Evaluate New Equipment or Technology Available for Roadside Fleet Repair

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16. Abstract
ODOT's Pickaway County Garage in Circleville is centrally located and equipped with a mechanic's truck available to travel to locations where equipment breaks down and make minor repairs on site. However, anything more serious, such as a tire change, requires a service call to a commercial vehicle towing service, which are located outside the county, and mostly to the north in Franklin County. Thus many minor breakdowns of equipment lead to very costly delays due to the effort to obtain service and the long drives involved from the vendor to the site and then the garage. The research team assessed the current equipment and the needs of the Pickaway County Garage and developed a list of attributes for an upgraded maintenance vehicle that could conduct a much larger variety of equipment service operations on-site. The research team also visited ODOT's District 5 and Licking County Garage where two vehicles of this type have been deployed and their advantages and uses described by local personnel. Such a commercial grade repair vehicle obtained for the Pickaway County Garage would cost about $110,000 and would save an estimated $107,000 over its lifetime compared to the present system by reducing productivity losses due to downtime during towing calls.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
AREA				
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
VOLUME				
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
NOTE: Volumes greater than 1000 L shall be shown in m^3.				
MASS				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
TEMPERATURE (exact)				
°F	Fahrenheit temperature	5(°F-32)/9 or (°F-32)/1.8	Celsius temperature	°C
ILLUMINATION				
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
FORCE and PRESSURE or STRESS				
lbf	poundforce	4.45	newtons	N
lbf/in^2 or psi	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
AREA				
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
VOLUME				
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.71	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
MASS				
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
TEMPERATURE (exact)				
°C	Celsius temperature	1.8°C + 32	Fahrenheit temperature	°F
ILLUMINATION				
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
FORCE and PRESSURE or STRESS				
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2 or psi

* SI is the symbol for the International Symbol of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.

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1 Project Background

In an article summarizing new technologies to improve and expedite roadside assistance for fleet vehicles, M. Antich and E. Gandarilla [2017] identified the top five incidents that required a call for roadside assistance in 2016: jump starts, flat tires, winch outs, lockouts, and empty fuel tanks. The top five towing needs included engine shutdowns; issues related to computer malfunctions; fuel supply issues related to pump, turbo, sensor, or computer issues; drivetrain malfunctions; impact incidents; and flat tires. In order to minimize downtime for operators, a service provider sent out on a repair call should be capable of performing diagnostics and on-site repairs when possible, or otherwise be able to tow the disabled vehicle back to the garage for repairs.

ODOT currently maintains a fleet of 1600 trucks statewide, currently a majority of these trucks are International brand trucks. These trucks provide snow and ice removal during the winter and haul a variety of materials during the summer. These vehicles require regular maintenance and repair, provided by ODOT mechanics who keep the fleet in working condition year round. They have several tools at their disposal but there is a need to identify new equipment or technology that can address current inadequacies and save time and money.to enhance roadside repairs of dump trucks and various kinds of equipment, such as back hoe, loader, tractor, and grader. Roadside tire changes for dump trucks and tractors have been identified as a particular need. To this extend it is important to realize that to efficiently change a truck tire on the side of the road requires several specialized tools including air jacks, crane to help lift the wheels, lift gate, air impact wrench and others.

ODOT crash data summaries between 2010 and 2014 indicate that 14% of all crashes reported for the state system and involved parked vehicles or passing sideswipe [ODOT, ca. 2015]. This is one danger a repair mechanic must consider when evaluating a roadside repair situation. Safety is paramount when providing the repair specialist with the equipment, vehicle, and tools necessary for safe repairs.

Other promising new technology includes digital systems to dispatch repair crews, and GPS to pinpoint the location of disabled vehicles. These would expedite roadside repairs, meaning less downtime for crews stranded on the side of a road, and less chance of an accident with passing traffic. In the case of snow plows, downtime also affects the safety of the traveling public, since downtime reduced the road mileage that is treated for safe public use. The costs and impacts of roadside repair incidents include not only the idle time for affected crews and lack of availability of the affected equipment, but also travel delays experienced by the general traveling public from repair operations constricting traffic and delayed snow removal or other work. There are also safety issues for both ODOT crews and the driving public to consider.

2 Objectives

The overarching goal of this study is to provide ODOT's fleet mechanics with techniques and tools that will improve the safety and efficiency of roadside repairs. These tools are anticipated to increase safety, reduce labor hours, and decrease the need for tow truck assistance. ODOT also wants a draft Statewide Standard for Roadside Fleet Repair.

The research team met the goal by completing the following objectives:

1. **Evaluate ODOT's current process for roadside fleet repair.** The team, in coordination with Pickaway County and Central Office garages, will visit the Pickaway county garage

to conduct on site interviews with mechanics and others knowledgeable about current practices. Demonstrations and discussion of current practices and a list of the equipment affected will be gathered. Historic data for work orders and type of work performed will be requested and collected when possible and analyzed.

2. **Conduct a comprehensive literature review and synthesis** of published documents and reports that discuss and evaluate available solutions for roadside fleet repair used by DOTs and other agencies around the US.
3. **Compare and contrast alternative solutions** that are available today and provide a recommendation on the viable solution(s). Factors taken into consideration include, but are not limited to: downtime, labor costs, flexibility, efficiencies, and safety.
4. **Conduct a cost/benefit analysis** considering the cost of the equipment, safety, maintenance of equipment, labor costs, and efficiencies. The "change nothing" option was used as a baseline for comparison.

This is the final report of the project, which was initially the interim report for Phase 1 of the project, including the findings from all the above tasks and recommendations for solutions proposed. Solutions reflect a combination of existing equipment, available products/technologies, and process improvements. Equipment recommendation are presented in a comprehensive table incorporating all aspects of the analysis.

