing facilities. Candidate facilities are those within a specified search radius (or maximum coverage distance) of the overcrowded facility. The maximum coverage distance between candidate facilities and overcrowded existing facilities is set to 40 miles, or approximately 30 to 60 minutes of drive time. From the list of possible candidate locations, considering the set of all candidate locations (e.g., the candidates for each overcrowded existing facility) the model seeks a solution to meet the budget limitation while maximizing the amount of unmet demand that can be reallocated to improved facilities (existing or new). The mathematical formulation for the problem is called a maximal coverage problem for capacitated multiple facility locations with multiple services (MCPCMFL).

Operations Research (OR) techniques are used to solve the optimization problem and have been widely used to formulate and solve problems with explicit objective functions and constraints, including facility location problems. In OR, an objective function(s) is formulated with the goal of minimizing or maximizing a value under a set of constraints. Then, OR solvers find optimal or near-optimal solutions. For large-scale problems, like that explored by ParkSIM, finding the optimal solution is not a trivial task and requires significant computational resources. In such cases, a good practice is to terminate the optimization process when high-quality solutions (near-optimal) are found in a reasonable time.

Model Inputs

For existing facilities, capacity expansions consider the available land surrounding the existing facility and the cost of paving and striping to get additional spaces. For new facilities, possible locations were selected by the research team from the list of available commercial locations reported by the Arkansas Economic Development Commission (AEDC). The details for site selection are provided in *Appendix B: Candidate Facility Selection*. Briefly, the sites were zoned commercial or industrial, were large enough to accommodate truck parking and related services, and were located within close proximity to the interstate. The user can alter the list of new facilities by editing or replacing the geographical file (.shp) file contained in the ParkSIM input files.

Three service levels are considered in the model for the cost of new facilities:

ParkSIM User Manual

1) facility with no services, e.g., the facility contains a paved lot
2) facility with partial service, e.g., the facility contains a paved lot, striping, and restrooms
3) full service, e.g., the facility contains a paved lot, striping, restrooms and showers, fuel, and dining

Each service level has an associated cost that is based on the size of the available land parcel, and construction cost estimates for the facility infrastructure. There are 168 existing facilities, 50 of which have land area suitable for capacity expansion. There are 42 new locations each of which can be considered for expansion under three service levels. Thus, there are 126 possibilities for new facilities. In total, there are 176 possible expansion sites considering existing and new facilities.

The user can change the following parameters which will affect the recommendations made by the optimization model: simulation length (default to 14 days), the tick length (default to 10 minutes), and the budget (no default). Users can select the available budget between the maximum and minimum values of $0 and $30 million.

Model Outputs as Recommendations

Once the simulation has been run once, the optimization model can be run again without requiring the entire simulation to be run again. This is useful for users that would like to test the effect of different budgets on the recommendations generated by the model. To run the optimization model again, adjust the budget slider, if necessary, and then click the button on the interface labeled, Run Optimization Model:
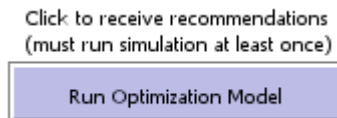
The output of the optimization model can be viewed on the interface in the box labeled, *Recommendations*, as well as on the map itself and in a text file, recommendations.txt. The text file shows the same content that is provided in the interface. Stations recommended by the model will appear on the map in pink (**Figure 43**). Locations shown as circles are public facilities and those shown as rectangles are private facilities. Note that some locations still appear in yellow, red, or green to indicate their average usage ratios at the end of simulation.

In addition to the map output, the optimization model outputs a text narrative summarizing the recommendations in more detail. The text output first lists the recommendations by their location and then lists the percentage of previously unmet demand accommodated by that facility. For instance, a sample output of the optimization model with a $4,000,000 budget is shown **Figure 44**. In this example, 14 facilities are selected for capacity expansion.

Truck Symbol: BLUE trucks are entering trucks, ORANGE trucks are existing trucks. Off-duty trucks are WHITE.
Parking Facility Symbol, P: rectangular stops are privately owned, circular stops are publicly owned.(Full: Red, Half-full: Yellow, and Empty: Green)
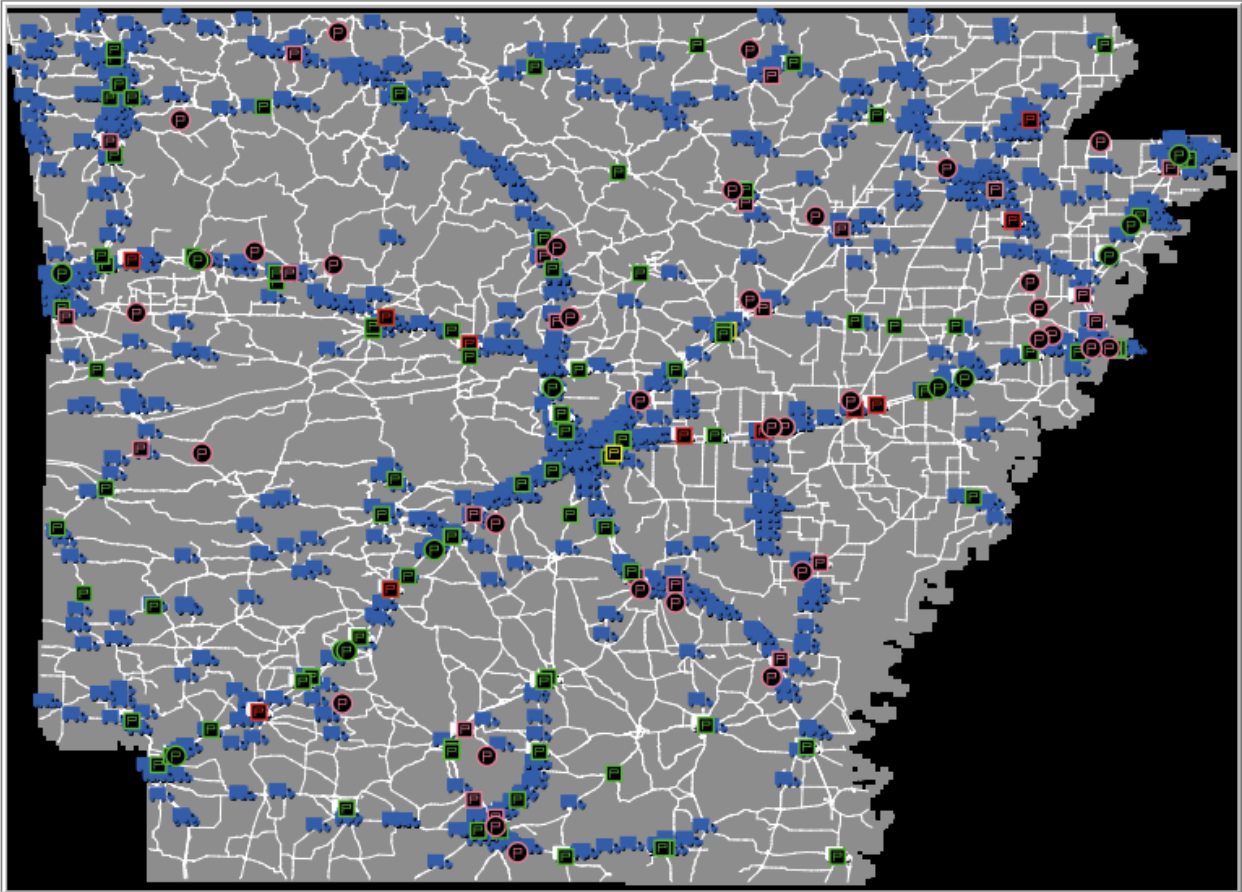
Figure 43. Final Model Recommendations in Map Format

Expand the White River Rest Area on I-40 Exit 199 Westbound Parking in White River. Add 2 parking spaces for a cost of $76591.1. This facility is an existing facility.

Expand the Ozark Rest Area on I-40 Exit 36 Westbound Parking in Ozark. Add 3 parking spaces for a cost of $122116.9. This facility is an existing facility.

Expand the West Memphis Welcome Area on I-55 Exit 278 Southbound Parking in West Memphis. Add 2 parking spaces for a cost of $70956. This facility is an existing facility.

Expand the Fast Market #36 (Citgo) on I-55 Exit 14 (CR 4 E) in Marion. Add 10 parking spaces for a cost of $384634.7. This facility is an existing facility.

Expand the Sumac Mart (Valero) on 4374 AR 7 S in Smackover. Add 2 parking spaces for a cost of $80009.21. This facility is an existing facility.

Expand the Exit 44 Quick Mart on I-30 Exit 44 (US 371 S) in Prescott. Add 24 parking spaces for a cost of $925856.6. This facility is an existing facility.

Expand the Snappy Mart #23 (Exxon) on I-55 Exit 21 (AR 42 W) in Turrell. Add 2 parking spaces for a cost of $77905.32. This facility is an existing facility.

Expand the Conoco 1 Stop on AR 1 Bypass & AR 1 Business in Dewitt. Add 3 parking spaces for a cost of $123735.4. This facility is an existing facility.

Expand the Snappy Mart # 7 (Exxon) on US 67-167 Exit 55 (US 167 N) in Bald Knob. Add 6 parking spaces for

(a) Summary of Facility Expansion Locations

11.76% of demand for facility Marion City Rest Area on I-40 Exit 274 Westbound Parking in White River is satisfied by expanding facility West Memphis Welcome Area on I-55 Exit 278 Southbound Parking in West Memphis.

58.82% of demand for facility Marion City Rest Area on I-40 Exit 274 Westbound Parking in White River is satisfied by expanding facility Fast Market #36 (Citgo) on I-55 Exit 14 (CR 4 E) in Marion.

75% of demand for facility White River Rest Area on I-40 Exit 199 Eastbound Parking in Hilton is satisfied by expanding facility Conoco 1 Stop on AR 1 Bypass & AR 1 Business in Dewitt.

25% of demand for facility White River Rest Area on I-40 Exit 199 Eastbound Parking in Hilton is satisfied by expanding facility Exxon Travel Center on US 67-167 Exit 16 B (AR 5) in Cabot.

100% of demand for facility Ozark Rest Area on I-40 Exit 36 Westbound Parking in Ozark is satisfied by expanding facility Tobo's 66 on I-49 Exit 58 (CR 26) in Greenland.

60% of demand for facility Pit Stop (BP) on I-40 Exit 221 (AR 78 S) in Wheatley is satisfied by expanding facility Snappy Mart # 7 (Exxon) on US 67-167 Exit 55 (US 167 N) in Bald Knob.

