A-P-T RESEARCH, INC.

COMPREHENSIVE TRANSPORTATION RISK MODEL DEVELOPMENT

Project #45 / TA-1

Final Report

Contract #: 693JK319C000009

COMPREHENSIVE TRANSPORTATION RISK MODEL DEVELOPMENT

FINAL REPORT

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ACRONYMS

AADT	Average Annual Daily Traffic
API	Application Programming Interface
APT	A-P-T Research, Inc.
DDESB	Department of Defense Explosives Safety Board
DOT	Department of Transportation
FE	Functional Element
GUI	Graphical User Interface
HM	Hazardous Materials
IME	Institute of Makers of Explosives
ISSS	International System Safety Society
NEW	Net Explosive Weight
P_e	Probability of Event
PERT	Program Evaluation and Review Technique
PHMSA	Pipeline and Hazardous Materials Safety Administration
PRA	Probabilistic Risk Assessment
PRET-T	Population Risk for Explosives Transport by Truck
SOW	Statement of Work
SRD	Software Requirements Document
TA	Technical Algorithm
TDD	Technical Description Document
TRB	Transportation Research Board

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1.0 Overview

Under contract with the Department of Transportation (DOT) Pipeline and Hazardous Materials Safety Administration (PHMSA), A-P-T Research, Inc. (APT) developed a proof-of-concept transportation risk model for transporting explosives by truck.[1] The primary product of this contract is the software tool, Population Risk for Explosives Transport by Truck (PRET-T), which was delivered as installed software on laptop computers. To develop this tool, APT produced numerous artifacts. This final report documents the artifacts and represents the final milestone of work that began in 2019 under R&D projects solicited by PHMSA through a Broad Agency Announcement[2] in 2017.

2.0 Project Scope

The purpose of this project was to develop a transportation risk model for transporting explosives by truck. This model is intended to be the first phase of a larger model that will assess risk of any hazmat by any mode: Truck, rail, air, or water. The project requirements are for a modular tool with the ability to add functionality such as other hazardous material (HM) consequences models and transportation modes.

Ultimately, this tool will enable a more rigorous assessment of risks in HM transportation that more clearly defines hazards, and more quickly identifies mitigations at a lower cost. It is designed for risk management and not risk governance. Risk management applies a logical and well-documented process that can be simplified into four essential elements: 1) Identify risks, 2) Assess the risks, 3) Reduce risks, and 4) Accept residual risks. The proposed probabilistic risk assessment (PRA) tool will support identification, assessment, and reduction of risks.

The tool will ultimately be used to identify and reduce risk to people, property, and the environment. For this effort, the focus of risk was limited to people.[3]

The general objectives of this project were to:

1. Conduct research into the contributors of risk for transporting explosives by truck.

2. Develop the tool using APT's software processes and procedures.

3. Deliver full documentation of software development including a user's manual and a technical description document (TDD), which includes the software algorithms.

Included in this report as appendices are the statement of work (SOW), program PERT chart, Software Requirements document, a summary of work "sprints," a data security plan, a list of software versions, the Test Plan and Results, and User's Manual. A Technical Description document was also provided, but is not included as an attachment in this report.

3.0 Background

Currently, PHMSA does not have an endorsed transportation PRA model. A comprehensive transportation PRA model would enhance PHMSA's ability to provide protection for the safe

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[1] Contract No. 693JK319C000009
[2] BAA Solicitation No. DTPH5617PHMSABAA
[3] Additional proposed phases include transportation of explosives by truck via rail, air, water, and intermodal transportation, as well as the transportation of other HMs via truck.

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transportation of energy and other hazardous materials essential to our daily lives. A PRA tool in digital format would be useful to PHMSA and industry as it will enable them to consider all risks in transporting hazmat in different modes via different routes.

To develop the software tool, research was needed in each of three areas associated with the specific risk equation used in the risk model (risk = probability of event x consequence x exposure). The research refined the contributing factors leading to the derivation of a lower-level risk formula in sufficient detail to be used in the software tool.

The software is designed as a stand-alone tool with open architecture, which allows it to be expanded later to include different transportation modes and multiple hazardous materials. This final report encompasses Phase 1 of software development, which is a risk model for transporting explosives by truck.

4.0 Program Management Approach

The project requirements are for a modular tool with the ability to add functionality such, as other HM consequences models and transportation modes. The overarching approach was to establish discrete teams, each performing tasks that integrate into the contract management plan. The management team established research, analysis, software, and testing teams and coordinated activities within the teams, as well as frequent communication with PHMSA.

At the start of the project, APT created a program plan, which defined tasks to be accomplished, time and funds required, and assigned responsibility for each task. It also contained a program evaluation and review technique (PERT) chart for the entire contract containing the schedule, assigned activities, and task descriptions. The final PERT chart is shown in Appendix B.

For this project, APT applied agile management methods. Agile management is an iterative, incremental method of managing the design and build activities for engineering or information technology development projects in a highly flexible, interactive manner.[4] The main benefit of agile project management is the ability to respond to quickly uncover and respond to issues as they arise throughout the course of the project. Efficiency and cost-effective management are key elements.

Agile program management depends on key methods known as "scrums" and "sprints." Scrums are gatherings of technical personnel to solve technical issues faced by the development team. The APT team conducted work in two- to three-week "sprints," or short development cycles, which were tracked to completion on a master spreadsheet. Twenty-five discrete sprints were conducted, with the actions assigned and progress made in each sprint as documented in Appendix D.

5.0 Research Approach

The work of each team (research, analysis, software, and testing) contributed to refinement of the overall analysis architecture. Shown in Figure 1 is the proposed conceptual design with 11 numbered functional elements (FEs); Figure 2 shows the as-built design. By comparison, none of the conceived FEs changed at the top level during development. However, at a more detailed level, several of the elements were redesigned in order to achieve the desired element functionality. In general, the conceptual design remained as originally defined with only a few

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[4] https://en.wikipedia.org/wiki/Agile_software_development#Agile_management

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changes for the entire development cycle. This is due to the fact that research was able to answer the key questions needed to implement the conceptual design.

Key research questions were asked and answered primarily during the first three months of the project, including:

1. **Q:** Is there a credible historical source for probability of event (P_e) data? **A:** Yes, the Orica study document[5] the P_e for several road types and explosives. This data included ample explanation allowing interpretation. Discussions with the Orica study validated proper interpretation of data used. In addition, the supporting data had been reviewed by industry and governments (particularly the U.K. Health and Safety Executive) and has excellent technical pedigree.

2. **Q**: Is there a useful source of road traffic data? **A**: Yes. Several available sources are available. The most complete is developed by each state and is maintained on road type and traffic. These are downloadable in the form of shapefiles.

3. **Q**: Is there a credible source of population data to determine exposure? **A**: Yes. Census data and LandScan data are provided in GeoTIFF raster binary format and are widely used by NASA, DoD, and other federal and industry users.

4. **Q**: Which traffic routing program is most suitable for this application? **A**: Our team researched multiple options and selected Microsoft Bing Maps because it was considered a best fit to meet PRET-T requirements. It contains a robust set of embedded capabilities, excellent software development support, and was the most cost-effective, flexible solution. Other options considered were Google Maps, OpenStreetMaps, Mapkit JS, MapBox GL JS API and Mapbox Studio, Leaflet, and OpenLayers API.

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[5] Polich, Jenny. Transport Risk Analysis, Orica Explosives International, 2001

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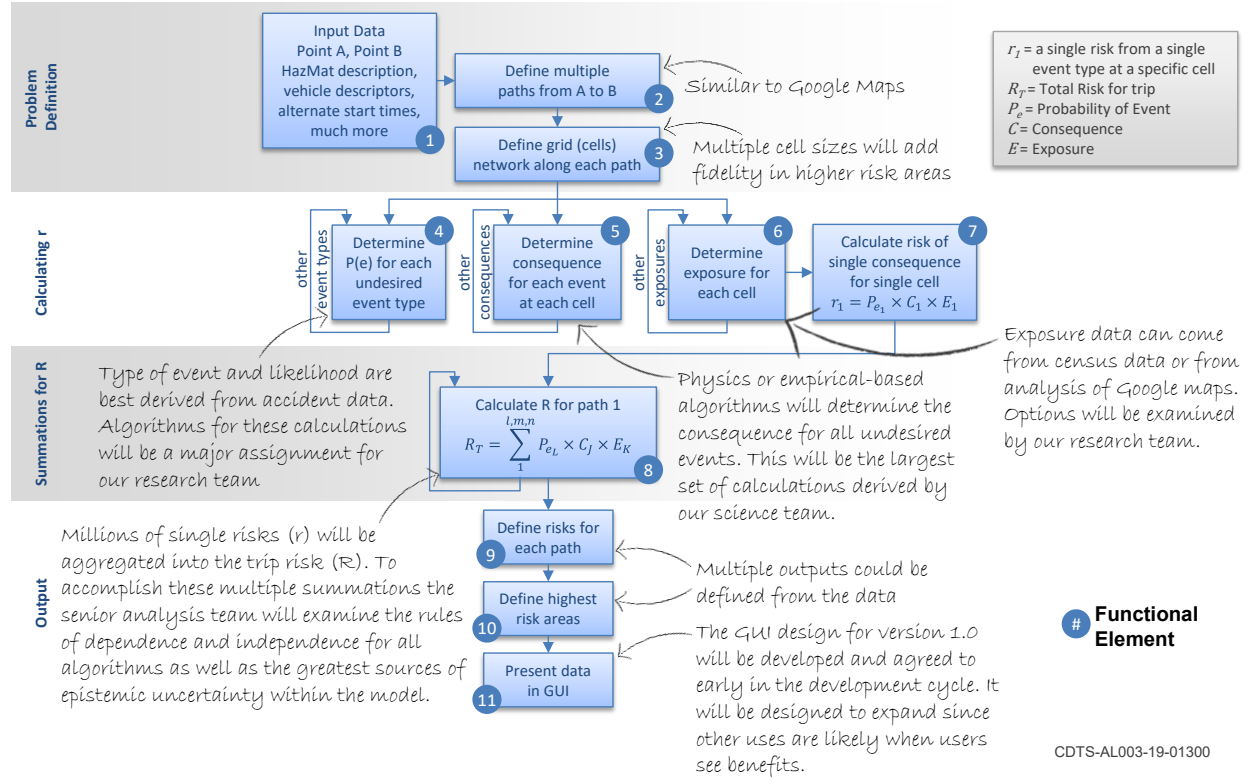
Figure 1: Transportation Risk Model Analysis Architecture (as originally designed). The proposed "functional elements" are numbered.

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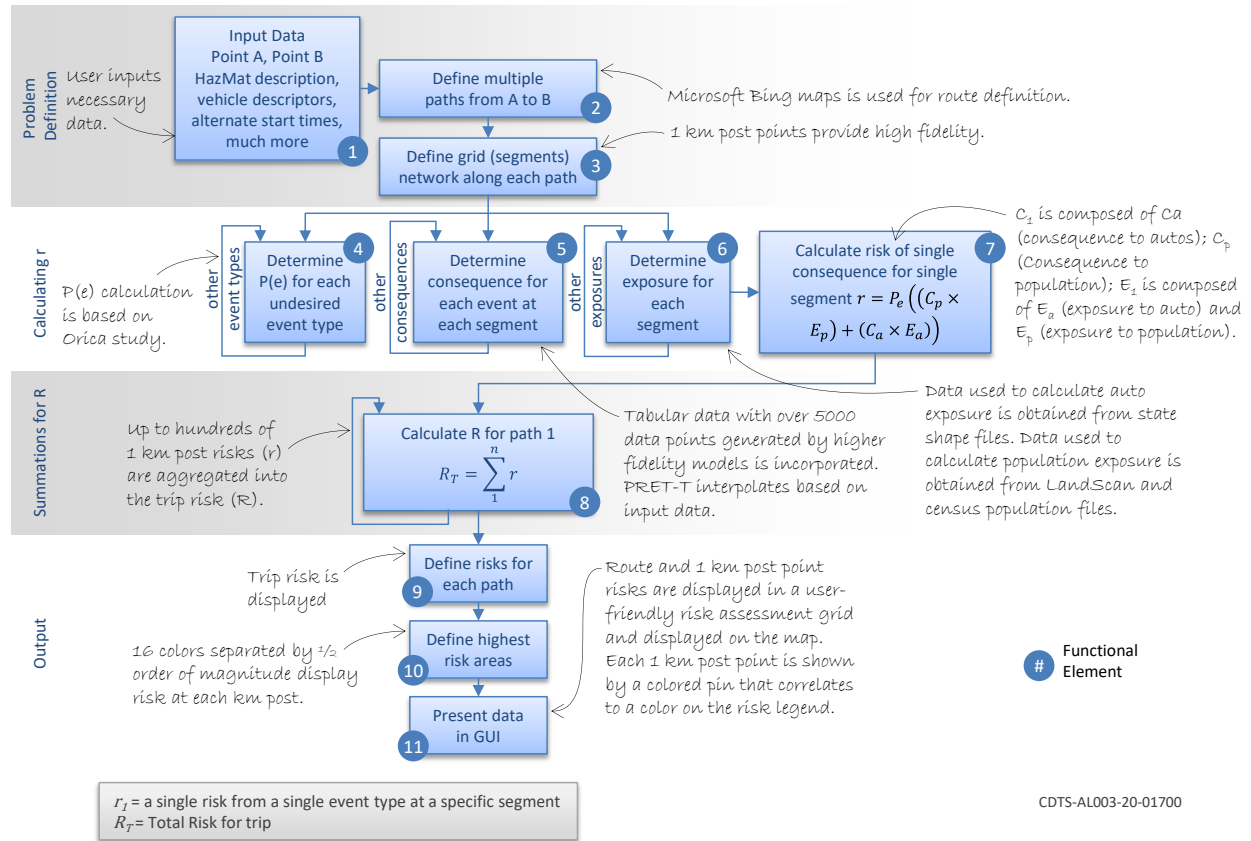
Figure 2: Transportation Risk Model Analysis Architecture as built.

6.0   Analysis Approach

From the research conducted, the analysis team defined the actual math algorithms to be used in PRET-T. This work was mostly accomplished during months 4-6 of the effort. The results of this work is documented in a separate, stand-alone report delivered with this report, entitled the PRET-T Technical Description Document (TDD). The key issues identified and addressed during this research are listed below:

1. What is the risk that occurs along a route from the origin to the destination? The first analytical step was to define the selected path (or multiple paths) and subdivide the path into multiple increments, which are designed to facilitate the calculation of incremental risks along the path. This is accomplished by defining a segment size for incremental assessments along the path. This size needed to be short enough that the risk would be constant across its length, but as long as practicable to keep run time down. Several differing segment lengths were considered. A standard distance of 1 km was chosen.

The approach in risk modeling is to computationally apply the basic risk equation of three elements, where risk = probability of event x consequence x exposure. For each segment, these three parameters are calculated based on algorithms developed by our science and research team. The P_e models are developed by either using historical data or an analytical approach. This led to a few more key questions:

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1. The consequence algorithms involve mainly the physical sciences, including many hazardous effects from many potential events to people and structures found along a given path. Consequence models exist that are high fidelity but slow running. Therefore, the question was how can we incorporate this higher fidelity, state-of-the-art data in a way that allows the software to provide accurate estimates without requiring significant runtime? The scientists on the analysis team developed a series of tables generated from these higher fidelity models with data at specific net explosive weights (NEWs). An interpolation algorithm allowed the use of these tables to determine the probability of fatality given an event ($P_{f|e}$).

2. The exposure term is determined from either existing census data or satellite imagery. The question was which data to use? Initially, we envisioned using census data. However, the state-of-the-art satellite imagery is rapidly advancing and can readily add fidelity as an overlay of census information. Therefore, we defined a method to use both sets of data to determine population during the day or night.

7.0 Software Development Approach

The following subsections describe the development process, design, and development of the PRET-T software.

7.1 SOFTWARE DEVELOPMENT PROCESS

Figure 3 shows the overview of the PRET-T software development process including the development of software design flow diagrams that were used to design and code the software.
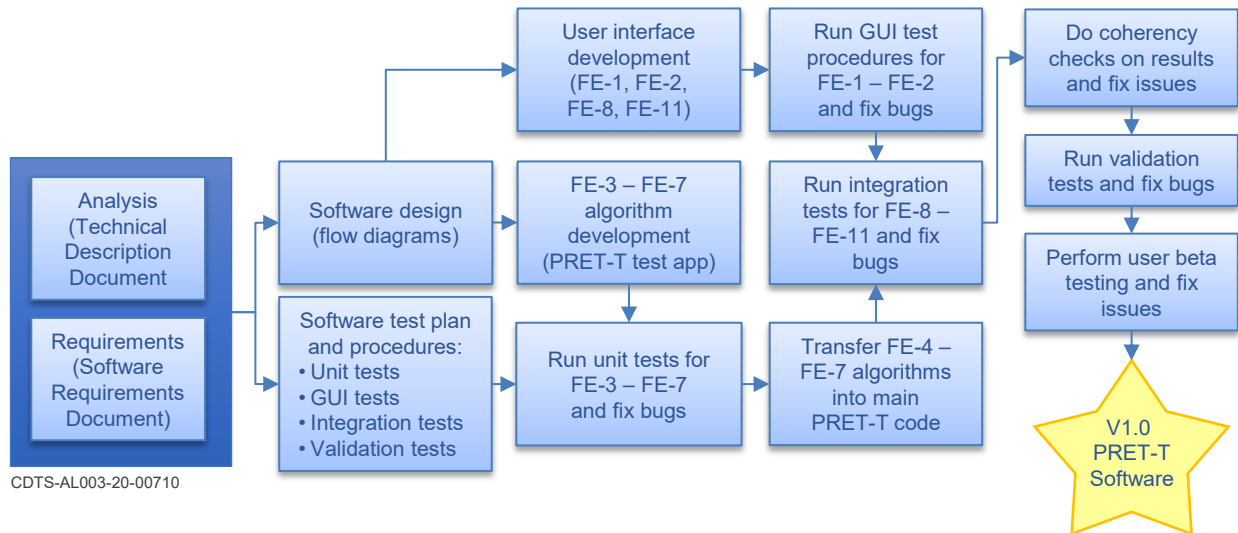
Figure 3. PRET-T Software Development Process

Early in the PRET-T development, two documents, the TDD and the Software Requirements Document (SRD) were produced. The TDD describes the algorithms and equations that were designed and coded into the software. Throughout PRET-T development, the TDD became a "living" document that was continually updated with new information as technical issues were identified and resolved. The TDD contained the technical requirements for the software; the SRD contained high-level, functional and user interface-related requirements for PRET-T.

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These two documents (in Appendices A and B) provide the basis of all PRET-T software development. From these documents, software design artifacts in the form of flow diagrams were developed, as well as a software test plan and software test procedures. The development of design and test artifacts were performed simultaneously and independent from one another. This allowed further "vetting" of the TDD. The goal of the TDD was to provide concise, unambiguous technical data for the software team to accurately code the software algorithms and to provide clear documentation of the work. The TDD was updated and improved as required during the process.

The software flow diagrams were used to code all of the FEs. The User Interface and the algorithm code development were independent and simultaneous activities. A PRET-T Test App was developed to initially code the software algorithms. Unit test procedures were developed to test the algorithms and identify issues to be corrected. Once the algorithms were tested and fully working, they were then incorporated into the main PRET-T software. Integration and validation testing, coherency checking by the analysis team, and user beta testing were performed before final delivery.

The TDD and all software flow diagrams underwent team peer reviews for accuracy and consistency.

7.2   SOFTWARE DESIGN

Using the TDD and SRD, the software team developed a series of flow diagrams. A high-level software architecture flow diagram was initially produced, as shown in Figure 4.

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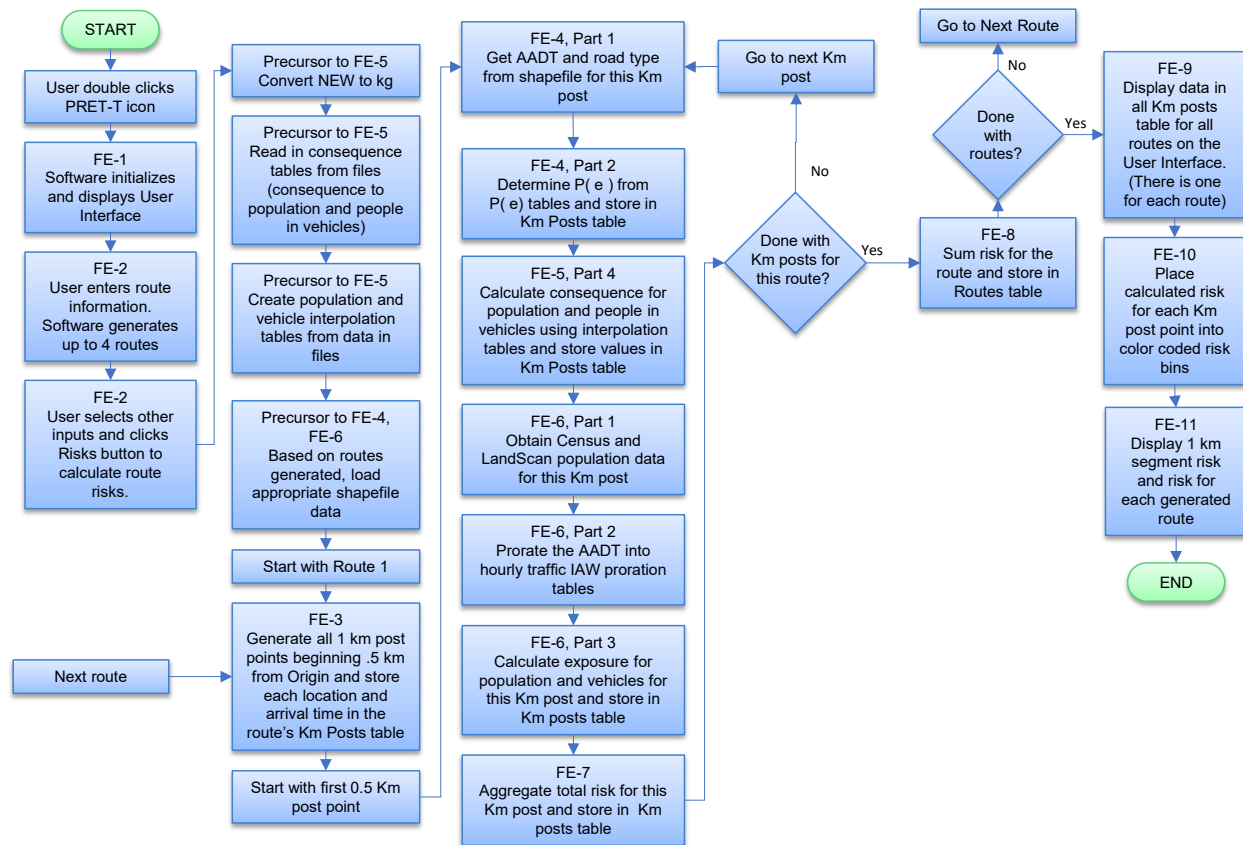
Figure 4: PRET-T High-Level Software Architecture Flow Diagram

Detailed design flow diagrams for each FE were then defined. Each of these software flow diagrams interprets the math algorithms defined in the TDD. These diagrams also specified the inputs and outputs for each FE, internal data structures, and the flow through the software. The following detailed design flow diagrams were produced:

- Main: More detailed than the high-level architecture flow diagram; it describes obtaining data from shapefiles and population data and also covered FE-1, FE-2, FE-8 – FE-11.
- FE-3: Algorithm to calculate locations of 1 km post points.
- FE-4: Determine Probability of Event.
- FE-5, Parts 1, 2, 3: Convert user-specified explosive quantity from lbs to kgs; load in appropriate population and vehicle consequence tables given the user-specified vehicle type and explosive type; calculate interpolated consequence values.
- FE-5, Part 4: Calculate consequence to population and autos.
- FE-6: Calculate exposure to population and vehicle.

7.3 SOFTWARE COMPONENTS DEVELOPMENT

The PRET-T code consists of two main software components: 1) the PRET-T Framework Component, and 2) the Technical Algorithm (TA) Component, which contains the underlying technical algorithms. They were developed independently. The TA Component was integrated into the main PRET-T code containing the Framework Component after unit testing was complete.

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The code was designed to be modular so that major functionality can be readily changed.

7.3.1 PRET-T Framework Component

The PRET-T Framework Component contains a layered architecture of sub-components, any of which can be updated independently. For example, Microsoft Bing Maps can be changed to a different mapping component. Similarly, algorithms in the TA Component can be updated. The PRET-T Framework Component consists of three sub-components: the PRET-T Graphical User Interface (GUI) sub-component, the Microsoft Bing Maps interaction sub-component, and the shapefiles sub-component.

7.3.1.1 PRET-T GUI Sub-Component

The PRET-T GUI presents several panels to the user: route definition, truck type, and explosive input fields, the maneuver point panel, the risk assessment grid, and the map itself. These are described in greater detail in the PRET-T user's manual. The PRET-T framework and most of the GUI were developed in the C# programming language using Microsoft Visual Studio 2019. The route definition panel was developed in Java to facilitate finer tuning of addresses that are displayed when entering source and destination locations. The other panels and inputs plus graphics on the map were developed using a software development third-party GUI toolset called Telerik controls.

