# Application of Spreadsheets to Standardize Transportation Radiological Risk Assessments*

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## INTRODUCTION

Because of the complexity, volume of data, and calculations required, one preferred analytical tool to perform transportation risk assessments is the RADTRAN computer code (RADTRAN, Neuhauser). RADTRAN combines user-determined material, packaging, transportation, demographic, and meteorological factors, with health physics data to calculate expected radiological consequences and accident risk from transporting radioactive materials by all commercial modes including truck, rail, ship, air, and barge. The computer code consists of two major modules for each transport mode: the incident-free module, in which doses from normal transport are calculated, and the accident module, in which dose consequences and probabilities are evaluated to generate risk estimates.

The RADTRAN input data structures and the resulting outputs may be extensive. Post-processing manipulations may be useful when analyzing complex shipping models. One method greatly automating the performance and standardization of transportation radiological risk assessments is the development of a series of consecutive, related spreadsheets which simplify the calculational processes and associated quality assurance.

The purpose of this presentation is to describe the development of a standardized procedure to perform transportation radiological risk assessments employing conventional spreadsheet programs to automate generation of RADTRAN input files and post-processing analysis of the resulting output. The series of spreadsheets described herein were initially developed chronologically during an actual transportation study. The presentation is similarly organized to additionally demonstrate direct application of the methodology. However, it is important to note the approach is general in nature, and the

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spreadsheets developed may be modified and applied to any transportation radiological risk assessment. Related beneficial aspects inherent in adoption of the procedure are discussed as such incidental features naturally arise during development of the spreadsheet methodology.

The sections that follow present an outline of a calculational scheme that can be used to perform risk calculations for a transportation environmental risk analysis. The outline discussed is not the only possible sequence. One early notable advantage of the described scheme is that the order of the calculational sequences is retained in the logic of the spreadsheet program. Should review of the calculational sequences be required after a period of time has elapsed, all step-by-step mathematical manipulations performed on the data are resident within the cells of the developed spreadsheets.

## DEVELOPMENT OF ROUTE DESCRIPTIONS

One of the first pieces of information necessary when performing an environmental analysis is a description of the routes that may be used in the transportation environmental analysis that is to be performed. This paper will deal with a single route as an example, but in actual analyses multiple shipment routes usually will be analyzed. The route description includes identification of the origin and destination of the shipment, the number of kilometers along the route between major geographic nodes, and the population density for each segment. In many cases, only the origin and destination pairs are initially known and a route is calculated using some sort of routing program. There are several routing programs available, and in order to determine the population densities along the route, it is necessary to combine government census data with the route description to obtain a population profile. Population densities may be grouped into three categories (rural, suburban and urban population density zones). It is also necessary to determine the number of full-load shipments that will occur along the route, and whether limitations (e.g. weight limits) would require partial loads for all or part of the shipments in order to develop an estimate of the expected total number of shipments. If several (or many) routes make up the transportation system description, then the process described above must be repetitively performed for each route. The information for each route can be loaded into a spreadsheet for record retention and later use in the risk analysis. The transport route description is divided into separate links each of which may have a different length, accident rate, vehicle velocity, and population density. Each link can be evaluated separately; the total route is then the composite of these links.

## MATERIAL FORM AND SHIPMENT DESCRIPTION

This section presents the information that describes the form of the radioactive material that is being transported. This information is used in the appropriate analysis code to evaluate the transportation incident-free dose and the accident risks. Radioactive material descriptive parameters include:

- Isotopic description of material form (number of isotopes, curies of each isotope)

- Material form (solid, powder, liquid, gas, and other physical-chemical properties)

- Source term (release fractions during accident conditions, percent aerosolized during accident conditions, etc.)

- Package to be used (Type A or Type B (shielding factors))

- The amount of material transported in each package ( kgs)

- The number of packages on the transport conveyance that comprises a full-load shipment, and known weight limits, curie limits, dose rate limits, etc.