81.82% of demand for facility Shell Fuel Stop #84 on I-30 Exit 31 (AR 29) in Hope is satisfied by expanding facility Exit 44 Quick Mart on I-30 Exit 44 (US 371 S) in Prescott.

100% of demand for facility Jordan's Kwik Stop #6 (66) on I-30 Exit 78 (AR 7 N) in Caddo Valley is satisfied by expanding facility Exit 44 Quick Mart on I-30 Exit 44 (US 371 S) in Prescott.

53.33% of demand for facility Mapco Express #3154 on I-40 Exit 221 (AR 78 S) in Wheatley is satisfied by expanding facility Bald Knob Travel Center (66) on US 67-167 Exit 55 (US 167 N) in Bald Knob.

(b) Unmet Demand Accommodated by Expanded Facilities

Figure 44 Final Model Recommendations in Text Format

Along with the output detailing the individual facility expansions, the recommendations also include summaries of the total budget used, optimality of the solution (where 0.0% indicates an optimal solution was found), and amount of demand satisfied. In the example, on average 36.69 % of demand is met with a budget of $4,000,000 (**Figure 45**). Since the facility expansion costs are based on construction cost estimated given the unique site sizes and service requirements, the budget used ($3,997,372) may be less than the user-specified budget ($4,000,000). In this example, with a budget of $4,000,000, only 36.69% of all unmet demand can be satisfied.

> Budget to spend on the new and expanded facilities is $ 3,997,372
>
> This solution is near optimal with optimality gap of 0.4%
>
> The average met demand is 36.69 %

Figure 45. Final Model Recommendations Summary

Other Model Details and Sensitivity Analysis

Since the location model is large-scale with 59,312 variables and 59,523 constraints, finding optimal solutions is a challenge for open-source solvers. Hence, a time limit of an hour is set to allow the solver to search for an optimal solution. In many cases, the optimal solution can be found within 15 minutes. However, it is possible that after reaching the time limit, the final result is not optimal but of high quality (near-optimal) like the provided example. Open-source solvers were selected to best integrate with the other open source tools, e.g., NetLogo and R applications, and they are free to use and compatible with a wide range of operating systems and computer configurations.

ParkSIM allows the user to specify a budget under which to consider parking facility expansions. Since a budget may not be fixed, ParkSIM can be used to determine budget thresholds for acceptable overcrowding accommodations. For example, the optimization model can be re-run with different budget scenarios to find the percent of demand satisfied by the parking facilities. In **Figure 46**, the optimization model is run using budgets of $1 to $17 million. The amount of parking demand met by the expansions considered under each budget increase as the budget increases. With $1 million, around 9% of demand is met while with $17 million, 100% of demand is met.
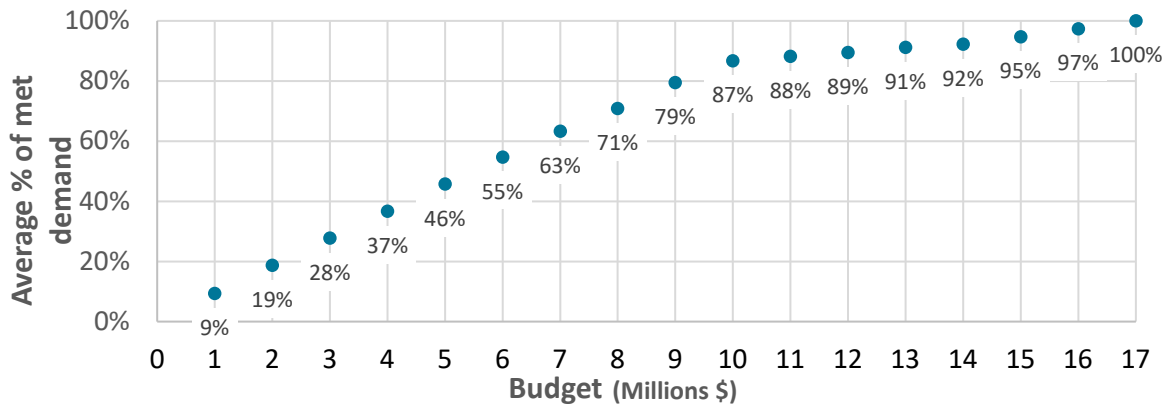
Figure 46. Impact of Increasing Budget on The Met Demand

References

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3. Plotner, S. C. (Ed.). (2016). *Building construction costs with RSMeans data 2017*. Gordian RSMeans Data.

4. RS Means Company. (2005). *Square foot costs*. RS Means Company.

Appendix

A. Existing and Potential New Facility Inventory

A total of 150 private truck stops in Arkansas were gathered from the Trucker's Friend database, which is a national truck stop directory that provides detailed information on truck stop locations and amenities. The parking facilities with IDs starting with "AR" are private truck parking facilities, e.g., ID AR003 is a pilot travel center (Table A.1). An additional 18 public parking facilities were gathered from the ARDOT Overnight Study. The IDs of public facilities are numeric, e.g., ID 13 is the Texarkana Welcome Center. The IDs containing "CS" represents candidate facilities that can be built to mitigate the overcrowding at existing parking facilities. The acronym "CS" is combined with site ID to easily identify the candidate facilities; the site IDs are taken from the Arkansas Economic Development Commission (AEDC) database for available commercial properties in Arkansas. The next section provides a brief overview of the selection process of candidate facilities.

The last column of Tables A.2 and A.3 divides the parking facilities in three categories: existing, existing-extension, and candidate. The existing facilities are those current facilities that are not considered for any capacity extension, existing-external facilities are current facilities that have the potential to expand, and candidate facilities are entirely new facilities that may be built to alleviate overcrowding.

Table A.1. Existing public truck parking facilities and their locations

ID	Name	Highway location	Latitude	Longitude	Facility Type
13	Texarkana Welcome Center	I-30 Exit 7 Eastbound Parking	33.516838	-93.936201	Existing-Extension
45	Marion City Rest Area	I-40 Exit 274 Westbound Parking	35.156005	-90.241395	Existing-Extension
56	White River Rest Area	I-40 Exit 199 Eastbound Parking	34.835662	-91.471575	Existing
57	Hilton Rest Area Northbound	I-55 Exit 45 Northbound Parking	35.660804	-90.075428	Existing
60	Gurdon Rest Area Eastbound	I-30 Exit 56 Eastbound Parking	33.929352	-93.259969	Existing
63	Mayflower Rest Area	I-40 Exit 134 Eastbound Parking	34.996238	-92.413160	Existing
79	Forrest City Rest Area Eastbound	I-40 Exit 235 Eastbound Parking	34.998594	-90.864077	Existing
90	Van Buren Welcome Center	I-40 Exit 3 Eastbound Parking	35.458624	-94.399095	Existing
92	Ozark Rest Area Eastbound	I-40 Exit 36 Eastbound Parking	35.519760	-93.851494	Existing
98	Social Hill Rest Area	I-30 Exit 93 Eastbound Parking	34.350844	-92.891888	Existing
104	Bardstown Rest Area Southbound	I-55 Exit 34 Southbound Parking	35.529637	-90.170608	Existing
114	White River Rest Area	I-40 Exit 199 Westbound Parking	34.836827	-91.471577	Existing-Extension
116	Gurdon Rest Area Westbound	I-30 Exit 56 Westbound Parking	33.938878	-93.249730	Existing
119	Mayflower Truck Parking Area	I-40 Exit 134 Westbound Parking	34.996330	-92.414458	Existing
123	Blytheville Welcome Center	I-55 Exit 69 Southbound Parking	35.941929	-89.875989	Existing
135	Forrest City Rest Area Westbound	I-40 Exit 243 Westbound Parking	35.038521	-90.759242	Existing
139	Ozark Rest Area Westbound	I-40 Exit 36 Westbound Parking	35.517666	-93.837065	Existing-Extension
481	West Memphis Welcome Area	I-55 Exit 278 Southbound Parking	35.164973	-90.172755	Existing-Extension

Table A.2. Existing private truck parking facilities and their locations

ID	Name	Highway location	Latitude	Longitude	Facility Type
AR003	Pilot Travel Center #492	I-30 Exit 78 (AR 7 N)	34.186844	-93.071220	Existing
AR007	E-Z Mart #721 (Shell)	US 71 S (1 mi N of US 270)	34.752274	-94.075806	Existing-Extension
AR010	TA Earle #033	I-40 Exit 260 (AR 149 N)	35.136482	-90.488876	Existing
AR011	Red River Truck Stop	I-30 Exit 18 (US 67)	33.612617	-93.802750	Existing
AR018	Exxon Auto/Truck Center #101	US 67-167 Exit 28 (US 67 Bus N)	35.068962	-91.912209	Existing
AR019	JJ's Truck Stop	I-30 Exit 106 (Military Rd)	34.484543	-92.725182	Existing-Extension
AR024	Truckomat	I-40 Exit 161 (Galloway Rd S)	34.779541	-92.131584	Existing
AR025	Petro North Little Rock #326 (Shell)	I-40 Exit 161 (Galloway Rd S)	34.781136	-92.128723	Existing
AR029	65 - 81 Truck Stop (Citgo)	US 65-425 (3 mi S) & AR 81	34.195271	-91.922134	Existing-Extension
AR037	Pilot Travel Center #429	I-40 Exit 280 (MLK Dr)/I-55 Exit 4	35.156910	-90.137421	Existing
AR042	Pit Stop (BP)	I-40 Exit 221 (AR 78 S)	34.927399	-91.108963	Existing
AR043	Fordyce Quick Mart (Gulf)	US 79-167 Bypass & AR 8 N	33.825962	-92.426994	Existing
AR044	White Oak #15 (Shell)	US 65 S & US 62-412 E	36.190968	-93.031242	Existing
AR045	Shell Fuel Stop #84	I-30 Exit 31 (AR 29)	33.693401	-93.599564	Existing
AR050	Superstop #80 (Shell)	I-30 Exit 98 A (US 270 S)	34.389488	-92.830139	Existing
AR051	Fast Market #36 (Citgo)	I-55 Exit 14 (CR 4 E)	35.261154	-90.225739	Existing-Extension
AR054	Country Express (66)	I-40 Exit 20 (CR 63 S)	35.512619	-94.113449	Existing
AR057	Filling Station (Citgo)	US 65 & 800 N Bryant	34.237968	-92.070297	Existing-Extension
AR062	Sumac Mart (Valero)	4374 AR 7 S	33.343994	-92.730560	Existing-Extension
AR201	Littlefield Express	I-540 Exit 12 (US 71 S)	35.314190	-94.400597	Existing
AR202	New Shell Lake Travel Center (Valero)	I-40 Exit 260 (AR 149 N)	35.136688	-90.489166	Existing