7.3.1.2 Microsoft Bing Maps Interaction

Microsoft Bing Maps was selected as the third-party tool to query and obtain route information. The PRET-T framework code uses route starting and ending points, plus optional user-specified "waypoints," to build a query to the MS Bing Mapping Application Programming Interface (API) and obtain route information. The query was built to obtain up to three routes. Additionally, a query using specialized parameters was used to query MS Bing Truck API to obtain a "truck route."[6] The parameters included truck weight and dimension information based on the truck type the user entered. Therefore, an additional route for the truck was also produced that excludes certain features of a route where a truck carrying explosives cannot travel (e.g., tunnels and overpasses).

7.3.1.3 Shapefiles Sub-Component

Another component of the PRET-T Framework was loading and applying state shapefiles. Based on the routes selected, the software determines which state data to load. PRET-T Version 1.0 currently supports 19 states.[7] Each state's data originated from Federal Highway Administration information and is stored in separate files included in the PRET-T installation.

Shapefiles contain two attributes of interest to PRET-T: the Average Annual Daily Traffic (AADT) and road type. These are extracted from the shapefiles and provided to the TA

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[6] Two queries were needed because the Bing truck route query produces a single path and comparisons are needed.
[7] The conceptual design goal was to include 48 states. This resulted in a design trade where the number of states included in a given route sometimes slowed the run time because a single laptop processor was used for this prototype. At Milestone 4 during development, the PHMSA COTR agreed that the 19 selected states would adequately demonstrate the proof of concept. A proposed Version 2, operating in the cloud, would not have the same processing limit and implement the entire lower 48 states.

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component. The seven functional road types include interstate, principal arterial freeways, principal arterial other, minor arterial, major collector, minor collector, and local.

7.3.2 TA Component

The TA Component contains code for all the technical algorithms, equations, and internal tables for FE-4 through FE-8, as described in the TDD. It was developed in the C# programming language using Microsoft Visual Studio 2019 and was developed separately from the PRET-T framework code. It was initially coded into a simple desktop program called the PRET-T Test App. The purpose of the PRET-T Test App was to provide unit testing for individual FEs (FE 4 – 8).

After initial unit testing was complete, the TA component was integrated into the main PRET-T code so that integration and GUI testing (display of the results) could be tested.

7.3.3 Framework and Technical Algorithm Component Interface

The interface between the PRET-T Framework and the TA component consists of data that the framework gathers and populates before calling the TA component. The TA component calculates results and provides them back to the framework for display on the GUI. The data that is provided to and from the Framework and TA components is depicted in Figure 5.
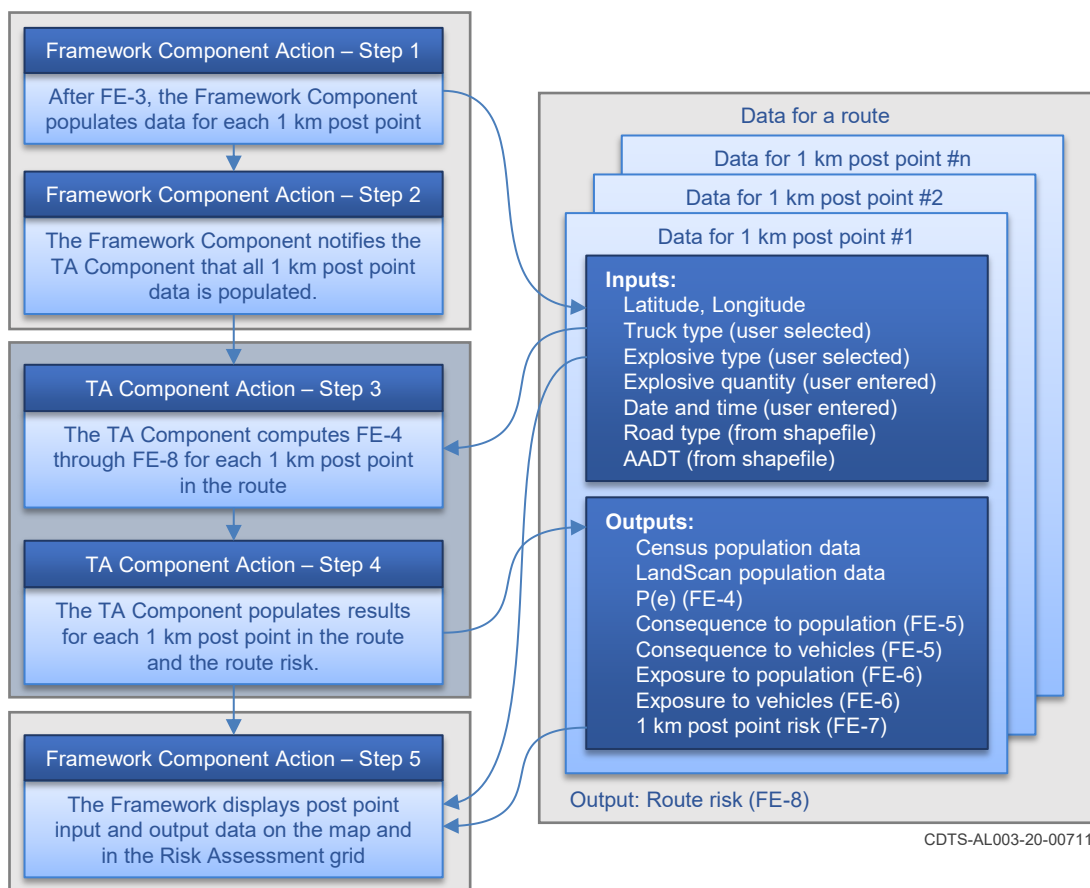

Figure 5: Interaction between the PRET-T Framework and TA component

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7.4   CONFIGURATION MANAGEMENT

7.4.1   Source Control

Phase 1 efforts had planned to use the Microsoft Azure DevOps for source control using Git[8] and configuration management.

Due to the COVID-19 pandemic, during which most of the team worked remotely, the developers could not use a common source code repository. Instead, they exchanged MS Visual Studio 2019 project solutions via Google Drive or a flash drive. Previous code versions were backed up, archived, and numbered such that past versions could be retrieved. This process was successful, although tedious and time consuming.

7.4.2   Versioning PRET-T Releases

For Version 1.0 development, there were two types of version releases – internal versions delivered to the team, and external versions provided to the customer. Each internal delivery was identified by a unique version number. An internal version became an external customer version when it was ready to be delivered and/or demonstrated to the customer. This is called "baselining" the software; therefore, each baseline of an internal version becomes the external customer version.

7.4.2.1   External Customer Version Numbering

Releases of external customer versions resulted in either a demo of the software to the customer or delivery of the software itself. These versions were formatted in the form of "x.y"

where $x = 0$ for versions before final delivery of PRET-T, and $x = 1$ for the final PRETT version, and $y =$ an incremented number that denotes major functionality releases.

Therefore, versions that were demonstrated/delivered throughout development that contained major functionality were numbered 0.1, 0.2, 0.3, and 0.4, leading up to the final version of Version 1.0.

7.4.2.2   Internal (APT only) Version Numbering

PRET-T internal version numbers were formatted as "x.y.z." This expands the customer numbering with an additional digit "z."

Each time a new internal PRET-T version was released to the team, either the major or minor number was incremented. A spreadsheet was updated for each PRET-T delivery with the changes/fixes that were included in the version.

When an internal PRET-T version was ready for delivery to the customer, the external version's major number ("y") was updated and stored.

Information for each PRET-T internal and external version is in Appendix F.

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[8] Git is a free, open-source distributed version control system for tracking changes in source code during software development.

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7.5   INTERNAL BUG REPORTING

An internal bug reporting process was developed as a communication method for the PRET-T team to track and manage bugs found during testing. It also provides a mechanism to capture requested enhancements to the software.

When a bug was found by the test team in either the PRET-T main code or in the PRET-T test app while unit testing, the tester entered the bug in an issue-tracking spreadsheet. The tester provided the following information: the date the issue was found, the software component where the bug occurred, a description of the issue, the version the issue was found in and the severity of the issue (crash, major functionality issue, minor cosmetic issue). An issue has a status of "Open" while the software developer investigated the issue. If the issue could be reproduced, the software developer fixed the problem and instructed the tester to retest using the next version of the software. When the issue was resolved, it was set to "Closed" in the spreadsheet.

The version information for each PRET-T internal and external delivery as found in Appendix F also described bug fixes and changes to each software version.

8.0   Test Plan

While unspecified in the contract, testing is an important aspect of development. Our verification and validation program consists of five internal elements, plus beta testing with the customer as described below.

8.1   PRET-T INTERNAL TESTING

Five types of internal testing were identified to be performed during PRET-T development: Unit testing, GUI and Workflow testing, Integration testing, Validation testing, and Regression testing. These are described in detail in the PRET-T Test Plan and Procedures Document. This document, included as Appendix G, also includes testing artifacts that describe when testing was done, by whom, and the test results.

8.1.1   Unit Testing

The unit tests focused on testing individual risk calculations for FE-3 through FE-7, as shown previously in Figure 2.

The algorithms and calculations as described in the TDD were coded independently in Excel. Test cases containing combinations of input parameters for FE-3 through FE-7 were developed and recorded in separate Excel spreadsheets. Expected results from the Excel code were recorded for each test case. As described previously, the PRET-T Test App was used in unit testing to calculate risk values for one route segment using the same parameters. The PRET-T Test App allowed the tester to input all of the parameters needed to calculate risk to one 1 km post point. The PRET-T Test App did not use external shapefiles or population files; the tester entered those parameters as part of unit test. Output of FE-4 through FE-7 was displayed on the user interface. Results from the PRET-T Test App were used to compare against the expected results. Each test case was denoted by a Pass/Fail status. Test results are shown in Appendix G. These show that all issues found during testing were fixed and that all tests passed.

8.1.2   GUI and Workflow Testing

A series of GUI tests were developed for testing FE-1 and FE-2. These included:

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- Product start-up tests – verified that PRET-T software started up and initialized correctly.
- Map and User Input tests – verified that all panels, input fields, and buttons operated as expected.
- Routes tests – verified that valid routes were generated and displayed.

8.1.3 Integration Testing

This series of tests was developed for testing FE-8 through FE-11. Once the risk calculation code was integrated into PRET-T, the risk calculations results were tested to ensure they displayed correctly on the GUI. This included examination of the display of the colored map pins at each 1 km post point and their associated risk colors and ensuring that all risk results and associated data displayed correctly in the risk assessment grid.

Another important aspect of integration testing was conducting coherency checks by the analysis team to examine the calculated results in the risk assessment grid. These coherency checks validated that the calculations produced by the software properly included all elements of the risk equation and produced results that were coherent from one evaluation point to the next.

8.1.4 Validation Testing

The purpose of validation testing was to verify that all the requirements in the PRET-T Software Requirements Document were met. Since most validation tests referred to a specific unit, GUI, or integration test, validation testing was accomplished incrementally throughout the testing phase. At Milestone 6, a PRET-T Test Plan was delivered showing validation that had been accomplished. The PRET-T Test Plan and Report in Appendix G contains all testing and validation results.

8.1.5 Regression testing

Regression testing was performed throughout PRET-T software development to verify that any changes made to the software did not break the functionality of any element previously developed. Regression testing was not complete until changes stemming from beta testing were incorporated and tested.

8.2 TEST CASES

During integration testing and the coherency checks that were conducted by the analysis team, test cases were developed to examine the output results under certain conditions.

The most used test case was called "Three Paths to Guntersville." This test case showed travel through both a highly populated area with high traffic densities and lightly populated and traveled (rural) areas. The starting location was specified as the address of APT Headquarters in Huntsville, AL, and the ending location at a harbor in Guntersville, AL. The truck type, explosive type, and quantity were sometimes varied to examine if the differences in the calculated results made sense; otherwise, the truck type was set to Van Truck, the explosive type to HD 5.1 and the quantity to 1,000 lbs. This test case was used to compare results between a previous run of PRET-T to a newer version containing algorithm changes, for example.

Other test cases focused on routes with even more variance in population/traffic densities, where the population and traffic densities were much higher than Huntsville and to even more rural areas. One of these test cases used the city of Atlanta, GA, as a starting location to Cherokee

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County, AL, as the ending location. The risk results were examined by the analysis team to see how they compared to the three paths to Guntersville results. These two cases were particularly beneficial to the development team because their familiarity with the roads allowed trouble-shooting reviews to quickly highlight code errors.

Lastly, a test case often used was one provided by the customer during the Milestone 4 briefing.[9] This included Poolesville, MD, as the starting location and Leesburg, VA, as the ending location. This provided a fairly short route that included a ferry crossing.

8.3   PRET-T BETA TESTING

At Milestone 5/6, APT delivered to two PHMSA customers a laptop loaded with PRET-T V0.4. The objective was for the customers to conduct beta testing on the software and provide feedback on its usability, any bugs found, and suggestions for future enhancement.

8.3.1   Beta Testing Results

The following feedback was received from the PHMSA beta testers with APT's response:

1. The tool was not always able to get more than one route that was useable for trucks.

Response: As PRET-T Version 1.0 is considered a proof of concept, the software was developed to obtain one truck route with alternate auto routes in order to illustrate comparison of risks among the produced routes. A consideration to offer only routes that a truck could travel on will be addressed in the future version of the software.

2. The software is slow in calculating risks, especially for longer routes.

Response: As PRET-T Version 1.0 is considered a proof of concept, it was not optimized for performance. The main requirement of the software is to prove that risks to population could be calculated along multiple routes and to compare risk answers. To accomplish this, it was developed as a desktop application as opposed to a more complicated web-based application or one that is "hosted in the cloud." Therefore, state shapefiles are stored locally on the computer's hard drive. Performance issues in the software have been noted and is a direct result of loading state shapefiles corresponding to the states the route(s) pass through from the hard drive and obtaining the needed information (AADT and road type) for each 1 km post point. Some of these shapefiles contain much more information than others, causing the process to calculate risks for routes passing through these states much more time-consuming. Once the software is hosted in the cloud, this will no longer be an issue because the shapefiles will no longer be stored locally on the computer.

3. The software generated an exception (i.e., it crashed) when calculating risks for long routes.

Response: This error occurred because the software ran out of memory when loading and processing the state shapefiles. The software has been fixed not to crash and to alert the user to try a shorter route. When the software is hosted in the cloud, this will no longer be an issue

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[9] Milestone descriptions are provided in Appendix A, Statement of Work.

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because the state shapefiles will not be located on the computer's local hard drive. The user should be able to generate longer routes without memory and performance issues.

In addition to the beta testing feedback, a few other proposed future improvements were noted in discussions with PHMSA.

1. The maneuver points grid, located on the bottom left of the software is not user-friendly. This grid was originally added as a "nice to have" functionality, and the information in it is not required to perform risk assessment. If it is an item that is desired in future versions of the software, it will be updated to be more user-friendly; otherwise, it will be removed.

2. The user must exit out of the software to run a different route/risks. The capability to modify routes during a single session was deemed to be complex and not a requirement for PRET-T V1.0. If the customer wishes this functionality in future versions, it will be considered for implementation.

9.0 Data Security Plan

This plan was previously delivered as part of Milestone 5/6 and is shown in Appendix E. In general, for this prototype model with limited distribution, the data security issues are relatively minor for four reasons:

1. The model does not communicate the resulting data beyond its own display screen.

2. The only external versions of the tool are on the laptop(s) delivered to the customer and it cannot be transferred.

3. The resulting data is not retained when the analysis is complete or the computer is turned off.

4. The results that are calculated can be transferred to a file (for example to Excel) and that file security is the responsibility of the user.

Data security will become a larger issue in the future when, for example, a later version is hosted in the cloud. Individual user logins will be required to operate the software. At that time, the data security plan and methodology will need to be revisited based on the design of the model.

10.0 Consensus-Building Activities

An important aspect of this project is to build interest and consensus on the tool through briefings and presentations to industry. Participation in tool development by members of the transportation industry will ease technology transfer from PHMSA to industry once the tool has matured to a readily useable state. Under a modification to the original contract, APT presented briefings to the Transportation Research Board (TRB) (Jan. 14, 2020) and Institute of Makers of Explosives (IME) Spring Meeting in March 2020. These presentations are summarized below.

TRB presentation. On January 14, 2020, APT gave a high-level briefing to the Risk Management Subcommittee of the TRB Committee on the Transportation of Hazardous Materials. The subcommittee consisted of approximately 20 individuals from industry, industry associations, government (Department of Energy, U.S. Coast Guard, DOT, U.S. Army Corps of Engineers), and academia. The briefing outlined the scope of the project, how the tool works,

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and its benefits to government and industry. It also explained that the tool is designed for risk management and not risk governance.

IME presentation. During a telecon of the IME Spring Meeting on March 16, 2020, APT presented an hour-long briefing of the tool to IME, which consisted of approximately 20 individuals from both large and small makers of explosives, including Orica, Dyno Nobel, Nelson Brothers, Austin Powder Co., Detotec, etc., as well as several IME staffers (President Deb Satkowiak, Susan Flanagan, and Josh Hoffman). The briefing outlined the scope of the project, how the tool works, and its benefits to government and industry. It also emphasized that the tool is designed for risk management and not risk governance. During the following Q&A session, several questions were asked regarding whether PHMSA intended to use the tool for regulatory purposes. Later, a majority of the major explosives manufacturers voiced strong support for the development of the tool.

IMESAFR Science Panel. At a July 2020 meeting of the Science Panel supporting development of the IMESAFR tool, the APT demonstrated PRET-T tool Version 0.4. This panel, with approximately 15 members, is co-chaired by ATF and industry, with membership comprising regulatory and commercial explosives industry representatives from the U.S., Canada, and Australia. The model was received with interest; questions were asked and answered. The most common question was when can they use it.

Gatherings of Professional Safety organizations. APT will demonstrate the V1.0 model at several (at least four) future gatherings of safety professionals including: a future monthly meeting of the Huntsville chapter of the International System Safety Society (ISSS), the next meeting of the risk assessment group of the TRB, and the annual convention of the ISSS, and the bi-annual meeting of the Department of Defense Explosives Safety Board (DDESB). The schedule for all of these gatherings has been affected by the Corona virus. However, the presentations will be made when the meetings eventually convene.

11.0 Conclusions

1. The primary purpose of this contract was to demonstrate a proof of concept for an easy-to-use tool to manage risks of transporting explosives by truck. The resulting tool easily surpasses that goal of proof of concept. This tool, without further change, clearly demonstrates how the greater use of objective risk data, generated by tools of this nature, reduces day-to-day risks faced by industry and overseen by PHMSA.

2. This work is far from complete. This tool is an infant. The technology can be expanded in multiple directions. Its efficiency can be improved by using cloud-based techniques. Its underlying science can be improved with yet more sophisticated algorithms. Its techniques can be expanded to other transportation modes and other hazardous substances.

3. This effort demonstrates that both government and industry can move forward into an era where the risk that has previously been managed mainly by subjective opinions can now be managed with the aid of objective, science-based data.

4. As the nation's risk manager for hazardous material transport, PHMSA now has the opportunity to continue to improve this technology for broader use by government and

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industry, as described in the current contract language.[10] Multiple continuation options are available that can lead this technology into mainstream use.

5. When a technology reaches a maturity for broader use by government and industry, it should be funded for <u>operational</u> use, rather than research and development under a BAA.

6. To develop the best use by government, a collaborative effort is needed between developer and user to refine the best application of the newly demonstrated technology. BAAs under a fixed-price contract do not facilitate needed collaboration.

7. Software development using agile software processes is without a doubt the preferred method for developments of this magnitude. These methods, requiring frequent team interaction to quickly resolve issues as they arise, are not ideally suited for remote work, as required during the corona virus era. For this reason, the development time required consumed approximately 13 months – slightly more than the scheduled 10 months, but well in advance of the 24-month contracting period. This added calendar time and resulting expense has been considered by APT management as well as the fixed-price terms. While there were no additional requests for funding, this lesson learned should lead to greater flexibility in future contracts.

8. It can be demonstrated with academically accepted statistical methods that the use of this technology will save lives in the long term. This knowledge should be used to define the path ahead for the technology.

12.0 Recommendations

1. Our primary recommendation is that PHMSA, as the nation's risk manager for HM transportation, continue to lead the development of this technology toward its ultimate utility. This development is a significant step. However, on its own merit, it is not yet mature enough to survive long-term without stewardship. That stewardship may include expansion into other modes and selection of HMs as envisioned in the terms of this contract. However, more importantly, responsible stewardship includes consideration of how tools like PRET-T can be used to increase safety in a regulatory environment. As an example, in the EU, science-based risk analyses are required for trucks carrying explosives to cross national borders. Thus, by marrying an easy-to-use tool with a requirement to take a serious look at the risks provides a level of protection unavailable heretofore.

2. PHMSA should organize and fund a collaborative effort to develop, plan, and execute a path ahead for using this technology. To organize this, we recommend that APT host a 1-2 day funded workshop with PHMSA and invited industry leaders to define alternative paths forward for transfer of this technology. In addition, APT could be funded to make the tool faster running and more suitable for near-term industry transfer.

3. Internal use by the U.S. Government should focus on the benefits of risk management wherein relative risks are compared, allowing industry to apply the lowest-risk solutions.

4. Use by the U.S. Government should not focus on setting a quantitative risk standard. This prescriptive approach is fraught with many shortcomings and if attempted will impede

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[10] From the contract SOW (C.2): "This model is intended to be the first phase of a larger model that will assess risk of any hazmat by any mode. Ultimately, this tool shall enable a more rigorous assessment of risks in hazmat transportation, more clearly defining hazards, and more quickly identifying mitigations at a lower cost."

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further use of this emerging technology. Instead, we recommend that the onus be placed on industry to conduct science-based analyses of the risk that they own. Tools such as this facilitate, but don't regulate. This approach will, in the long run, save lives and reduce injuries, a primary mission of PHMSA.

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Appendix A – Statement of Work

C.1 Background

Currently, PHMSA does not have an endorsed transportation probabilistic risk assessment (PRA) model. A comprehensive transportation PRA model would enhance PHMSA's ability to provide protection for the safe transportation of energy and other hazardous materials essential to our daily lives. A PRA tool in digital format would be useful to PHMSA and industry as it would allow them to consider all risks in transporting hazmat in different modes via different routes. Before the PRA can become a software tool, research is primarily needed in three areas associated with the specific risk equation used in the risk model (risk = probability of event x consequence x exposure). Research will be conducted into each of these three areas to refine the contributing factors and derive a lower-level risk formula in greater detail to be used in the software tool. This tool will be used to assess the risk to surrounding populations from hazmat transportation. The software will be designed as a stand-alone tool with open architecture, which will allow it to be readily expanded later to include different transportation modes and multiple hazardous materials. Phase 1 of software development will be a risk model for transporting explosives by truck. This scope is for Phase 1, consisting of Phase 1A and 1B. Phase 1A will develop and demonstrate the initial functionality of each module. Phase 1B will consist of coding and testing the software.

C.2 Objective

This project will develop a transportation risk model for transporting explosives by truck. This model is intended to be the first phase of a larger model that will assess risk of any hazmat by any mode. Ultimately, this tool shall enable a more rigorous assessment of risks in hazmat transportation, more clearly defining hazards, and more quickly identifying mitigations at a lower cost. Risk management applies a logical and well-documented process that can be simplified into four essential elements: 1) Identify risks, 2) Assess the risks, 3) Reduce risks, and 4) Accept residual risks. The proposed PRA tool will become a primary source of assessment. The tool will ultimately be used to identify and reduce risk to people, property, and the environment. In Phase 1, the focus of risk will be limited to people.

The general objectives of this project are to:

1. Conduct research into the contributors of risk for transporting explosives by truck.

2. Develop the tool using the contractor's software processes and procedures

3. Deliver full documentation in the form of a user's manual and a software algorithm and technical description document

C.3 Work Scope/Tasks

A general outline of the tasks involves:

1. Exploration of risk contributors, data gathering

2. Architecture definition

3. Functional Elements (FE) design specification

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4. FE development

5. Data security plan development

6. Module verification testing

7. Module demonstration with PHMSA

8. Complete software requirements document for end to end model

The major tasks and deliverables are outlined below.

Task 1: Hold a kick-off meeting to review project expectations

During task 1 the contractor shall prepare an agenda for a kick-off meeting with PHMSA representatives (to include the COR and technical POC). The contractor shall prepare a detailed list of all planned tasks, schedules, milestones and deliverables to be conducted during the project. The meeting shall be held within one month of contract award.

Deliverables: Meeting, project schedule

Task 2: Conduct research into the contributors of risk for transporting explosives by truck, define the software architecture and FE design specifications

During task 2 the contractor shall define the data sources to be used by the software, how they shall be incorporated, define the risk calculations/models to be used for software development and acquire the data needed for the software. Additionally, the contractor shall explain in depth the software architecture and the FE design requirements. A report outlining the software architecture, data sources and integration methods for this tool shall be delivered to the COR no later than 10 months after contract award.

Deliverable: Data and software requirements report

Task 3: Develop one FE and demonstrate to COR

During task 3 the contractor shall develop the first FE and give a demonstration of it to the COR no later than 12 months after contract award.

Deliverable: First FE demonstration (contractor site or PHMSA headquarters or virtually if possible)

Task 4: Develop the next four FEs and demonstrate to COR

During task 4, the contractor shall develop the next four FEs and debug the first FE based on comments given by COR in the first FE demonstration and incorporate those comments into the development of the next four FEs. At the end of task 4, the contractor shall demonstrate all five FEs developed to the COR no later than 14 months after contract award.