The emphasis of this presentation is on route-related variables. It should be noted, however, that the source terms, which are highly package dependent, are developed from event trees, package test data, and other data not discussed here. Many packages have been analyzed by Sandia National Laboratories and these results are publicly available. The development of source-term values for new packages, however, is an undertaking the prospective analyst must identify as an essential early step in the risk assessment process.

## DEVELOPMENT OF RADTRAN INPUT FOR A SINGLE SHIPMENT - UNIT RISK METHOD

All of the transport data previously described can be assembled into the format required by a given analysis code. At Sandia National Laboratories, the RADTRAN code is customarily used in such calculations. The risk calculations can be performed for a single shipment for a single kilometer of travel, for each material form (if there are several) and for each population density zone. The output of these calculations represent unit consequences for incident-free transportation and unit risks for transport accident calculations.

The unit values for each material form and population density zone described above may be used in conjunction with the transport route descriptions to assemble the consequence and risk values for all of the shipments that have been projected to occur over the full route length.

An advantage to this calculational scheme is that if the unit values are carefully calculated utilizing the best information available, they can be used as unit value building blocks to assemble total incident-free consequences and accident risks for the entire shipping campaign. If the basic radioactive material parameters remain unchanged, then multiple shipment scenarios can be evaluated by reassembling the unit values in the spreadsheet format, to evaluate the consequences and risks for each scenario. It is not uncommon for the shipment scenarios to change during the course of an analysis. In the spreadsheet methodology, the number of RADTRAN runs can be held to a minimum and the various shipment scenarios fully evaluated even when the proposed shipping patterns change. A disadvantage of this method is that unit-risk factors cannot be used for highly route-specific analyses. The preferred method where route-specificity is required takes advantage of the RADTRAN LINK option discussed next.

## DEVELOPMENT OF RADTRAN INPUT FOR A SINGLE SHIPMENT -- ROUTE-SPECIFIC METHOD

The DOE now prefers to perform route-specific analyses. The LINK option of RADTRAN may be used to model the actual route with data for the proposed transportation links. Employing the LINK option to perform route-specific analyses captures the detailed spatial characteristics of the route, including road-type, population distribution, vehicle speed, and persons sharing the transportation link. The spreadsheet methodology is the most manageable means of comparing alternative routes in a route-specific analysis. For example, alternative routes by the same mode from a common origin to a common destination necessarily share some route segments. The spreadsheet method allows the distinct segments to be readily identified and quantitatively compared. It also facilitates rapid response to unforeseen changes in routes - a newly announced abandonment, for example, may force an alternative route to be identified, and only the new segments need to be added to the spreadsheet. As the complexity of a route-specific analysis increases, the spreadsheet method becomes even more attractive. For example, radiopharmaceuticals are often shipped by air to a distribution point and then off-loaded onto trucks which carry the packages to a series of hospitals for use. Variations in origin points, package types, and delivery routes can be most readily analyzed with a minimum of RADTRAN runs if the modal segments and intermodal transfer points are entered into a spreadsheet which can be used to mix and match these components.

## SUMMATION OF INDIVIDUAL SHIPMENTS FOR AN ENTIRE CAMPAIGN

A logistical analysis or flow-assignment is incorporated into the routing analysis which takes into account how much material must be moved from the shipment origin point(s) to the shipment destination(s). This information may be coupled with the unit-consequence and unit-risk values for single shipments and finally multiplied by the number of shipments on each route. If there are a number of routes and radionuclides, then the consequences and risks for each route are placed in a single summary table in the spreadsheet, the sum of which will represent the total risk for the shipment campaign. Alternatively, route-segment-specific values for single shipments may be multiplied by the total number of shipments and summarized as before.