3 Literature Review

A detailed literature review on roadside fleet repair and related safety issues was performed. Extensive literature searches were conducted through web-based queries and through specific agency search engines (such as the Transportation Research Board, TRIS/TRID, Google Scholar, ArticlesPlus and ScienceDirect). Literature and library searches were designed to include all relevant transportation journals, civil engineering journals, trade journals and other published reports and documents.

Each item selected was critically reviewed for the following: objectives, concerns, data and analysis tools, performance measures, evaluation methodology, impacts, innovative technology used, and results.

The published documents that address the specific topic of this research is sparse, but the following summarizes what was found. The literature search will be divided into two sections, one that will deal with specific documents related to cost/benefit analysis and the other will tackle the availability of new technology to increase efficiency of the road side repairs.

3.1 Cost/Benefit analysis

R. Dekker [1996] provided a review of maintenance optimization models published to date. Even though the article is dated, the conclusions that the author sites are relevant. The authors states that although maintenance optimization thrives as a mathematical discipline, and he expected the field to continue growing given the advances in computer simulations, but the impact of these mathematical models on actual maintenance operations is limited and will continue to be limited until proper tools are adapted by maintenance managers to realize the benefits from these models.

A. Garg and S.G. Deshmukh [2006] published a literature review summarizing 142 articles on maintenance management in research. They say maintenance attitudes have changed from the

1940s and 1950s, when corrective maintenance dominated, to the 1980s, where preventative and reliability-centered maintenance started to appear, to the operations research models used today. They also state that unlike other scheduling tasks, maintenance schedules are very sensitive and will stop working as soon as an urgent job is received requiring resources be channeled towards that job. This makes maintenance scheduling very challenging, and actual performance measures are necessary for well-functioning organization.

In July 2018, *Government Fleet* published an article on the City of Fort Wayne Indiana [Anonymous, 2018]. After 22 years of outsourcing the city's fleet maintenance, the city council approved a measure to end the outsourcing contract and bring back all fleet maintenance operations in-house. The city was expecting to save $350,000 per year. The city's Director of Public Works indicated bringing the service back will improve efficiency and reduce costs to the city.

In "Evaluating Options for Outside Service", D. Rondini [2017] makes the case that 10% of a fleet's vehicle-based operating costs are related to maintenance and repair. The article cites a productivity study showing fleets with fully staffed maintenance facilities improved productivity over the past few years by performing more maintenance in-house, and on average 14.5% of the productivity gain came from time saved doing the work as opposed to waiting on an outsourced vendor to do the work as well as time spent getting the vehicle to and from the vendor. The article also shows data from MacKay & Co. indicating in 2015 preventative maintenance accounted for 39% of service activities; 13% of service activities were related to electrical diagnostic repair; 28% to mechanical repair; 9% to paint and body work; and 11% to emergency roadside repair.

A more recent report [J. Mathew et al., 2018] Purdue University conducted for the Indiana DOT in the Fort Wayne area indicated roadside mowing operations are idle due to maintenance issues on average 26% of the time.

B. Stanton [2018], summarizes cases for and against outsourcing parts for a municipal fleet. The important point in making a decision is to make sure that the marketplace is performing the particular service to the fleet's expected standards. Taking the time and effort to generate a clear comparative analysis will yield proper results, otherwise neither side of the argument can be satisfied.

In summary, there are many fleet maintenance strategies that can used for cost/benefit analysis. It is also clear that emergency roadside repairs are a significant portion of a fleet's maintenance activity and can be disruptive to the organization if it is not handled properly. In addition, to make a clear and convincing comparison between strategies, it is important to collect proper data and information.

3.2 Availability of new technologies.

To access new technologies, a list of services available for roadside repairs must be made. *Fleet Equipment* magazine listed some of these in a March 2018 article [Babcox Media, 2018]. Quick response capability tops the list, which also includes having a mobile mechanic able to conduct roadside service in lieu of towing; flat tire assistance, tire replacement and tire repair; delivery service for fuel, oil, fluids, and replacement parts; jump starts and pull starts; and lock-out and replacement key services.

In a March 2016 in *Service Truck Magazine* article entitled "A Free-Range Mechanic", D. Anderson writes about a roadside service truck and its capabilities. The truck is equipped with a 10,000 lb (4500 kg or 44.5 kN) capacity crane and a slide-in power system incorporating a rotary screw air compressor, hydraulic pump, and generator powered by a three-cylinder diesel engine.

The choice of the diesel engine was important to save on fuel costs since it is more efficient than using the truck engine for power. In addition, the truck is equipped with safety features to handle the challenges of working near passing traffic, including strobe and work lights. The truck also includes multiple side cabinets and toolboxes so that an organized set of useful tools is handy and easily accessible. In addition to the hand tools required, such trucks now require computer diagnostic capabilities and access to shop manuals to assist with on-site repairs. Having a capable computer loaded with appropriate software and manuals for the fleet being serviced is essential. A self-cleaning engine reduces downtime for the truck.

An article in *WorkTruck Magazine* by Robert Bosch LLC described an off-road equipment diagnostics kit offered by Bosch [Bosch Global, 2018], which included 10 different cables to enable service mechanics to diagnose construction equipment, street sweepers and other vehicles used for mowing and other operations. This cable kit will allow a fleet mechanic to conduct diagnostics and possible roadside software updates on vehicles of multiple makes, models, and types. Other technologies include high pressure air bags able to operate in clearance as low as 1 in (25 mm), on-board diagnostics and software solutions available from the various equipment manufacturers, and inclusive electrical and lighting replacement kits to assist in conducting timely roadside repairs.

4 Method

4.1 Overview of Phase 1

This project included the following tasks:

1. Participate in project startup meeting
2. Coordinate with garage personnel to conduct site visits and interviews
3. Collect pertinent historic data
4. Review existing literature related to roadside fleet repair
5. Create a comprehensive list of technology and equipment used for roadside fleet repairs
6. Conduct cost/benefit analysis
7. Develop interim report for Phase 1
8. Manage project

Tasks 2-6 are discussed in more detail below.

