



Contract report 17776:

TMC RP 1118 Fuel Savings Calculator for Aerodynamic Devices Validation



Performed on behalf of the
Technology & Maintenance Council of the American Trucking Associations

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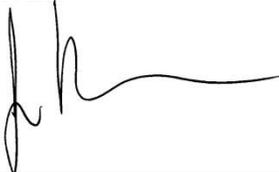


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Date: November 15, 2019

PIT Group

PIT Group is 1 of 11 research groups of FPIInnovations, which has more than 400 employees at 6 main offices across Canada and the United States, and in regional offices in each Canadian province.

PIT Group's team of researchers has been active in the field of transportation for more than 35 years. The team's mission is to improve each phase of the transportation system, cut costs and emissions, and increase the safety of operations.

By working together and by using the most recent technological and operational innovations, our world-class professionals specialize in delivering concrete solutions at reasonable costs, as we are a non-profit research and development institute.

As part of services offered to clients, PIT Group supports fleets and suppliers, implements solutions for specific problems, and develops combined integrated solutions for more complex problems depending on the clients' needs.

ISO 17025 certified tests

The Standards Council of Canada (SCC) granted the ISO/IEC 17025:2005 (CAN-P-4E) accreditation for tests conducted by PIT Group.

PIT Group testing activities under the ISO 17025 certification include fuel consumption testing for heavy-duty vehicles, such as testing according to SAE J1321 and TMC Fuel Consumption Test Procedure - Type II, SAE J1526 Fuel Consumption Test Procedure (Engineering Method), and TMC Fuel Consumption Test Procedure – Type III, EPA SmartWay Test Methods, fuel consumption testing for light-duty vehicles, and emissions testing using portable emission measurement system (PEMS) according to EPA regulations.

Our mission

Innovative, world-class engineering group contributing toward the development and accelerated implementation of safe, sustainable, and efficient technologies that support excellence in North America's transportation industry.

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Introduction

PIT Group of FPIInnovations was approached by The Technology & Maintenance Council of American Trucking Associations (TMC) to validate TMC Recommended Practice RP 1118, Fuel Savings Calculator for Aerodynamic Devices, utilizing the working model of a proposed revision to the original calculator developed in 2018 by TMC's S.11 Sustainability & Environmental Technologies Study Group.

TMC is an organization of more than 2 500 industry professionals. Comprised of a broad cross-section of experienced fleets, equipment suppliers and service providers, no other industry trade association can match the real-world experience and technical expertise of TMC's membership.

By providing leadership support and opportunities to collaborate, TMC helps members develop the industry's best practices that address the critical truck technology and maintenance issues that have the greatest impact on truck fleets. For more than 60 years, TMC's member-driven Recommended Maintenance and Engineering Practices have been setting the standards that help trucking companies specify and maintain their fleets more effectively.

TMC RP 1118, developed and first published in May 2016, provides equipment operators with an interactive mathematical tool to evaluate the potential fuel and economic savings of an aerodynamic device that has been tested using one of TMC's fuel economy testing procedures. The tool may also be compatible with rolling road wind tunnel testing conducted over a variety of drive cycles. The scope of this RP is limited to Class 6-8 tractors coupled to commercial trailers of all types. The speed range covered is from 40 to 75 mph.

To help equipment owners determine how this potential savings actually applies to a given fleet, TMC developed a fuel savings calculator as described below.

The calculator requires the following information to offer a result:

- Average miles travel per year per truck
- Average fuel economy per truck
- Cost of fuel per gallon
- Number of trucks to be evaluated
- Number of trailers to be evaluated
- The percentage of miles travelled at speeds less than 40 mph and more than 70 mph
- The fuel savings percentage the device provides at 65 mph or other speed tested

Given this information, the calculator will report:

- Projected fuel economy
- Fuel savings in tenths of a gallon
- Average fuel savings per truck with the device on the trailer
- Annual savings per year per trailer using a given aerodynamic device.