Deliverable: Second FE demonstration (contractor site or PHMSA headquarters or virtually if possible)

Task 5: Develop the next six FEs and demonstrate to COR

During task 5, the contractor shall develop the next six FEs and debug the last five FEs developed based on comments given by COR on the previous FE demonstration and incorporate them into the development of the next six FEs. At the end of task 5, the contractor

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shall demonstrate all 11 FEs developed to the COR no later than 16 months after contract award.

Deliverable: Third FE demonstration (contractor site or PHMSA headquarters or virtually if possible)

Task 6: Develop a data security plan and conduct internal validation

During task 6, the contractor shall outline a data security plan in a formal report. The contractor shall also conduct internal validation on the software tool. Validation will consist of testing for valid results and sensitivity testing, module by module and system-wide. At the end of task 6, the contractor shall deliver a report on the security plan and the results of the internal validation to the COR no later than 18 months after contract award.

Deliverable: Data security plan and internal validation report

Task 7: Integrate all FEs into the software, provide PHMSA with a beta version of the software and a demonstration

During task 7, the contractor shall integrate all the FEs into the software. At the end of task 7, the contractor shall deliver a beta version of the software to the COR and provide a demonstration no later than 22 months after contract award. The COR will provide input to the contractor on any issues.

Deliverable: Beta software demonstration

Task 8: Deliver the final software and its documentation

During task 8, the contractor shall make the recommended changes provided by the COR in the previous task. At the end of task 8, the contractor shall deliver the software and its documentation (user's manual, technical description document) to the COR no later than 24 months after contract award. Delivery of the final software platform can take place in form of a mailed-in CD or file transfer of the program.

Deliverables: Software and documentation

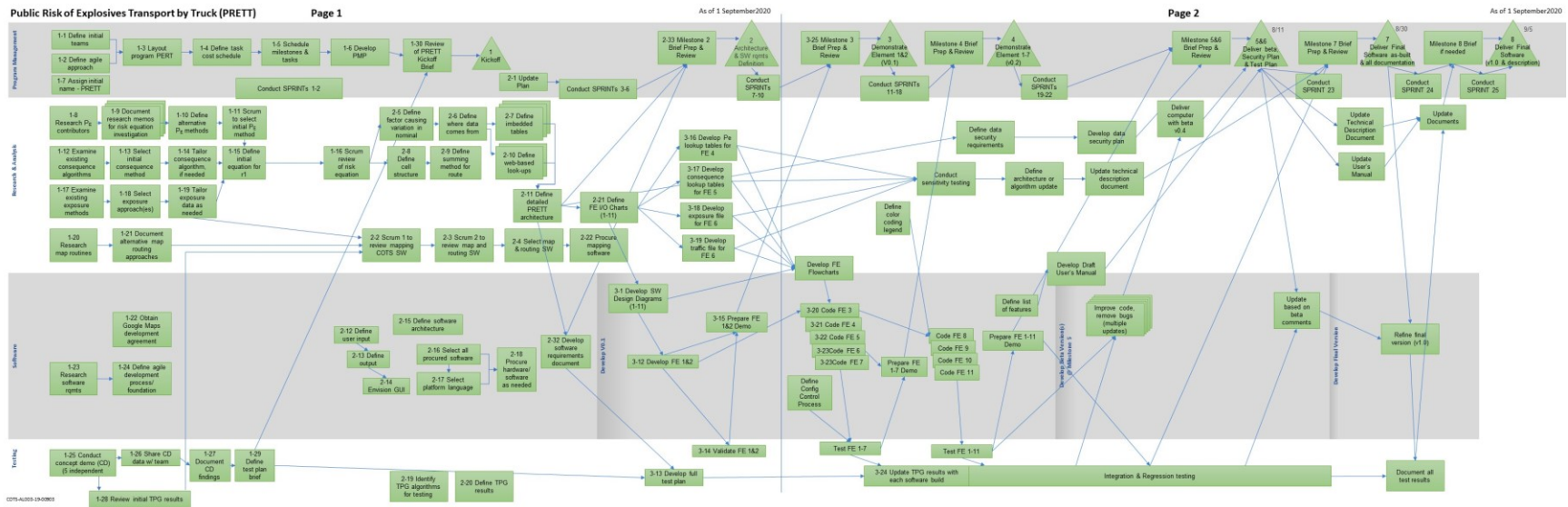## C.4 Major Project Milestones & Deliverables

A. Software documentation: The final software documentation (user's manual) must be 508-compliant to meet the ADA requirements for external publication.

B. Monthly progress reports. The contractor will provide the COR monthly progress reports in the form of an email or Microsoft Word document. Progress reports can be anywhere from half a page to a page (or longer) in length.

Major Project Milestones & Deliverables	Deliverables Timeline
1) Kick off meeting & Project schedule	Within 1 month from the effective date of the award
2) Data and software requirements report	Within 10 months from the effective date of the award
3) 1st FE demonstration	Within 12 months from the effective date of the award

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4) 2nd FE demonstration	Within 14 months from the effective date of the award
5) 3rd FE demonstration	Within 16 months from the effective date of the award
6) Data security plan report & Internal validation report	Within 18 months from the effective date of the award
7) Beta software demonstration	Within 22 months from the effective date of the award
8) Software and documentation	Within 24 months from the effective date of the award

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Appendix B – PERT Chart

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Appendix C – Software Requirements Document

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POPULATION RISK FOR EXPLOSIVES TRANSPORT BY TRUCK (PRETT)

Software Requirements & Architecture Document
Version 1.0

Prepared for:
Department of Transportation Pipeline and
Hazardous Materials Safety
Administration (DOT PHMSA)

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October 2019

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ACRONYMS

API	Application Programming Interface
APT	A-P-T Research, Inc.
CONUS	Continental United States
COTS	Commercial-off-the-shelf
DOT	U.S. Department of Transportation
FE	Functional Element
FHA	Federal Highway Administration
GIS	Geographic Information System
GPS	Global Positioning System
GUI	Graphical User Interface
HM	Hazardous Material
OHMS	Office of Hazardous Materials Safety
OS	Operating System
PHMSA	Pipeline and Hazardous Materials Safety Administration
PRA	Probabilistic Risk Assessment
PRETT	Population Risk for Explosives Transport by Truck
QD	Quantity-Distance
TBD	To Be Determined
TRM	Transportation Risk Model

1.0 Introduction

This document was developed by A-P-T Research, Inc., under Contract 693JK31900000 ("Comprehensive Transportation Risk Model Analysis") to the U.S. Department of Transportation (DOT) Pipeline and Hazardous Materials Safety Administration (PHMSA). The contract is for the first phase of a broader goal to be able to assess the numerical risk of transporting a full set of hazardous materials using multiple transportation modes (i.e., truck, rail, air, water, pipeline, etc.). Phase 1 is for transporting explosives by truck between any two points within the contiguous United States (CONUS). Phase 1 serves as a proof of principle demonstration and provides multiple artifacts that will be useful in developing the broader goal. These include research findings, mathematical methods, software development and test methods, platform selection, algorithm validation, language selection and more, as would be expected in the first phase of a multiphase development. Shown in Fig. 1 is the developer's vision of Phase 1 relative to future phases.

	Truck	Rail	Water	Air	Pipeline
Explosives	Phase 1	←	Phase 2	→	
Flammable Liquids	←		Phase 3		→
Hazardous Airborne Chemicals	←		Phase 4		→

Figure 1: Future Phases of Project 45

During Phase 1, eight milestones are scheduled for the development of the Population Risk for Explosives Transport by Truck (PRETT) prototype, as shown in Table 1. The contract includes eight tasks and eight milestone payments. This document is in partial completion of the requirements for task 2.

Table 1. Phase 1 PRETT Milestones

Milestone	Deliverable Description
Task 1: Kick-off meeting	Meeting, project schedule
Task 2: Conduct research into contributors of risk for transporting explosives by truck, define software architecture and functional element (FE) design specifications	Data and software requirements report
Task 3: Develop one FE and demonstrate to COR	First FE demo
Task 4: Develop the next four FEs and demonstrate to COR	Second FE demo
Task 5: Develop the next six FEs and demonstrate to COR	Third FE demo

Milestone	Deliverable Description
Task 6: Develop a data security plan and conduct internal validation	Data security plan and internal validation report
Task 7: Integrate all FEs into the software, provide PHMSA with a beta version of software and a demonstration	Beta software demo
Task 8: Deliver final software and its documentation	Software and demo

2.0 PRETT Tool Purpose

The principle purpose of Phase 1 of any multiphase program is to establish a solid foundation for the completed program. The

> *"Well begun is half done."*
> *-Aristotle*

PRETT tool will accomplish this with many artifacts that serve as building blocks. In addition, this tool will have stand-alone value by meeting designed purposes. It could be widely used by government and industry as an analytical tool in a risk-based management program. Alternatively, a specific and more basic use would be for the dispatcher of an explosives trucking company to select the routing and timing for an upcoming explosives shipment.

3.0 Objective of this Document

This Software Requirements Document acts as the foundation for the PRETT software. This document meets the requirements stated in Contract 693JK31900000 under Milestone 2 to deliver to PHMSA a written set of software architecture and design requirements. It will help serve as an artifact of communication among all the stakeholders, including PHMSA and APT. It will also define the functionality implemented for the first release of the software, and identify desired functionality for subsequent releases of this software.

4.0 PRETT Scope

The first delivery of PRETT will be a proof-of-concept prototype demonstration for transporting explosives by truck. PRETT development for this first delivery will lay the foundation for future functionality; for example, transporting explosives by rail, air, or water. The functionality of PRETT will be performed by the Functional Elements (FEs) as described in Section 5.2. Development of the functional elements will facilitate integration of new modules into the software. In future phases, functional elements can be easily modified, upgraded, and replaced by newer algorithms and/or functionality.

Even though Version 1.0 is a prototype, software development processes and procedures will lay the foundation for future work of enhancing and transitioning PRETT to a commercial product. The processes being used follow an Agile (Scrum) process, development and documentation of software design, technical algorithms, and other technical data. Development of a software test plan and procedures will also be performed and implemented during the PRETT development. The initial software test plan is scheduled for delivery at Milestone 3.

Version 1.0 features are described in Section 7.0, Technical Requirements.

5.0 Software Architecture Description

PRETT has an analysis architecture (described below) that is imbedded into the software architecture described thereafter. The functional elements of the PRETT tool are shown in the figure in Section 5.2.

5.1 TERMS AND DEFINITIONS

The following terms and definitions are presented below.

C_a – Consequence to people in automobiles expressed as a probability of fatality.

C_p – Consequence to people in the population expressed as a probability of fatality.

E_a – Exposure of people in automobiles expressed as an expected value.

E_p – Exposure of people in the population expressed as an expected value.

Evaluation point – The midpoint of a segment.

Path – One of the multiple alternative selected courses of travel from the starting point to the destination.

P_e – The probability of a violent chemical reaction (explosive event).

R_1 – The probability of fatality to a single segment.

R_T – The probability of fatality if this route is taken.

Section – A portion of the path where the road type is the same; could be made up of multiple segments.

Segment – A 1 km subset of the path.

5.2 PRETT FUNCTIONAL ELEMENTS

The high level PRETT analysis architecture shown in Figure 2 was defined in the APT proposal. Further research into this architecture confirmed that the architecture (at a high level) was appropriate for the development, and needed only to be refined with greater detail.
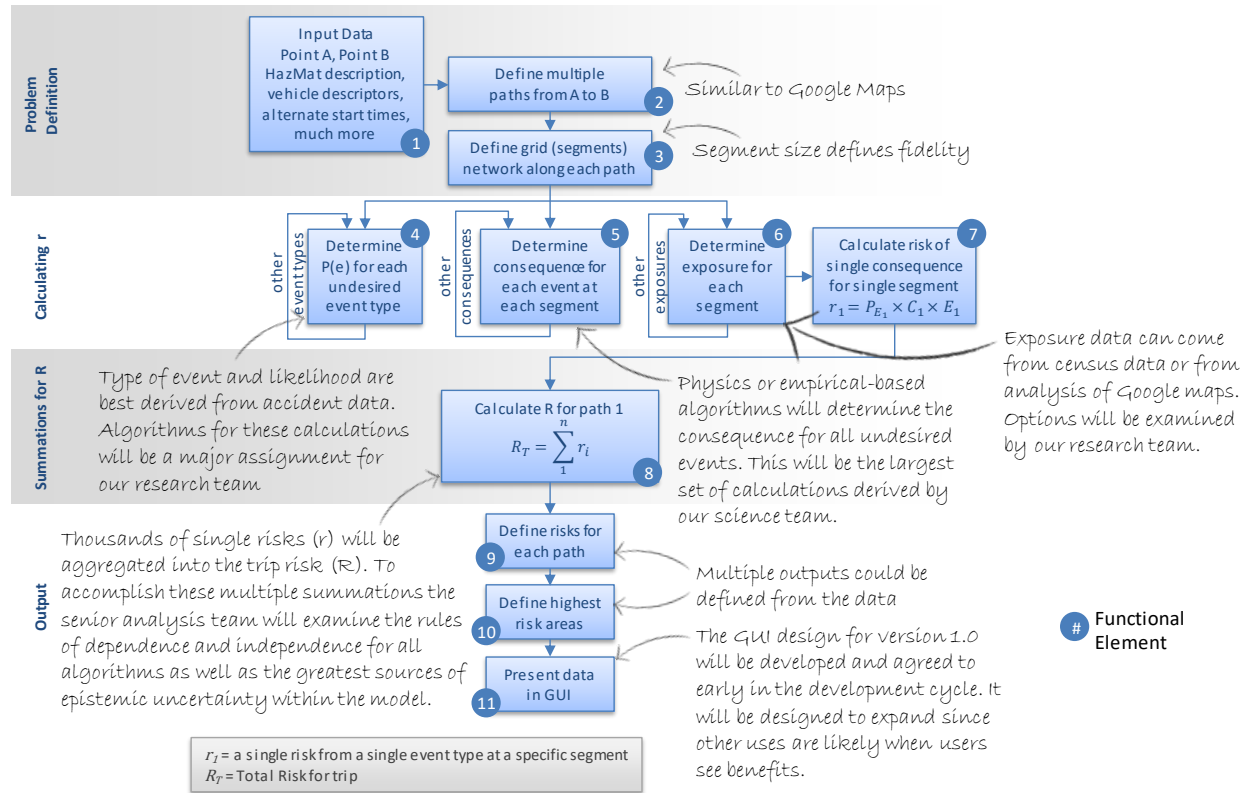
Figure 2: PRETT Analysis Architecture

Each of the 11 functional elements is further defined by an architecture flow diagram used by the PRETT analysis team. These flow diagrams define three parts:

1. Input: data needed to perform the function

2. How: the logic or methodology used to perform the function

3. Output: a definition of the resulting parameter and where it is sent

The following subsections describe each functional element.

5.2.1 FE1 - Launch software and enter inputs
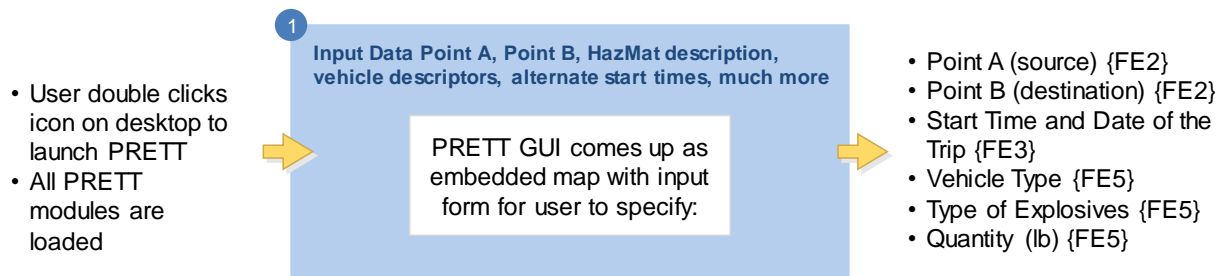
FE1 launches the PRETT software, which includes the display of an initial map and input form for the user to enter required information for the software. The output of FE1 is valid user inputs.

5.2.2   FE2 - Define multiple paths from A to B
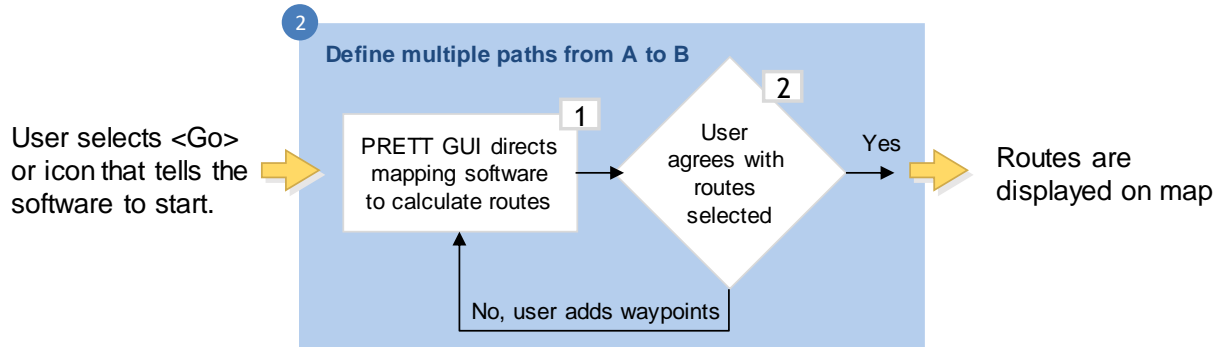
When the user indicates that the software should start calculating risk by clicking a "Go" button or similar icon, the user's inputs are stored internally in the software for use in subsequent FEs. FE2 then uses the input point A and point B to calculate paths from A to B. The selected paths are displayed on the map.

5.2.3   FE3 - Define segments along each path
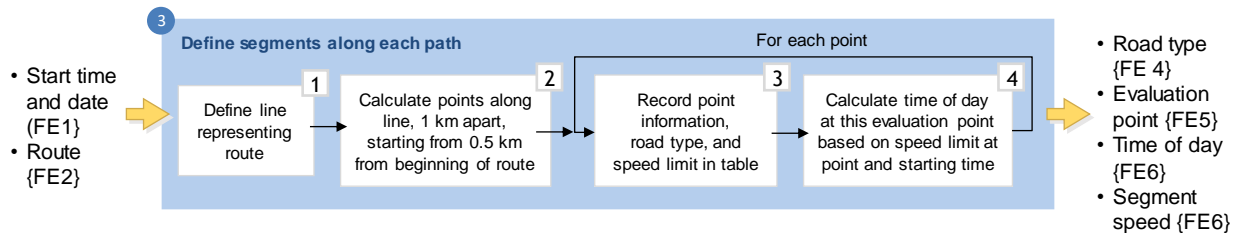
FE3 divides each path into 1 km segments and determines its evaluation point. Information stored for each segment includes the evaluation point information, road type, and speed limit. Using the time of day user input, the software calculates whether the segment is traveled during the day or night. This information is also stored internally.

5.2.4   FE4 - Determine P_e for each undesired event type
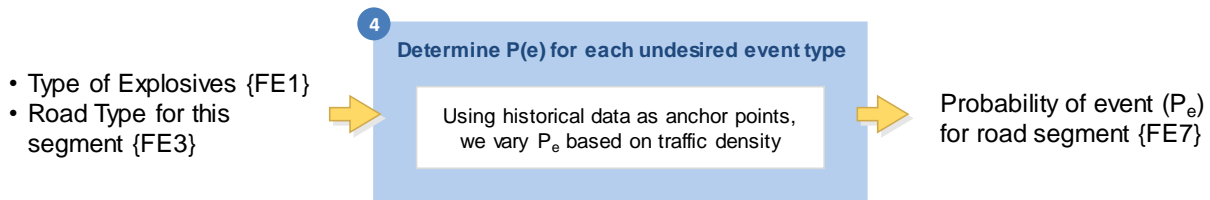
The software then uses the type of explosives entered by the user and road type for this segment to determine the P_e for this segment. This value is stored internally for the segment.

5.2.5 FE5 - Determine consequence for each event at each segment
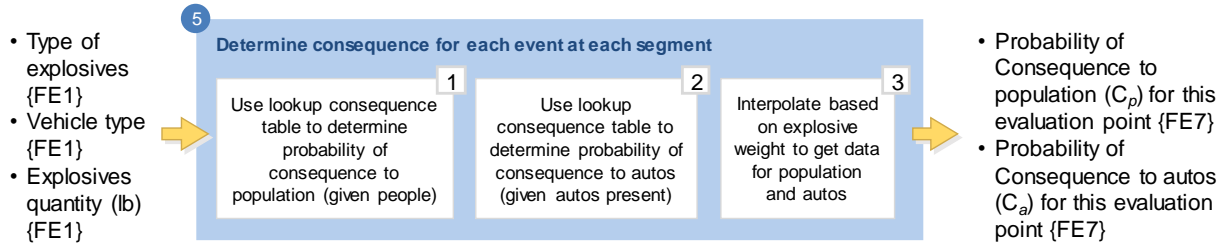
FE5 determines the consequence for each event using the user-entered explosives type, quantity, and truck type. The consequence for both population and autos is determined and stored internally for this segment.

5.2.6 FE6 - Determine exposure for each segment
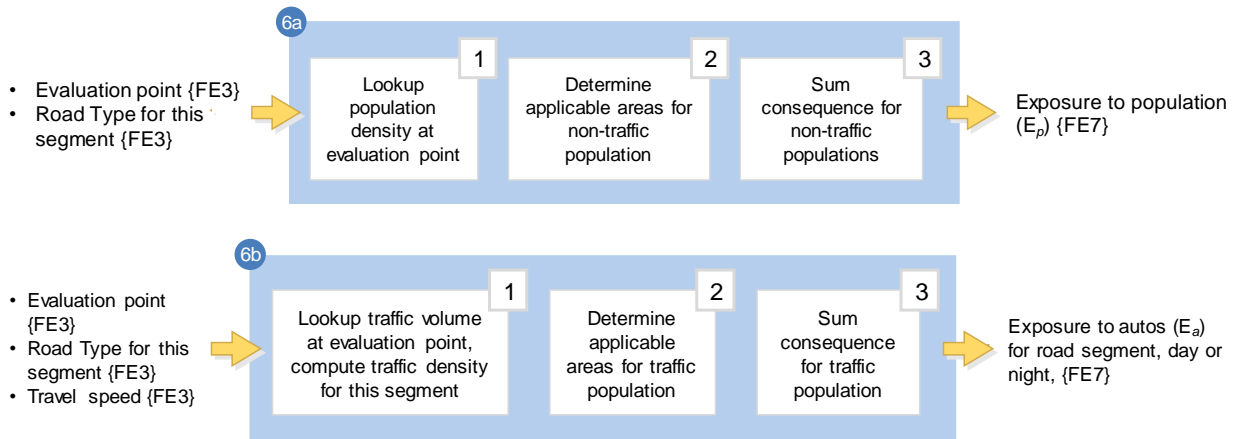
FE6 determines the exposure for each segment using the internally stored evaluation point and road type for the segment. The exposure for both population and autos is determined and stored internally for the segment.

5.2.7 FE7 - Calculate risk of single consequence for single segment

- Probability of Event (P_e) for road segment {FE4}
- Probability of Consequence to population (C_p) for road segment {FE5}
- Probability of Consequence to autos (C_a) for road segment {FE5}
- Exposure to population (E_p) for road segment {FE6}
- Exposure to autos (E_a) for road segment {FE6}

7

Calculate risk of single consequence for single segment

Repeat for all segments (1-n)

1

Calculate segment risk:

$$r = P_e\left((C_p \times E_p) + (C_a \times E_a)\right)$$

Store segment risk in table

Segment risk, r {FE8}

At FE7, all necessary variables have been obtained, and the risk to the segment is calculated. The segment risk is stored internally for this segment. This equation is derived from the basic risk equation in FE7 of Figure 2.

5.2.8 FE8 - Calculate R for the path

8

Calculate R for path 1

1

Calculate Path risk:

$$R_T = \sum_1^n r$$

Segment risk, r for each segment in a path. {FE7}

- Store $r_1 \rightarrow r_n$ for path 1
- Store R for path 1
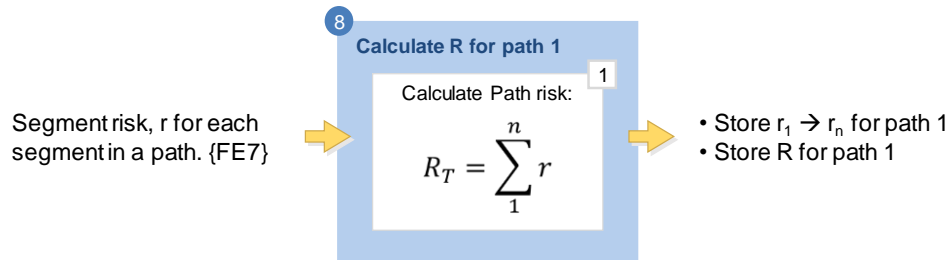
Once all the segment risks have been calculated for the path, FE8 sums them into a total risk for the path, which is stored internally.

5.2.9 FE9 - Define risks for each path

9

Define risks for each path

Repeat step 8 for each path

Segment risk, r for each segment in each route.

- Store $r_1 \rightarrow r_n$ for alternate paths
- Store R for alternate paths
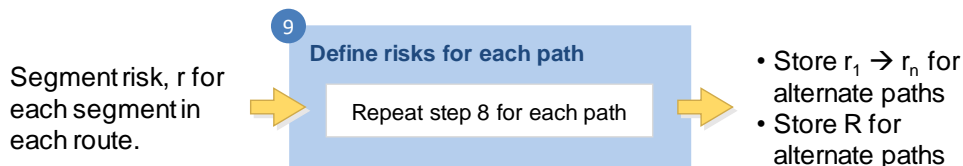
FE9 calculates risk for the remaining paths; each path risk is stored internally.