4.2 Task 2. Coordinate with garage personnel to conduct site visits and interviews

The Ohio University team coordinated with garage personnel ODOT District 6 Pickaway County Garage and the Central Office Garage and set up appointments to talk with personnel responsible for equipment repair and roadside assistance. The goal of the site visits was to understand and document the processes currently used in roadside repair, from the time an equipment .operator calls for assistance to the time the equipment is back in operation. The Pickaway county garage was visited twice in order to gain an understanding of the requirement and to get data for this project.

The initial visit to the Pickaway County garage on September 11th 2018 involved Brad Shannon, mechanic from Pickaway County garage; Chad Stickel, ODOT Central Garage OEM; Joshua Jordan and Issam Khoury from Ohio University; and Jim Stickel Sr. of Rush Trucking Centers. The discussion during the meeting centered on the challenges that the Pickaway County Garage faces for their roadside repairs. During this meeting the various repair scenarios were considered and the research team was shown the various equipment the garage has for fleet maintenance.

A subsequent visit to the Pickaway Garage was conducted on October 23rd 2018 Joshua Jordan and Issam Khoury from Ohio University interviewed Chad Stickel, Brad Shannon, and Scott Rice, who is Transportation Manager for the Pickaway County garage. Data were obtained from Scott Rice, in addition to further discussions on the processes involved with roadside repairs and breakdowns.

Findings from these interviews are in the next chapter.

4.3 Task 3. Collect pertinent historic data

After the initial visit to the Pickaway County garage, and after discussions with District Research Coordinator Jacqueline Martindale, Samuel Grier, Program Administrator at ODOT Office of Maintenance Operations was contacted to obtain pertinent historic data for this project. Relevant information from the Pickaway County garage was provided by Transportation Manager Scott Rice. Jim Roth, the Trip Program Coordinator at ODOT Office of Traffic Management was contacted regarding additional pertinent historic data. The results of the data collection and analysis are presented in Section 5.2.

4.4 Task 4. Review existing literature

A literature review was conducted and a summary presented in Chapter 3 of this report.

4.5 Task 5 (Phase 1). Create a comprehensive list of technology and equipment used for roadside fleet repairs

After the completion of the literature search, and in consultation with our project partners, a list of the most suitable equipment and technologies was created. In addition, deficiencies in current tools were identified and a list of the most pertinent improvements created.

4.6 Task 6 (Phase 1). Conduct cost-benefit analysis

Starting from the data compiled from the site visits and meetings with partners, a cost-benefit analysis was conducted to compare the cost of technologies, tools, and equipment available. The “change nothing” option was used as a baseline against which to evaluate improvements in efficiencies, downtime, labor costs, and safety of both the travelling public and ODOT personnel.

5 Results

5.1 Site Visits and Interviews

The initial visit to the Pickaway County garage included collecting pertinent information regarding the process of roadside repairs conducted by the garage. The Pickaway County garage currently has one mechanic's truck, shown in Figure 1. This is a basic truck with limited tool storage with some basic tools to enable some roadside repairs. The truck includes a small air compressor/generator unit and cutting torches shown in Figure 2. The Pickaway County Garage services multiple on-road and off-road vehicles. Figure 3 and Figure 4 depict eight of the many types of tires that may require roadside service. The hydraulic jack shown in Figure 5 is the sole lifting tool available for roadside repairs. Figure 6 shows one side of the front end of a truck used in Pickaway County. In the event this tire needed service in the field, the available hydraulic jack shown in Figure 5 is not sufficient, and the truck would need to be towed back to the garage for the tire replacement. More advanced equipment would enable this tire to be changed onsite.

Figure 1. The Pickaway County Garage Mechanic's Truck.

Figure 2. Air Compressor and Cutting Torches on the Pickaway County Garage Mechanic's Truck.

Figure 3. Some of the different tires used and serviced by the Pickaway County Garage.

Figure 4. More types of tires used and serviced by the Pickaway County Garage.

Figure 5. The hydraulic jack available for roadside repairs by the Pickaway County Garage.

Figure 6. View of front tire of dump truck at Pickaway County Garage.

After summarizing the information gathered from the mechanics during the initial visit to the Pickaway County Garage, it is evident that the mechanics lack a complete set of tools to efficiently and expeditiously complete some basic roadside repairs, such as changing a truck tire.

Pickaway County is situated between Franklin County to the north and Ross County to the south, both of which have significant industrial and commercial complexes which include specialized towing companies able to handle heavy commercial equipment on an emergency basis. Fleet towing in Pickaway County involves calling one of the specialized towing operators in Franklin or Ross County.

During the second visit to the Pickaway County Garage, the team discussed roadside repair issues encountered in Pickaway County with Brad Shannon and Scott Rice. Scott Rice is one of garage's two Transportation Managers and is responsible for calling tow companies when a vehicle needs to be towed to the garage for repairs. As shown in Table 1, Scott has at his disposal five tow companies with the capabilities required for towing vehicles used at the Pickaway County Garage. As can be seen in the table none of these companies are located in Pickaway County, and all are located more than 20 miles away from the garage.

Table 1. Commercial towing companies nearest to the Pickaway County Garage, with distances determined using Google Maps.

	Name	Street Address	City	County	ZIP Code	Distance to Garage
1	Capital Towing & Recovery	1111 Stimmel Road	Columbus	Franklin	43223	26.2 mi (42.2 km)
2	Pro Tow	1669 Harmon Avenue	Columbus	Franklin	43223	24.5 mi (39.4 km)
3	Rusty's Towing Service	4845 Obetz Road	Columbus	Franklin	43207	21.2 mi (34.1 km)
4	Eitel's Towing	7111 Stahl Road	Orient	Franklin	43146	22.6 mi (36.4 km)
5	Harper's Garage	16 South Main Street	Frankfort	Ross	45628	22.0 mi (35.4 km)

Figure 7 shows the location of the tow companies (yellow markers) with respect to the location of the ODOT garage in Circleville (red marker). The distances from the tow companies and to the Pickaway County Garage, determined by entering the addresses into Google Maps and selecting the shortest distance route, range from 21.2 mi (34.1 km) to 26.2 mi (42.2 km). Only one of the companies (Harper's Garage in Frankfort) is close to the southern portion of Pickaway County.