The calculator was developed using Microsoft Excel, and the Excel file may be downloaded from TMC's social networking and collaborative work platform, TMConnect (<http://tmconnect.trucking.org>).

Based on the discussions between PIT Group and TMC, the methodology used to conduct this project was as follows:

- Review of the PIT Group test results and other reliable sources to reference aerodynamic test data and compile the information;
- Propose derived data tables to be added to the revision of RP 1118 to assist the user of the calculator in choosing a realistic set of input;
- Review the calculator and provide recommendations to make it a more reliable tool for decision makers.

Review of aerodynamic technologies test data

PIT Group has tested aerodynamic devices, as well as many other types of technologies, since 2007. Most of PIT Group testing is conducted at the Transport Canada Motor Vehicle Test Centre, located in Blainville (QC), Canada, which is presently operated by PMG Technologies. The tests are performed on the high-speed test track (Figure 1), which is a high-banked, parabolic oval, with the length of 4.15 miles (6.66 km).

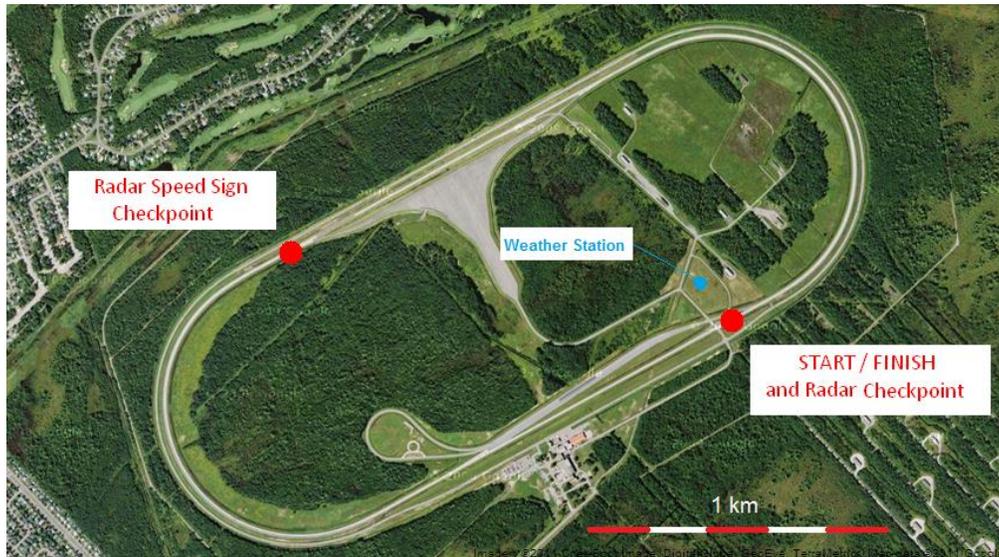


Figure 1. Test site with radar checkpoints and weather station positions.

The tests are conducted according to industry accepted fuel consumption test procedures, such as TMC Fuel Consumption Test Procedure - Type II RP1102A (TMC 2018b), and SAE J1321 Fuel Consumption Test Procedure - Type II (SAE International 2012).

Since 2012 the aerodynamic devices constant speed tests are conducted at 65 mph (105 km/h). However, until 2011, the tests were performed at test speed of 61 mph (98 km/h) or 62 mph (100 km/h). For the purpose of this project, the results obtained at different test speed other than 65 mph were extrapolated to 65 mph, using the algorithms embedded in the RP 1118 Fuel Savings Calculator. A trend curve was used to transpose the results with a coefficient of determination (R^2) of 0.9995 (Figure 2), which allowed reviewing the method of calculation used by the tool, and to project the test results for the test speed of 65 mph.