5.2.10 FE10 - Define highest risk areas
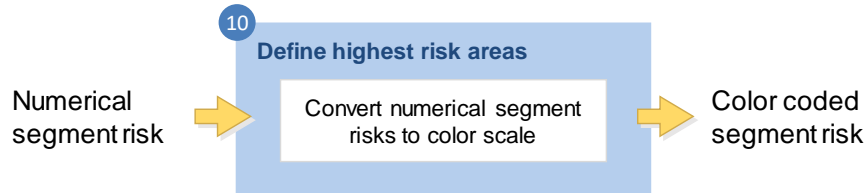
For each segment in each path, FE10 identifies a color code that is applied to the segment according to its risk. Color codes will be defined later in development.

5.2.11 FE11 - Present data in GUI
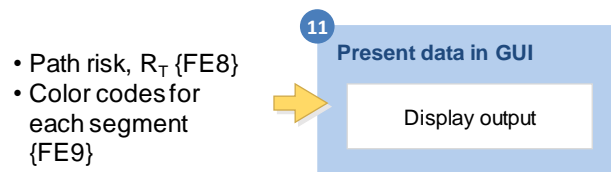
The color codes for each segment are displayed on the PRETT Graphical User Interface (GUI), along with the identification of the path with the highest risk.

5.3   PRETT SOFTWARE ARCHITECTURE ELEMENTS

Software development will be accomplished modularly, where many of the functional elements are developed and integrated independently. The PRETT software will consist of three major architecture elements: the GUI, the underlying PRETT engine, and PRETT science toolkit. The interfaces and hierarchy are shown in Figure 3.

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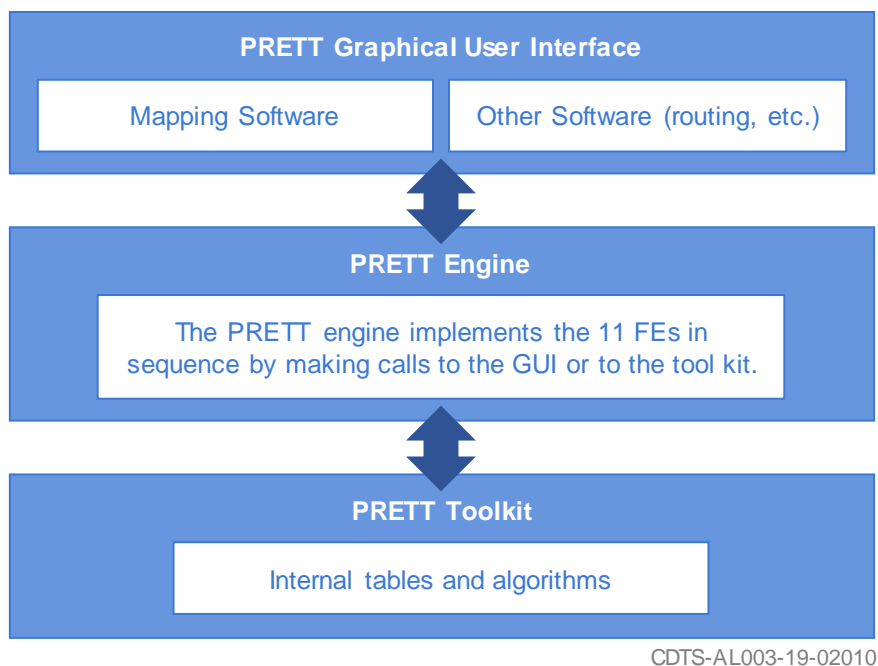
Figure 3: PRETT Software Architecture

5.3.1 PRETT Graphical User Interface (GUI) Module

The PRETT GUI module will consist of an embedded map, a custom input form, and output display. It will interface to commercial-off-the-shelf (COTS) mapping software, COTS routing software (if separate from the mapping software – this is currently TBD), and possibly others. The PRETT GUI module will also interface to the PRETT engine to calculate data and receive data to display on the map.

FEs 1, 2, and 11 will be performed by the engine making calls to the PRETT GUI module.

5.3.2 PRETT Engine Module

The PRETT engine module is the layer of software between the PRETT GUI and the PRETT toolkit. The PRETT GUI will make calls to: 1) the PRETT engine to store input parameters, 2) retrieve data to display on the map, and 3) perform higher-level calculations. The PRETT engine in turn will make calls to the PRETT toolkit to perform lower-level calculations and store internal results returned by the PRETT toolkit. The PRETT engine will be modularized so that the FEs can be updated and replaced easily without causing changes to other parts of the PRETT Engine.

FEs 3, 8, 9, and 10 will be performed within the PRETT engine module.

5.3.3 PRETT Toolkit

The PRETT toolkit is where all the science calculations are performed and most of the internal lookup tables reside. The PRETT engine module will make calls to it to calculate certain

parameters for the risk equations. The PRETT toolkit will be modularized so that FEs can be updated and replaced easily without causing changes to other parts of the PRETT toolkit.

FEs 4-7 will be performed by the engine making calls to PRETT toolkit module.

6.0 External Requirements

The following sections outline non-technical requirements for the development and delivery of the PRETT tool.

6.1 USERS

Ultimately, the end users of PRETT will be dispatchers who need to determine the best and safest route for transporting explosives via truck over U.S. highways and other types of roadways. However, since PRETT will initially be developed and delivered as a prototype, Version 1.0 will not be commercially available to dispatchers. Its purpose is for evaluation purposes by DOT PHMSA.

PRETT V 1.0 will be used by English-speaking users in the U.S. and will not be targeted for users in foreign countries at this time.

6.2 PRETT SOFTWARE APPLICATION

The PRETT tool will be developed as a stand-alone desktop application with embedded COTS mapping software, routing software (TBD), and possibly others. PRETT will run on Windows 10.

6.3 PRETT NETWORK ACCESS AND SECURITY

To use PRETT, the user must have a Wi-Fi connection so the COTS software can retrieve map information. Connecting to the internal PHMSA network is not possible; however, PHMSA has indicated that a wireless network is available for use at their facility.

Since the PRETT tool is a prototype delivered to PHMSA for evaluation, user access (i.e., capability to supply username / password for logging into the application) is not considered at this time.

APT will deliver two laptops with the Windows 10 operating system to PHMSA. The laptops will have the PRETT tool installed with the PRETT icon on the desktop. The PRETT tool will include all internal tables and associated data. There is no dependent software that the laptops must have to run the software. The security requirements will be defined and delivered under this contract as specified at Milestone 5.

6.4 PRETT SOFTWARE BETA DELIVERIES

APT will follow a software development process that provides beta versions of the software at different stages of the software development for testing. This allows PHMSA to provide

feedback on the development. Feedback, including bugs experienced while running the software, is encouraged. The first beta version will be numbered Version 0.1 at Milestone 3. Subsequent beta deliveries will be numbered Version 0.2, 0.3, and so on. If required, there will be additional beta versions before the final software delivery, numbered Version 1.0.

6.5   BUG REPORTING AND MAINTENANCE

APT will conduct thorough testing before each beta delivery and final delivery of the software to PHMSA. During software development and internal testing, the developers will fix all bugs found by the APT test team. APT will also document and fix bugs found by PHMSA in beta versions. These bug fixes will be incorporated into the next beta version delivery.

After final delivery of the V1.0 software, any feedback from PHMSA that identifies bugs and additional desired functionality will be documented by APT and considered for incorporation into a future version.

When PRETT is upgraded from prototype software to deliverable software, a maintenance plan and formal bug-reporting process will be developed, documented, and implemented.

6.6   PROMOTIONAL INFORMATION

The APT and PHMSA logos will appear on an "About" screen of the PRETT software. APT will design and produce a PRETT icon that will appear on the user's desktop for launching the software. The PRETT icon will be subject to approval by PHMSA.

Since the end product for this phase is a prototype used for evaluation, no decisions will be made at this time on how to promote the product and how it will be available to end users.

6.7   USER'S MANUAL

A user's manual will be developed and delivered within 60 days (or less) of final delivery of the PRETT tool. The user's manual will be a PDF document external to the software; in other words, it will not be accessible from within the PRETT software.

6.8   INTERFACES AND DEPENDENCIES

The PRETT software will internally interface to other third-party software, as described in the following sections.

6.8.1   Mapping Software

Mapping software, in the form of a library, will be embedded into the PRETT software. Currently Google Maps is the primary candidate. The PRETT software will make Application Programming Interface (API) calls to the software to display maps, provide it with source and destination data, and retrieve information from the map. This type of software typically incurs a cost per API call, with a certain number of API calls per month performed for free. This cost is

paid for by the user of the software. It is anticipated that for the PRETT prototype, that no cost will be incurred.

6.8.2 Routing Software

Routing software must be utilized to determine three routes from source to destination. It is TBD whether this is a function of Google Maps or if other COTS software is required.

6.8.3 Other Dependencies

Lookup tables will be used within the PRETT toolkit for calculations. Details of the mathematical calculations and look-up tables will be documented and delivered in an analysis description as part of Milestone 7.

7.0 Technical Requirements

Technical requirements are subdivided into GUI and Toolkit sections as described below.

Each requirement is preceded by an identification number (for example, PRETT_ID-300). Uniquely identifying each requirement with an ID number is useful in that:

1) A requirement that needs further discussion between PHMSA and APT can be referred to by its ID number so there is no ambiguity or confusion.

2) It provides a mechanism for traceability from each requirement to its software design element, section of code, and test procedure(s). This ensures each requirement is designed, implemented, and tested, and that no requirement is inadvertently omitted.

7.1 LOGGING REQUIREMENTS

7.1.1 Data Logging

A feature that will be added to the PRETT tool is detailed logging of each step and calculation to an external file. This feature is useful during software development to debug and troubleshoot issues, during testing to verify calculations, and for users to understand how answers were derived. A data log file will be created for every "run" of the software (for example, when the user has entered required data and instructed the software to calculate the risk to the displayed paths).

[PRETT_ID-300] The software will record information to a data log file that will at a minimum include:

- The current date and time at the beginning of the file.
- The FE number and description according to the PRETT architecture
- A description of the step performed within the FE
- Numbers obtained or derived from internal lookup tables
- Calculations performed within an FE

[PRETT_ID-301] The data log file shall be accessible to the user in human-readable format.

[PRETT_ID-302] A data log file shall be produced for each "run" of the software.

7.1.2 Anomaly Logging

Errors, warnings, and other information to alert the user will be recorded to an external error log file. An example is if traffic density cannot be determined for a particular segment and what the software did to address the issue. This information will inform the user of any anomalies in the software. This log file will not be created if no issues occurred while running the software.

[PRETT_ID-303] The anomaly log file will be created only if an error, warning, or other anomaly occurred in the software.

[PRETT_ID-304] The software will record error and warning information to a log file that will at a minimum include:

- The current date and time at the beginning of the file.
- The nature of the error or warning
- The FE number and / or step that it occurred in
- Steps taken by the software to address the issue

[PRETT_ID-305] The anomaly log file will be accessible to the user in human-readable format.

[PRETT_ID-306] After risk calculations are complete, the software shall alert the user if anomalies occurred during the process and how to access the log file.

7.2 PRETT GUI REQUIREMENTS

The PRETT GUI, as described in Section 5.3.1, presents the input and output displays for the user. Requirements for the PRETT GUI are as follows:

[PRETT_ID-100] The software will launch via an icon on the desktop or via the Windows Start menu.

[PRETT_ID-101] The software will initially display a map and an input form for the user to provide data to calculate the path risks.

[PRETT_ID-102] The software will display an error if it is unable to connect to the Internet to obtain map information.

 [PRETT_ID-103] The user will be able to pan and zoom in/out on the map.

[PRETT_ID-104] The software will provide the ability for the user to enter the following inputs:

- Point A (source location)
- Point B (destination location)
- Vehicle type
- Type of explosives

- Quantity (lbs)
- Start time of the trip

[PRETT_ID-105] All inputs will be required.

[PRETT_ID-106] The software will allow the user to enter a Point A (source location) anywhere in the continental United States (CONUS).

[PRETT_ID-107] The software will display an error if the entered Point A (source location) does not exist or is not valid.

[PRETT_ID-108] The software will allow the user to enter a Point B (destination location) anywhere in CONUS.

[PRETT_ID-109] The software will display an error if the entered Point B (destination location) does not exist or is not valid.

[PRETT_ID-110] For vehicle type, the user will choose only one of the following options from a dropdown list:

- Van truck
- Tractor trailer
- Bulk tank truck

[PRETT_ID-111] For type of explosives, the user will choose only one of the following options from a dropdown list:

- HD 1.1
- HD 1.5
- HD 5.1

[PRETT_ID-112] For quantity, the user will enter the value in pounds.

[PRETT_ID-113] For start time of the trip, the software will allow the user to choose any time of day using a calendar control (same or similar to how a meeting time is chosen using Microsoft Outlook).

[PRETT_ID-114] The software will provide the user the ability to click a button or otherwise signify all risk calculations to be performed. (For further requirements, this will be referred to as the "Go" button).

[PRETT_ID-115] The software will display an error if any inputs are not chosen / entered when the user clicks the Go button.

[PRETT_ID-116] The software will display an error if the quantity input for the given vehicle type is out of range when the user clicks the Go button.

[PRETT_ID-117] After the user clicks the Go button, the software will present to the user up to three paths shown on the map.

[PRETT_ID-118] The software will assume that "day" is from 6 a.m. to 6 p.m., and "night" is 6 p.m. to 6 a.m.

[PRETT_ID-119] The software will calculate the risk for all paths and display the risk for each path on the GUI.

[PRETT_ID-120] The software shall identify on the GUI the safest path (i.e., the path with the least risk).

[PRETT_ID-121] As part of the risk calculation, the software will calculate the risk for each path segment.

[PRETT_ID-122] The software will overlay onto each path a color code for each segment.

[PRETT_ID-123] The software will display a color code legend on the GUI, where each color code equates to a range of risk numbers.

[PRETT_ID-124] The software will query the COTS mapping software to obtain the type of road for a section of road.

[PRETT_ID-125] The software will determine if a segment is traveled during day or night given the user input time of day.

[PRETT_ID-126] The software will determine the midpoint of each segment (called the "evaluation point").

[PRETT_ID-127] A screen will be provided that when displayed, shows the version information and date of the PRETT software.

[PRETT_ID-128] The software will display an error if any queries to COTS software fail.

[PRETT_ID-129] The software will allow the user to select waypoints for a path.

[PRETT_ID-130] The evaluation point of a segment will be used to obtain traffic density for day or night.

[PRETT_ID-131] If the traffic density cannot be obtained for a given segment, the software will indicate an error in the anomaly log file.

[PRETT_ID-132] The software will not allow a number less than 1 or more than 15,000 to be entered for explosive quantity when the selected truck type is Van truck.

[PRETT_ID-133] The software will not allow a number less than 1 or more than 45,000 to be entered for explosive quantity when the selected truck type is Bulk tank truck.

[PRETT_ID-134] The software will not allow a number less than 1 or more than 80,000 to be entered for explosive quantity when the selected truck type is Tractor trailer.

7.3   PRETT TOOLKIT REQUIREMENTS

The PRETT Toolkit, as described in Section 5.3.3, contains most of the underlying algorithms and lookup tables needed to calculate the path risk.

[PRETT_ID-200] The software will consider only transportation of explosives by truck.

[PRETT_ID-201] The path risk will be calculated as expected fatalities from an explosion on the path.

[PRETT_ID-202] Segment risk will be calculated as expected fatalities from an explosive event with input truck type as it passes through the segment.

[PRETT_ID-203] A segment shall be defined as 1 km in length.

[PRETT_ID-204] Risk will be calculated from probability of event (P_e), consequence to population (C_p), consequence to automobiles (C_a), exposure to population (E_p), and exposure to automobiles (E_a).

[PRETT_ID-205] The P_e shall be calculated from the following variables stored in an internal lookup table:

- Probability of Fire
- Probability of explosive initiation / fire
- Probability of detonation / fire / initiation
- Probability of wreck
- Probability of initiation / wreck
- Probability of detonation w/ initiation

[PRETT_ID-206] The software will use internal lookup tables to determine C_p and C_a.

[PRETT_ID-207] The software will use interpolation of the explosives quantity input for determining C_p and C_a.

[PRETT_ID-208] When determining C_p, the type of road will be used to eliminate close-in consequence for surrounding population.

[PRETT_ID-209] Explosives events will include detonations and deflagrations.

[PRETT_ID-210] Explosives events will result in effects including blast, debris, and thermal.

[PRETT_ID-211] The software will obtain traffic density for a given segment.

[PRETT_ID-212] Annual traffic will be pro-rated into hourly traffic, using a 24-hour traffic profile.

[PRETT_ID-213] Hourly traffic will be evenly spaced to determine the number of vehicles and distance from truck.

[PRETT_ID-214] The software will obtain population density for a given segment.

[PRETT_ID-115] The population density will be distributed evenly to the segment.

8.0 Features for Subsequent Releases

The following list describes features that will not be incorporated into the PRETT Version 1.0, but will be evaluated for development and inclusion for a future commercial version.

- User login / password capability to use the PRETT tool.
- The capability to save user inputs from one session, and populate the input form with the saved inputs upon the next session of the PRETT tool.
- Support for sequential operations; for example, unloading explosive materials from a train and loading them onto a truck. Sequential operation considerations have been addressed in past work at APT. Functionality currently exists in other software and can be incorporated into future versions of the PRETT tool.
- Safe haven requirements.
- Other transportation types (air, rail, etc.).
- Other explosive types, such as HD 1.2.
- Consideration for traffic delays.
- Consideration for major injury as part of the risk metric.
- Real-time traffic data.

Appendix D – Sprint Summary

The work for PRET-T development was performed by teams comprised of Program Management, Analysis and Research, Software Development, and Test.

A separate Excel spreadsheet was used for each milestone to track and manage the tasks needed to complete the work for a milestone. Work tasks for each team were identified at the beginning of work towards a milestone delivery and listed on a worksheet called "Master."

Two or three-week "sprints" of work were used. At the beginning of a new sprint, work tasks identified to be worked during the sprint were copied from the Master to a new worksheet for the sprint. All team members met twice weekly in meetings to review sprint tasks and track progress. Completed tasks were marked "complete." If it was found that new tasks needed to be worked, they were added to the Master and copied over to the appropriate sprint worksheet. Tasks not completed were rolled over to the next sprint.

In all, 25 sprints were scheduled over the milestone deliveries. Table D-1 shows the number of sprint periods for each milestone.

Table D-1: Number of Sprint Periods for Each Milestone

Milestone Number	Number of Sprints
2	3
3	3
4	12
5/6	5
7/8	2

Sprint tasks were kept fairly general; too much detail made the tracking and managing of the tasks too onerous. Table D-2 outlines the number of these tasks worked and completed in each major area for each Milestone/Sprint.

Table D-2: Number of Tasks in Each Major Area for Each Milestone/Sprint

Sprint #	Program Management	Analysis & Research	Setting up Processes	Software Design & Code	Test	Documentation Deliverables	Subtotal	Total
Milestone 2								
1	9	16	4	1	0	2	32	
2	1	11	1	1	1	1	16	
3	8	16	8	3	0	4	39	
					Number of Tasks completed in Milestone 2:		87	87
Milestone 3								
4	3	7	1	12	1	0	24	
5	3	8	0	3	2	0	16	
6	4	5	0	7	2	0	18	
					Number of Tasks completed in Milestone 3:		58	58

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Sprint #	Program Management	Analysis & Research	Setting up Processes	Software Design & Code	Test	Documentation Deliverables	Subtotal	Total
Milestone 4								
7	Christmas and New Year Holiday							
8	3	2	2	2	2	0	11	
9	4	2	0	5	2	0	13	
10	3	3	1	1	1	0	9	
11	3	3	0	13	2	0	21	
12	2	4	3	6	2	0	17	
13	2	2	1	13	5	0	23	
14	3	1	1	2	3	0	10	
15	1	1	1	12	8	0	23	
16	1	4	1	24	3	0	33	
17	1	1	0	15	3	0	20	
18	5	0	0	14	3	0	22	
				Number of Tasks completed in Milestone 4:			202	202
Milestone 5/6								
19	2	1	0	9	1	0	13	
20	2	0	2	6	1	3	14	
21	2	1	0	3	4	0	10	
22	2	2	0	5	5	2	16	
23	9	1	0	5	3	6	24	
				Number of Tasks completed in Milestone 5/6:			77	77
Milestone 7/8								
24	2	1	0	1	3	2	9	
25	9	0	0	5	8	7	29	
				Number of Tasks completed in Milestone 7/8:			38	38
						TOTAL COMPLETED TASKS		**462**

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Appendix E – Data Security Plan

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A-P-T RESEARCH, INC.

COMPREHENSIVE TRANSPORTATION RISK MODEL DEVELOPMENT

Project #45 / TA-1

Data Security Plan

Contract #: 693JK319C000009

Date: Aug. 11, 2020
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COMPREHENSIVE TRANSPORTATION RISK MODEL DEVELOPMENT

DATA SECURITY PLAN

CDTS-AL003-20-01000
Aug. 11, 2020

Prepared by:
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Contract Details:
Contract #: 693JK319C000009, Project #: 45

CONTENTS

1.0 Overview

Under contract with the Department of Transportation (DOT) Pipeline and Hazardous Materials Safety Administration (PHMSA), A-P-T Research, Inc. (APT) developed develop a proof-of-concept transportation risk model for transporting explosives by truck.[1] This model, currently called Personnel Risk for Explosives Transportation by Truck (PRET-T), is intended to be the first phase of a larger model that will assess risk of any hazmat by any mode: Truck, rail, air, water. The project requirements are for a modular tool with the ability to easily add functionality such as other HM consequence models and transportation modes.

The purpose of this security plan is to define the system in relation to its security posture. The plan reflects the need to protect the system and to provide accurate and trustworthy information. This is a basic plan for a prototype system as delivered in Phase 1. An updated plan will change as the functionality of the system matures and more security related features are added, as user communities emerge and security threats increase.

2.0 Scope

This plan applies to the current proof-of-concept version of PRET-T and its users. It considers threats that apply to the PRET-T application running on a single, standalone laptop that is connected to a public network.

The primary considerations for this plan are data accuracy (trustworthiness) and the threats posed by malicious activity. Another main security goal is keeping route information secure from terrorists or from competitors; however, this will be addressed in Phase 2.

Phase 2 will transition to a cloud-based service where application and data security is further enhanced by adhering to cloud-based security standards. Phase 2 application and data security will incorporate a set of control-based safeguards and protections designed to protect resources from leakage, theft or data loss. In addition, architecting the cloud-based service will be done so as to segregate functionalities into inter-dependent tiers in order for security mitigation. Data and application access will also be based on user roles.

Other risks, such as hardware failures, do not pose a security risk for the system; therefore, they are outside the scope of this document.

3.0 System Identification

System Name: Transportation Risk Model for Transporting Explosives by Truck.
System Version: Proof of Concept (Version 1.0)
Developed By: APT Research, Inc.
Developed For: U.S. Department of Transportation

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[1] Contract No. 693JK319C000009

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4.0 System Environment

The PRET-T V1.0 software operates on a single laptop computer running the Windows 10 Professional operating system. The software was developed utilizing Microsoft Visual Studio, a Microsoft Windows-based development environment. The software operates as a desktop application. A wireless or wired internet connection is required in order to communicate with Microsoft Bing Maps portal; the software does not acquire any other data via the Internet.

5.0 Access Control

The Phase 1 PRET-T software does not contain any user management or login functionality. It is anticipated that the Phase 2 software will require a user to provide a username and password to access the software.

The Phase 1 software is protected by embedding a key based on the computer's media access control address (MAC address). The MAC address is a unique identifier assigned to the computer's network interface controller (NIC) for use as a network address in communications. Each computer has a unique MAC address. Therefore, each PRET-T software installation will be tied to the particular computer's MAC address. This means that the software cannot be copied to another machine and executed. This feature also provides robust security of the results

All risk results calculated by the software remain in volatile memory only while the software is up and running. The user has the option to save risk results to a Comma Separated Value (CSV) file on the local hard drive. Otherwise, the software does not store or retain any data. In other words, for Phase 1, route information is not saved to the user's computer. Therefore, when the user exits the software, all route information and risk results are deleted from memory, unless the user has chosen to export the risk results to the CSV file. Therefore, it is not possible to "hack into" the computer to find saved route information. Data exported to the CSV file consists of a set of latitude, longitude points with risk calculations for each. It is possible for someone to determine the route from the latitude, longitude points. Therefore, if the route needs to be secure, it is incumbent upon the user to protect the risk results information, by for example, using encrypted and signed functions to email the information to a colleague.

The only instance that the PRET-T software obtains data over the Internet is via the Microsoft Bing Maps portal in order to provide route information based on the user's input of source, destination, and waypoints. The software obtains route information by building and sending queries through the Bing Maps portal. All Bing queries are encrypted using FIPS 140-2 compliant, Secure Sockets Layer (SSL) and is secured via Hyper Text Transfer Protocol Secure (HTTPS). Furthermore, Bing Maps requires a specific API token before it will provide data. This token is embedded in the software and is unique to each PRET-T installation.