Scott described the timeline of a typical standard service call for roadside assistance. Figure 8 summarizes the best case scenarios for on-site repair and for towing. At 9:00 AM a vehicle operator calls the Pickaway County ODOT Garage to report the disabled vehicle. The Pickaway County ODOT garage will send a mechanic with the garage's mechanic's truck to the location of the disabled vehicle. After arriving at 10:00 AM, the mechanic will perform a diagnostic check on the disabled vehicle and will do one of two things. In the first and best case, the mechanic can perform the repair with the tools available on the truck, and the mechanic will repair the vehicle and return it to service in about an hour (estimated at 11:45 on the timeline). In the second case, the repair is not possible with the tools available, and the mechanic will call the garage to initiate a towing procedure. The garage personnel call the towing companies listed in Table 1 until a tow can be arranged, which can take 30 minutes or more depending on availability. The tow truck arrives at the site within 2 hours after the garage contacted the tower, at about 13:00 (1:00 PM). Meanwhile, the Pickaway County Garage mechanic will drive the stranded vehicle

operator back to the garage in the mechanic's truck once the tow has been arranged, and they arrive at the garage at approximately 12:30 PM, which allows the vehicle operator to return to work. The tow truck will hook up the disabled vehicle and tow it to the garage, which is estimated to take two hours depending on the travel distance and traffic. The vehicle thus arrives at 15:00 (3:00 PM) and is readied for service at the garage, which requires another half hour. Under these circumstances the vehicle will not be back to the garage until at least hours after the tow truck was called, and the vehicle operator has been unable to perform productive work for three and a half hours, which is 45 minutes longer than under the first case. The above timeline represents the best case scenario. Even if the vehicle can be repaired at the garage before the end of the work day, it will be out of service for an entire 24-hour day. Delays stemming from lack of available parts at the garage may increase the out-of-service time to 48 hours.

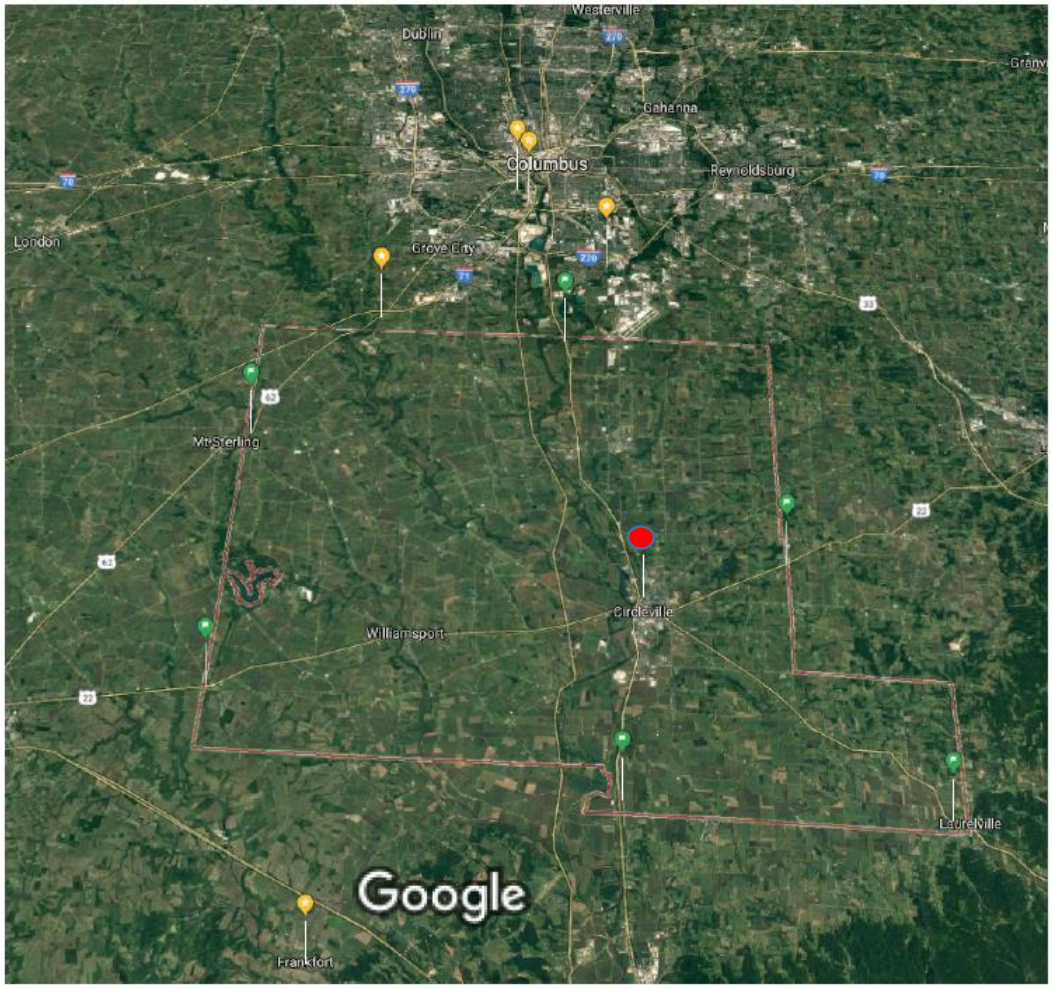

Figure 7. Pickaway County borders and location of tow companies (yellow markers) listed in Table 1. The red marker is the location of ODOT's Pickaway County Garage.