ParkSIM User Manual

ID	Name	Highway location	Latitude	Longitude	Facility Type
AR204	Morgan Truck Stop (Shell)	I-40 Exit 142 (AR 365)	34.884178	-92.382439	Existing
AR206	Exit 44 Quick Mart	I-30 Exit 44 (US 371 S)	33.810093	-93.419128	Existing-Extension
ID	Name	Highway location	Latitude	Longitude	Facility Type
AR208	Pilot Travel Center #430	I-40 Exit 84 (AR 331 S)	35.280201	-93.093590	Existing-Extension
AR301	Love's Travel Stop #236	I-40 Exit 161 (Galloway Rd N)	34.786469	-92.126289	Existing
AR302	Petro West Memphis #311	I-40 Exit 280 (MLK Dr)/I-55 Exit 4	35.153751	-90.135345	Existing
AR602	Marty Mart #12 (Citgo)	US 67-167 Exit 55 (US 167 N)	35.320808	-91.560661	Existing
AR604	Pit Stop (Shell)	AR 7 (3/4 mi S of US 278)	33.556480	-92.826973	Existing-Extension
AR607	Bailey's Super Store (Conoco)	US 79-167 Bypass & 4th	33.812920	-92.449799	Existing
AR608	Southfork Truck Stop (Citgo)	I-30 Exit 63	33.999416	-93.184853	Existing-Extension
AR610	I-40 Kwik Stop (Citgo)	I-40 Exit 233 (AR 261 S)	34.981022	-90.903290	Existing
AR615	Wycamp Truck Stop (Conoco)	3053 US 49 (4 mi W)	34.554462	-90.714661	Existing
AR616	Sweet Pea #401	I-40 Exit 221 (AR 78 N)	34.931641	-91.108315	Existing-Extension
AR617	Exxon Super Station	901 US 59-71 N & AR 8 E	34.585621	-94.222397	Existing
AR716	Shell #3	AR 7 (2 mi S of US 79-278) & Fairview SE	33.535263	-92.825935	Existing
AR727	Missile Mart #08 (Mobil)	4050 US 167 N	33.257561	-92.645081	Existing-Extension
AR728	Break Time (Valero)	7911 US 167 N	33.329506	-92.551588	Existing
AR729	Expressway (Mobil)	US 167 Bypass & US 63 (N Jct)	33.213768	-92.632523	Existing
AR735	E-Z Mart # 39	1938 US 71	34.173904	-94.315071	Existing
AR774	Teddy Bears #6	US 82	33.109760	-92.356445	Existing
AR777	Camp I-30 Truck Stop	I-30 Exit 2 (Loop 245 S)	33.474312	-94.010704	Existing-Extension
AR784	Wynne Truck Plaza (66)	700 US 64 E & AR 1	35.253081	-90.780811	Existing

ParkSIM User Manual

ID	Name	Highway location	Latitude	Longitude	Facility Type
AR786	PJ's Country Store #4 (BP)	I-40 Exit 271 (AR 147 S, W on US 70-79)	35.147350	-90.292030	Existing
AR787	Love's Travel Stop #450	I-40 Exit 280 (MLK Dr)/I-55 Exit 4	35.155193	-90.138329	Existing
AR790	Jordan's Kwik Stop #6 (66)	I-30 Exit 78 (AR 7 N)	34.186790	-93.071381	Existing-Extension
AR792	Superstop #469 (66)	I-440 Exit 5 (Fourche Dam Pike S)	34.713291	-92.190155	Existing
AR793	Flash Market #017 (Citgo)	US 67 & AR 18 (W to AR 367)	35.638000	-91.251205	Existing
AR794	Winner's Circle # 1 (66)	I-30 Exit 98 A (US 270 S)	34.393551	-92.828842	Existing
AR797	Tiger Mart #102 (Exxon)	US 167 S & AR 14	35.735661	-91.639282	Existing-Extension
AR798	Doublebee's (Conoco)	I-40 Exit 183 (AR 13)	34.796268	-91.750626	Existing
AR799	Scott Petroleum	2881 US 65 (N of AR 8 W)	33.111816	-91.257034	Existing
AR804	Flying J Travel Plaza #606	I-30 Exit 7 (AR 108 N)	33.513130	-93.949249	Existing
AR806	Mapco Express #3154	I-40 Exit 221 (AR 78 S)	34.926441	-91.108200	Existing-Extension
ID	Name	Highway location	Latitude	Longitude	Facility Type
AR807	Gasoline Alley	US 65 & AR 9 (5 mi S of Clinton)	35.527843	-92.442314	Existing-Extension
AR808	Quick Draw (Exxon)	I-440 Exit 5 (Fourche Dam Pike N)	34.718552	-92.188553	Existing
AR811	PDQ #247 (66)	AR 7 & AR 247 E	35.228321	-93.140205	Existing
AR812	Big Red (Valero)	I-530 Exit 34 (US 270 E)	34.260513	-92.102440	Existing
AR813	Morgan Valero #471	I-40 Exit 142 (AR 365)	34.886719	-92.376816	Existing
AR814	Jordan's Kwik Stop #15 (Shell)	I-30 Exit 78 (AR 7 N)	34.187523	-93.071449	Existing
AR816	Flying J Travel Plaza #607	I-40 Exit 280 (MLK Dr)/I-55 Exit 4	35.153118	-90.143791	Existing
AR817	Roadway Food Mart #3 (Exxon)	US 71 S	33.663212	-94.120476	Existing
AR818	Road Mart (Exxon)	US 82 & AR 133	33.136494	-91.953547	Existing
AR822	Powell's One Stop	5452 US 62 W & AR 103 S	36.339142	-93.459290	Existing-Extension

ParkSIM User Manual

ID	Name	Highway location	Latitude	Longitude	Facility Type
AR823	Corner Store #1791 (Valero)	I-40 Exit 175 (AR 31)	34.806168	-91.885277	Existing
AR825	Big Red #121 (Valero)	I-530 Exit 20 (US 46 E)	34.440498	-92.194321	Existing
AR826	Fast Trax #7 (Conoco)	I-49 Exit 85 (US 71 E)	36.335072	-94.181625	Existing
AR828	Love's Travel Stop #267	I-40 Exit 107 (AR 95)	35.172729	-92.744270	Existing
AR829	Pilot Travel Center #332	I-40 Exit 161 (Galloway Rd S)	34.781898	-92.127625	Existing
AR830	Paramount Travel Center (Valero)	I-30 Exit 46 (AR 19 N)	33.828403	-93.395523	Existing
AR831	Flying J Travel Plaza #605	I-40 Exit 84 (AR 331 N)	35.284103	-93.089294	Existing
AR833	Love's Travel Stop #271	I-40 Exit 37 (US 219)	35.511448	-93.821564	Existing-Extension
AR835	Hard Hat #7 (Exxon)	I-55 Exit 67 (AR 18 - 1.5 mi E)	35.927860	-89.841103	Existing
AR836	Snappy Mart #19 (Exxon)	US 63 Exit 39 (AR 18 N)	35.804218	-90.625428	Existing
AR839	Snappy Mart #23 (Exxon)	I-55 Exit 21 (AR 42 W)	35.364281	-90.280167	Existing-Extension
AR843	Pilot Travel Center #145	I-49 Exit 72 (1/4 mi W on US 412)	36.175613	-94.193771	Existing
AR844	Alma Travel Mart (Valero)	I-40 Exit 13 (US 71)	35.487450	-94.225861	Existing
AR845	Hwy 109 Truck Plaza	3309 AR 109	35.427234	-93.529383	Existing
AR846	Flash Market # 46 (Citgo)	481 US 65 N Bypass	35.596214	-92.458565	Existing
AR847	Family Stop #3 (66)	US 71 S	35.277920	-94.374390	Existing-Extension
AR848	Gas N Go (Valero)	US 62 W	36.283894	-92.491646	Existing-Extension
AR852	PDQ - South (66)	2750 AR 7 S & AR 326	35.251236	-93.136879	Existing
AR855	Flash Market # 32 (Shell)	US 63 Exit 29 (AR 69 E)	35.677593	-90.549706	Existing
AR858	On The Run (Exxon)	728 US 62-412 E & AR 126	36.287750	-92.482376	Existing
AR859	Missile Mart #09 (Exxon)	US 167 & AR 278	33.537708	-92.469612	Existing

ID	Name	Highway location	Latitude	Longitude	Facility Type
ID	Name	Highway location	Latitude	Longitude	Facility Type
AR860	Citgo Convenience #389	9259 US 65 N	35.473495	-92.417763	Existing
AR861	Gas Mart	2115 US 79 N	33.618500	-92.770821	Existing-Extension
AR862	Conoco 1 Stop	AR 1 Bypass & AR 1 Business	34.291407	-91.338001	Existing-Extension
AR863	Ward's Fuel Stop (BP)	504 US 70 W	34.116436	-94.022514	Existing
AR865	Shell Truck Stop	I-55 Exit 48 (AR 140 E)	35.698273	-90.047607	Existing-Extension
AR868	Love's Travel Stop #275	I-40 Exit 233 (AR 261 N)	34.985996	-90.905731	Existing-Extension
AR869	Snappy Mart # 7 (Exxon)	US 67-167 Exit 55 (US 167 N)	35.321987	-91.561729	Existing-Extension
AR870	Exxon Travel Center	US 67-167 Exit 16 B (AR 5)	34.951364	-92.067887	Existing-Extension
AR871	Magnolia Travel Center (Valero)	10 US 82 W & US 371	33.296314	-93.251472	Existing-Extension
AR873	Flash Market # 23 (Citgo)	US 63 Exit 29 (AR 69 E)	35.678825	-90.550102	Existing
AR874	Tigermart Auto/Truck Center #107 (Exxon)	I-40 Exit 55	35.463421	-93.522949	Existing
AR876	E-Z Mart #425 (Shell)	AR 102 (1 blk W of US 62-71)	36.356839	-94.183949	Existing
AR877	Kum & Go #0379	3430 US 63-412 (1/2 mi NW of river)	36.104698	-91.099266	Existing
AR879	Quick Draw #6 (Citgo)	409 US 82 W	33.134996	-91.966650	Existing
AR880	Flash Market #104 (Citgo)	3309 US 65 & US 165	33.548870	-91.384148	Existing
AR887	E-Z Mart #432 (Shell)	54 US 71	35.933264	-94.178967	Existing
AR888	Love's Travel Stop #277	I-30 Exit 46 (AR 19 S)	33.828426	-93.393677	Existing
AR889	71 Express (Shell)	504 US 71 E	35.063778	-94.246979	Existing
AR895	Pilot Travel Center #118	I-30 Exit 121	34.608810	-92.533943	Existing
AR896	Hob Nob Shell	I-40 Exit 84 (AR 331 N)	35.284191	-93.092674	Existing