The software also queries other third-party components to obtain data to calculate risk results, but these components are local to the computer's hard drive and are provided with the software installation. One component is state shapefiles used to obtain Annual Average Daily Traffic (AADT) and the road type for specific latitude, longitude points. A shapefile is a geospatial data format for use in geographic information system (GIS) software. Shapefiles contain attributes that can be extracted using a specific location, two of which are the average annual daily traffic

(AADT) and road type (one of six pre-defined types). These are used by the software to calculate risk factors. For Phase 1, 20 state shapefiles were downloaded from the DOT website and are accessed by PRET-T on the hard drive of the local computer.

The software also queries LandScan and U.S. Census population files to extract population data for specific latitude, longitude points. These population files are in a GeoTIFF raster data format, and like shapefiles, are accessed by PRET-T on the hard drive of the local computer.

System access is controlled by the operating system and is described in Section 7.0.

6.0 Configuration Management

The software is developed using Microsoft Visual Studio. Only the (two) APT software developers have access to the software code. The computers used by the developers have antivirus software installed on them and only the developers have the credentials to log on to them. Therefore, the software code cannot be tampered with.

Software code and versions are configuration controlled using a manual system managed by the software developers. Internal versions are delivered to the PRET-T team for both review and testing. A record is kept of each version describing the version number, what it contains (fixes and new functionality), and the purpose of the version.

7.0 System Controls

For Phase 1 software, two laptops will be delivered to the customer, each with a unique installation of PRET-T Version 1.0.

Individual user accounts will be created for each laptop. The laptop will also be configured with an administrative account. Per standard best practices, the administrative account should be separate and only used when necessary.

Certain Microsoft (and other) updates require administrative privileges. The laptop user will also be provided access to the Administrator account. Individual user accounts should be used when running the software.

The laptop will be configured to automatically allow Windows operating system updates to be performed in order to resolve vulnerabilities. The antivirus software is set to automatically update its definition files daily in order to provide malware/antivirus protection. It is up to the user to resolve alerts provided by the antivirus software since this cannot be monitored by the PRET-T development team.

The Microsoft Windows Firewall is enabled and should remain enabled at all times.

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8.0 Data Integrity

The PRET-T software is reliant on available connectivity to Microsoft Bing Maps. The system will not function without this connection.

Bing Maps requires an embedded API "key" within the communication in order to verify the authenticity of APT's request (and for billing purposes). The system trusts the response to be genuine and does not perform authentication on the data it receives. The system is reliant on trustworthy Domain Name System (DNS) service and Internet Protocol (IP) routing as part of its security posture.

Queries to shapefiles and population files are performed the same way every time, thereby always assuring that the results are the same every time. Therefore, there are no security or reliability concerns with obtaining data from the shapefiles and population files.

The PRET-T V1.0 system is provided in a secure state, free from malware and malicious code. It is reliant on continuous physical and network protections to maintain the reliability of results. The responsibility for maintaining the secure environment will transfer to the customer (user) upon receipt (delivery of the product).

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Appendix F – List of Software Versions

This Appendix contains information about each PRET-T version that was released both internally and to the customer. Version information includes the version number, release date, the reason for the release, and the functionality/fixes that the version contained.

In the early stages of development, V0.1 and V0.2 were documented as shown in Table F-1.

Table F-1 Early Development Version Descriptions

Version #	Release Date / Description	What this version contains
V0.1	Demo to PHMSA - Dec 2019	FE-1, FE-2
V0.2	Team Demo - Feb 23	FE-1, FE-2 updates

As the software matured, a formalized software version numbering process was developed in late March 2020 and used for subsequent internal and customer versions of the software. Internal versions were numbered 0.x.y, where x was the major release number, and y was the minor release number. Customer versions followed the numbering scheme of 0.x (where x was the major release number).

Versions 0.3.y contained implementation of most remaining FEs and fixes to the software as shown in Table F-2.

Table F-2 Development Version 0.3 Descriptions

Version #	Release Date / Description	What this version contains
V0.3.1	Team Demo - April 9	FE-3
V0.3.2	Team Demo - May 7	FE-1 - FE-7 + FE-9, minus FE-6 population
V0.3.3	Release to Test - May 13	Minor fixes
V0.3.4	Team Demo - May 14	Bug fixes + FE-6 complete (Census and LandScan population). Incorporated traffic speed methodology. More work on FE-9 to correlate post points on map with those on the grid.
V0.3.5	Team Demo - May 19	Added PP #s to the map to correlate with the user grid. Creation of output data table that can be put in Excel. Fixed/changed population exposure equation.
V0.3.6	Team Demo - May 21	Fixes to FE-4. Minor changes to user grid.
V0.3.7	Team Demo - May 22	Incorporate multi-state shapefiles and refine parameters to allow for multiple routes. Label routes with colors
V0.3.8	Management Demo - May 26	Asynchronous generation of routes. Modified user data log to print route name so it could be correlated with routes on the UI.
V0.3.9	Demo to Customer - May 27	AADT / road type refinements

V0.3.9 was released as a demo to the customer for Milestone 4 and was referred to as customer version V0.3.

After Milestone 4, work continued on the software for Milestones 5 and 6. The major number was incremented accordingly, and versions for V0.4.y are shown in Table F-3. These versions

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implemented the remaining FEs and further fixes to the software for bugs found during testing and coherency checks conducted by the PRET-T analysis team.

Table F-3 Development Version 0.4 Descriptions

Version #	Release Date / Description	What this version contains
V0.4.1	Team Demo - June 3	Incorporated FE-8, FE-11 code.
V0.4.2	Team Demo - June 16	Cosmetic changes to route risk display on user interface. Incorporated FE-10, Risk legend and coloring pins and route labels, and a new risk assessment grid. Minor changes to FE-4 and FE-7. Fix to analysis: Multiply P_e by 0.02 and remove 0.02 from FE-7 risk equation.
V0.4.3	Team Demo and data runs for analysis team for coherency check meeting - June 18	Implemented updated risk legend. Removed user data log; it has been replaced by Export from the user grid. Updates to code to improve AADT coherency.
V0.4.4	Team Demo and data runs for analysis team for coherency check meeting - June 25	Fixed incorrect display of data and in risk assessment grid and made enhancements to it. Methodology to adjust AADT (if not available) was implemented. Code to obtain population values was changed to run faster.
V0.4.5	Data provided to analysis team - June 29 Informal demo with customer - July 2	Minor fixes/updates to risk assessment grid.
V0.4.6	Provided version to Test - July 9	Incorporated splash screen. Fixed bugs in user interface as found by Test. Enhanced user interface to provide better useability.
V0.4.7	Data provided to analysis team - July 13	Update to P_e methodology based on HD type
V0.4.8	Data provided to analysis team and version to Test - July 15	Fixed bugs in FE-6, the risk assessment grid, and validation for explosive quantity.
V0.4.9	Team demo - July 28 Version to Test - July 30 Customer delivery - July 30	Implemented enhancements to user interface: for pins that are common between routes, display one pin but describe in the callout the routes and segment #s it corresponds to. Fixed minor bugs in user interface. Incorporated updated splash screen and icon. Implemented updated analysis methodology for FE-4, FE-5 (including updated consequence tables), FE-6, and FE-7.

V0.4.9 was released to the customer for Milestone 5/6 and was referred to as customer version V0.4. It was installed on two laptops that were delivered to the customer.

After Milestone 5/6, minor updates were made to the software. The major number was incremented accordingly, and versions for V0.5.y are shown in Table F-4.

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Table F-4 Development Version 0.5 and Final Descriptions

Version #	Release Date / Description	What this version contains
V0.5.1	Demo to customer - 8/11/2020	The Export button has been moved to under Risk assessment grid. The Cancel button is disabled after Risks is clicked.
V0.5.2	Provided version to Test - 8/31/2020	An alternate User Interface was issued to evaluate better useability. The Consequence algorithm (FE-5) was updated.
V0.5.3	Provided version to Test - 9/4/2020	The User Interface was reverted to the V0.4.9 (beta version). Incorporated V1.0 splash screen. Added error checking code and graceful error messages to user if software ran out of memory or route went through unsupported states. Incorporated correct VT Vehicle HD 1.5 and 5.1 consequence tables.
V0.5.4	Provided version to Test - 9/7/2020	Removed the points column from the risk assessment grid. Fixed error when running routes through South Carolina. Added check for connectivity when software is initializing. Implemented a mechanism to prevent unauthorized users from running PRETT.
V1.0	TBD	

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Appendix G – Test Plan and Results

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A-P-T RESEARCH, INC.
AN EMPLOYEE-OWNED COMPANY

COMPREHENSIVE TRANSPORTATION RISK MODEL DEVELOPMENT
PRET-T TEST PLAN/RESULTS

BAA Project No. 45 / TA-1
Contract No. 693JK319C000009

Internal Validation Report
CDTS-AL003-20-00800
September 9, 2020

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COMPREHENSIVE TRANSPORTATION RISK MODEL DEVELOPMENT
PRET-T TEST PLAN/REPORT

CDTS-AL003-20-00800
September 9, 2020

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Contract Details:
Contract #: 693JK319C000009, Project #:45
TA-1: Comprehensive Transportation Risk Model Development

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CONTENTS

ACRONYMS

AHT	Average Hourly Traffic
APT	A-P-T Research, Inc.
CONUS	Continental United States
COTS	Commercial-off-the-shelf
DOT	U.S. Department of Transportation
EXE	Executable
FE	Functional Element
FHA	Federal Highway Administration
GIS	Geographic Information System
GUI	Graphical User Interface
HM	Hazardous Material
OHMS	Office of Hazardous Materials Safety
OS	Operating System
PHMSA	Pipeline and Hazardous Materials Safety Administration
PRA	Probabilistic Risk Assessment
PRET-T	Population Risk for Explosives Transport by Truck
SRS	Software Requirements Specification
SDD	Software Design Document
TBD	To Be Determined
TRM	Transportation Risk Model

1.0 Introduction

This document was developed by A-P-T Research, Inc., under Contract 693JK31900000 ("Comprehensive Transportation Risk Model Analysis") to the U.S. Department of Transportation (DOT) Pipeline and Hazardous Materials Safety Administration (PHMSA).

1.1   PURPOSE OF THIS DOCUMENT

This document describes the test plan and the results for the Population Risk for Explosives Transport by Truck (PRET-T) Version 1.0 software. The purpose of this document is to ensure that the software requirements of PRET-T, as documented in the Software Requirements Document, are implemented correctly. A draft version was previously delivered to PHMSA. The final version will be delivered as part of the final report including annexes documenting test results.

1.2   SCOPE OF THIS DOCUMENT

The scope of this document is to describe the overall testing strategy for the PRET-T prototype.

This includes testing of the Graphical User Interface (GUI) and the risk calculations contained in the software. Other items include:

- Proper interaction with the map and routing software
- Proper display of user interface components and windows
- Proper display of error, warning, and informational messages to the user
- Proper calculations of the risk values
- Proper display of risk values on the map and in the risk results grid
- Proper export of risk calculations to a comma separated values (CSV) file

1.3   REFERENCES

Document Title	Document Number	Publishing Organization
PRET-T Software Requirements Document	CDTS-AL-AL003-0200	A-P-T Research, Inc.
Technical Description Document	CDTS-AL003-20-00300	A-P-T Research, Inc.

1.4   MAJOR CONSTRAINTS

There were no known constraints that restricted testing of the software.

2.0 Objective of this Document

This Software Test Plan Document acts as the foundation for testing the PRET-T software. This document meets the requirements stated in Contract 693JK31900000 to deliver the plan and test procedures for PRET-T Version 1.0. The document serves as an artifact of communication among all the stakeholders, including PHMSA and APT.

3.0 Test Plan

This plan describes the types of testing to be accomplished during the software development stages. All testing was in accordance with APT policy on developing deliverable software and in consideration that this is a proof-of-principal tool.

The following areas of testing are described: unit testing for risk calculations, GUI testing, integration testing between the GUI and risk calculations, and finally, validation testing.

GUI testing and unit testing for the risk calculations were accomplished independently and in parallel. Integration testing followed to ensure the proper display of the risk calculation results on the GUI. Validation testing was performed throughout the testing phase to ensure that all functional, behavioral, and performance requirements of the system were met.

3.1   UNIT TESTING

This section describes the testing strategy in detail for unit testing.

Unit Level testing was conducted for FE-3 through FE-8 to verify expected software results. The FEs for unit level testing are defined as:

- FE-3: Define Segments
- FE-4: Calculate Probability of Event (P_e)
- FE-5: Determine Consequence
- FE-6: Determine Exposure to Population
- FE-7: Segment Risk
- FE-8: Path Risk

Test cases containing combinations of input parameters for FE-3 through FE-8 were developed and recorded in separate Excel spreadsheets. Each time a test needed to be run as a result of testing new functionality or regression testing, the new set of results and the reason for the new run was documented. The name of the tester and the date the tests were performed were also documented. Testing worksheets for each unit are found in Appendix A.

FE-3 through FE-7 were unit tested as described below. Unit testing for FE-8 is described in "FE-8: Path Risk" in Appendix A.

- The algorithms and calculations as described in the Technical Description Document were coded independently in Excel.
- A range of hardcoded values for certain parameters, such as Average Annual Daily Traffic (AADT) and population data, were used. Expected results from the Excel code were recorded for each test case.
- A separate program, called the PRET-T Test App, was used for the next step. The PRET-T Test App was used to calculate risk values for one route segment. It was used to debug and vet the algorithms before incorporating into the PRET-T software. Inputs for each test case were entered into the PRET-T Test App, and the results were used to compare

against the expected results by documenting them into the test spreadsheet. Each test case was denoted by a Pass/Fail status. All tests that failed were examined by the software developer, and if a fix was made, a new version of PRET-T Test App was made available to perform regression testing or retesting of the cases that failed.

3.2 GUI UNIT AND WORKFLOW TESTING

The following are the GUI components and workflows tested. The testing strategy for nearly all the items below was visual inspection.

Many tests involved keying in invalid data for the edit field. In most cases, an error message was displayed, and the tester should make sure that the content of the error message is consistent with the error that occurred.

Refer to the PRET-T Software Requirements Document regarding proper display of GUI components, for example a list of items that should appear in each combo box, proper enabling/disabling of fields, and error message content. These tests were done in the following order as they built upon each other:

1) **Product Startup tests**. This verified that when the user double clicks on the PRET-T icon, the map with user input form appeared.

2) **Map and User Input form tests.** This verified that the main interface started up properly. These also verified that the proper operation occurred given the execution of a drop-down box or buttons. These tests were only ensuring that the proper form or message box displayed. In this section, APT also checked that the map was fully functional and that the dockable panels were movable.

3) **Routing tests**. These tests verifed that the PRET-T application software and routing software were communicating, and that paths were returned for evaluation. This test verified that routes were generated given the source and destination location and waypoint information. It was not designed to verify that each generated route was the best/correct route. APT assumed that MS Bing Maps provided correct routing information.

Appendix B contains the workflow for the GUI testing.

3.3 INTEGRATION TESTING

Once all risk algorithms and calculations were unit tested using the Excel spreadsheets and the PRET-T Test App, and all tests passed, the algorithms and calculations were then transferred to the PRET-T software. Integration testing ensured that the risk calculations displayed correctly on the GUI.

1) **Route Risk.** These tests ensured that all risks for each 1 km post point were summed correctly.

2) **Verify Output Results**. In these tests, once routes were generated and risks calculated, the tester verified that the risk for each 1 km post point displayed correctly in the Risk Assessment grid and the pins were the correct color on the map based on the legend.

Part of this testing was to verify that all 19 states that APT has shapefile data for could generate routes and risks. The addresses used were noted by the table in Appendix C Integration Testing worksheets.

3.4   VALIDATION TESTING

The purpose of validation testing was to verify that all the requirements in the PRET-T Software Requirements Document were met. Since most validation tests refer to a GUI, Unit, or Integration test, validation testing was accomplished throughout the testing phase. A separate list of validation tests was generated as a formality to confirm that all the requirements were met. The table contained in Appendix D was used for the validation testing. Each software requirement is listed and the applicable test from either GUI, Unit, or Integration testing is referenced.

3.5   REGRESSION TESTING

The purpose of regression testing was to verify that any changes made to the system did not break the functionality of any element previously developed. Changes that may require regression testing could include bug fixes or software enhancements.

To accomplish regression testing, the tester reran all the test cases. This technique was chosen because each element builds off the previous one. Therefore, APT wanted to ensure that no errors occurred before or after changes were made in the code.

During testing, a checkmark or a "Pass" or "P" represented successful execution of the component in the "Actual Results" field of the table. If the test failed, the tester documented the error. The test results were denoted in red as the error is described. The errors were then entered in an Issue Tracking spreadsheet and provided to the software developer. Once the error was fixed, a new software build was provided for retesting. This process was repeated until no more errors were noted.

Appendix A – Unit Tests

Provided in each unit test is a sample of the Excel spreadsheet results and the actual results from the PRET-T Test App. In order to fit these samples into this document, not all rows and columns were included.

FE 3: Define Segments

The purpose of this testing was to verify that PRET-T defines the post point segments with the first segment at 0.5 km from the start location and 1 km after each. To do this, the constants and formulas were inserted into an Excel spreadsheet to compare the total distance given by PRET-T and the total distance calculated in Excel.

Constants:

Earth's radius: 6371.0088 km
The latitude, longitude of the start location is 34.73162, -86.66439.
Converted to radians: 0.606181124, -1.51257895.
The latitude, longitude of the end location is 34.361795, -86.290676.
Converted to radians: 0.59972646, -1.50605641.

The table below is a sample of the test conducted. The latitude and longitude numbers came from PRET-T. A conversion was then done to turn the coordinates into radians. After another calculation, we get the distance from one segment to the next. The distance from the starting point to the first segment is 0.659598. This is close to the 5km distance expected. All other distances after that were approximately 1km.

| Segment | PRETT Values | | Radians Conversion | | |
	Lat	Lon	RadLat	RadLon	distance
0	34.73059	-86.6583	0.606163	-1.51247	
1	34.72616	-86.6535	0.606086	-1.51239	0.659598
2	34.72461	-86.6441	0.606059	-1.51223	0.8735
3	34.71565	-86.6439	0.605902	-1.51222	0.996511
4	34.7178	-86.6356	0.60594	-1.51208	0.795397
5	34.71995	-86.625	0.605977	-1.51189	0.9961
6	34.72331	-86.6149	0.606036	-1.51172	0.996675
7	34.72639	-86.6048	0.60609	-1.51154	0.991394
8	34.72937	-86.5967	0.606142	-1.5114	0.808519
9	34.72093	-86.5937	0.605995	-1.51135	0.97695
10	34.71992	-86.5835	0.605977	-1.51117	0.9417

FE 4: Calculate P_e

This test checked that the software was correctly finding the probability of an event using a supplied AADT value and the explosives type. In the Excel Spreadsheet, the tester used Table 3: Probability of event per kilometer from the Technical Description Document. Using the PRET-T Test App and the Excel Spreadsheet, the tester was able to compare the expected and actual results in the table below.

| Test # | Inputs | | Probability of event | |
	HD	AADT	Expected Results	Actual Results
1	1.1	1	1.23E-12	1.23E-12
2	1.1	500	1.23E-12	1.23E-12
3	1.1	1999	1.23E-12	1.23E-12
4	1.1	2000	1.86E-12	1.86E-12
5	1.1	3000	1.86E-12	1.86E-12
6	1.1	4999	1.86E-12	1.86E-12
7	1.1	5000	1.26E-10	1.26E-10
8	1.1	10000	1.26E-10	1.26E-10
9	1.1	24999	1.26E-10	1.26E-10
10	1.1	25000	4.73E-10	4.73E-10

FE 5: Determine Consequence

FE 5 used TDD Table 1: Example Embedded Consequence Table and TDD Table 4: Generic Road Widths from the Technical Description Document to calculate the consequence value for people in vehicles and people not in vehicles. Inputs to FE 5 include: road type and consequence tables for a given truck type and explosive type.

This test checked the calculations for the consequence. Using the Excel spreadsheet, the calculations were done to find the consequence to people in vehicles and people not in vehicles. The "Expected" column shows where these calculations were done. The "Actual" column contains the work done by the PRET-T Test App.

Segment	Road type	Explosive	Explosive Quantity	Truck Type	Cp Expected	Cp Actual	Ca Expected	Ca Actual
1	Interstate	1.1	100	Van Truck	2.08E-03	2.08E-03	2.55E-02	2.55E-02
2	Principal Arterial – Other Freeways and Expressways	1.1	100	Bulk Tank Truck	3.73E-03	3.37E-03	3.29E-02	3.29E-02
3	Principal Arterial – Other	1.1	100	Tractor Trailer Truck	5.76E-03	5.76E-03	4.21E-02	4.21E-02
4	Minor Arterial	1.1	700	Van Truck	1.20E-02	1.20E-02	1.00E-01	1.00E-01
5	Major Collector	1.1	700	Bulk Tank Truck	1.00E-02	1.00E-02	8.70E-02	8.70E-02
6	Minor Collector	1.1	700	Tractor Trailer Truck	1.06E-02	1.06E-02	7.47E-02	7.47E-02
7	Local	1.1	2000	Van Truck	2.45E-02	2.45E-02	1.62E-01	1.62E-01
8	Interstate	1.1	3000	Bulk Tank Truck	2.10E-02	2.10E-02	1.27E-01	1.27E-01
9	Principal Arterial – Other Freeways and Expressways	1.1	4000	Tractor Trailer Truck	2.51E-02	2.51E-02	1.30E-01	1.30E-01
10	Principal Arterial – Other	1.1	6500	Van Truck	3.88E-02	3.88E-02	2.24E-01	2.24E-01

FE 6: Population

In FE 6, population and traffic data are converted to the appropriate units. The inputs to FE 6 are the AADT, traffic speed, day of week (weekday/weekend), hour of day, and the traffic side road width. The outputs needed to verify this step were Average Hourly Traffic (AHT), exposure to people in vehicles, and exposure to people not in vehicles. The tester then compared the expected and actual results.

Test	Road Type	Traffic Volume	Day of week	Hour of day	Census	Landscan	AHT Expected	AHT Actual	Exposure (vehicle) Ea Expected	Exposure (vehicle) Ea Actual	Exposure (open) Ep Expected	Exposure (open) Ep Actual
1	Interstate	1	Weekday	12:00:00 AM	0	0	3.60E-03	3.60E-03	6.01E-05	6.01E-05	0.00	0
2	Principal arterial – other freeways and expressways	500	Weekday	1:00:00 AM	100	600	1.03E+00	1.03E+00	1.90E-02	1.90E-02	100.00	100
3	Principal arterial – other	1999	Weekday	2:00:00 AM	150	80	6.15E+00	6.15E+00	1.37E-01	1.37E-01	150.00	150
4	Minor arterial	2000	Weekday	3:00:00 AM	260	120	4.00E+00	4.00E+00	1.11E-01	1.11E-01	260.00	260
5	Major collector	3000	Weekday	4:00:00 AM	320	150	1.20E+01	1.20E+01	5.01E-01	5.01E-01	320.00	320
6	Minor collector	4999	Weekday	5:00:00 AM	470	400	4.95E+01	4.95E+01	3.31E+00	3.31E+00	470.00	470
7	Local	5000	Weekday	6:00:00 AM	580	1000	1.68E+02	1.68E+02	2.80E+01	2.80E+01	1420.00	1420
8	Interstate	10000	Weekday	7:00:00 AM	710	900	7.03E+02	7.03E+02	1.17E+01	1.17E+01	1090.00	1090
9	Principal arterial – other freeways and expressways	24999	Weekday	8:00:00 AM	990	1050	1.37E+03	1.37E+03	2.55E+01	2.55E+01	1110.00	1110
10	Principal arterial – other	25000	Weekday	9:00:00 AM	1000	300	9.69E+02	9.69E+02	2.16E+01	2.16E+01	300.00	300

FE 7: Segment Risks

FE 7 takes the input data from the previous FEs to compute the segment risks. The inputs for FE 7 are the probability of event (FE 4), C_p – consequence for people not in vehicles (FE 5), C_a – consequence for people in vehicles (FE5), E_p – population density (FE 6), and E_a – traffic density (FE 6). The equation used for this test is on page 16 of the Technical Description Document.

For this test, only the expected and actual outcomes are shown, since the previous FE data was tested and correct.

Segment Risk (r)	
Expected Results	Actual Results
1.89E-18	1.89E-18
4.59E-13	4.59E-13
1.07E-12	1.07E-12
5.84E-12	5.84E-12
6.04E-12	6.04E-12
9.68E-12	9.68E-12
4.95E-09	4.95E-09
3.07E-09	3.07E-09
3.93E-09	3.93E-09
7.79E-09	7.79E-09

FE 8: Path Risk

FE 8 calculates the risk for one route. The overall risk for the route is the sum of the segment risks. The testing done on FE 4-7 included hardcoded values and test cases. There was not a way to produce those same values in PRET-T.

To verify this test, APT produced routes and risks in PRET-T and exported the data. This data was then compared using the PRET-T Test App. By entering the same user input data to the Test App and then using the values for Start Time, Road Type, AADT, Landscan, and Census, the tester verified that PRET-T performed the same calculations and the Risk for each segment matched. Then values were summed and compared that to the Total Risk given by PRET-T.