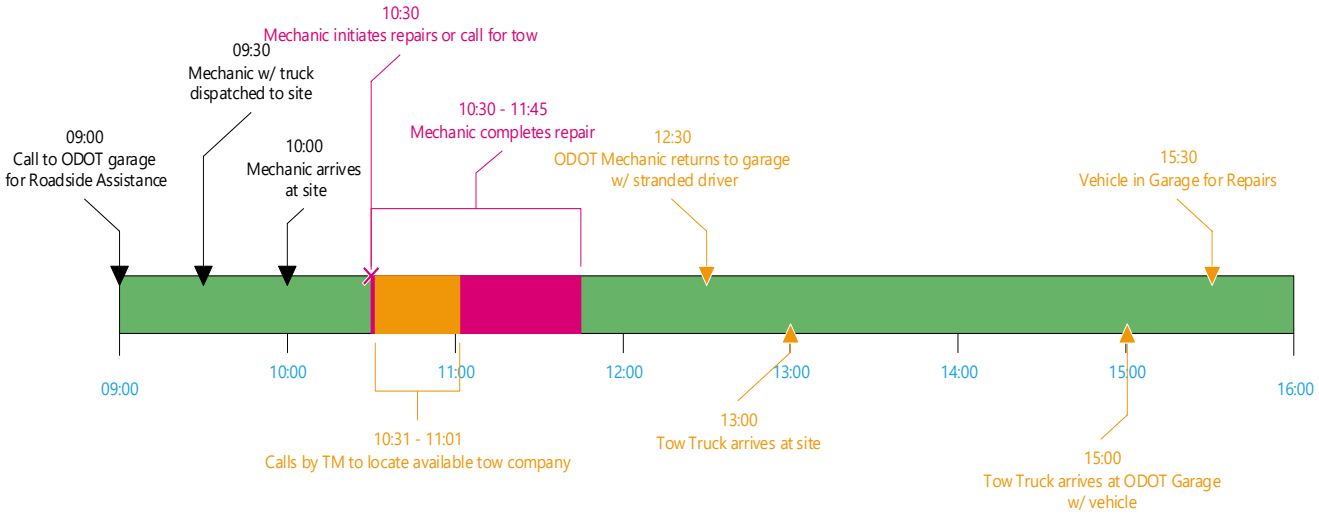

Figure 8. Roadside assistance best case scenario timeline.

5.2 Results from Analysis of Historical Data

ODOT central office provided historical data on the total number of hours that the Pickaway County Garage had spent on snow and ice removal and mowing operations for fiscal years 2015 through 2018. The summary data provided is shown in Table 2. The Pickaway County Garage personnel spent between 3100 and 7400 hours for Snow and Ice operations between 2015 and 2018 fiscal years, and 2400 to 3400 hours mowing two-lane and multilane roads during calendar years 2015-2017 (2018 data were not a complete calendar year). The average hours spent are 5370 for snow and ice, 3193 for mowing, and 8021 combined (8258 if the incomplete year 2018 is not included).

Table 2. Summary of hours of effort on maintenance operations by the Pickaway County Garage.

Owner	Activity	Fiscal Year	SUM Total Hours
0006 6700 - Pickaway County Garage	M690-001 - Snow and Ice	2015	7,391.80
0006 6700 - Pickaway County Garage	M690-001 - Snow and Ice	2016	4,668.30
0006 6700 - Pickaway County Garage	M690-001 - Snow and Ice	2017	3,133.30
0006 6700 - Pickaway County Garage	M690-001 - Snow and Ice	2018	6,286.50

Owner	Activity	Calendar Year	SUM Total Hours
0006 6700 - Pickaway County Garage	M692-001 - Mowing - 2 Lane	2015	2,377.80
0006 6700 - Pickaway County Garage	M692-001 - Mowing - 2 Lane	2016	3,762.40
0006 6700 - Pickaway County Garage	M692-001 - Mowing - 2 Lane	2017	2,910.00
0006 6700 - Pickaway County Garage	M692-001 - Mowing - 2 Lane	2018	744.1
0006 6700 - Pickaway County Garage	M692-002 - Mowing - Multilane	2015	52
0006 6700 - Pickaway County Garage	M692-002 - Mowing - Multilane	2017	477.7
0006 6700 - Pickaway County Garage	M692-002 - Mowing - Multilane	2018	279

Scott Rice provided the research team with a list of all repairs to vehicles in the Pickaway County Garage system for fiscal years 2015 through 2018. A total of 1103 repair incidents were identified during the time period provided, including 29 tire repairs and 10 towing incidents. Of the all the recorded repairs, 1098 were identified by the Pickaway County mechanics as items that could have been performed on the roadside if the proper equipment was available, including hydraulic line fixes, electrical wire connections, and tire repairs. The ODOT repair codes are listed in Table 3. The data collected do not track which specific repair items that were performed on the roadside, and neither does it track time spent waiting on tow assistance or for repair parts.

Table 3. ODOT activity codes for fleet maintenance activities.

	Activity Code
1	67208 - ELECTRICAL - STROBE LIGHTS/INSTALL/REMOVE/REPL/RPR (208) (Labor Hrs)
2	67209 - ELECTRICAL - SWITCHES/RPL/RPR (209) (Labor Hrs)
3	67210 - ELECTRICAL - BATTERY/REPLACE (210) (Labor Hrs)
4	67211 - ELECTRICAL - BATTERY/CHARGING/CLEANING/CHECKING/CABLE (211) (Labor Hrs)
5	67215 - ELECTRICAL - LIGHTING SYSTEM (215) (Labor Hrs)
6	67216 - ELECTRICAL - ALTERNATOR/GENERATOR/REPLACE (216) (Labor Hrs)
7	67219 - ELECTRICAL TROUBLESHOOTING (219) (Labor Hrs)
8	67220 - ELECTRICAL - WIRE REPLACE/REWIRE (220) (Labor Hrs)
9	67230 - ELECTRICAL - HEATING/VENTILATION (230) (Labor Hrs)
10	67232 - ELECTRICAL/OTHER (232) (Labor Hrs)
11	67266 - TIRES/RPR/RPL W/USED/RPL TUBE/ROTATE (266) (Labor Hrs)
12	67267 - TIRES REPLACE W/NEW/INCLD BALANCE (267) (Labor Hrs)
13	67268 - TIRES - WHEEL/RIM/HUB/BEARINGS/SEALS/ETC (268) (Labor Hrs)
14	67307 - HYDRAULIC/TROUBLESHOOTING (307) (Labor Hrs)
15	67361 - HYDRAULIC CYLINDERS/PISTONS (361) (Labor Hrs)
16	67362 - HYDRAULIC PUMPS/MOTORS (362) (Labor Hrs)
17	67363 - HYDRAULIC /P.S.RESERVOIR&FILTERS/ADD FLUID (363) (Labor Hrs)
18	67365 - HYDRAULIC LINES/HOSES/FITTINGS (365) (Labor Hrs)
19	67375 - HYDRAULIC SPINNER MOTOR/RPL/RPR/RBLD/NOT STK (375) (Labor Hrs)
20	67375 - HYDRAULIC SPINNER MOTOR/RPL/RPR/RBLD/NOT STK (375) (Labor Hrs)