ParkSIM User Manual

ID	Name	Highway location	Latitude	Longitude	Facility Type
AR897	Flash Market #177 (Citgo)	I-55 Exit 67 (AR 18 W)	35.928753	-89.879013	Existing
AR898	TA Prescott #224	I-30 Exit 44 (US 371 N)	33.812019	-93.427895	Existing
AR899	Flash Market # 49 (Citgo)	I-40 Exit 216 (US 49 N)	34.911739	-91.195808	Existing
AR900	Exit 57 Auto/Truck Express (Shell)	I-40 Exit 57	35.456291	-93.483543	Existing-Extension
AR901	Colt's Quick Draw (Mobil)	1075 US 65 N (1/2 mi S of AR 25 jct)	35.260053	-92.387818	Existing-Extension
AR903	Flash Market # 7 (Citgo)	US 67-167 Exit 45 (Truman Baker Dr)	35.234592	-91.699074	Existing
AR904	Hermitage Shell	149 US 63 Bypass	33.445717	-92.170174	Existing-Extension
AR906	Cash's Travel Plaza (Citgo)	607 US 65 (1.5 mi N of US 165)	33.901249	-91.492050	Existing-Extension
AR908	Tobo's 66	I-49 Exit 58 (CR 26)	35.997200	-94.198280	Existing-Extension
ID	Name	Highway location	Latitude	Longitude	Facility Type
AR909	Kings River Country Store	22784 US 412	36.139069	-93.584152	Existing
AR912	Newport Truck Plaza (Exxon)	US 67 & AR 18 W	35.638298	-91.243729	Existing-Extension
AR914	Corner Store #1796 (Valero)	I-440 Exit 5 (Fourche Dam Pike S)	34.713428	-92.188469	Existing-Extension
AR915	Missile Mart #10 (Mobil)	3700 US 82 W	33.208595	-92.720589	Existing-Extension
AR917	Bald Knob Travel Center (66)	US 67-167 Exit 55 (US 167 N)	35.323944	-91.561226	Existing-Extension
AR918	Blackwell Travel Center (Citgo)	I-40 Exit 101	35.221299	-92.825839	Existing
AR919	Hilltop Travel Center (Shell)	I-49 Exit 24 (AR 282 E)	35.539299	-94.229073	Existing
AR921	Corner Store #1779 (Valero)	US 270 Exit 2 (US 70 Bus E)	34.478994	-93.112733	Existing
AR922	Love's Travel Stop #457	I-30 Exit 128 (Otter Creek W)	34.656934	-92.413636	Existing
AR923	8 Mile Store	US 64 E & AR 36 N	35.077400	-92.304649	Existing-Extension
AR924	Hawg's Exxon	US 167 N (S of N junction AR 25/AR 69)	35.788216	-91.641869	Existing

ParkSIM User Manual

ID	Name	Highway location	Latitude	Longitude	Facility Type
AR925	Flash Market #391 (Citgo)	US 64 & US 49	35.251221	-91.030052	Existing
AR926	Forest Tower Food Mart I (Shell)	US 167 (12 mi N of Sheridan)	34.483929	-92.348923	Existing
AR927	Big Red (Valero)	AR 5 & AR 16 (W junction)	35.459328	-92.051712	Existing-Extension
AR928	Corner Store #1789 (Valero)	I-30 Exit 98 B (US 270 N)	34.404003	-92.822655	Existing-Extension
AR929	White Oak Station #38 (Shell)	I-49 Exit 76	36.226997	-94.174919	Existing
AR930	Kum & Go #0414	US 412 E & CR 265	36.167615	-94.118974	Existing
AR931	Kwik Serv #1 (Valero)	US 62-63-412 S & AR 175	36.302418	-91.445381	Existing
AR932	The I-40 Travel Center (Valero)	I-40 Exit 35 (AR 23 N)	35.524241	-93.863836	Existing
AR933	North Point (Valero)	US 49 N & US 49 Bypass	36.078712	-90.490341	Existing
AR934	Doublebee's #140 (Conoco)	US 67 Exit 44 (AR 367 N)	35.224592	-91.721549	Existing
AR935	Scotty's (66)	US 59-71 S & AR 4	34.432987	-94.411964	Existing
AR937	T Ricks (Citgo)	I-40 Exit 193 (US 63 S)	34.816367	-91.567688	Existing
AR938	West 66 Food Mart (Valero)	1939 AR 66 W	35.864335	-92.150944	Existing-Extension
AR939	Hillbilly U-Pump	645 US 62-412 W	36.371903	-91.835192	Existing
AR940	Rick's (Valero)	I-30 Exit 83 (AR 283 SE)	34.234492	-93.006099	Existing
AR941	Stop N By #17 (Exxon)	I-55 Exit 63 (US 61 N)	35.888919	-89.919328	Existing-Extension
AR943	Red Mule Mart	1706 US 62-412	36.259372	-91.537873	Existing-Extension
AR944	FG Express #3 (Citgo)	US 64 & AR 17 N Jct	35.268462	-91.200419	Existing
AR945	D J's Convenient Store	AR 9 & AR 113 (S jnct)	35.121931	-92.741873	Existing
ID	Name	Highway location	Latitude	Longitude	Facility Type
AR946	Corner Store #1795 (Valero)	I-430 Exit 12 (AR 100 - 1 mi N)	34.822206	-92.369137	Existing
AR947	Circle K #35 (Exxon)	1108 US 62 E	36.382890	-90.176913	Existing

ParkSIM User Manual

ID	Name	Highway location	Latitude	Longitude	Facility Type
AR948	Corner Store #1783 (Valero)	3371 AR 7 N	34.625949	-93.053379	Existing
AR949	Corner Store #1787 (Valero)	I-440 Exit 7 (US 165 S)	34.732319	-92.157975	Existing
AR950	Corner Store #1772 (Valero)	274 US 425 N	33.632583	-91.801460	Existing
AR951	Love's Travel Stop #557	US 67-167 Exit 44	35.218878	-91.716898	Existing
AR952	Love's Travel Stop #607	US 63 Exit 40	35.803403	-90.635167	Existing-Extension

Table A.3. Candidate truck parking facilities and their locations

ID	Name	Highway location	Latitude	Longitude	Facility Type
CS1228	Prescott Industrial Park	Interstate 30	33.815788	-93.408683	Candidate
CS1244	SEA001-Benton	Benton Ave.	35.228140	-91.716628	Candidate
CS1250	SEA008	Brantly Rd.	35.197125	-91.748698	Candidate
CS1290	Guaranty Site - I-40 Interstate Frontage	North Airport Road (State Highway 118)	35.170467	-90.213706	Candidate
CS1338	Interstate 40 Clarksville Business Park	204 Massengale Road	35.458021	-93.515698	Candidate
CS1346	Maumelle Commercial Park	Maumelle Blvd and Commerce Drive	34.860158	-92.400448	Candidate
CS1349	Gillette/Stuckey (OS14)	I-555 and West Main	35.672943	-90.550716	Candidate
CS1397	Guaranty Loan Industrial Park	Airport Road and Hino Blvd.	35.171717	-90.230533	Candidate
CS14378	West Memphis I-40 Megasite	Bolling Lane	35.158570	-90.274643	Candidate
CS1451	Millwood Commercial	2750 North Hazel Street	33.692873	-93.600677	Candidate
CS14656	Airport Road Site	Airport Road	35.512999	-93.828056	Candidate
CS1487	Barling Site	1003 Frank Street	35.323230	-94.306553	Candidate
CS14877	McBride Farms	Apple Blossom Road	36.236194	-94.146874	Candidate
CS14894	Goldsby North Site	Mound City Road	35.169147	-90.142642	Candidate
CS14936	Uptown District - Commercial Development Area	Interstate 40 Frontage Road East	35.168836	-90.177928	Candidate
CS15115	Covington Commercial Dave Ward Park - Rear Lots	955 Covington Way	35.064096	-92.436324	Candidate
CS1635	NE of Lindsey Rd and Foursche Dam Pike	NE of Lindsey Rd and Foursche Dam Pike	34.716289	-92.184863	Candidate
CS16389	12 Acres on Highway 279	13162 Hwy 279	36.423926	-94.331343	Candidate

ID	Name	Highway location	Latitude	Longitude	Facility Type
CS16662	Commercial lot.	177 SFC 419	35.062274	-90.686210	Candidate
CS16672	Lindsey Road North Site	Lindsey Road & Industrial Harbor Site	34.716813	-92.179347	Candidate
ID	Name	Highway location	Latitude	Longitude	Facility Type
CS2097	406 Highway 64 E	406 Highway 64 E	35.085185	-92.347748	Candidate
CS2218	Peck Addition properties	600 West Commerce Boulevard	33.683056	-93.604711	Candidate
CS2235	Bluff View	I-40 & Bekaert Road	35.456545	-94.387794	Candidate
CS2239	2900 Fayetteville Road	2900 Fayetteville Road	35.478600	-94.353762	Candidate
CS2252	Blytheville Interstate Site	I-55 & US HWY 61	35.885063	-89.913946	Candidate
CS2262	Cliff Drive and Old Greenwood Road	Cliff Drive and Old Greenwood Road	35.346021	-94.379869	Candidate
CS2271	206 SE 4th St	206 SE 4th St	34.589605	-92.488146	Candidate
CS2352	16.50 Acres 10601 Stagecoach Rd	10601 Stagecoach Rd	34.654471	-92.424696	Candidate
CS2354	16 Acres Otter Creek Rd and I-30	SW of Otter Creek Rd and I-30	34.654733	-92.413961	Candidate
CS2358	Miller Property	I-55 Access Rd	35.244635	-90.214346	Candidate
CS2379	16.50 Acres SE of I-530 and Highway 63	SE of I-530 and Highway 63	34.170060	-92.004200	Candidate
CS2411	Russellville Village Centre	Interstate 40 at Exit 83	35.294564	-93.110732	Candidate
CS2421	River Valley Auto Park	River Valley Drive	35.316126	-94.399093	Candidate
CS2474	Galloway and I-40 North Little Rock Tract 1	SE of I-40 and Galloway	34.772147	-92.116936	Candidate
CS2478	Galloway and I 40 North Little Rock Tract 12	NE of I-40 and Galloway	34.781735	-92.123060	Candidate
CS2515	NW of Crystal Hill Rd and Standridge Rd	NW of Crystal Hill Rd and Standridge Rd	34.818146	-92.329354	Candidate

ParkSIM User Manual

ID	Name	Highway location	Latitude	Longitude	Facility Type
CS2551	12 Acres Wildwood Ave and Highway 67	NW of Wildwood Ave and Highway 67	34.816817	-92.202946	Candidate
CS2574	21286 I-30	21286 I-30	34.610139	-92.524967	Candidate
CS2592	15.70 Re-Development	1505-1575 E Oak St	35.090805	-92.406027	Candidate
CS2623	10004 Highway 5 12.78 Acres	10004 Highway 5	34.956605	-92.070370	Candidate
CS500	Proposed facility 1 in Gurdon	Gurdon I-30 Westbound	34.017060	-93.164630	Candidate
CS500	Proposed facility 2 in Social Hill	Social Hill I-30 Westbound	34.271337	-92.972224	Candidate

B. Candidate Facility Selection

The Arkansas Economic Development Commission (AEDC) identifies potential sites for new commercial and industrial development. Along with location information, the publicly accessible AEDC database provides information on land area, sale or lease price, former use, and interstate and highway proximity. Based on several screening criteria, a total of 40 candidate sites were identified for new parking facility construction projects. Two already planned facilities in Gurdon and Social Hill are also added to the list of candidate facilities, making the total number of candidate facilities to 42.