INPUTS	
Starting Address	4950 Research Dr NW, Huntsville, AL
Ending Address	29 Paddle Wheel Dr, Guntersville, AL
Truck Type	Van Truck
Explosive Type	HD 1.5
Quantity	8000
State date and time	9/4/2020 22:00:00

AADT	RoadType	Landscan	Census	ArrivalTime	PofE	CofP	CofA	EofP	EofA	Risk
1250	Minor Arterial(4)	1134	18	10:00 PM	1.6E-14	4.4E-02	2.4E-01	18	0.7	1.5E-14
1250	Minor Arterial(4)	2413	117	10:01 PM	1.6E-14	4.4E-02	2.4E-01	117	0.7	8.5E-14
20780	Minor Arterial(4)	2186	0	10:02 PM	2.0E-12	4.4E-02	2.4E-01	0	11.63	5.5E-12
17880	Minor Arterial(4)	120	14	10:02 PM	2.0E-12	4.4E-02	2.4E-01	14	10	6.0E-12
111000	Interstate(1)	727	522	10:03 PM	7.6E-12	3.5E-02	2.0E-01	522	37.26	2.0E-10
11000	Princ Arterial Other(3)	943	666	10:04 PM	2.0E-12	4.3E-02	2.4E-01	666	4.92	5.9E-11
91160	Interstate(1)	1048	494	10:05 PM	7.6E-12	3.5E-02	2.0E-01	494	30.6	1.8E-10
91160	Interstate(1)	1206	850	10:06 PM	7.6E-12	3.5E-02	2.0E-01	850	30.6	2.7E-10
91160	Interstate(1)	1264	161	10:07 PM	7.6E-12	3.5E-02	2.0E-01	161	30.6	9.0E-11
91160	Interstate(1)	1104	1468	10:07 PM	7.6E-12	3.5E-02	2.0E-01	1468	30.6	4.4E-10
48780	Princ Arterial Other(3)	7459	220	10:08 PM	7.6E-12	4.3E-02	2.4E-01	220	21.83	1.1E-10
31560	Princ Arterial Other(3)	533	726	10:09 PM	7.6E-12	4.3E-02	2.4E-01	726	14.12	2.6E-10
31560	Princ Arterial Other(3)	503	472	10:10 PM	7.6E-12	4.3E-02	2.4E-01	472	14.12	1.8E-10
31560	Princ Arterial Other(3)	492	552	10:11 PM	7.6E-12	4.3E-02	2.4E-01	552	14.12	2.0E-10
30160	Princ Arterial Other(3)	505	355	10:12 PM	7.6E-12	4.3E-02	2.4E-01	355	13.5	1.4E-10
2850	Major Collector(5)	163	175	10:13 PM	2.6E-14	4.4E-02	2.4E-01	175	2.39	2.1E-13
2850	Major Collector(5)	34	48	10:13 PM	2.6E-14	4.4E-02	2.4E-01	48	2.39	7.0E-14
27840	Princ Arterial Other(3)	4	15	10:14 PM	7.6E-12	4.3E-02	2.4E-01	15	12.46	2.7E-11
27840	Princ Arterial Other(3)	20	154	10:15 PM	7.6E-12	4.3E-02	2.4E-01	154	12.46	7.2E-11
27850	Princ Arterial Other(3)	425	281	10:16 PM	7.6E-12	4.3E-02	2.4E-01	281	12.46	1.1E-10
27130	Princ Arterial Other(3)	129	70	10:17 PM	7.6E-12	4.3E-02	2.4E-01	70	12.14	4.4E-11
27130	Princ Arterial Other(3)	514	176	10:18 PM	7.6E-12	4.3E-02	2.4E-01	176	12.14	7.8E-11
28160	Princ Arterial Other(3)	572	97	10:18 PM	7.6E-12	4.3E-02	2.4E-01	97	12.6	5.4E-11
21930	Princ Arterial Other(3)	180	104	10:19 PM	2.0E-12	4.3E-02	2.4E-01	104	9.81	1.4E-11
21930	Princ Arterial Other(3)	588	563	10:20 PM	2.0E-12	4.3E-02	2.4E-01	563	9.81	5.3E-11

PRETT TEST APP RESULTS					
PofE	CofP	CofA	EofP	EofA	Risk
1.6E-14	4.4E-02	2.4E-01	18	0.70	1.5E-14
1.6E-14	4.4E-02	2.4E-01	117	0.70	8.5E-14
2.0E-12	4.4E-02	2.4E-01	0	11.63	5.6E-12
2.0E-12	4.4E-02	2.4E-01	14	10.00	6.0E-12
7.6E-12	3.5E-02	2.0E-01	522	37.26	2.0E-10
2.0E-12	4.3E-02	2.4E-01	666	4.92	5.9E-11
7.6E-12	3.5E-02	2.0E-01	494	30.60	1.8E-10
7.6E-12	3.5E-02	2.0E-01	850	30.60	2.7E-10
7.6E-12	3.5E-02	2.0E-01	161	30.60	9.0E-11
7.6E-12	3.5E-02	2.0E-01	1468	30.60	4.4E-10
7.6E-12	4.3E-02	2.4E-01	220	21.83	1.1E-10
7.6E-12	4.3E-02	2.4E-01	726	14.13	2.6E-10
7.6E-12	4.3E-02	2.4E-01	472	14.13	1.8E-10
7.6E-12	4.3E-02	2.4E-01	552	14.13	2.0E-10
7.6E-12	4.3E-02	2.4E-01	355	13.50	1.4E-10
2.6E-14	4.4E-02	2.4E-01	175	2.39	2.2E-13
2.6E-14	4.4E-02	2.4E-01	48	2.39	7.0E-14
7.6E-12	4.3E-02	2.4E-01	15	12.46	2.7E-11
7.6E-12	4.3E-02	2.4E-01	154	12.46	7.2E-11
7.6E-12	4.3E-02	2.4E-01	425	12.46	1.1E-10
7.6E-12	4.3E-02	2.4E-01	70	12.14	4.4E-11
7.6E-12	4.3E-02	2.4E-01	176	12.14	7.8E-11
7.6E-12	4.3E-02	2.4E-01	97	12.60	5.4E-11
2.0E-12	4.3E-02	2.4E-01	104	9.82	2.0E-11

Appendix B – GUI Tests

1. Product Startup tests.

Tester Name: E. Montgomery
PRET-T Version: V0.4.4

	Workflow	Expected Result	7/6 Results	7/10 Results
a.	Double click on product.	Map and User Input form displays.	✔	✔
b.	Click on the Maximize screen button.	Window fills the screen.	✔	✔
c.	Click +/- arrows to zoom in/out/pan map.	Map zooms in/out/pans.	✔	✔
d.	Minimize the zoom screen in the top right corner.	Screen is minimized and shows only an arrow to expand.	✔	✔
e.	Move around windows.	Windows are moveable and can be dragged to different positions on screen.	✔	✔

2a. Map and User Input form tests.

Tester Name: E. Montgomery
PRET-T Version: V0.4.4

Setup: Start PRET-T with a new scenario.

The following table shows the test data used in this scenario.

User Inputs	Test Data
Start Address	4950 Research Dr NW, Huntsville, AL
Destination Address	29 Paddle Wheel Drive, Guntersville, AL
Truck Type	Van Truck
Explosive Type	HD 1.1
Quantity	0/100.5/1/7500/14999/15000/20000
Start Date	07/06/2020
Start Time	5:00:00

	Workflow	**Expected Results**	**7/6 Results**	**7/10 Results**
a.	Enter an address in the "Enter Starting Location" field.	Software should assist with address. Starting address displays in the field.	✔	✔
b.	Enter an address in the "Enter Ending Location" field.	Software should assist with address. Destination address displays in the field.	✔	✔
c.	Click on drop down for Truck type.	Verify that all truck types are listed (van truck, tractor trailer truck, bulk tank truck).	✔	✔
d.	Select Van Truck from the drop-down box.	Verify that the correct truck type is selected.	✔	✔
e.	Click on drop down for Explosive type.	Verify that all hazard division types are listed. (HD1.1, HD1.5, HD5.1)	✔	✔
f.	Select a HD1.1 from the drop-down box.	Verify that HD 1.1 is selected.	✔	✔
g.	Type 0 in the Quantity field.	Message box should appear that the value is invalid.	✔	✔
h.	Type 100.5 in the Quantity field.	Message box should appear that the value is invalid.	Unhandled exception has occurred in your application. Input string was not in a correct format.	✔ Previous error has been fixed.
i.	Type 20,000 in the Quantity field.	Message box should appear that the value is invalid.	Fail. Van truck cannot carry this much load.	✔ Previous error has been fixed.
j.	Type 1 in the Quantity field.	Verify that the correct number is shown in the field.	A value entered must be greater than 100 pounds.	✔ Previous error has been fixed.
k.	Type 7,500 in the Quantity field.	Verify that the correct number is shown in the field.	✔	✔
l.	Type 14,999 in the Quantity field.	Verify that the correct number is shown in the field.	✔	✔

	Workflow	Expected Results	7/6 Results	7/10 Results
m.	Type 15,000 in the Quantity field.	Verify that the correct number is shown in the field.	✓	✓
n.	Enter the start date.	Verify that the correct date is shown.	✓	✓
o.	Enter the start time.	Verify that the correct time is shown.	✓	✓

3a. Output tests.

Tester Name: E. Montgomery

PRET-T Version: V0.4.4

Setup: In this test, the tester should be proceeding directly from Test 2a. The Main Dialog box should be displayed at this time.

	Workflow	Expected Result	7/6 Result	7/10 Results
a.	Press the "Routes" button.	Verify that the map is shown with colored routes from the starting address to the destination address.	✓	✓
		Verify "Route Maneuver Points" file is created.	✓	✓
b.	Press the "Risks" button.	Verify that the pinpoints are color-coded to show the risk per segment for each path.	✓	✓
		Verify that the total risk value for each of the routes is shown.	✓	✓
		Verify that the risk legend showing the color code for the risk values is shown.	✓	✓
		Verify "Risk Outputs" file is created.	✓	✓
c.	Press the "Export" button.	Verify window appears for file saving.	✓	✓
		Verify message box appears confirming file was saved.	✓	✓
	Press "Yes" to open the file.	Verify file opens in Excel.	✓	✓

2b. Map and User Input form tests.

Tester Name: E. Montgomery
PRET-T Version: V0.4.4

Setup: Start PRET-T with a new scenario.

The following table shows the test data used in this scenario.

User Inputs	Test Data
Start Address	Urbana, Illinois
Destination Address	Lafayette, Indiana
Truck Type	Bulk Tank Truck
Explosive Type	HD 1.5
Quantity	0/1000.5/1/22500/44999/45000/50000
Start Date	07/06/2020
Start Time	10:00:00

	Workflow	Expected Results	7/6 Results	7/10 Results
a.	Enter an address in the "Enter Starting Location" field.	Software should assist with address. Starting address displays in the field.	✔	✔
b.	Enter an address in the "Enter Ending Location" field.	Software should assist with address. Destination address displays in the field.	✔	✔
c.	Click on drop down for Truck type.	Verify that all truck types are listed (van truck, tractor trailer truck, bulk tank truck).	✔	✔
d.	Select Bulk Tank Truck from the drop-down box.	Verify that the correct truck type is selected.	✔	✔
e.	Click on drop down for Explosive type.	Verify that all hazard division types are listed. (HD1.1, HD1.5, HD5.1)	✔	✔
f.	Select a HD1.5 from the drop-down box.	Verify that HD 1.5 is selected.	✔	✔
g.	Type 0 in the Quantity field.	Message box should appear that the value is invalid.	✔	✔

	Workflow	Expected Results	7/6 Results	7/10 Results
h.	Type 1000.5 in the Quantity field.	Message box should appear that the value is invalid.	Unhandled exception has occurred in your application. Input string was not in a correct format.	✔ Previous error has been fixed.
i.	Type 50000 in the Quantity field.	Message box should appear that the value is invalid.	Fail. Van truck cannot carry this much load.	✔ Previous error has been fixed.
j.	Type 1 in the Quantity field.	Verify that the correct number is shown in the field.	A value entered must be greater than 100 pounds.	✔ Previous error has been fixed.
k.	Type 22500 in the Quantity field.	Verify that the correct number is shown in the field.	✔	✔
l.	Type 44999 in the Quantity field.	Verify that the correct number is shown in the field.	✔	✔
m.	Type 45000 in the Quantity field.	Verify that the correct number is shown in the field.	✔	✔
n.	Enter the start date.	Verify that the correct date is shown.	✔	✔
o.	Enter the start time.	Verify that the correct time is shown.	✔	✔

3b. Output tests.

Date: 07/06/2020
Tester Name: E. Montgomery
PRET-T Version: V0.4.4

Setup: In this test, the tester should be proceeding directly from Test 2b. The Main Dialog box should be displayed at this time.

	Workflow	Expected Result	7/6 Result	7/10 Result
a.	Press the "Routes" button.	Verify that the map is shown with colored routes from the starting address to the destination address.	✔	✔
		Verify "Route Maneuver Points" file is created.	✔	✔

	Workflow	Expected Result	7/6 Result	7/10 Result
b.	Press the "Risks" button.	Verify that the pinpoints are color-coded to show the risk per segment for each path.	✔	✔
		Verify that the total risk value for each of the routes is shown.	✔	✔
		Verify that the risk legend showing the color code for the risk values is shown.	✔	✔
		Verify "Risk Outputs" file is created.	✔	✔
c.	Press the "Export" button.	Verify window appears for file saving.	✔	✔
		Verify message box appears confirming file was saved.	✔	✔
	Press "Yes" to open the file.	Verify file opens in Excel.	✔	✔

2c. Map and User Input form tests.

Tester Name: E. Montgomery
PRET-T Version: V0.4.4

Setup: Start PRET-T with a new scenario.

The following table shows the test data used in this scenario.

User Inputs	Test Data
Start Address	Charlotte, NC
Destination Address	Charleston, SC
Truck Type	Tractor Trailer Truck
Explosive Type	HD 5.1
Quantity	0/10000.5/1/40000/79999/80000/100000
Start Date	07/06/2020
Start Time	21:00:00

	Workflow	Expected Results	7/6 Results	7/10 Results
a.	Enter an address in the "Enter Starting Location" field.	Software should assist with address. Starting address displays in the field.	✔	✔

	Workflow	Expected Results	7/6 Results	7/10 Results
b.	Enter an address in the "Enter Ending Location" field.	Software should assist with address. Destination address displays in the field.	✔	✔
c.	Click on drop down for Truck type.	Verify that all truck types are listed (van truck, tractor trailer truck, bulk tank truck).	✔	✔
d.	Select Tractor Trailer Truck from the drop-down box.	Verify that the correct truck type is selected.	✔	✔
e.	Click on drop down for Explosive type.	Verify that all hazard division types are listed. (HD1.1, HD1.5, HD5.1)	✔	✔
f.	Select a HD 5.1 from the drop-down box.	Verify that HD 5.1 is selected.	✔	✔
g.	Type 0 in the Quantity field.	Message box should appear that the value is invalid.	✔	✔
h.	Type 10000.5 in the Quantity field.	Message box should appear that the value is invalid.	Unhandled exception has occurred in your application. Input string was not in a correct format.	✔ Previous error has been fixed.
i.	Type 100000 in the Quantity field.	Message box should appear that the value is invalid.	Fail. Van truck cannot carry this much load.	✔ Previous error has been fixed.
j.	Type 1 in the Quantity field.	Verify that the correct number is shown in the field.	A value entered must be greater than 100 pounds.	✔ Previous error has been fixed.
k.	Type 40000 in the Quantity.	Verify that the correct number is shown in the field.	✔	✔
l.	Type 79999 in the Quantity field.	Verify that the correct number is shown in the field.	✔	✔
m.	Type 80000 in the Quantity field.	Verify that the correct number is shown in the field.	✔	✔
n.	Enter the start date.	Verify that the correct date is shown.	✔	✔

	Workflow	Expected Results	7/6 Results	7/10 Results
o.	Enter the start time.	Verify that the correct time is shown.	✓	✓

3c. Output tests.

Tester Name: E. Montgomery
PRET-T Version: V0.4.4

Setup: In this test, the tester should proceed directly from Test 2c. The Main Dialog box should be displayed at this time.

	Workflow	Expected Result	7/6 Result	7/10 Results
a.	Press the "Routes" button.	Verify that the map is shown with colored routes from the starting address to the destination address.	✓	✓
		Verify "Route Maneuver Points" file is created.	✓	✓
b.	Press the "Risks" button.	Verify that the pinpoints are color-coded to show the risk per segment for each path.	✓	✓
		Verify that the total risk value for each of the routes is shown.	✓	✓
		Verify that the risk legend showing the color code for the risk values is shown.	✓	✓
		Verify "Risk Outputs" file is created.	✓	✓
c.	Press the "Export" button.	Verify window appears for file saving.	✓	✓
		Verify message box appears confirming file was saved.	✓	✓
	Press "No" to file open.	Verify message box disappears and returns to main UI.	✓	✓

Date: 9/2/20
Tester Name: E. Montgomery
PRET-T Version: V0.5.

Product Start Up

	Workflow	Expected Result	Actual Result
a.	Double click on the PRETT icon.	Splash screen appears.	Fail.
		Map display appears.	✔
b.	Right click and open PRETT.	Splash screen appears.	Fail.
		Map display appears.	✔
c.	Click on the Maximize window button.	Window fills the screen.	✔
d.	Click on the Minimize window button.	Window minimizes.	✔
e.	Click +/- arrow to zoom in/out/move map.	Map zooms in/out/pans.	✔
f.	Minimize the zoom screen in the top right corner.	Screen is minimized and shows only an arrow to expand.	✔
g.	Move around windows/place in different spot.	Small menu appears for you to decide where to place the panels.	✔

User Inputs	Test Data
Start address	4950 Research Dr NW, Huntsville, AL 35805
Destination Address	29 Paddle Wheel Dr, Guntersville, AL
Truck Type	Van Truck
Explosives Type	HD 1.5
Explosives Quantity	0/17000/10000
Start Date	9/1/2020
Start Time	22:00:00

User Input Form and Outputs

	Workflow	Expected Result	Actual Result
a.	Enter an address into the "Enter Starting Location" field.	Software should assist with the address. Starting address displays in the field.	✔

	Workflow	Expected Result	Actual Result
b.	Enter an address into the "Enter Ending Location" field.	Software should assist with the address. Starting address displays in the field.	✓
c.	Click on the drop-down arrow for Truck Type.	Verify that all truck types are listed (van truck, bulk tank truck, tractor trailer).	✓
d.	Select Van truck from the drop-down menu.	Verify that Van truck is the selected item in the field.	✓
e.	Click on the drop-down arrow for Explosive type.	Verify that all hazard division types are listed (HD 1.1, HD 1.5, HD 5.1).	✓
f.	Select HD 1.1 from the drop-down menu.	Verify that HD 1.1 is the selected item in the field.	✓
g.	Type 0 in the Quantity field.	0 is typed in the quantity.	✓
h.	Enter the start date.	Verify start date is 9/1/2020.	✓
i.	Enter the start time.	Verify start time is 12:00:00.	✓
j.	Click on the "Routes" button.	Error message should appear that the explosive quantity entered is invalid.	✓
k.	Type 17000 in the Quantity field.	17000 is in the quantity field.	✓
l.	Click on the "Routes" button.	Error message should appear that the explosive quantity entered is invalid.	✓
m.	Type 10000 in the Quantity field.	10000 is in the quantity field.	✓
n.	Click on the "Routes" button.	Verify that the map is shown with colored routes from the starting address to the destination address.	✓
		Verify "Route Maneuver Points" grid fills in data.	✓
o.	Press "Risks" button.	Verify that the Risk Legend is shown.	✓
		Verify that the pin points are color coded to show the risk per segment for each path.	✓
		Verify that the total risk value for each of the routes is shown.	✓
		Verify the "Risk Assessment" grid is populated with data.	✓

	Workflow	Expected Result	Actual Result
p.	Press "Export" button.	Verify a window appears for file saving.	✔
		Message box appears confirming successful file save and asks if you want to open the file.	✔
q.	Press "Yes" to open the file.	Verify file opens in Excel.	✔

Date: 9/8/20
Tester Name: E. Montgomery
PRET-T Version: V1.0

Product Start Up

	Workflow	Expected Result	Actual Result
a.	Disconnect from internet and open PRET-T.	Error appears and tells you to connect to a network.	✔
b.	Click "OK" and close PRET-T.	PRET-T opens with all panels blank and closes.	✔
c.	Double click on PRET-T.	Splashscreen appears with current version and data.	✔
		Map display appears.	✔
d.	Click on the Maximize screen button.	Window fills the screen.	✔
e.	Click on the Maximize screen button.	Window minimizes.	✔
f.	Click the +/- arrows to zoom in/out/move map	Map zooms in/out/pans	✔
g.	Minimize the zoom screen in the top right corner	Screen is minimized and shows only an arrow to expand.	✔
h.	Move around windows/place in different spot	Moveable windows.	✔

User Inputs	Test Data
Start address	4950 Research Dr. NW, Huntsville, AL
Destination address	29 Paddle Wheel Dr, Guntersville, AL
Truck Type	Van Truck
Explosives Type	HD 1.1

User Inputs	Test Data
Explosives Quantity	0/17000/10000
Start Date	9/8/2020
Start Time	12:00:00

User Input Form and Outputs

	Workflow	Expected Result	Actual Result
a.	Enter an address into the "Enter Starting Location" field.	Software should assist with the address. Starting address displays in the field.	✔
b.	Enter an address into the "Enter Ending Location" field.	Software should assist with the address. Starting address displays in the field.	✔
c.	Click on the drop-down arrow for Truck Type.	Verify that all truck types are listed (van truck, bulk tank truck, tractor trailer).	✔
d.	Select Van truck from the drop-down menu.	Verify that Van truck is the selected item in the field.	✔
e.	Click on the drop-down arrow for Explosive type.	Verify that all hazard division types are listed (HD 1.1, HD 1.5, HD 5.1).	✔
f.	Select HD 1.1 from the drop-down menu.	Verify that HD 1.1 is the selected item in the field.	✔
g.	Type 0 in the Quantity field.	0 is typed in the quantity.	✔
h.	Enter the start date.	Verify start date is 9/8/2020.	✔
i.	Enter the start time.	Verify start time is 12:00:00.	✔
j.	Click on the "Routes" button.	Error message should appear that the explosive quantity entered is invalid.	✔
k.	Type 17000 in the Quantity field.	17000 is in the quantity field.	✔
l.	Click on the "Routes" button.	Error message should appear that the explosive quantity entered is invalid.	✔
m.	Type 10000 in the Quantity field.	10000 is in the quantity field.	✔
n.	Click on the "Routes" button.	Verify that the map is shown with colored routes from the starting address to the destination address.	✔

	Workflow	Expected Result	Actual Result
		Verify "Route Maneuver Points" grid fills in data.	✔
o.	Press "Risks" button.	Verify that the Risk Legend is shown.	✔
		Verify that the pin points are color coded to show the risk per segment for each path.	✔
		Verify that the total risk value for each of the routes is shown.	✔
		Verify the "Risk Assessment" grid is populated with data.	✔
p.	Press "Export" button.	Verify a window appears for file saving.	✔
		Message box appears confirming successful file save and asks if you want to open the file.	✔
q.	Press "Yes" to open the file.	Verify file opens in Excel.	✔

Appendix C – Integration Test Cases

	State	Starting Location	Destination Location	Tested
1.	Alabama	4950 Research Dr NW, Huntsville, AL	29 Paddle Wheel Dr, Guntersville, AL	Yes
2.	Delaware	Holts Landing Rd, Dagsboro, DE	Taylor Landing Rd, Girdletree, MD	Yes
3.	Florida	4607 State Park Ln, Panama City, FL	101 State St W, Jacksonville, FL	Yes
4.	Georgia	139 Kimsey St, Blairsville, GA	Herring Pkwy, Alpharetta, GA	Yes
5.	Illinois	210 N Central Ave, Urbana, IL	2100 US-231, Crawfordsville, IN	Yes
6.	Indiana	2100 US-231, Crawfordsville, IN	210 N Central Ave, Urbana, IL	Yes
7.	Kentucky	I-64, Lexington, KY	OH-126, Cincinnati, OH	Yes
8.	Maryland	Taylor Landing Rd, Girdletree, MD	Holts Landing Rd, Dagsboro, DE	Yes
9.	Mississippi	MS-14, Kosciusko, MS	I-240, Memphis, TN	Yes
10.	New Jersey	I-95, East Brunswick, NJ	Lakeville Rd, Lake Success, NY	Yes
11.	New York	Lakeville Rd, Lake Success, NY	I-95, East Brunswick, NJ	Yes
12.	North Carolina	5501 Josh Birmingham Pkwy, Charlotte, NC	100 Tower Dr, Greenville, SC	Yes
13.	Ohio	OH-126, Cincinnati, OH	I-64, Lexington, KY	Yes
14.	Pennsylvania	Ridge Rd, Elizabethtown, PA	I-70, Bedford, PA	Yes
15.	South Carolina	100 Tower Dr, Greenville, SC	5501 Josh Birmingham Pkwy, Charlotte, NC	Yes
16.	Tennessee	I-240, Memphis, TN	MS-14, Kosciusko, MS	Yes
17.	Virginia	I-95, Woodford, VA	I-395, Washington, DC	Yes
18.	Washington DC	I-395, Washington, DC	I-95, Woodford, VA	Yes
19.	West Virginia	I-64, Kenova, WV	US-19, Fayetteville, WV	Yes

1. Route Risk Test. This test used results from the FE 8 unit test. This test verified that the Risk was correctly summed.