5.3 Identification of technology and equipment used for roadside fleet repairs

After visiting the Pickaway County Garage and talking with the mechanics, it was clear that the mechanic's truck available to the garage, seen in Figure 1 and Figure 2, falls well below the current standard for trucks used by fleet mechanics. As exemplified by the article by D. Anderson [2016], and shown in Figure 9, modern roadside repair trucks include many features to expedite safe roadside repairs.

In order to get a better idea of what is a roadside assistance truck and the different options and configurations available, the research team including Ohio University personnel, Pickaway County mechanic Brad Shannon, ODOT Central Garage OEM, Chad Stickel, Scott Grimes from ODOT District 7 and Dave Kellough from ODOT District 9 visited the Rush Truck Center garage in Columbus, Ohio. During the visit various truck configurations were presented and the different options available were shown and discussed.

In addition, during this visit and through our discussion, the research team learned that ODOT District 5 Garage might be operating one or more trucks with similar features to those in discussion. It was further decided that the research team would visit the District 5 and Licking County Garages to research the equipment prior to providing additional recommendations for this research.

Figure 9. Examples of modern roadside vehicle assistance trucks.

5.4 Visit to ODOT District 5 and Licking County Garages to discuss roadside fleet repair vehicles used.

On January 22nd 2019, the research team from Ohio University and Chad Stickel and Brad Shannon met Nate Mack, Equipment Manager for ODOT District 5. Nate explained that District 5 operates a "Special Projects Truck" which features equipment suited for roadside repairs of special equipment. The truck is also used with other District 5 resources for activities such as guard rail repair and road sign replacement. Pictures of the District 5 "Special Projects Truck" are shown in Figure 10 through Figure 12. The truck incorporates several features seen in roadside repair trucks during our previous visit to Rush Truck Centers, including a built-in crane, tool boxes, air compressor, welder, generator, emergency strobes and lighting, and other specialized tools. The truck did not have the means of lifting low profile trucks to enable service such as roadside tire changes, which the District 5 mechanic identified as a need. It was also evident that the truck had insufficient storage space because the mechanic was using the back seat to store tool boxes.

During this trip, the adjacent ODOT Licking County Garage was visited. Their mechanic truck was an upgrade compared to the Pickaway County Garage mechanic's truck discussed in Section 5.1. The ODOT Licking County mechanic's truck included a built-in crane, ample storage for tools and tires, a welder, an air compressor, and a generator. The Licking County mechanic explained that the built-in crane allows him to conduct roadside tire repairs when needed on the county garage equipment. Figure 13 shows the built-in crane and the welder, generator, and air compressor in the back of the Licking County Garage mechanic's truck. Figure 14 shows the side tool boxes. The Licking County mechanic also indicated that adding a low profile air bag would be of great assistance for repairing low profile trucks.

The mechanics from both garages indicated that even though tow providers are plentiful in their jurisdictions, the equipment on board these respective trucks reduces calls to commercial tow providers to incidents where the repair can't be completed in the field and the equipment needs to be towed back to the garage.

In summary, the District 5 "Special Projects Truck" and the Licking County ODOT mechanic truck have features included in the recommendation section below. These include built-in crane, built-in air compressor, welder, and generator. The truck is equipped with a full set of mechanic tools necessary for safe and efficient roadside fleet repairs. The truck can also be used for other purposes, such as work on guard rails and signs. ODOT's Licking County garage has an upgraded mechanic's truck which includes a number of the recommended features, although not as much as the District 5 special projects truck. Both mechanics indicated that these trucks are used on a daily basis, have reduced commercial towing bills, and recommend these features. Including a lift gate in lieu of the built-in crane sacrifices the tailgate area as a roadside work surface, as shown in Figure 10 but is a less expensive option.

Figure 10. ODOT District 5 "Special Projects Truck", including built-in crane.

Figure 11. View of ODOT District 5 "Special Projects Truck" showing driver's side tool storage.

Figure 12. View of ODOT District 5 "Special Projects Truck" showing passenger side tool storage.

Figure 13. ODOT Licking County Garage mechanic's truck with built-in crane and compressor/generator unit.

Figure 14. ODOT Licking County Garage mechanic's truck with passenger side tool cabinets open.

5.5 Equipment recommendations

From our discussions with our research team, in consultation with our ODOT liaison and from our discussion and visit to the ODOT District 5 garage, we have compiled a list of features shown below for a roadside fleet repair truck, a more comprehensive list is given in Appendix A:

- Truck large enough to carry all necessary equipment in organized compartments so as to enable easy access to tools and equipment when working within close proximity to traffic
- Truck should have ample storage for spare tires to be carried to the site
- Truck should have a built-in crane or a lift gate to allow lifting of tires or heavy objects to expedite repairs.
- Trucks should include air compressor, generator and welding equipment that can be operated independently of the truck engine. This will allow for economical operation of these equipment.
- Truck should be equipped with work lights to assist in situations where daylight is minimal specially during the winter season
- Truck should be equipped with emergency strobe lights to allow for safe roadside work.