The screening criteria for site selection include land use classification, land area available for sale, proximity to interstates and highways, terrain types, and allowance for land subdivision. City zoning maps were used to find the zoning classification of each property. Usually, truck parking facilities are allowed in 'C-2' zoned sites. Based on literature review regarding parking facility construction projects, a minimum of 5 acres land area was identified as the threshold to build a new facility. Thus, the identified new sites all have land area more than 5 acres. Since most of the truck traffic moves on the interstates and highways, proximity to these type roadways are important for parking facility location. A 1-mile straight-line distance band was used for interstate and highway proximity. Again, whether the terrain is flat, hilly, or needs clearance for trees and shrubs are important consideration for location selection of parking since cost can easily go up in site preparation stage depending on the terrain characteristics of a site. Finally, subdivision is important for large properties, for instance, if a property is large, e.g., 50 acres and it is not subdividable, it is unnecessary to purchase this land as parking facilities do not require that large of an area. The project team also considered extending the current parking facilities. Based on satellite imageries of the current facilities, a total of 50 facilities were identified to have room for extension.
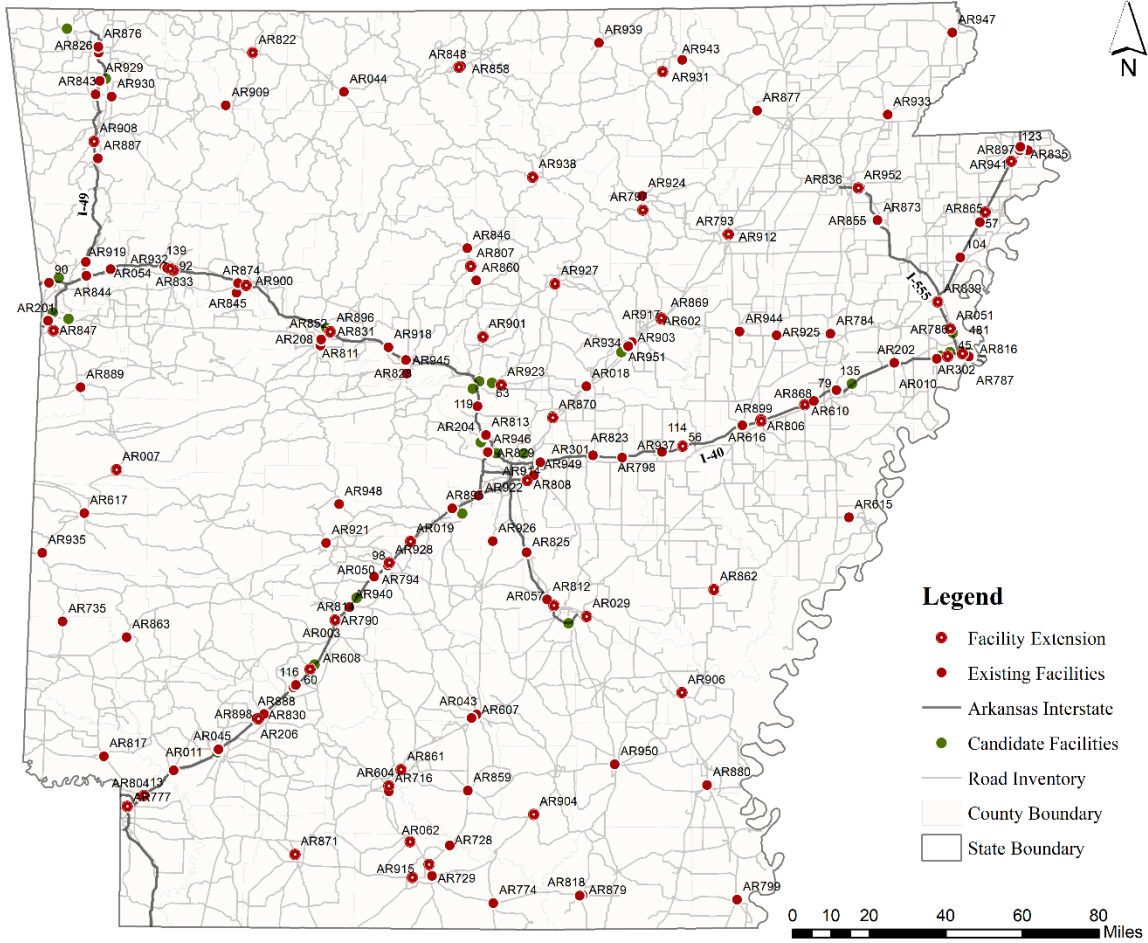
Figure B.1. Spatial Distribution of Existing and Potential New Facilities

C. Cost Estimation for Capacity Extension

To estimate the cost of constructing new truck parking facilities, a proprietary database RSMeans was used. RSMeans is one of the leading constructions estimating databases in the country that provides both aggregated and disaggregated cost data. Two RSMeans databases were used: Square foot costs with RSMeans data (2016) and Heavy construction costs with RSMeans Data (2016). To estimate the cost of a new parking facility, cost of site clearance, earthwork, and improvements were estimated first. Then, cost of bundled improvements such as restroom, restaurant, and convenience store construction costs were estimated. The details of amenities such as number of showers in a typical parking facility were decided based on a site visit.

The project team visited two truck parking facilities in Russellville and documented the specifics of amenities provided by those facilities. The new facilities are divided in three categories based on amenity availability: (i) Full service denoting the facilities that will have fuel, food, stores, showers, and restroom services; (ii) Partial services are facilities that will have some combination of amenities (not all) that are provided to the full service facilities; and (iii) No service facilities are those that only have unpaved lots, no amenities are placed on them.

The capacity of each type facilities is decided based on average size of each type in the existing facility inventory. The final estimated cost also considers contractor fees, architect fees, sales taxes, and contingency costs. The estimated costs of new facilities were validated by conducting stakeholder interviews with experts from several trucking industry stakeholders—ARDOT, NATSO, ATA, and ATRI. The estimated costs were also compared with the ARDOT's contract level item summary data. Table C.1 provides cost of three different types of service class facilities and Table C.2 provides detailed cost breakdown of a full-service facility like Flying J. in Russellville.

Table C.1. Estimated costs for new facility construction

Service Class	Cost	Capacity
Full Service	$14,083,462.18	77
Partial Service	$5,834,315.17	40
No Service	$2,795,013.84	20

Table C.2. Cost Estimation for a Service Class 1 Facility (Full Service)
Model: Flying J. in Russellville

	Item	Description	Unit	Unit Price	Quantity	Extended Cost	Contractor Fees (25%)	Architect Fees (8%)	Sales Tax (5%)	Contingency (15%)	Final Cost
Site	Site Clearing	Remove trees & stumps up to 6" diameter by cut & chip & stump haul away	1 Acre	7,150.00	4.9	$35,035	$8,758	$2,802	$1,751	$5,255	$53,603
	Site Earthwork	Trenching, common earth, no slope, 4' wide, 2' deep, 3/8 C.Y. bucket	L.F.	5.64	43560	$245,678	$61,419	$19,654	$12,283	$36,851	$375,887
		Excavate common earth, 1/2 CY backhoe, two 8 CY dump trucks, 1 MRT	Cubic Yard	9.61	80666.67	$775,206	$193,801	$62,016	$38,760	$116,281	$1,186,066
	Site Improvements	Parking lot, 90-degree angle parking, 6" bituminous paving, 6" gravel base	Each CMV	2,094.44	83	$173,838	$43,459	$13,907	$8,691	$26,075	$265,973
		Pavement	Square Feet	11.64	411,948	$4,793,345	$1,198,336	$383,467	$239,667	$719,001	$7,333,818
Amenities	Convenience Store	1 story building with 12' story height and 4,000 square feet of floor area. Exterior wall wood clapboard.	Square Feet	111.50	15000	$1,672,500					$1,672,500
	Restaurant	1 story building with 12' story height and 3500 square feet of floor area. Exterior wall wood clapboard.	Square Feet	209.25	5000	$1,046,250					$1,046,250
	Bathroom	Bathroom with urinals, water closet, sink	Each	33,838.00	2	$67,676	$16,919	$5,414	$3,383	$10,151	$103,544
	Shower and Changing	Stall, with drain only. Fiberglass, one piece, with 3 walls, 32"*32" square	Each	2,809.00	15	$42,135	$10,533	$3,370	$2,106	$6,320	$64,466
	Security Cameras	Closed circuit television system (CCTV) surveillance, one station (camera and monitor)	Total	29,300.00	1	$29,300	$7,325	$2,344	$1,465	$4,395	$44,829
	Lighting	Light poles, anchor base. Aluminum poles 35' high	Each	4,650.00	20	$93,000	$23,250	$7,440	$4,650	$13,950	$142,290
	Truck Wash	1 story building with 12' story height and 1000 square feet of floor area	Square Feet	333.95	1000	$333,950					$333,950
	Truck Scales	Truck Scales, Digital, Electric, 60'x10' Platform	Each	71,700.00	1	$71,700	$17,925	$5,736	$3,585	$10,755	$109,701
	Service Station	1 story building with 12' story height and 2200 square feet of floor area	Square Feet	236.70	5600	$1,325,520					$1,325,520
	Fences	Chain link fences and gates, gate, chain link, vinyl clad, single, 4' * 10', excludes excavation	Each	819.00	20	$16,380	$4,095	$1,310	$819	$2,457	$25,061
Total						$10,721,515					$14,083,462

ParkSIM User Manual

D. Optimization Model

Maximal Coverage Problem Optimization Formulation

Notation:

S	Overcapacity level
SL	Simulation length
tL	Tick length
T	Total number of ticks during simulation
t	Index of time where t= $1, \dots, T$
L	Set of distinct geographic facility locations
k	type of candidate facilities, k=1(Build no service), 2 (Build partial service), 3 (Build full service), 4 (Expansion)
U_k	Set of candidate facilities of type k
I	Set of all candidate facilities, $I = \cup_{k=1}^{4} U_k$
ℓ_i	The geographic location of candidate facility i for $i \in I$
J	Set of all existing facilities
d_{jt}	Amount of demand overcapacity for existing parking facility j at time t
q_i	Capacity of candidate facility $i \in I$
f_i	Cost of building or expanding facility $i \in I$
d_j	Number of overcapacity (demand) on the existing facilities $j \in J$
c_{ij}	Distance between supply node i and demand node j
B	Available budget
D	Maximum distance of coverage between the supply and demand nodes
y_i	Binary variable that takes value 1 if site $i \in I$ is created or expanded and take 0 otherwise
x_{ij}	Fraction of demand of node j supplied from facility i
z_{ij}	Binary variable that takes value 1 if demand of node j is supplied from facility i.