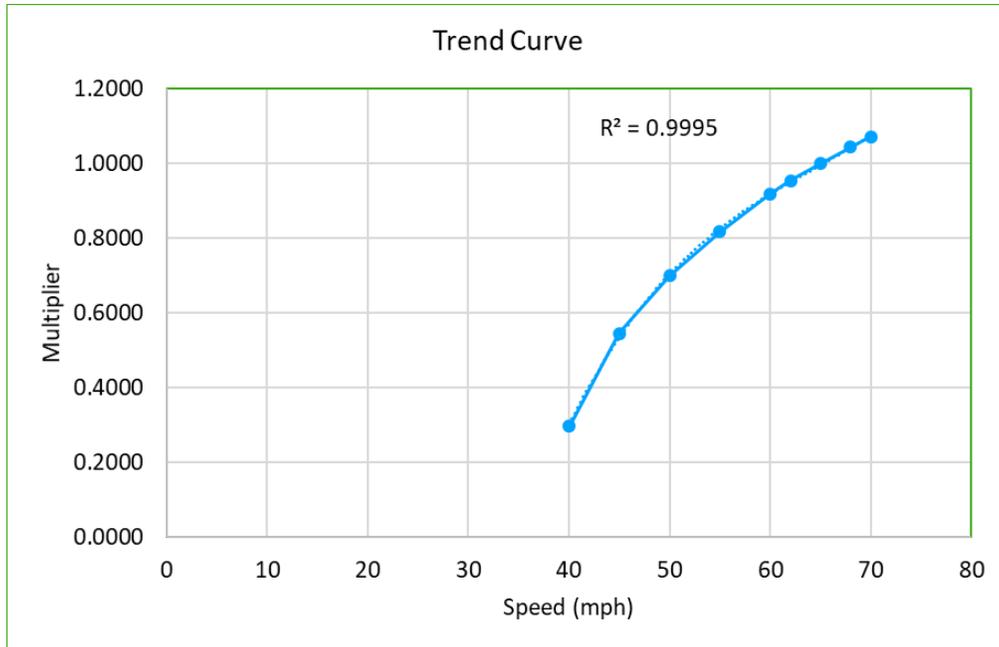


Figure 2. Trend curve derived from RP 1118 Fuel Savings Calculator data.

An Excel spreadsheet was created to analyze the aerodynamic technology data. For the technologies tested by the PIT Group, the following information was considered: the year of the test, the type of product, a description of the product, the test method, the fuel savings result (%) obtained at the actual test speed, and the fuel savings extrapolated for the test speed of 65 mph.

A total of 134 test results were analyzed, of which 87 tests have been reviewed and listed into eleven categories of technologies and practices falling within the scope of the project. Tests with uncertain results were not used to calculate the average fuel savings for the category.

In addition to the PIT Group test results, data coming from unbiased organizations such as the North American Council for Freight Efficiency, the International Council for Clean Transportation and the National Academy Press were considered and correlated with PIT Group test results and provide additional information.

Although EPA SmartWay is a good source of information, their method of classifying technologies is rather general and lacks detailed results. For that reason, SmartWay data was not included.

The technology categories are presented below.

Trailer side fairings

Trailer side fairings, also known as trailer skirts, are the most popular aerodynamic devices used on trailers. It is in this category that PIT Group performed most of the aerodynamic devices tests in the last 11 years. The tests also showed that the position of the skirts on the trailer is important to obtain the best aerodynamic drag reduction, which is important when a fleet wants to do their own after-market installation. The average of the thirty-seven PIT Group tests showed 4.3 % fuel savings, and the best result was 8.0 % fuel savings.

Trailer boat tail - long

PIT Group tests over the years showed that the rear deflectors are more efficient when they are longer and have larger surfaces. As a rule of thumb, for each foot of length of a boat tail 1 % of fuel savings can be achieved. The average fuel savings for 2 to 5 feet long boat tails is 3.0 %, and the best results for a five-foot long boat tail was 5.3 %.

Trailer boat tail - short

Short boat tails are less than two feet long extending beyond the end of the trailer or could be panels attached to the trailer's rear walls and roof that do not extend beyond the end of the trailer. The average fuel savings for this type of device is 1.9 %, and the top performer showed 3.4 % fuel savings.