In addition to the above truck equipment, each roadside assistance truck should at minimum include the following equipment:

- Truck should carry a full set of mechanics tools to allow for safe roadside repairs
- Truck should carry a full set of cutting torches and the ability to safely store and transport required gas tanks necessary for these operations.
- Truck should include tools necessary for hydraulic line repairs or replacements including replacing fittings if necessary
- Tools should include the capability to connect to the vehicle computer system and download diagnostic information and allow uploading of necessary software to implement a repair
- Tools should include electrical and lighting repair kits to perform these repairs on the roadside
- Truck tools should include battery chargers and tools for servicing and changing vehicle batteries.
- Truck should carry a full set of cribbing, hydraulic jacks and tools required to perform safe roadside tire repairs
- Truck should carry a set of low profile air bags to assist in lifting of low clearance vehicle.

The specifications for the low profile air bags must include the ability to lift up to 70 ton (63,500 kg or 620 kN)), from a low ground clearance of no more than 1 in (25 mm), and inflatable using normal tire pressure ranges (up to 120 psi (827 kPa)) to a height of more than 16 in (400 mm) to allow for the insertion of a low profile hydraulic bottle jack if needed to further lift the vehicle for repairs, and have a long term warranty against punctures and defects. These air bags should be steel or fiber reinforced It is recommended that each mechanic truck be equipped with at least one of these air bags.

5.6 Cost-Benefit Analysis

A full and comprehensive cost-benefit analysis requires adequate supporting data. For this project, the data required include a complete list of roadside repairs conducted by the Pickaway County Garage, an accounting of the time it took to accomplish each repair, including associated travel time. In addition, an accounting of time lost by all personnel involved waiting on tow equipment due to the current inability of performing roadside repairs, or waiting on tow equipment to assist with roadside repairs. In addition time lost waiting on the delivery of repair parts needs to be documented.

The lack of such detailed data made it impossible to conduct a full cost-benefit analysis. However, from the data collected from the Pickaway County Garage, the timelines given by the mechanics and Transportation Managers of Pickaway County Garage, it can be estimated on average roadside breakdown of equipment costs the Pickaway County Garage between eight and sixteen man-hours of lost productivity. In addition, if the Pickaway County Garage mechanics have to wait on tow trucks to deliver disabled vehicles and further wait on parts to be delivered, the disabled vehicle can be out of service more than 48 hours.

From the documentation gathered, in the calendar year 2017 the garage had 5 tow incidents (ODOT code 278), 6 instances of sending personnel to acquire parts (ODOT code 283) or pick up/deliver equipment (ODOT code 282), 3 instances of tire repairs (ODOT code 266 and 267), 36 instances of fixing electrical connections (ODOT code 208,209, 210, 215, 216, 219, 220, 229, 230, and 274), and 13 hydraulic issues (ODOT code 307,361, 362, 363, 365, 374, 375, and 377), making a total of 63 incidents. Most of these could have been done roadside to expedite the repairs and reduce lost productivity.

For a simple cost analysis, the minimum cost of the 63 instances can be calculated using a minimum mechanic and operator wage of $20.00/hour. Assuming eight man-hours lost per incident, $63 \times 8 \times \$20.00 = \$10{,}080$ of lost productivity per year. A modern truck capable of roadside repairs could be used year-round and has an expected life span of 12 years. The productivity lost over 12 years would cost the Pickaway County Garage $136,724. A standard mechanic truck, similar to the one at the Pickaway County Garage, currently costs ODOT approximately $40,000, and is replaced every 10 to 15 years, according to ODOT's Central Garage OEM.

If a modern mechanic truck with roadside repair equipment can be obtained for $110,275.00 (per quote supplied by Rush Truck Centers), then ODOT would save more than $107,000.00 over the life of the truck just by preventing lost productivity. A table showing the calculation of the lifetime savings is included in Appendix B. In addition, the costs of paying private firms for towing would be eliminated for the majority of instances. Thus the cost of a new mechanic truck for ODOT's Pickaway County Garage will be recovered well within its life span and allow for further savings by improving repair times, reducing lost employee hours, and reducing towing costs from private vendors. It will also modernize the process of roadside repair for the garage.

6 Conclusions and Recommendations

6.1 Conclusions

This study examined the efficiencies and costs of roadside repair incidents for ODOT's Pickaway County Garage. Pickaway County does not have any commercial tow operators within its borders, forcing garage personnel to call tow operators located outside the county for assistance when needed. The Pickaway County Garage does have a basic mechanic truck with a rudimentary set of tools and equipment insufficient for most roadside repairs, including simple tire changes or any other repair requiring heavy lifting on site. The truck does not have enough space to store any additional parts or tools aside from those already on board. The mechanics in Pickaway County have said they are constrained by their current resources and need better equipment to more effectively serve the needs of the garage.

During the course of this the research team found out ODOT's District 5 Garage and ODOT's Licking County Garage operate fleet maintenance vehicles with features similar to those required by ODOT's Pickaway County Garage. The ODOT District 5 and Licking County Garages were visited and the vehicles examined and photographed, as recounted in Section 5.4. A more complete list of features desired in a service vehicle is given in Appendix A.

Data to allow a complete cost-benefit analysis were unavailable, but the available data indicate at least eight man-hours are lost for each roadside incident that requires a tow call, such as those involving tires, hydraulics, or electrical issues. The number of such incidents indicates a modern roadside repair vehicle would pay for itself over its lifetime in reduced productivity losses and repair costs.