The MCPCMFL estimates the maximal demand coverage through expansion of existing or building new parking facilities by considering an overcapacity level, S, a maximum available budget, B, and a maximum coverage distance between supply and demand nodes, D. The overcapacity level is a parameter between 0%-100% that indicates the threshold over which an existing facility's utilization is considered overcapacity. In this work, we set S=100%.

First, the total number of ticks, $T = SL/tL$ is found. Second, the number of overcapacity trucks at existing parking facilities j, d_j is found using Equation (1).

$$d_j = \max_{t=1,\dots,T}(0 , d_{jt} - S * q_j) \qquad (1)$$

where the product of each facility's overcapacity level is subtracted from the capacity of the maximum of demand for parking at the existing facility over time and return 0 if the outcome is a non-positive number. We interpret the overcapacity of each existing facilities, d_j , as the demand to be supplied through added capacities of building or expanding candidate facilities. The candidate facilities are classified into four different sets U_1, U_2, U_3, and U_4. New facilities are U_1, U_2, and U_3 with no, partial, and full service levels, respectively. We note that each new facility can have at most one of the three service levels. The existing facilities with the capability of expansion are classified into set U_4. The optimization model is then as follows.

$$\text{Maximize} \quad \frac{\sum_{i \in I}\sum_{j \in J} d_j x_{ij}}{\sum_{j \in J} d_j} \qquad (2)$$

Subject to:

$$\sum_{i \in I} f_i y_i \leq B \qquad (3)$$

$$\sum_{i \in I} x_{ij} \leq 1 \qquad \forall j \in J \qquad (4)$$

$$\sum_{j \in J} d_j x_{ij} \leq q_i y_i \qquad \forall i \in I \qquad (5)$$

$$z_{ij} c_{ij} \leq D y_i \qquad \forall i \in I, \forall j \in J \qquad (6)$$

$$x_{ij} \leq z_{ij} \qquad \forall i \in I, \forall j \in J \qquad (7)$$

$$\sum_{i \in I:\, \ell_i = \bar{l}} y_i \leq 1 \quad \forall i \in \bar{l} \in L, \qquad (8)$$

$$x_{ij} \in [0,1], z_{ij} \in \{0,1\} \quad \forall i \in I, \forall j \in J \text{ and } y_i \in \{0,1\} \quad \forall i \in I \quad (9)$$

Equation (2) is the objective function where we seek to maximize the percentage of met demand given the set of constraints in Equation (3-9). In Constraint (3), we ensure that the cost of building new facilities and expanding existing facilities is less than or equal to the available budget. In Constraints (4), we enforce that the percentage of met demand of each existing facility from different candidate facilities is less than or equal to 100%. In Constraints (5), we ensure that each candidate facility's total allocated demand is less than or equal to its capacity. In Constraints (6), we enforce that each candidate facility can cover the demand within a predefined maximum distance or radius, D. In Constraints (7), disallows the satisfaction of demand by a candidate facility that is not built or expanded. In Constraints (8), we enforce that each new facility can be built with at most one of the three levels of services - no service, partial service, or full service. We define the type, lower-bounds, and upper-bounds of decision variables in Constraints (9).

ParkSIM User Manual

Maximal Coverage Problem Optimization Code

Packages

This is a document to illustrate our code to solve **maximal coverage for a capacitated facility location problem**. First we load the packages and note that for the first time use, we need to install packages using **install.packages()** command.

```r
library(listviewer)
library (Rglpk)
library(dplyr)
library(magrittr)
library(ROI)
library(ROI.plugin.glpk)
library(ompr)
library(ompr.roi)
library(gtools)
library(R.utils)
library(reader)
library(stringr)
```

Parameters and inputs

We have 42 candidate facility location with three level of services (1- building no service, 2- partial service, 3- Full service). Besides, we have 50 existing facilities that are extendable. Hence, we have 176 candidate in total. The number of existing facilities are 168. We assume the overload of a parking facility can be covered by another facility within the **max_Distance** miles. The available budget for the expansion is **max_budget** dollars.

```r
rm(list=ls())
M1 <-176
N1 <-168
max_Distance<-40
max_budget<-10000000
Start = Sys.time()
```

```r
Reading from the simulation or adjusting based on the simulation
Tick<-10
Number_Tick_Per_Hours <-60/Tick
Simulation_Day<-14
Simulation_Hours<-Simulation_Day*24
Simulation_Lenght<-Simulation_Hours*Number_Tick_Per_Hours
# if we report names Report=0 and if we use IDs report=1.
Report<-1
```

Read distance matrix, cost and capacity vectors and station results

```r
setwd("/Users/asadi/Desktop/MaxCoveringallFiles")
Sys.setenv('R_MAX_VSIZE'=64000000000)
Sys.getenv('R_MAX_VSIZE')
Distances <- read.delim("DistanceFull.txt", sep = "", header= FALSE)
CostsCapacities <- read.delim("CostCapacity.txt", sep = "", header= FA
LSE)
D = read.csv("stationsresultsSep4.csv", header =TRUE)
Facilities_176 <- read.delim("176Facilities.txt", sep = "\t", header=
FALSE)
Facilities_168 <- read.delim("168Facilities.txt", sep = "\t", header=
FALSE)
```

Create "build and expansion cost" f, and capacity of candidates q

```r
f <-CostsCapacities$V1
f <-as.matrix(f)
q <-CostsCapacities$V2
q <-as.matrix(q)
```

Make the correct order of facilities and Create overcapacity Matrix

```r
D = D[mixedorder(as.character(D$Parking.ID)),]
D$ID <- seq.int(nrow(D))
D$ID <-(D$ID %/%Simulation_Lenght)+1
D$OverCapacity<- with(D, round(pmax(Ratio-1,0)*Parking.Capacity))

h<-runif(N1, 0)
d<-runif(N1, 0)

# d[k] is the vector of overcapcity facilities
for (k in 1:N1){
  h[k]<-D %>%
    filter(ID==k) %>%
    select(OverCapacity) %>%
    summarise(x = max(OverCapacity))
  d[k]<-h[[k]]
}
```

Help solver

We remove the existing facilities with zero demand (overcapacity) from **d** and associted distances from **Distance** matrix and save them into **d1** and **Distance1**, respectively. We keep the index of remaining nodes into **NamesVec**, and use it when are reporting our solution.

```r
d1 <-data.frame()[1,]
Distances1<-data.frame()[1:M1, ]
```

```r
NamesVec <-data.frame()[1,]
for (j in 1:N1){
  if (d[j]!=0){
    Distances1<-cbind(Distances1, Distances[,j])
    d1<-cbind(d1,d[j])
    NamesVec<-cbind(NamesVec,j)
  }
}

NamesVec<-t(NamesVec)
d1<-t(d1)
rownames(d1)<-c(NamesVec)

rownames(Distances1)<-(1:M1)
colnames(Distances1)<-c(NamesVec)

# N2 is the number of exisiting facilities with demand not equal to 0.
N2<-as.numeric(ncol(Distances1))

# w(i,j) is the distance between nodes i and j in the MIP model.
w<-function(i,j){
  vapply(seq_along(i), function(k) Distances1[i[k], j[k]], numeric(1L)
)
}
```

MIP model and refine solutions

We create our model using **ompr** package and solve it with **glpk** solver. We use **sink()** command to create a log file for the solver report.

```r
sink("./logofcode.txt")
model<-MIPModel() %>%
  add_variable(y[i], i = 1:M1, type = "binary") %>%
  add_variable(x[i,j], i = 1:M1, j=1:N2, type = "continuous", lb = 0,
ub =1 ) %>%
  add_variable(z[i,j], i = 1:M1, j=1:N2, type = "binary") %>%

  set_objective(sum_expr(x[i,j]*d1[j], i = 1:M1, j=1:N2)/sum_expr(d1[j
], j=1:N2), "max") %>%

  add_constraint(z[i,j]*w(i,j) <= y[i] * max_Distance , j=1:N2, i = 1:
M1) %>%
  add_constraint(x[i,j]-z[i,j] <=0.0  , i = 1:M1, j=1:N2) %>%
  add_constraint(sum_expr(f[i]*y[i], i = 1:M1)<= max_budget) %>%
  add_constraint(sum_expr(x[i, j], i = 1:M1) <= 1.0, j = 1:N2) %>%
```

```
  add_constraint(sum_expr(d1[j]*x[i, j], j = 1:N2)<= y[i] * q[i] , i =
1:M1) %>%
  add_constraint(y[k]+y[k+42]+y[k+84] <= 1.0, k = 1:42)
model
# Time limit is 3600 second or an hour.
result <- solve_model(model, with_ROI(solver = "glpk", verbose = TRUE,
tm_limit = 1000*100))
sink()
```

Refine solver report for near optimal solution

We report the optimality gap for the near optimal solution using the string saved in
OptimalityGap3.

```
LogfileLines<-as.numeric(countLines("logofcode.txt", chunkSize=5e+07))
my_txt_ex2 <- n.readLines(paste("logofcode.txt", sep = ""),header = FA
LSE, n = 1,  skip =LogfileLines-3 )
startPercentage<-str_locate(my_txt_ex2,"%")[1,1]
endPercentage<-str_locate(my_txt_ex2,"%")[1,2]
OptimalityGap<-substring(my_txt_ex2, startPercentage-4, endPercentage)
OptimalityGap3<-paste("near optimal with optimality gap of", Optimalit
yGap)

if (result$objective_value >0 & result$objective_value <1 & result[["s
tatus"]] =="infeasible"){
  result[["status"]] = OptimalityGap3
}else if (result[["status"]] =="infeasible" & max_budget>1000000){
  result[["status"]] = "opt"
  cat("reduce maximum budget from $", max_budget, "\n")
}
```