Trailer fairing combinations

These can be either combinations of side skirts with short or long boat tail or side skirts with gap reducer and vented mud flaps. The combinations tested by PIT Group resulted in average fuel savings of 6.9 % and the best result was 8.9 %.

Trailer gap reducer

Although PIT Group tested only a few trailer gap reducers, the results are aligned with other organizations results: an average of 1.3%, with best performance of 1.6 % fuel savings.

Trailer underbody devices

Trailer underbody devices are installed on the underside of a semi-trailer to reduce aerodynamic drag and increase fuel economy. PIT Group tests on these devices, though limited, resulted in average fuel savings of 1.8 % with a best performance of 2.2 %.

Vortex generator

The test results with this technology are mixed and the fuel economy with this technology is not assured. For the devices showing positive results, the overall performance of fuel savings was roughly 1%. Considering the margin of error, the fuel savings would be between 0 % and 1 %.

Vented mud-flaps

Two different makes of vented mud flap were tested and both showed the same result, 1.4 % fuel savings. The tests were carried out with vented mud-flaps installed on both trailer and tractor. It would be beneficial to test them independently, either on tractor or on trailer.

Wheel covers

The tests with wheel covers installed on a tractor - tandem tanker semi-trailer combination did not show fuel savings. Problems occurred during the installation of the wheel covers and modifications were made to fit them securely on the wheels. More test should be conducted with this type of device to better evaluate their potential.

However, the test with a combination of wheel covers and tandem fairings installed on tractor showed 1.6 % fuel savings.

Tractor-trailer gap reduction

More of a good practice than a technology, reducing the gap between the back panel of the tractor and the front wall of the trailer showed fuel savings. The larger the gap, the more air rushes in front of the trailer

thus creating extra turbulence. At 65 mph, reducing the gap from 50 in. to 36 in. resulted in fuel savings of 1.9 %, from 45 in. to 36 in. showed 1.4 % fuel savings, and 1.6 % fuel savings were observed when the gap was reduced from 45 in. to 33 in. The average fuel savings were 1.6 %.

Tarp system for dump trailer

Covering an empty open box with a tarp will improve the aerodynamic shape of the vehicle and prevent air being forced against the tailboard at the back of the box. A tarp can reduce the air resistance and aerodynamic drag. Fuel savings obtained from regular dump truck to 53-ft. semi-trailer average at 11.7 %, while the best result was 15.9 % for a 53-ft. dumper trailer.

Derived tests data table

The Excel spreadsheet features test results and data for various aerodynamic technologies. From this spreadsheet, it is possible to integrate the desired information into a derived dynamic table that can be incorporated into the RP 1118 Fuel Savings Calculator.

An example is presented in the “Derived dynamic table” page in the spreadsheet. The dynamic information selector board it is a drop-down menu that allow the user to choose a specific technology. When chosen, a description of the technology appears, as well as the average and best fuel economy at 65 mph (Figure 3). The user can simply input the desired fuel savings value he chooses into the appropriate box of the RP 1118 Fuel Savings Calculator or use the radio buttons to select either the average fuel economy or the best fuel economy to automatically input the fuel savings value in the calculation box (cell N24 in the actual spreadsheet).

| | | |
|--------------------------------|---|--|
| Select a technology: | Trailer Side Fairings | |
| Technology description: | Also known as trailer skirts, these devices go underneath a trailer on each side, reducing the air resistance and increasing fuel economy at highway speed. | |
| Average fuel economy at 65 mph | 4.3% | <input type="radio"/> Select average |
| Best fuel economy at 65 mph | 8.0% | <input checked="" type="radio"/> Select best |
| User input | 0.0% | <input type="radio"/> Select user input |
| Fuel economy chosen | 8.0% | |

Figure 3. Derived table information selector board.