Date: 9/4/2020
Tester Name: E. Montgomery
PRET-T Version: V0.5

Workflow	Expected Result	Actual Result
Run a route in PRET-T.	Routes appear.	✔
Calculate Risks.	Risk output appears.	✔
Export the file and open.	File opens in Excel.	✔
Using results from FE 8 unit test, look at the total Risk and verify that the Risk given by PRET-T and the risk calculated by using SUM in Excel are the same.	The sum of all post point risks should equal the total Risk calculated by PRET-T.	✔

2. Verify Validity Output Results. This test also stemmed from Unit Test FE 8 and 9. This test verified that the risk for each post point was displayed correctly in the Risk Assessment Grid and the pins were the correct color based on the legend.

Date: 9/4/2020
Tester Name: E. Montgomery
PRET-T Version: V0.5

Workflow	Expected Result	Actual Result
Run a route in PRET-T.	Routes appear.	✔
Calculate Risks.	Risk output appears.	✔
Select a sample of pins.		✔
Find them in the Risk Assessment Grid.		✔
Verify the color of the pin is the correct color based on its risk.	Pin is the color expected.	✔
Look at the Total Risk.		✔
Verify that it is the correct color in the legend.	Risk is assigned the correct color.	✔

Appendix D – Validation Test Cases

Date: 9/8/20
Tester Name: E. Montgomery
PRET-T Version: V1.0
GUI: V1.0 tested on 9/8/2020

Software Requirement	Test Reference	Validated
FE1: Starting Address	GUI Test Case a. Visual verification that user can enter starting address.	✔
FE1: Destination Address	GUI Test Case b. Visual verification that user can enter destination address.	✔
FE1: Truck type	GUI Test Case c-d. Visual verification that user can truck type via a combo box.	✔
FE1: Explosives type	GUI Test Case e-f. Visual verification that user can explosives type via a combo box.	✔
FE1: Explosive quantity	GUI Test Case g, k, m. Visual verification that user can enter the explosives quantity.	✔
FE1: Start time and date	GUI Test Case h-i. Visual verification that user can enter start time and date.	✔
FE2: Multiple paths are displayed from starting point to destination	GUI Test Case n. Visual verification that multiple paths are displayed.	✔
FE3: Define segments along each path.	GUI Test Case o. Visual verification that individual segments are color-coded for each path.	✔
FE4: Determine P_e for each undesired event type.	Unit Test FE4. Look at output results and verify P_e.	✔
FE5: Determine consequence for each segment.	Unit Test FE5. Look at output results and verify consequence.	✔
FE6: Determine exposure for each segment.	Unit Test FE6. Look at output results and verify exposure to population. Unit Test FE6. Look at output results and verify exposure to vehicles.	✔

Software Requirement	Test Reference	Validated
FE7: Calculate risk for a single segment.	Unit Test FE7. Look at output results and verify risk calculated by segment.	✔
FE8: Calculate risk for a single path.	Unit Test FE8 and Integration Test 1. Look at output results and verify risk calculated for a path.	✔
FE9: Calculate risk for each path	GUI Test Case o and Integration Test 2. Look at output results and verify risk calculated for each path.	✔
FE10: Define highest risk areas	GUI Test Case o. Look at output results and verify that segments along each path are color-coded.	✔
FE11: Present data in GUI.	GUI Test Case n-o. Visual verification results are displayed on Output screen.	✔

Appendix H – User's Manual

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A-P-T RESEARCH, INC.

COMPREHENSIVE TRANSPORTATION RISK MODEL DEVELOPMENT

Project #45 / TA-1

User Manual

Contract #: 693JK319C000009

COMPREHENSIVE TRANSPORTATION RISK MODEL DEVELOPMENT

USER MANUAL

CDTS-AL003-20-01100
Sept. 21, 2020

Prepared by:
A-P-T Research, Inc., 4950 Research Drive, Huntsville, AL 35805

Prepared for:
Pipeline and Hazardous Materials Safety Administration
Office of Hazardous Materials Safety
U.S. Department of Transportation
1200 New Jersey Ave., Washington, D.C. 20590

Contract Details:
Contract #: 693JK319C000009, Project #: 45

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ACRONYMS

AADT	Annual Average Daily Traffic
APT	A-P-T Research, Inc.
COTS	Commercial Off the Shelf
CSV	Comma-separated Value
DOT	Department of Transportation
FE	Functional Element
GIS	Geographic Information System
HD	Hazard Division
HM	Hazardous Material
MS	Microsoft
PHMSA	Pipeline and Hazardous Materials Safety Administration
PRA	Probabilistic Risk Assessment
PRET-T	Population Risk for Explosives Transport by Truck

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GLOSSARY

Maneuver points - list of directions for each route

Shapefile - a geospatial data format for use in geographic information system (GIS) software

Waypoint - an intermediate point on a route or line of travel

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1.0 Introduction

1.1 BACKGROUND: WHY WAS PRET-T DEVELOPED?

Under contract with the Department of Transportation (DOT) Pipeline and Hazardous Materials Safety Administration (PHMSA), A-P-T Research, Inc. (APT) developed a proof-of-concept transportation risk model for transporting explosives by truck.[1] This probabilistic risk assessment (PRA) tool, entitled Personnel Risk for Explosives Transportation by Truck (PRET-T) V1.0 was intended to be the first phase of a larger model that will assess risk of any hazmat by any transportation mode (truck, rail, air, water). The project requirements are for a modular tool with the ability to add functionality such as other hazardous materials (HM), consequences, models and transportation modes.

1.2 WHAT DOES PRET-T DO?

PRET-T is designed to calculate the risk to population when transporting explosives by truck via one or more routes. The tool first defines alternative routes using existing commercial off-the-shelf (COTS) methods. These routes are then subdivided into 1km segments and calculates the risk for each segment (r) before summing the risk into the trip risk (R). This tool is designed for use by dispatchers and risk managers to identify and reduce risk.

1.3 APPLICATIONS AND LIMITATIONS

PRET-T can be used to assess the risks associated with transporting explosives via truck.

PRET-T has a finite number of options for explosives types and truck types. It also limits the explosive quantity that the user can enter based on the truck type.

The intended use of the tool is to calculate relative risk and show higher risk areas. Since the model uses conservative assumptions, the model is not designed to define absolute risk.

1.4 WHO SHOULD USE PRET-T?

This tool can be used by industry, government, or municipalities to identify the safest route for trucks containing explosives.

Within industry, the primary users would be risk management and safety personnel as well as dispatchers.

1.5 PC SYSTEM REQUIREMENTS

The following are requirements for this software:

Operating System – Windows 10 64-bit
RAM – minimum 8GB, recommended 16 GB
Hard Drive space – Minimum 700 MB to install and run

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[1] Contract No. 693JK319C000009

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2.0 PRET-T Model Architecture

Figure 1 shows the architecture of PRET-T V1.0. Functional element (FE) 1 is user inputs. FE 2 defines the paths. FE 3 divides the paths into multiple evaluation points. FE 4-8 are internal calculations, and FE 9-11 are the display of output results. The architecture is designed in a modular form so that improvements can easily be incorporated into the model.
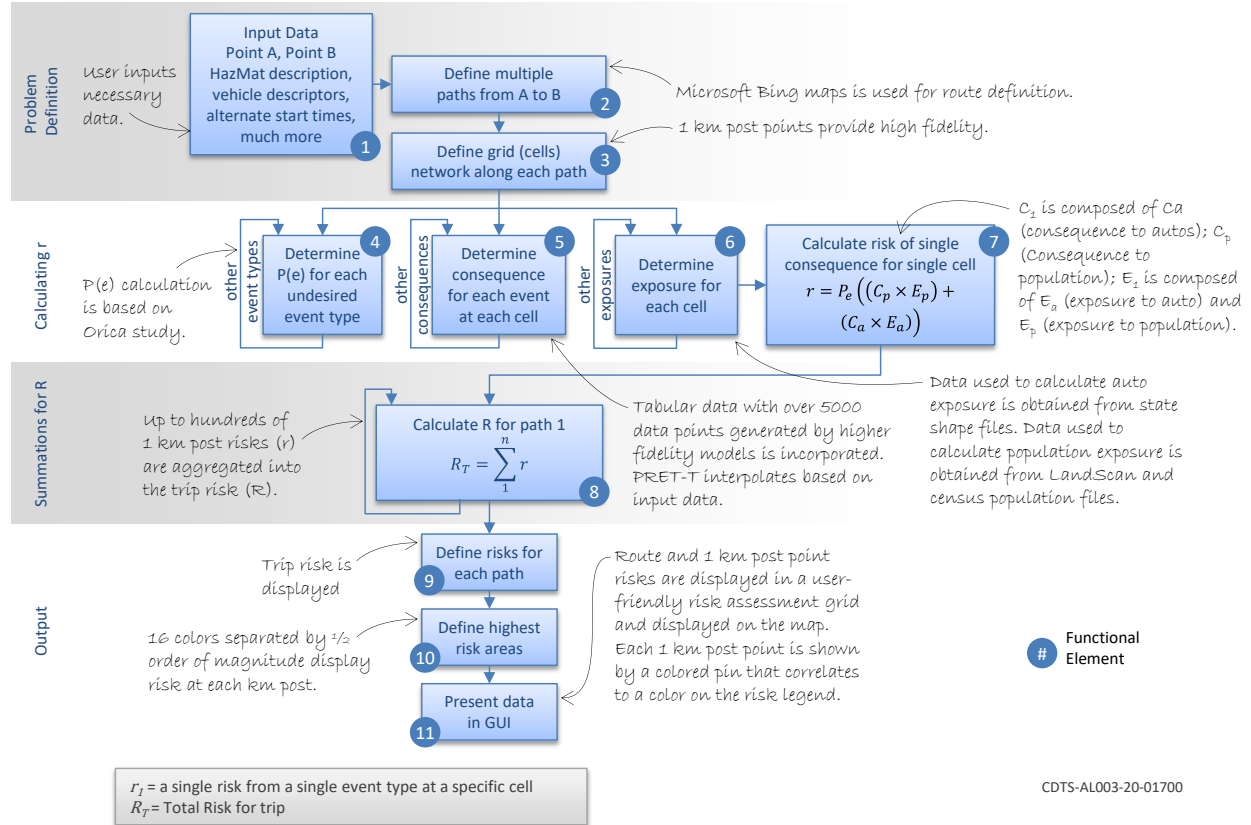

Figure 1: Transportation Risk Model Analysis Architecture. The "functional elements" are numbered.

This analysis accesses and obtains data from external third-party sources.

Microsoft Bing Maps is used when users have selected all inputs and clicked the Routes button. The software builds a query to send to Bing Maps to obtain route information given the source, destination, and optional waypoints. This is the only time that PRET-T obtains information from over the Internet. Up to four routes are generated as described later in this document.

The software uses embedded shapefiles to obtain Annual Average Daily Traffic (AADT) and the road type for specific latitude, longitude points. The software also queries LandScan and U.S. Census population files to extract population data for specific latitude, longitude points. U.S. Census population data is defined as nighttime, whereas LandScan data mixes day and nighttime population activity during nighttime hours (6 p.m. to 6 a.m.). The shapefiles and population files reside with the PRET-T installation and are accessed internal to the program.

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# 3.0 Steps Through PRET-T

3.1 DOWNLOADING THE SOFTWARE

The software will be shared to you by use of Google Drive. You will receive notification of the software via an email. The following are the steps you will take to download and run PRET-T.

Download Prett_V1_0.zip from Google Drive

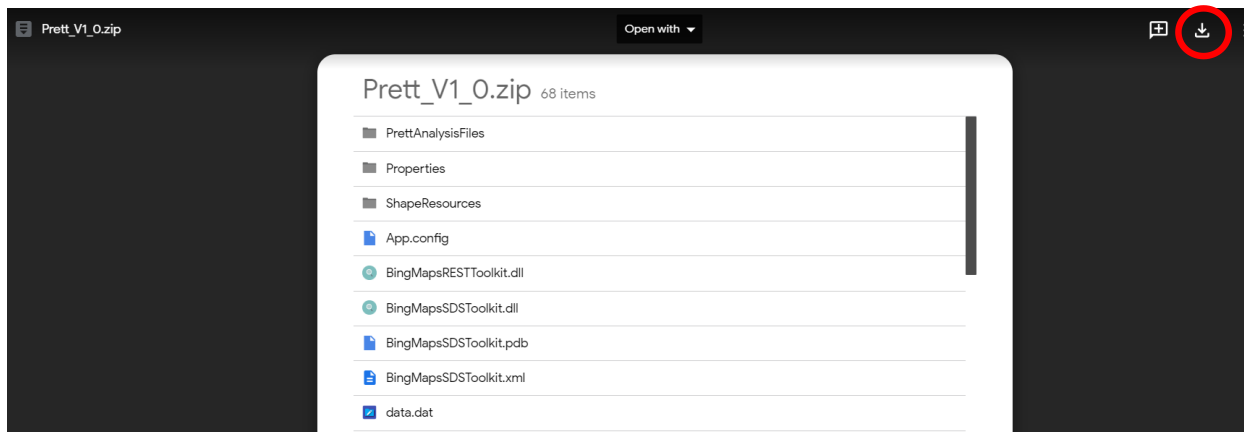1. Copy and paste this link into your browser:
https://drive.google.com/file/d/1JY2R3rhaMopOTj9YKr58kcEcb6Yhsp6P/view?usp=sharing

2. A message will display instructing you to request access to download the software. Click the "Request access" button.
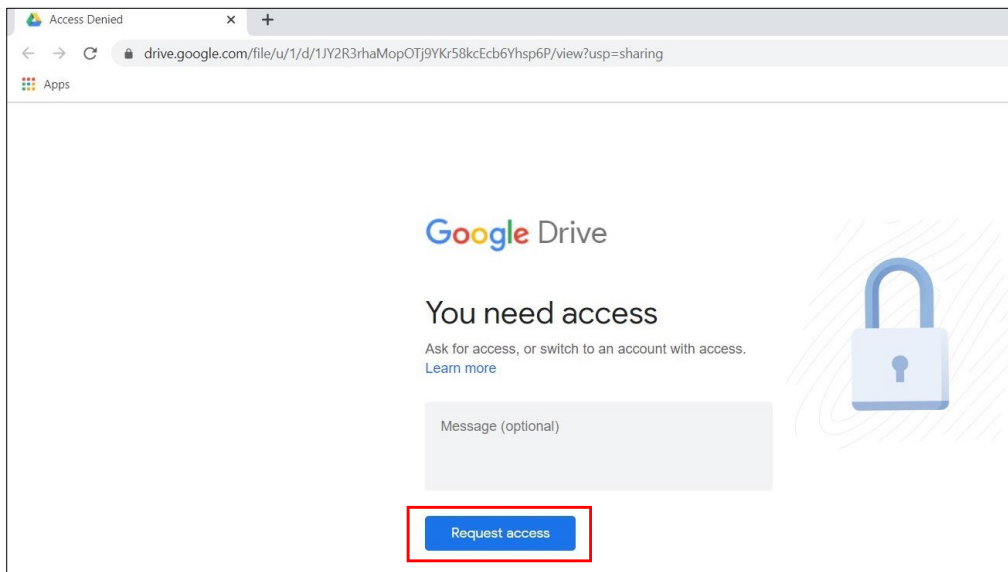
An email will be sent to the administrator to grant you access.

3. Once you have received an email that you have access, click the link in the email. The browser will display a screen similar to the following. Click the Download button indicated by the red circle.

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4. A message will display "Google Drive can't scan this file for viruses." This is OK. Click the "Download anyway" button.

5. Wait for the file to download to your Downloads folder. The browser can then be dismissed.

Extract PRETT V1.0

1. Go to your Downloads folder and locate the "Prett_V1_0" zip file.
2. Move it to the Documents folder (Right click and select Cut then navigate to the Documents folder and right click and select Paste).
3. Right click on the "Prett_V1_0" zip and select "Extract All". Select "Next" on the next form to extract PRET-T to the Prett_V1_0 folder under the Documents folder.

Create a PRET-T shortcut

1. Navigate to the Prett_V1_0 folder and locate the file "PrettV1_0" as shown below:

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This PC > Documents > Prett_V1_0

Name	Date modified	Type	Size
BingMapsSDSToolkit.dll	9/18/2020 2:59 PM	Application extens...	144 KB
BingMapsSDSToolkit.pdb	9/18/2020 2:59 PM	PDB File	324 KB
BingMapsSDSToolkit	9/18/2020 2:59 PM	XML Document	183 KB
data.dat	9/18/2020 2:59 PM	DAT File	1 KB
HTMLPage1	9/18/2020 2:59 PM	Microsoft Edge HT...	20 KB
log4net.dll	9/18/2020 2:59 PM	Application extens...	270 KB
log4net	9/18/2020 2:59 PM	XML Document	1,512 KB
Microsoft.Bcl.AsyncInterfaces.dll	9/18/2020 2:59 PM	Application extension	21 KB
Microsoft.Bcl.AsyncInterfaces	9/18/2020 2:59 PM	XML Document	18 KB
Newtonsoft.Json.dll	9/18/2020 2:59 PM	Application extens...	684 KB
Newtonsoft.Json	9/18/2020 2:59 PM	XML Document	692 KB
PrettMainForm.resx	9/18/2020 2:59 PM	RESX File	8 KB
PrettUserDataLog	9/18/2020 2:59 PM	Text Document	1 KB
PrettV1_0	9/18/2020 2:59 PM	Application	405 KB
PrettV1_0.exe	9/18/2020 2:59 PM	CONFIG File	5 KB
Splash	9/18/2020 2:59 PM	CS File	2 KB
Splash.Designer	9/18/2020 2:59 PM	CS File	4 KB
Splash.resx	9/18/2020 2:59 PM	RESX File	338 KB
System.Buffers.dll	9/18/2020 2:59 PM	Application extens...	21 KB
System.Buffers	9/18/2020 2:59 PM	XML Document	4 KB
System.Memory.dll	9/18/2020 2:59 PM	Application extens...	138 KB

2. Right click on it and choose "Create Shortcut". A file called "PrettV1_0 – Shortcut" will be created.

3. Drag and drop "PrettV1_0 – Shortcut" to the desktop.

4. Double click the shortcut to run PRET-T.

3.2   SETUP AND RUNNING PRET-T

To run PRET-T, double click the PRET-T V1.0 shortcut icon located on the desktop.

When the software first comes up, the map is centered on the Huntsville, AL, location. In order to center the map on a different location, locate the file called PrettV1_0.exe.config in the installation directory. You can edit the following parameters during the startup of the application to center the map on a different location:

- In the app Settings section:
    - CenterLatitude – initial latitude location the map will be centered on
    - CenterLongitude – initial longitude location the map will be centered on
- In the log4net appender section, you can change the location for logging. Usually, you will not need view this file. However, if the software generates an error, this file may be useful for the PRET-T developers to diagnose and fix the problem. You may be asked to provide this file when generating a bug report (described in Section 4.0.)
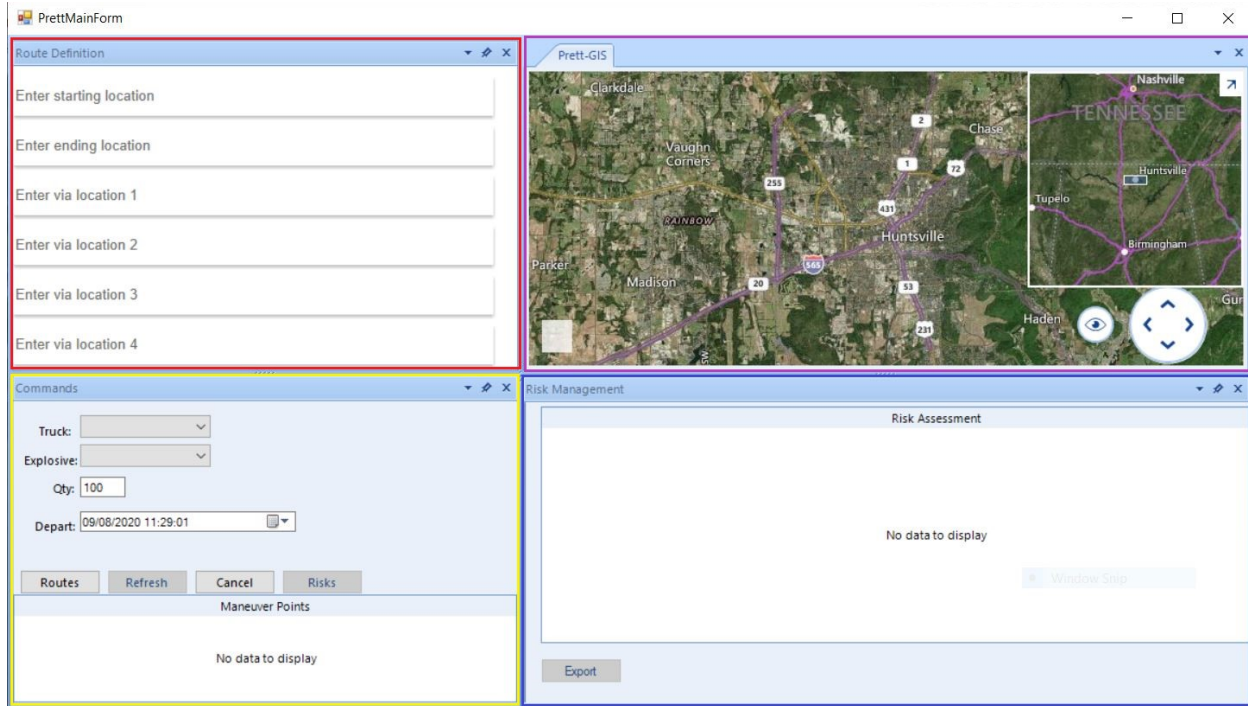
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- o In the PrettV1_0.exe.config file, locate the words <appender name="MyFileAppender".
- o On the next line, edit the "file value" full path and file name.

3.3 USER INTERFACE LAYOUT

The title bar displays the name of the product, PrettMainForm, and the minimize, maximize, and exit buttons are shown on the upper right.
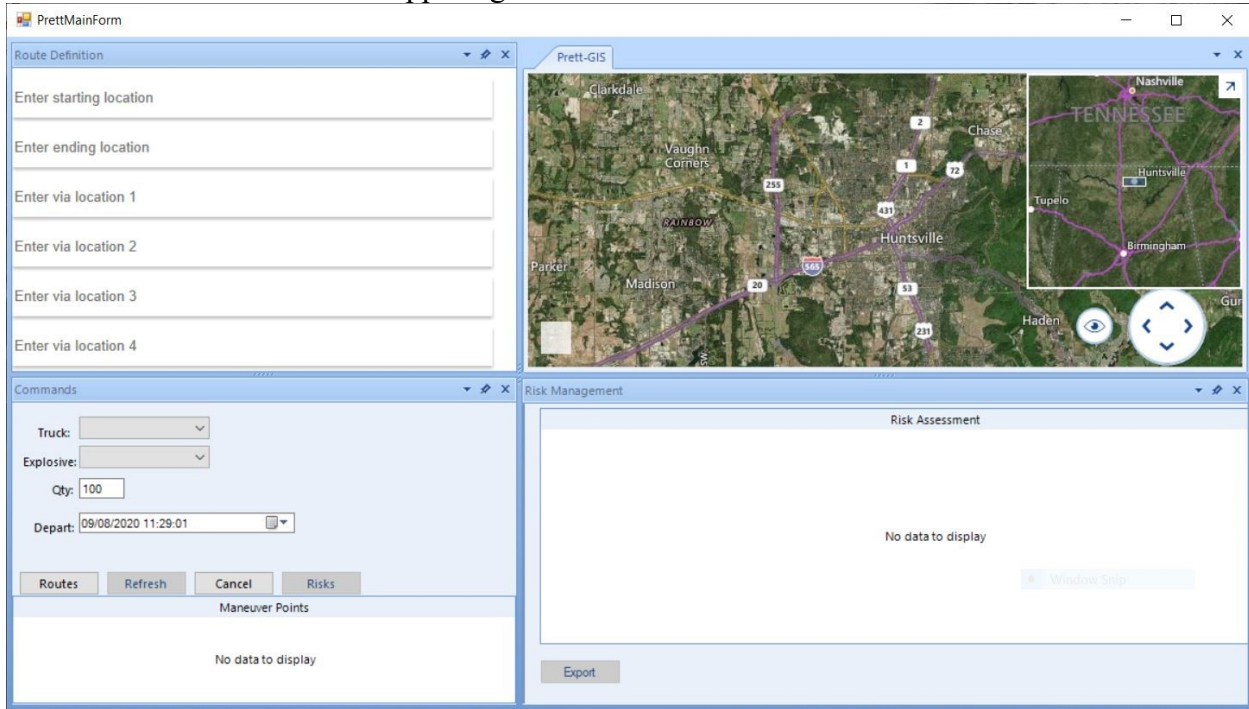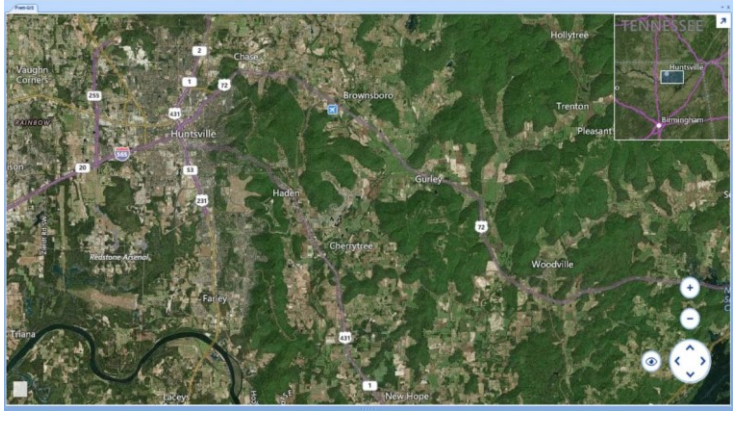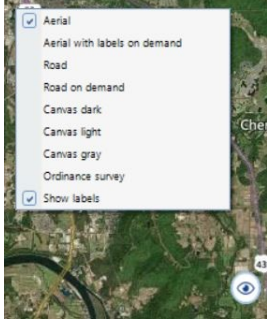

PRET-T is built using four dockable panels from which the user can manage the screen space and how they view PRET-T.