Refine solver for incorrect infeasible solution

We observe that when the budget is very high and an amount of budget remain unused while
the demand is satisfied with a significant lower budget, the solver report infeasible. In this
section we reduce budget behind scene to find a solution and avoid ompr or glpk bug.

```
while(result[["status"]]=="opt"){

  rm(model)
  rm(result)

  max_budget = max_budget - 2000000

  sink("./logofcode.txt")
  model<-MIPModel() %>%
```

```
    add_variable(y[i], i = 1:M1, type = "binary") %>%
    add_variable(x[i,j], i = 1:M1, j=1:N2, type = "continuous", lb = 0
, ub =1 ) %>%
    add_variable(z[i,j], i = 1:M1, j=1:N2, type = "binary") %>%

    set_objective(sum_expr(x[i,j]*d1[j], i = 1:M1, j=1:N2)/sum_expr(d1
[j], j=1:N2), "max") %>%

    add_constraint(z[i,j]*w(i,j) <= y[i] * max_Distance , j=1:N2, i =
1:M1) %>%
    add_constraint(x[i,j]-z[i,j] <= 0  , i = 1:M1, j=1:N2) %>%
    add_constraint(sum_expr(f[i]*y[i], i = 1:M1)<= max_budget) %>%
    add_constraint(sum_expr(x[i, j], i = 1:M1) <= 1 , j = 1:N2) %>%
    add_constraint(sum_expr(d1[j]*x[i, j], j = 1:N2)<= y[i] * q[i] , i
= 1:M1) %>%
    add_constraint(y[k]+y[k+42]+y[k+84] <= 1.0, k = 1:42)
  model
  result <- solve_model(model, with_ROI(solver = "glpk", verbose = TRU
E, tm_limit = 1000*300))
  sink()

  # Create log file
  LogfileLines<-as.numeric(countLines("logofcode.txt", chunkSize=5e+07
))
  my_txt_ex2 <- n.readLines(paste("logofcode.txt", sep = ""),header =
FALSE, n = 1,  skip =LogfileLines-3 )
  startPercentage<-str_locate(my_txt_ex2,"%")[1,1]
  endPercentage<-str_locate(my_txt_ex2,"%")[1,2]
  OptimalityGap<-substring(my_txt_ex2, startPercentage-4, endPercentag
e)
  OptimalityGap3<-paste("near optimal with optimality gap of", Optimal
ityGap)

  if (result$objective_value >0 & result$objective_value <1 & result[[
"status"]] =="infeasible"){
    result[["status"]] = OptimalityGap3
  }else if (result[["status"]] =="infeasible" & max_budget>1000000){
    result[["status"]] = "opt"
    cat("reduce maximum budget from $", max_budget, "\n")
  }
}
```

Solution

Make data ready for presenting solution

```r
matching <- result
lapply(matching$solution,head)
summary(matching)

soln.x <- get_solution(result, x[i, j])
write.table(soln.x, "Xij.txt", sep="\t")
soln.y <- get_solution(result, y[i])
write.table(soln.y, "Yi.txt", sep="\t")


# Find facilities name from 168 facilities based on what we have in th
e demand Vec
DemandFacWithNames<-Facilities_168[Facilities_168$V1 %in% NamesVec,]
DemandFacWithNames<-cbind(DemandFacWithNames, Temp_ID = seq(1:nrow(Nam
esVec)))


soln.y<-cbind(soln.y, Facilities_176$V2)
soln.y<-rename(soln.y, "ID" = "Facilities_176$V2")
soln.y$ID<-as.character(soln.y$ID)
soln.y<-cbind(soln.y, Facilities_176$V3)
soln.y<-rename(soln.y, "Name" = "Facilities_176$V3")
soln.y$Name<-as.character(soln.y$Name)
soln.y<-cbind(soln.y, CostsCapacities$V1, CostsCapacities$V2)


y1<-filter(soln.y, soln.y$i <  43  & soln.y$value==1)
y2<-filter(soln.y, soln.y$i >= 43  & soln.y$i<=85 & soln.y$value==1)
y3<-filter(soln.y, soln.y$i >= 85  & soln.y$i<=126 & soln.y$value==1)
y4<-filter(soln.y, soln.y$i >= 127 & soln.y$value==1)

ID_Supplies<-as.character(rep(Facilities_176$V2, times = N2))
ID_Demands<-as.character(rep(DemandFacWithNames$V2, each = M1))
Name_Supplies<-as.character(rep(Facilities_176$V3, times = N2))
Name_Demands<-as.character(rep(DemandFacWithNames$V3, each = M1))
soln.x<-cbind(soln.x, ID_Supplies,ID_Demands, Name_Supplies, Name_Dema
nds)

x1<-filter(soln.x, soln.x$i <  43  & soln.x$value!=0)
x2<-filter(soln.x, soln.x$i >= 43  & soln.x$i<=85 & soln.x$value!=0)
x3<-filter(soln.x, soln.x$i >= 85  & soln.x$i<=126 & soln.x$value!=0)
x4<-filter(soln.x, soln.x$i >= 127 & soln.x$value!=0)
```

Create report

```r
# 0 if report based on name and 1 if we report based on ID
Report<-0
myFunction<-function(result, Report){

  if (result[["status"]] == "infeasible"){
    cat("No solution is found with the current budget. Please increase
the budget to find a feasible solution.", "\n")
  } else if(result[["status"]] == "opt"){
    cat("This problem has optimal solution. Please reduce the budget t
o see the optimal solution.", "\n")
  }else{

    if (nrow(y1)==0 & nrow(y2)==0 & nrow(y3)==0 & nrow(y4)==0 )
      print("No change is necessary")
    else{

      if (Report ==1){
        if (nrow(y1)>0)
          for (j in 1:nrow(y1))
            cat("Add the new facility ", y1[j,4], ". Add ", y1[j,7], "
parking spaces for a cost of $", y1[j,6], ". The facility will be a no
service facility.", sep ="", "\n")
        if (nrow(y2)>0)
          for (j in 1:nrow(y2))
            cat("Add the new facility  ", y2[j,4], ". Add ", y2[j,7],
" parking spaces for a cost of $", y2[j,6], ". The facility will be a
partial service facility.",sep ="", "\n")
        if (nrow(y3)>0)
          for (j in 1:nrow(y3))
            cat("Add the new facility ", y3[j,4], ". Add ", y3[j,7], "
parking spaces for a cost of $", y3[j,6], ". The facility will be a fu
ll service facility.",sep ="", "\n")
        if (nrow(y4)>0)
          for (j in 1:nrow(y4))
            cat("Expand facility ", y4[j,4], ". Add ", y4[j,7], " park
ing spaces for a cost of $", y4[j,6], ". This facility is an existing
facility.",sep ="", "\n")



        if (nrow(x1)>0)
          for (j in 1:nrow(x1))
            cat(round(x1[j,4]*100,digits = 2), sep ="", "% of demand f
```

```
or facility ", as.character(x1[j,6]), " is satisfied by buliding new f
acility ",  as.character(x1[j,5]),"  with no serivce.","\n")
       if (nrow(x2)>0)
         for (j in 1:nrow(x2))
           cat(round(x2[j,4]*100,digits = 2), sep ="", "% of demand f
or facility ", as.character(x2[j,6]), " is satisfied by buliding new f
acility ",  as.character(x2[j,5]),"  with partial serivce.", "\n")
       if (nrow(x3)>0)
         for (j in 1:nrow(x3))
           cat(round(x3[j,4]*100,digits = 2), sep ="", "% of demand f
or facility ", as.character(x3[j,6]), " is satisfied by buliding new f
acility ",  as.character(x3[j,5]),"  with full serivce.","\n")
       if (nrow(x4)>0)
         for (j in 1:nrow(x4))
           cat(round(x4[j,4]*100,digits = 2), sep ="", "% of demand f
or facility ", as.character(x4[j,6]), " is satisfied by expanding faci
lity ",  as.character(x4[j,5]), ".\n")
       }


     else {
       if (nrow(y1)>0)
         for (j in 1:nrow(y1))
           cat("Add a new facility near the ", y1[j,5], ". Add ", y1[
j,7], " parking spaces for a cost of $", y1[j,6], ". The facility will
be a no service facility.",sep ="", "\n")
       if (nrow(y2)>0)
         for (j in 1:nrow(y2))
           cat("Add a new facility near the ", y2[j,5], ". Add ", y2[
j,7], " parking spaces for a cost of $", y2[j,6], ". The facility will
be a partial service facility.",sep ="", "\n")
       if (nrow(y3)>0)
         for (j in 1:nrow(y3))
           cat("Add a new facility near the ", y3[j,5], ". Add ", y3[
j,7], " parking spaces for a cost of $", y3[j,6], ". The facility will
be a full service facility.",sep ="", "\n")
       if (nrow(y4)>0)
         for (j in 1:nrow(y4))
           cat("Expand the ", y4[j,5], ". Add ", y4[j,7], " parking s
paces for a cost of $", y4[j,6], ". This facility is an existing facil
ity.",sep ="", "\n")
```

```
        if (nrow(x1)>0)
           for (j in 1:nrow(x1))
              cat(round(x1[j,4]*100,digits = 2), sep ="", "% of demand f
or facility ", as.character(x1[j,8]), " is satisfied by building new f
acility ",  as.character(x1[j,7]),"with no service","\n")
        if (nrow(x2)>0)
           for (j in 1:nrow(x2))
              cat(round(x2[j,4]*100,digits = 2), sep ="", "% of demand f
or facility ", as.character(x2[j,8]), " is satisfied by building new f
acility ",  as.character(x2[j,7])," with partial service", "\n")
        if (nrow(x3)>0)
           for (j in 1:nrow(x3))
              cat(round(x3[j,4]*100,digits = 2), sep ="", "% of demand f
or facility ", as.character(x3[j,8]), " is satisfied by building new f
acility ",  as.character(x3[j,7])," with full service","\n")
        if (nrow(x4)>0)
           for (j in 1:nrow(x4))
              cat(round(x4[j,4]*100,digits = 2), sep ="", "% of demand f
or facility ", as.character(x4[j,8]), " is satisfied by expanding faci
lity ",  as.character(x4[j,7]), ".\n")


      }
    }
  }

  a = 0;

  for (i in 1:M1) {
    a = a + f[i]*soln.y[i,3]
  }

  if (result[["status"]] != "opt"){
    cat("Budget to spend on the new and expanded facilities is $",a, s
ep="",".", "\n")
    cat("This solution is", result$status, "\n")
    cat("The average met demand is ", round(result$objective_value*100
,digits = 2),"%", sep ="",".", "\n")
  } else
  {
    cat("The average percentage of met demand with this budget is 100%
.", "\n")
  }
}
```

ParkSIM User Manual

```
myFunction(result, Report)


End = Sys.time()
End - Start
```

ParkSIM User Manual

E. Model Input File List

The following list includes all the files needed by ParkSIM. All files are included in the ParkSIM folder download. The file types include: .dbf, .prj, .qpj, .sbn, .sbx, .shp, .shx, .cpg, .xml, .csv, .txt, .ini, .R.