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Review of the RP 1118 Fuel Savings Calculator

Layout

Based on the development of PIT Group tools, with the goal of offering an intuitive interface, data entry sections are usually separated from the results section. Sections could be split within the same page or on different pages. In the actual RP 1118 Fuel Savings Calculator, data input boxes are interspersed within the spreadsheet. These boxes could be placed in one section with information on technologies (information selector board, for example), and a second section for results.

Eliminating the grid between the elements is recommended so as to reduce the busyness of the page, as well as incorporating colors to delineate sections, and if desirable, pictures or icons. Representative images for each technology could be included in the description to increase the quality of the content and enhance the user's experience.

Color schemes could be employed to have a good blend between colors when many are used. Some websites can help by offering color palette and layout ideas.

The chart presentation is suggested for the output section where the results are presented. Information can both be represented graphically and numerically within a single graph. This graphic aspect gives an interesting visual rendering for the user. The savings achieved each year by using the aerodynamic device at each speed is a good example of information that can be represented using a graph.

User interface design is a specialty, but with the few ideas above, this could make a remarkable difference.

Appendix A presents an example of one of PIT Group tools, with tool input page and result page.

Content

The RP 1118 Fuel Savings Calculator is certainly helpful for fleet managers and owner-operators to evaluate the options for the adoption of aerodynamic technologies. The Proposed Update to RP1118 Calculator is an evolving tool, and it will eventually be improved throughout the finalizing process. Following a summary analysis of the tool, some observations, questions or suggestions are presented below.

Although most of the input information requested should be known by the user, this may not be the case for the percent of total of miles traveled at a specific speed (cell C22:C31). If the user's telematic system is not specifically set-up to obtain this information, many will not be able to fill the grid accurately. In this case, an alternative option could be offered to the user, such as adding a transportation category selection that would provide a speed profile. Category examples could be line haul TL, line haul LTL, and regional (because the calculator evaluates aerodynamic technologies, other categories, such as city delivery, can be excluded).

The user could then choose the category that represents his duty cycle, as well as his usual highway cruise speed. From these two inputs, the grid could automatically be filled with a predefined speed profile. For example, if the user selects the line haul TL category and enters his usual cruise speed at 65 mph, the grid could be filled as follows (Figure 4): 89% at 65 mph, 5% under 40 mph and the remaining percentage spread evenly across the grid. This would also add an automation step to the tool, making it even more user-friendly.

Note that if the manual entry for speed is eliminated, the whole grid could also disappear from the interface and remain in hidden cells of the calculator. Otherwise, it could be redesigned to make it smaller and more attractive, avoiding repeating the same sentence ten times, which only clutters the grid.

| Percentage of miles traveled at a road speed (mph) of | |
|---|--------------|
| 0.0% | 70 |
| 0.0% | 68 |
| 89.0% | 65 |
| 1.0% | 62 |
| 1.0% | 60 |
| 1.0% | 55 |
| 1.0% | 50 |
| 1.0% | 45 |
| 1.0% | 40 |
| 5.0% | under 40 |
| 100.0% | Total |

Figure 4. Example of speed distribution for Line haul TL operation.

For the Proposed Update to RP1118 Calculator:

- On the first-year sheet of the ROI calculator, the tool allows to enter the retail price for up to 3 devices (row 21, 22, 23). This gives interesting possibilities, but by doing so, the user may wonder why it is not possible to also enter up to three technologies in the fuel savings calculator sheets.
- Again referring to the possibility of entering the cost for three different technologies or devices, if this option is kept, the tool should also offer the opportunity to add the installation, shipping, and maintenance costs for each technology (row 21 to 32 ROI calculator page) in order to provide detailed information for each of them and eliminate the need for the user to sum these costs separately.
- On the third-year sheet of the ROI calculator, the costs of installation and maintenance (C24:C32 and D24:D32) vary compared to previous ROI pages and this seems to be a formula error. On the other hand, this observation led to another suggestion; when the chosen technology has an annual maintenance cost, the tool could offer to insert an annual percentage of indexation (automatic or manually entered) to cover the expected price increases for parts and labor year after year.
- Making a tool that makes projections over years opens-up possibilities: with a great number of trailers, a fleet may decide to install a technology on a limited number of units or over a number of years as opposed to all in one year. Either they want to dispose of old trailers in the near future or they just don't have the financial or human resources to install all the technology within the same year. Whatever the reasons, it may be appropriate to allow the user to enter the number of trailers they want to equip each year.
- The Whole Life Analysis sheet seems not to be finalized and contains some formulae and misconception errors. For example, cells C15 to F15 indicate related costs for the technologies (base unit pricing, other cost, estimated installation cost and shipping) and these figures fluctuates according to the percentage of trailers drawn by owner-operators. This does not seem right. Cost of technology should be fixed regardless of who pulls the trailers. If this calculation is used for anything else, then it should be concealed so as not to cause confusion.
- If prices for devices 1 and 2 are entered on the first year ROI sheet (ROI Calc Yr 1), on the Whole Life Analysis sheet one cost appears in cell D10 (Other cost for Device Option 1) and the other in

cell D 15 (Other costs for Device Option 1 with percent of owner-operator), instead of having the total of the two in each of these cells.

- Again, for the Whole Life Analysis sheet, another observation is made for cells on row 15 (columns pertaining to years). Without going into a detailed explanation, sometimes there is no correlation between the percentage of owner-operated trailers on page ROI Calc Yr 1 (cell D7) and the results in these cells. For example, if the user changes the percentage the results on the Whole Life Analysis sheet are not consistent with the modification, or they are erratic. There are also unhidden values on row 17, which should eventually be fixed in the final version.
- All in all, this tool has some very interesting features. One of the difficulties of developing this type of tool is to try to keep it simple, uncluttered, and automated but wanting to offer as much information as possible. These two wishes clash and therefore, one must strike a balance between the two.

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Conclusion

PIT Group reviewed information deriving from 87 tests conducted since 2007, which was separated into eleven categories of technologies and practices related to aerodynamic technologies for trailers. In addition to the PIT Group test results, data coming from other reliable sources was judged to correlate with PIT Group test results and included to provide additional information.

An Excel spreadsheet was used to analyze the aerodynamic technology data. For the technologies tested by the PIT Group, the following information was considered: the year of the test, the type of product, a description of the product, the test method, the fuel savings result (%) obtained at the actual test speed, and the fuel savings extrapolated for the test speed of 65 mph.

An example of a derived table was created. The dynamic information selector board uses a drop-down menu to allow the user to choose a specific technology and obtain the desired information, in addition to using a method to automate certain functions in the calculation tool.

General indications and examples on how to layout and present the elements of the calculator were suggested. The design of an interface should consider the location of components in sections, the use of color, images, automated functions as well as the usage of graphs to allow the users an optimum experience.

Finally, regarding the content of the tool, it was suggested to add an option where the user can build his speed profile from a transport category selection instead of inputting his own data.

The RP 1118 Fuel Savings Calculator is certainly helpful for fleet managers and owner operators to evaluate the options for the adoption of aerodynamic technologies. The Proposed Update to RP1118 Calculator is an evolving tool and will eventually be improved throughout the finalizing process. Following a summary analysis of the tool, some observations, questions, and suggestions were presented.

References

- SAE International. (2012). *Fuel Consumption Test Procedure – Type II*, SAE Surface Vehicle Recommended Practice J1321. Warrendale, PA.
- TMC. (2018a). *TMC Fuel Savings Calculator for Aerodynamic Devices*, RP1118. Technology & Maintenance Council – American Trucking Association In. Arlington, VA.
- TMC. (2018b). *TMC Fuel Consumption Test Procedure Type II*, RP1102A. Technology & Maintenance Council – American Trucking Association In. Arlington, VA.