6.2 Recommendations

Additional research and data collection would enable fuller documentation of the benefit of an improved repair vehicle to ODOT's Pickaway County Garage. Such a study would include:

- A comparison of time lost for ODOT county garages that have more access to tow companies to those similar to Pickaway County which do not.
- Pickaway County and other ODOT County Garages in the study need to record complete data for each repair incident to track the actual amount of time and effort lost, as well as costs of any towing and repairs.
- After collecting under current conditions (the "do nothing" option) for a full year, ODOT's Pickaway County Garage should be provided with a modern roadside assistance truck, and another year of repair incident data collected from each garage to quantify the benefit of the truck.

6.2.1 Equipment Recommendations

A modern roadside repair truck suitable for the Pickaway County Garage's need for expedited and safe roadside service should including the following features:

- Sufficient and accessible storage space for all tools and equipment.
- Low-profile air bags for lifting low-clearance vehicles.
- Sufficient storage to carry spare tires to and from the site.
- Built-in crane and/or lift gate capable of lifting tires and other heavy objects.

- Air compressor, generator, and welding equipment which can be powered while the truck engine is off.
- A full set of cutting torches and adequate ability to store associated gas tanks.
- Tools, supplies, and fittings for repairing or replacing hydraulic lines.
- Tools and supplies for electrical repairs.
- Ability to download diagnostic information from vehicle computer and upload software upgrades if needed.
- Work lights to enable repairs at night.
- Emergency strobe lights and other safety markings/devices.

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8 Appendix A

Mechanic Truck to enable fitment of service body shown below:

- Medium Duty Truck, Cab and Chassis
- Crew Cab
- 2 or 4 wheel drive
- GVWR 16,000 lbs.

Service body specifications for fitment onto a medium duty cab/chassis:

Service body

- 132" (3.35 m) service body for 84" (2.13 m) DRW chassis
- 94" (2.39 m) body width with 54" (1.37 m) floor
- LED flush-mounted stop, tail, turn, and back-up lights
- LED safety strobe lights in stop, tail, turn, and back-up lights
- Standard shelving package:
    - 2 shelves each front vertical compartment
    - 1 shelf in one horizontal
    - 1 shelf in each rear vertical compartment
- Chrome and polymer automotive rotary door latches
- Stainless steel continuous door hinges
- Finish painted white to match cab
- Compartment doors painted only on inside
- Compartment interior finished painted medium grey from factory
- LED compartment light strips in all compartments
- 2" (51 mm) square tube receiver hitch with trailer wiring
- Spray-on liner on floor, compartment walls, bulkhead, tailgate and compartment tops
- Hook up factory back-up camera system
- 2 manually adjustable spotlights
    - Mounted to top rear corners of service body side packs
    - 1,300 lumens each
    - Includes: lighted rocker switch if no upfitter switches available
- Corner safety strobe light system
    - 2 amber strobe lights mounted in behind chassis grill
    - Activate existing strobe lights in service body
        - LED compartment lights, spotlights, and strobe lights are to be wired into factory upfitter switches
- Body fully undercoated by the manufacturer

Electric/hydraulic crane (16,000 ft-lb (22,000 N-m) rating)

- 4,000 lb (18 kN) capacity at 4' (1.22 m)
- 2,000 lb (8.9 kN) capacity at 8' (2.44 m)
- 1,250 lb (5.6 kN) capacity at 12' (3.66 m)

- 900 lb (4.0 kN) capacity at 16' (4.88 m)
- Power boom elevation
- Continuous power rotation
- Power boom extension from 8' (2.44 m) to 12' (3.66 m)
- Manual boom extension from 12' (3.66 m) to 16' (4.88 m)
- Capacity overload shut-off system
- Anti-two-blocking system
- Electric winch with 80' (24 m) of 5/16" (8 mm) aircraft quality wire rope/cable
- Snatch block with swivel hook and safety latch
- 25' (7.6 m) plug-in remote control pendant
- Master disconnect switch
- Boom rest
- Corner mounted crane reinforcement kit
    - Designed for 4,000 lb (18 kN) capacity cranes (16,000 ft-lb (22,000 N-m))
    - Must be ordered from manufacturer and built with body
- Manual full outriggers (manual pull out and pin system with pin and crank-down legs)

Compressor/welder/jump-starter/generator

- 24 cfm (680 liter/minute) @ 175 psi (1.21 MPa) reciprocating air compressor (11.5 gallon (44 l) capacity tank)
- 250 amp DC CC/CV welder
- 5 kilowatt (7 hp) generator with 120V and 240V outlets
- 300 amp battery boost/jumper cable (50 amp 12V charger)
- Remote control panel
- Welding cable set
- Battery booster cables (25' (7.6 m))

1600 lb (7.1 kN) lift gate for utility bodies with 54” (1.37 m) wide opening

- 1600 lb (7.1 kN) lifting capacity and 42" (1.07 m) of vertical travel
- Dual lift cylinders
- 55" (1.40 m) × 38" (0.97 m) + 6" (0.15 m) ramp folding tread plate steel platform
- Curbside toggle switch control with safety timer
- Hidden activation switch
- Fully enclosed hydraulic system, located within the main frame
- 150 amp circuit breaker
- All metal framework items are painted factory black before assembly

Source: Rush Truck Centers standard requirements.

9 Appendix B

Cost analysis calculations:

Value of Current Mechanic Tool Box	$	(15,000.00)
Life expectancy of current truck (years)		12
Value of Current Mechanic Truck	$	(40,000.00)
Minimum Man-Hours lost		(8.00)
Incidents in 2017		63
Minimum hourly wage	$	20.00
Minimum Productivity loss/year	$	(10,080.00)
Current Inflation rate		2.0%
Term (years)		12
Future Value of lost Productivity	$	136,724.53
Future Value of Existing Truck	$	80,880.00
Total value lost in 12 years (Productivity lost plus cost of current mechanic truck)	$	217,604.53
Value of Proposed mechanic truck (Cab/Chassis)	$	66,500.00
Value of Proposed Mechanic tool box	$	43,775.00
Value of Proposed Truck with tool box	$	110,275.00
Total Savings over 12 years	**$**	**107,329.53**

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