File Name	Description
Spatial Maps for Facility Locations and Highway Network	
AR (.dbf, .prj, .qpj, .sbn, .sbx, .shp, .shx)	Used to create a map of Arkansas on the NetLogo interface
NewStations (.cpg, .dbf, .prj, .qpj, .shp, .shx)	Used to display the stations recommended by the optimization model
Connectors (.cpg, .dbf, .prj, .qpj, .sbn, .sbx, .shp, .shx)	Used to create a map of Arkansas on the NetLogo interface
InterstatesHighwaysAR (.cpg, .dbf, .prj, .qpj, .sbn, .sbx, .shp, .xml, .shx)	Used to create a map of Arkansas on the NetLogo interface
ExistingStations (.cpg, .dbf, .prj, .qpj, .shp, .shx)	Used to generate and display the existing parking facilities on the map of Arkansas
CSV Files for Initialization of Simulation	
EnteringTrucksDestinations.csv	The possible destinations a truck entering the state can travel to first, based on the external link where they enter the state
EnteringTrucksProfiles.csv	A list of possible profiles that can be assigned to generated trucks entering the state
ExistingTrucksProfiles.csv	A list of possible profiles that can be assigned to trucks that exist somewhere in the state when the simulation begins
ExternalLinks.csv	The possible highway links where trucks can enter the state
ExistingOnDutyMidnightLocation.csv	The possible locations for On Duty existing trucks to start when the simulation begins
ExistingOffDutyMidnightLocation.csv	The possible locations for Off Duty existing trucks to start when the simulation begins
CSV Files for Optimization Model	
StationsResults.csv	Generated by the simulation, contains the capacity of each station in the simulation, per tick. Used by the optimization model to generate recommendations
.R Files for Optimization Model	
myFunction.R	Used by the optimization model to output and display recommendations to the user

ParkSIM User Manual

File Name	Description
Text Files for Optimization Model	
168Facilities.txt	Used by the optimization model to calculate and generate recommendations. A list of existing stations.
176Facilities.txt	Used by the optimization model to calculate and generate recommendations. A list of possible new stations and expanded existing stations
CostCapacity.txt	Used by the optimization model to calculate recommendations. Includes data about how much each type of new station or station expansion will cost and how many spots each new or expanded station adds
DistanceFull.txt	Used by the optimization model to calculate recommendations. A matrix of distances between each existing station and each possible new station
Model File for NetLogo	
schema.ini	Initializes the .xml files used in the simulation

F. Overnight Observation Comparison

In this section, we provide a brief visual comparison of the overcrowding patterns observed during ARDOT's annual overnight truck parking study and the results of ParkSIM. For this comparison, two noted discrepancies in the two methodologies (Overnight Study and ParkSIM) should be noted:
1. ARDOT conducts the overnight count study once per year around the first week of September. The data shown in the figure below is from the 2016 study. The data used to calibrate ParkSIM also comes from the year 2016, but results represent the average usage over a two-week simulation period including all days of the week and times of the day. This temporal discrepancy is attributed to some differences in observed and simulated truck parking usage.
2. The ARDOT Overnight study represents an instantaneous observation of truck parking. If the observers happen to arrive during a significant period of overcrowding, then the facility was marked as overcapacity. It is likely that if the observers took a longer observation window, the overcrowding may have reduced as trucks found alternate parking locations nearby or elsewhere along the corridor.
3. The ARDOT Overnight study only includes observations at interstate-adjacent parking areas. These include truck stops, gas stations, rest areas, hotels, restaurants, large retail stores, and other large parking areas where trucks were found. Some of the locations in the ARDOT Overnight study were thus not actual truck stops. The ParkSIM sites include off-interstate locations that were included in the Trucker's Friend parking facility database and considers only truck stops and rest areas, both public and private.

Figure F.1 and F.2 show the percent of overcrowding at truck parking facilities in Arkansas. In general, the areas of overcrowding as observed in the single overnight study and the ParkSIM simulation are in agreement. Noted similarities and differences in overcrowding include:
1. The degree of overcrowding along I-40 East of Little Rock between Little Rock and West Memphis. ParkSIM shows three facilities along this corridor that are above 200% capacity while the ARDOT Overnight Study shows only one facility at this level of overcrowding.
2. The ARDOT Overnight Study shows overcrowding above 200% in the Ft. Smith area which is not captured by the ParkSIM model.
3. The ARDOT Overnight Study shows overcrowding above 200% along HWY 67 in White and Jackson Counties but the ParkSIM model does not capture this overcrowding.
4. The ParkSIM model and ARDOT Overnight Study both show overcrowding along the I-30 corridor between Little Rock and Texarkana. However the specific location of overcrowding differs. This may be due to the closure of a public rest area on this corridor that affected the data used to calibrate the simulation.
5. The ParkSIM model and ARDOT Overnight Study show mild overcrowding in the Little Rock area.

The ParkSIM model effectively serves as a way to compare alternate capacity expansion solutions under the same assumed system usage and driver behavior patterns. The ParkSIM model can be re-calibrated and fine-tuned with more recent (newer than 2016) data to better reflect changes in driving patterns, volumes, and/or rest area usage.
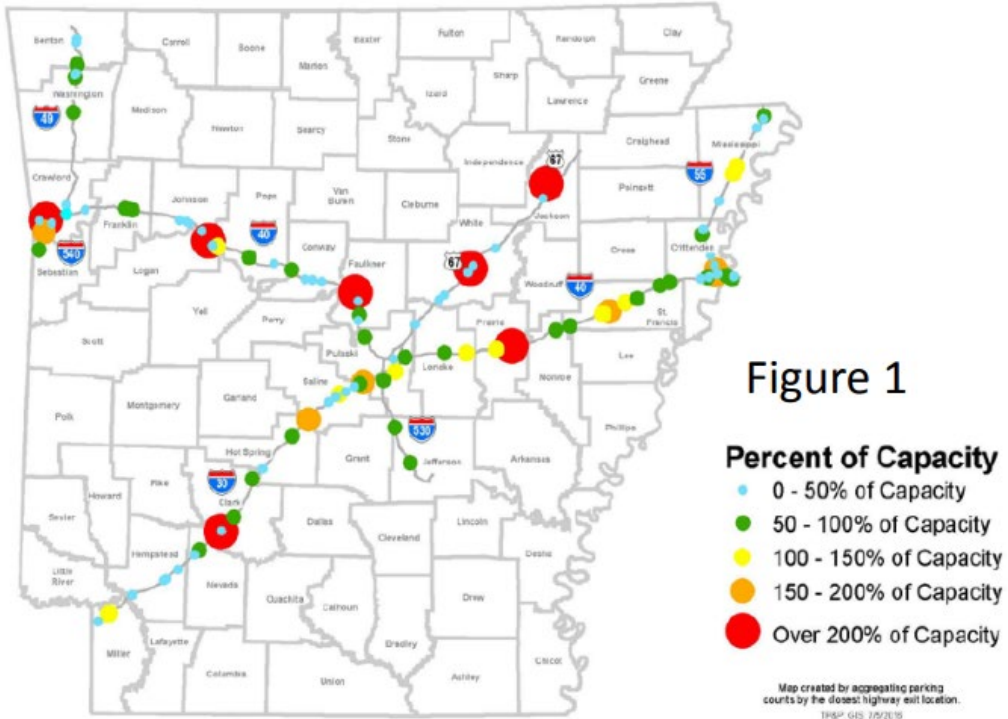
Figure F.1. Truck Parking Facility Overcrowding from the 2016 ARDOT Overnight Study
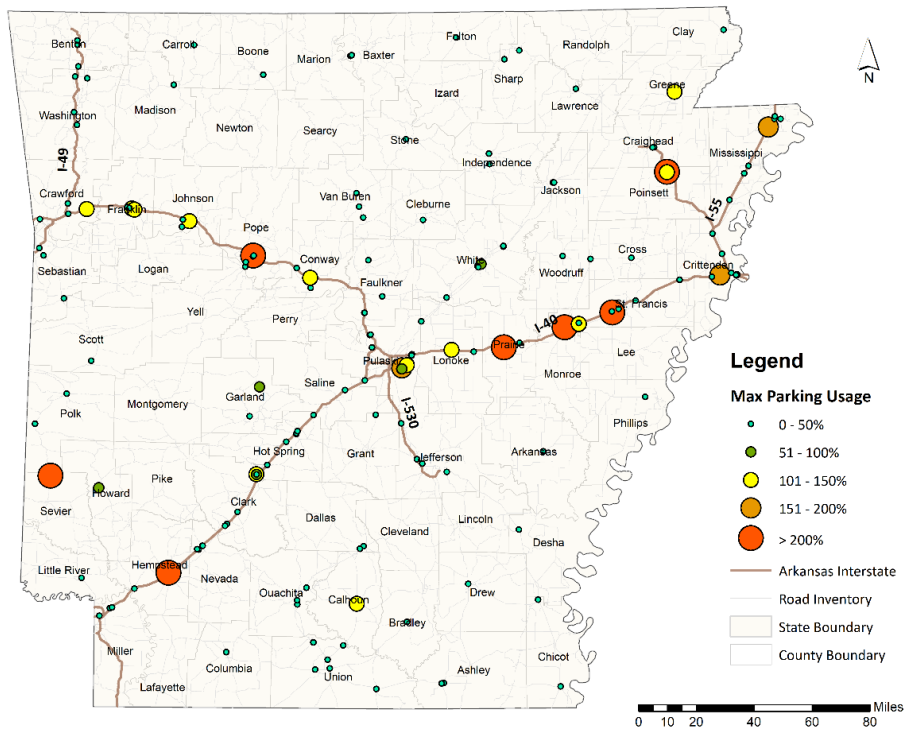*(map from ARDOT)*

Figure F.2. Truck Parking Facility Overcrowding from the ParkSIM Model