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These panels are:
1. Route Definition (outlined in red)
   - The users define the route to be generated. A starting and end location is required as a minimum. The user may also define up to four waypoints in addition to the start and end location.
2. Commands (outlined in yellow)
   - Truck type: Van Truck, Tractor Trailer, or Bulk Tank
   - Explosive: HD 1.1, HD 1.5, or HD 5.1
   - Quantity: The explosive quantity. See Section 3.4.5.
   - Departure date and time
   - Buttons
     o Routes – enabled
     o Refresh – not enabled. User will receive a message when clicking this button.
     o Cancel – This button may be clicked to generate new routes. After entering all the inputs and clicking "Routes," the user can cancel and re-enter inputs. After the "Risks" button is clicked, the cancel button is no longer operable.
     o Risks – available after routes have been generated
   - Maneuver Points
     o See Section 3.4.8
3. Risk Management (outlined in blue)
   - Risk Assessment Data Grid – See section 3.7
   - Buttons
     o Export – See Section 3.7
4. Prett – GIS (outlined in purple)

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The following graphics are all components of the Prett-GIS panel. Each of these components can change the view of the map display.

| Map display	
Map View Types	
Zoom in Zoom out Pan	
Location Box	

3.4 ROUTE GENERATION

To generate the routes, the user must first enter all the required inputs. Until the routes are generated, the Risks button is disabled. The user must generate routes before risks can be calculated.
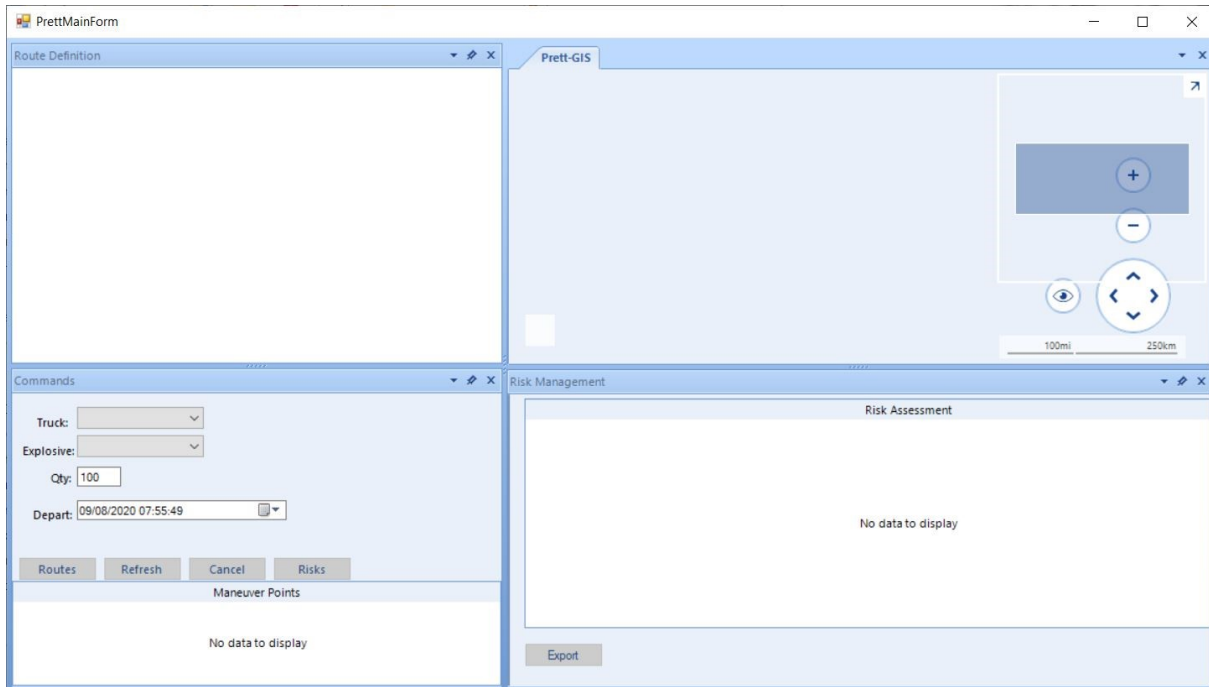
For PRET-T Version 1.0, it is recommended to limit routes to 200 miles or less due to the time it currently takes to gather all shapefile and population information and to calculate and display risks for each 1 km post point on all of the routes. The processing time is closely related to the distance of the route, the number of states the route travels through, and the amount of shapefile data for each state the route travels through.

3.4.1 Internet Connectivity

PRET-T needs internet to run properly. If your device is not connected to internet, you will receive the following error.
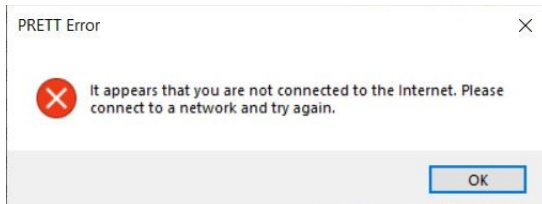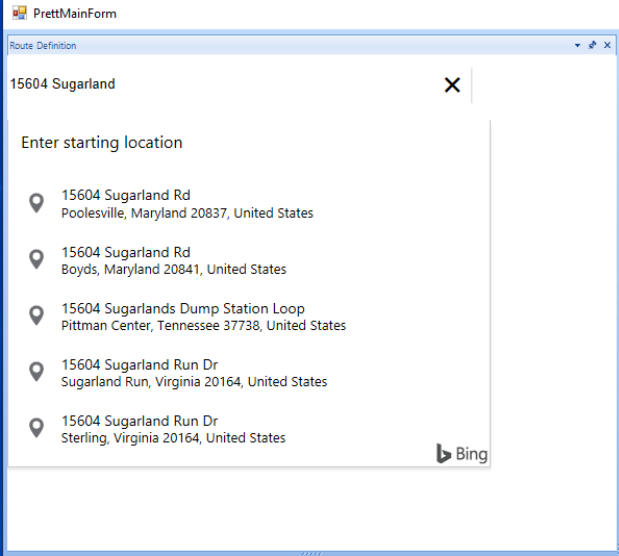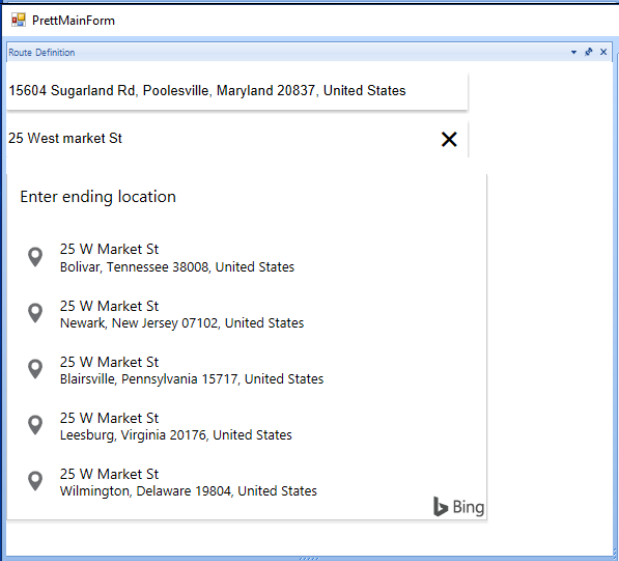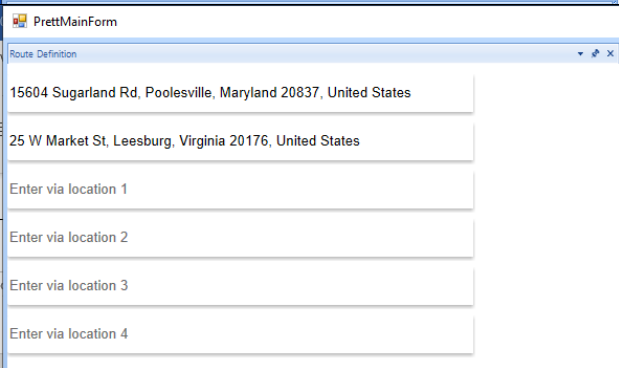

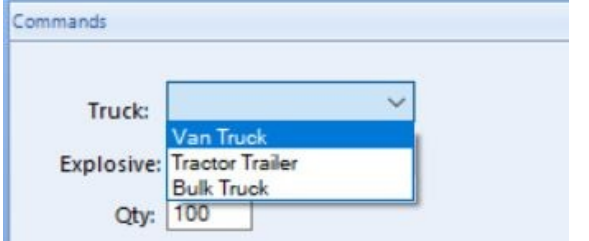After clicking "OK," PRET-T will open to the form below.

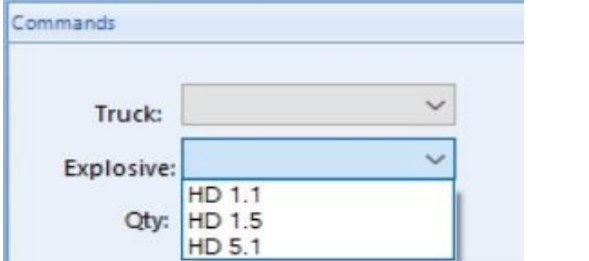You will then need to close out PRET-T, connect to a network, and reopen PRET-T.

3.4.2 Enter Addresses

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Enter the starting location. This entry should be an address. The software will assist the user in validating the address.	
Enter the destination location. This entry should be an address. The software will assist the user in validating the address.	
Optionally, the user can enter up to four waypoints on the route.	

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3.4.3 Select Truck Type

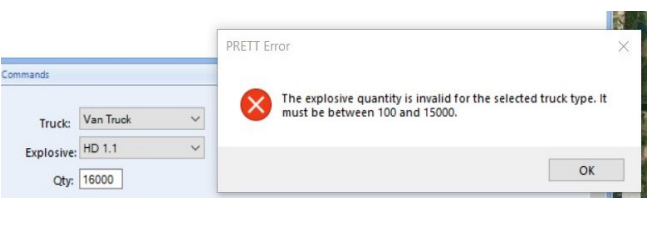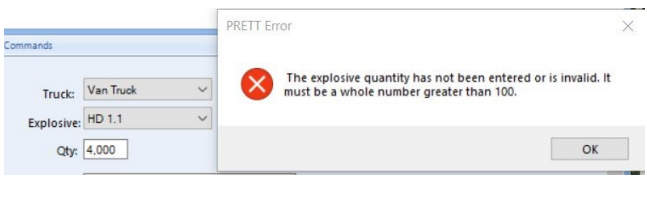| Select the truck type from the drop-down menu.	

3.4.4 Select Explosive Type

Select the explosive type from the drop-down menu.	

3.4.5 Enter Explosive Quantity
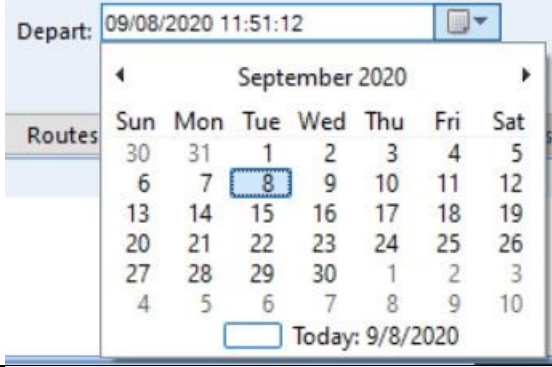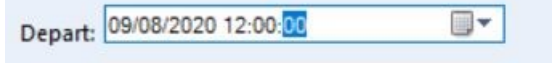
Enter the explosives quantity in pounds.
The following are valid inputs that each truck type can haul:
- Van Truck: 100 – 15,000 lbs.
- Bulk Tank: 100 – 45,000 lbs.
- Tractor Trailer: 100 – 80,000 lbs.

If explosive quantity is not valid for the truck type that was selected, an error message will be produced.	
When entering the quantity, commas and decimal points are not a valid format and will produce an error message.	

3.4.6 Select Departure Date and Time

Enter the date and time of when the trip is expected to start.

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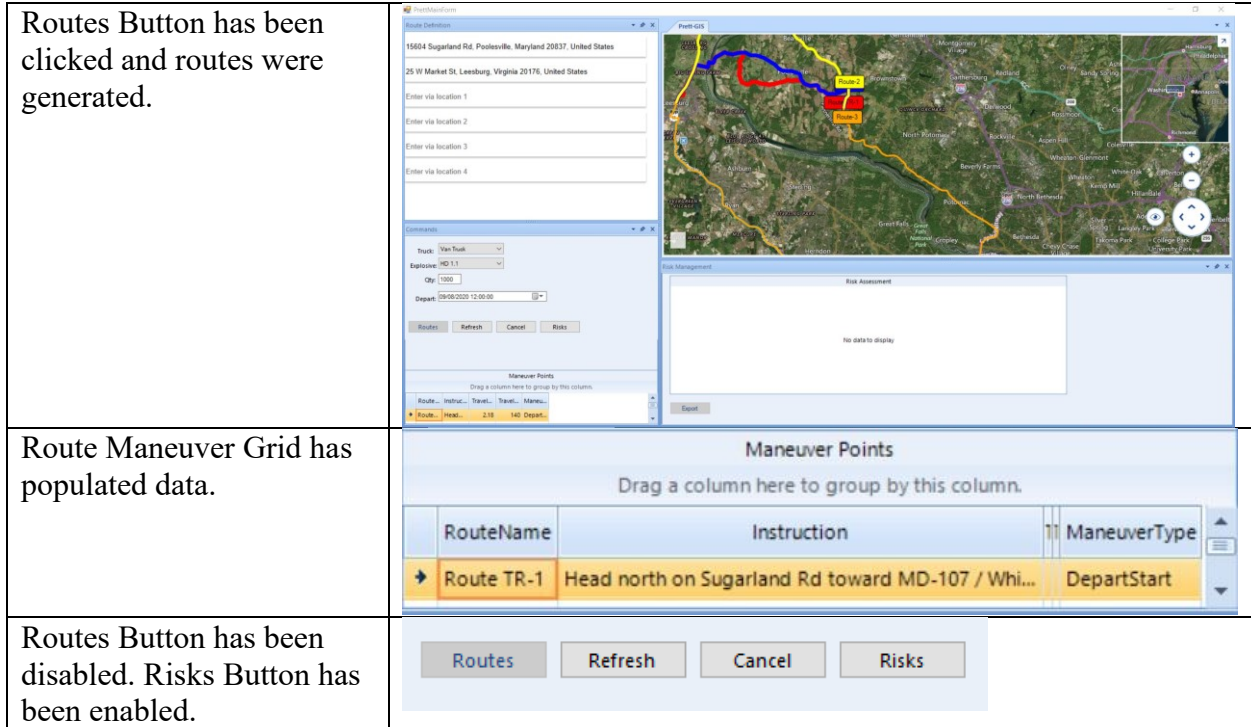|	
Select the drop-down arrow on the right. A calendar will appear for the user to select the day of departure.	
Select the time by highlighting the hour, minute, second and typing the time in each of those fields. The time is in military format; therefore, for times from 1:00 p.m. to 11:59 p.m., enter 13 – 23 for the hour. All time inputs are local times at the start location.	

3.4.7 Click Routes Button

After all required inputs are entered, the user can click the Routes button to generate the routes. PRET-T will usually provide a truck route and up to three auto routes. Routes will be generated based upon the number of addresses entered in the route definition. The following will be generated:

- Start and end location – up to four possible routes
- Start, End, and waypoint(s) – up to two possible routes

The routes are labeled and colored to make differentiating the routes easier. The truck route is labeled as "Route TR-1" and the other routes as "Route-1," "Route-2," etc. These labels are placed close to the source location. Users may have to zoom into the source location since the labels may be overlaid on each other. At this time, the Route Maneuver Points grid will be shown.

The Routes button will be disabled when the routes have been generated.

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Routes Button has been clicked and routes were generated.	
Route Maneuver Grid has populated data.	
Routes Button has been disabled. Risks Button has been enabled.	

3.4.8 Route Maneuver Grid

The Maneuver Points grid contains a list of directions for each route. This grid gives the instructions, the travel distance on each instruction, the duration of travel, and what type of maneuver you make (start/turn left/turn right/keep straight/arrive).

Users can drag the columns to expand and click on a column to sort.

3.5 RISK CALCULATIONS

After the routes have been generated, the Risks button will be enabled. After this button is clicked, the software begins calculating the risks for each segment for each route.

The software determines which shapefiles to use based on the states the route(s) travel through. For example, if the route starts in Philadelphia and ends in Baltimore, the shapefiles for Pennsylvania and Maryland and all states in between are loaded. Shapefiles contain attributes that can be extracted using a specific location, two of which are AADT and road type. These are used by the software to calculate risk factors. The software then divides the route into 1 km "post points," starting with 0.5 km from the source. The software uses each post point's latitude, longitude coordinate to determine its location in the shapefile. The software then extracts the AADT and road type from the shapefile given the post point.

Each state is responsible for collecting and maintaining road attribute data, and sometimes this information is not available for a given post point. In this case, the software runs an algorithm to assign a coherent AADT number and road type.

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For each 1 km post point, the software uses an external utility program to look up its corresponding population values in the LandScan and Census files.

3.5.1 Select Risks Button

When users click on the Risks button, the cursor will begin to rotate as the software gathers data and calculates the risks.
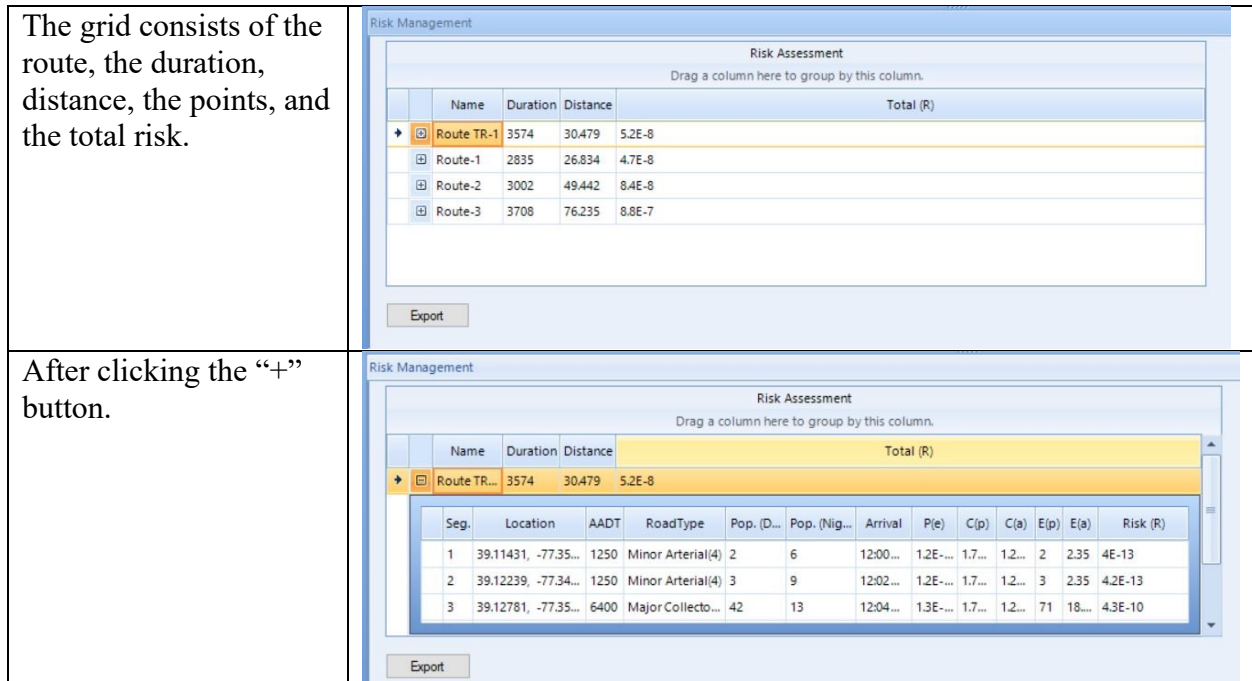
3.6 OUTPUT RESULTS INTERFACE

The following figure is the results of the Risk Assessment. There is now a Risk Assessment Levels Legend. Two items refer to this legend, the overall risk for each route and the post points pins. These pins correspond to each 1 km post point along each route. By hovering over a pin, users will see the routes the pin belongs to and the post point numbers. The post point number correlates to the Risk Assessment Grid at the bottom of the screen. Users can zoom in and out to further examine post points.
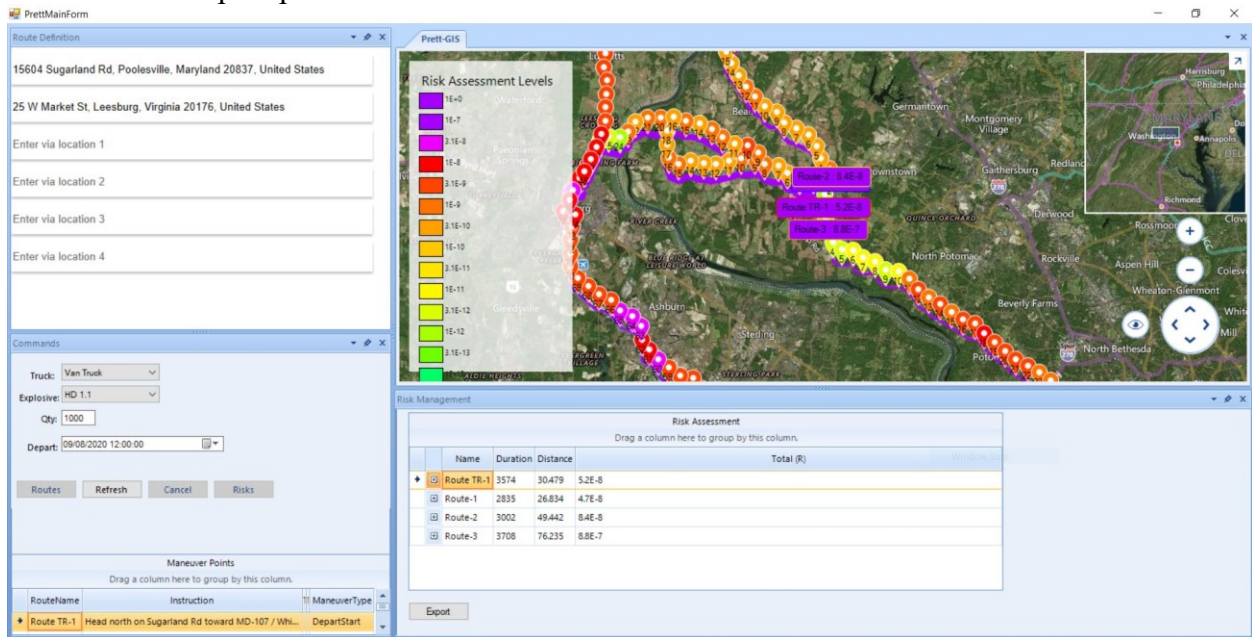
3.7 ANALYZING THE INITIAL RESULTS

To analyze the results, users can either click the "+" on the route they wish to examine or click the "Export" button to the right of the Risk Assessment grid to open as a comma-separated value (CSV) file in Excel.

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The grid consists of the route, the duration, distance, the points, and the total risk.	
After clicking the "+" button.	

The same columns are available in the export. Exporting makes examining the data a little easier.

3.8   MODIFYING ROUTE PARAMETERS

The routes are not modifiable. In order to generate new routes, the cancel button must be selected to re-initialize and at this point a new route can be generated.

Users must dismiss the software and start over in order to modify user inputs and run routes/risks again. Therefore, to compare risks from separate runs, data can be exported to Excel for comparison with initial results.

3.9   IDENTIFYING HOTSPOTS

An area of high risk associated with one or more 1 km post points can be evaluated by analyzing the appropriate row in the exported Excel. The data should provide indications that AADT or population, for example, is the risk driver.

3.10 CHANGING PARAMETERS

Currently, this is not a feature available in Version 1.0. Modifying any parameter in the user interface is outside the scope of Phase 1. The Excel file that can be exported only holds the values of the calculations and not the actual formulas for calculations. Therefore, there is no ability to recalculate the risk if the user wishes to modify AADT for example.

3.11 SEARCHING FOR MITIGATION METHODS

To search for risk mitigation methods, examine all parameters feeding the high-risk location. These "hot spots" are typically caused by AADT, population, time of day, explosives type, or explosives quantity. Varying these parameters may point to a means of mitigation. There is no

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ability to vary AADT or population. To vary the other parameters, users can run new routes and compare those results with the previous run.

4.0 Bug reporting/ Feedback

In order to provide the most efficient process for error reporting, APT has provided a Google Form link for the user to fill out. This form can be used for enhancements, bugs, documentation errors, or other issues you may encounter. Provide as much detail as possible on the feedback form.

https://docs.google.com/forms/d/e/1FAIpQLSesmeaHIUuZ9rb5bcM0J4HFfRB5n_Br39jo6Q9JB pllUIfRvw/viewform?usp=sf_link

https://forms.gle/bmG68EQ27gEUWgtc9