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Appendix A. Example of PIT Group tool interface

ROI Calculator

INPUTS

FLEET INFORMATION

| | Tractor | Trailer | units |
|-----------------|---------|---------|-------|
| Total | 10 | 20 | |
| Lifecycle | 6 | 12 | years |
| Annual distance | 200,000 | 100,000 | km |

SYSTEM TYPE

| | Tractor | Trailer | |
|--------------------------|---------|---------|---------|
| Category | TPES | TPES | |
| Number of units to equip | 10 | 20 | |
| Technology cost | 250 | 250 | \$ |
| System maintenance costs | 144.75 | 144.75 | \$/year |

TIRE INFORMATION

| | Tractor | Trailer | |
|--------------------------|---------|---------|---------|
| Tire style | Duals | Duals | |
| Number of axles per unit | 2 | 2 | qty |
| Number of tires | 100 | 160 | tires |
| Reduction in tire life | 7.35 | 9.70 | % |
| Cost of tire | 500 | 350 | \$/tire |

FUEL

| | Tractor | Trailer | |
|-----------------------|---------|---------|----------|
| Cost of fuel | 1.05 | | \$/litre |
| Avg. fuel consumption | 35 | | L/100 km |
| Fuel overconsumption | 0.59 | 0.78 | % |

MAINTENANCE

| | Tractor | Trailer | |
|-------------------------------|---------|---------|----------|
| # of tire maintenance checks | 4 | 3 | per year |
| Labor time per check (tech.) | 4 | 4 | minutes |
| Hourly rate of the technician | 85 | 85 | \$ |

FLEET ROAD CALLS

| | | |
|-----------------------------|-------|----------|
| Tires related road calls | 10 | per year |
| Avg. cost per road call | 650 | \$ |
| Avg. hourly rate (downtime) | 35 | \$/hour |
| Downtime | 892.5 | \$/year |

OTHER TIRE COSTS

| | | |
|-------------------------------------|----|---------|
| Avg. additional cost per road calls | 85 | \$/call |
|-------------------------------------|----|---------|

Results

Figure 5. Example of PIT Group tool input page.

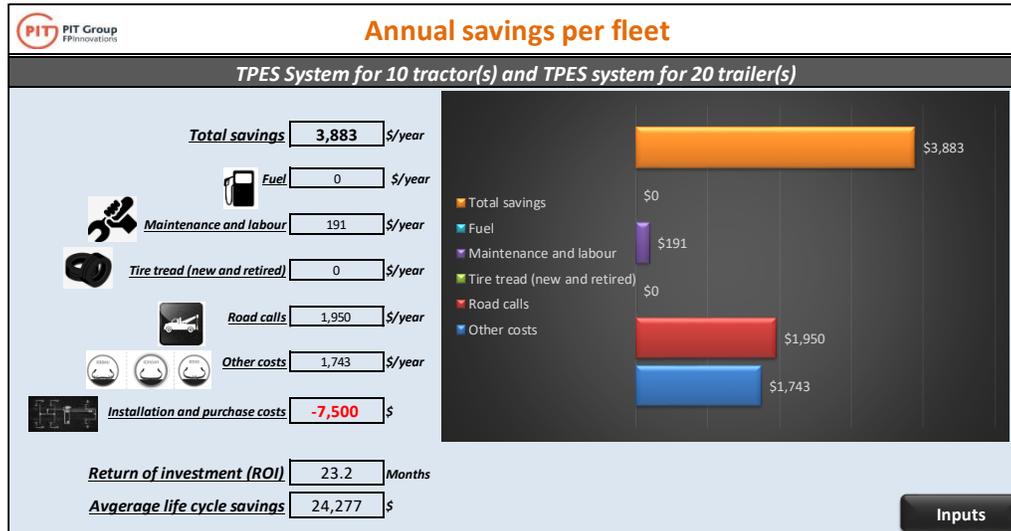


Figure 6. Example of PIT Group tool results page.



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