## TABULATION OF UNIT RISK VALUES FOR EACH POPULATION-DENSITY ZONE OR ROUTE SEGMENT

Table 1 displays an example of the unit-risk method. Unit route risks and consequences for each population density zone are shown for a single kilometer of travel in that population-density zone. The number of km in each population zone is given in the route descriptions. The unit values of consequence and risk are multiplied by the number of km in each zone; this multiplication can be performed in the spread sheet cells. An analogous method would be used for the route-specific analyses, where the number of units increases to equal the number of route segments. Aggregate data are shown here for simplicity and ease of presentation, since route-specific data are handled in the same general manner.

## TABULATION OF CONSEQUENCE/RISK VALUES FOR A SINGLE SHIPMENT ON EACH ROUTE

In the example in Table 1, the columns are summed to determine the environmental effect of transporting a single shipment the entire length of a single route. For this example, the route is named Route 1. The total effect of all shipments of this radionuclide category along Route 1 is the total environmental consequence and risk multiplied by the total number of shipments. This logic is repeated for all radionuclide categories and for all routes. The summary of these environmental effects is described in the next section.

## SUMMATION OF RISKS FOR ALL ROUTES

The methodology described above is essentially the same for each route, although different radionuclides may be shipped on different routes. In this section we describe the assembly of all of the consequence and risk information into a single table. An example is given in Table 2, which displays the format for compiling the consequences for all radionuclides being shipped on all routes, which we indicate as being numbered from Route 1 to Route N. Such a format is convenient since it summarizes all of the consequences and risks. This information is derived from the basic building blocks of consequence and risk and transferred to the summary table, not by retyping the information, but through "copy" and "paste" operations which are inherent commands of the spreadsheet software. Such operations reduce the possibility of introducing numerical errors during data entry and allow the process of performing quality-assurance checks to proceed with rapidity.

## BENCHMARKING RISK VALUES AGAINST KNOWN STANDARDS

The benchmarking process is an important step in the conduct of a transportation analysis. The dose-consequence and dose-risk values derived in the calculational process described above are in units of person-rem. For those outside the field of health physics, the person-rem may not be a familiar unit. Further, the outcome of performing a transportation environmental risk assessment is that the results of the analysis will in all likelihood be scrutinized by various public interest groups. Because of this, it is often convenient to show a more familiar unit, that being the latent cancer fatality (LCF). In addition, the magnitude of the consequences of incident-free transportation and the risks of transportation accidents should be compared against some standard. One standard for comparison is the background exposure that the general population would receive during the course of the transportation operations of the study. If the risks and consequences are small with respect to background exposure then this can be noted. If the risks and consequences are large with respect to the background exposure, then the organization sponsoring the transportation operations might want to consider mitigating factors or reconfiguration. The estimated risks and consequences might possibly be reduced by changing the transport operational plans. It is the comparison of the analysis results with a known standard, such as background exposure, that provides a measure of the relative magnitude of the consequence and risk results. Quite often it is this comparison that needs to be made available in dialogues between waste-management program managers, government officials, and public interest groups.

## CONCLUSION

The objective of this presentation has been to document a process which allows one to perform an environmental analysis for radioactive material transportation using state-of-the-art calculational tools that are presently available. The calculational process rests on the performance of unit calculations using the analysis codes, and expanding these unit calculations into the full-fledged analysis of the entire operational shipment plan. By partitioning the calculational process, one can concentrate the basic health physics and material dispersion aspects of the analysis into the basic or unit calculations. These unit calculations can be expanded into the entire transportation operations model. Sometimes transportation operations change, and in such cases the transportation operations model must be altered although the basic health physics building block remains unchanged.

In many instances, the performance of a transportation risk assessment must be conducted on an expedited basis. The adaptation of data sets from previous studies can be used to initiate the calculational process or give an estimate of the consequences and risks. The use of inexpensive commercially available spreadsheets allows the reproduction of data sets that have previously been quality checked. The familiar cut, copy, and paste operations that are available in modern spreadsheets, plus the ability to perform a variety of mathematical operations allows the calculations to proceed rapidly. Finally, the logic of the calculational process within the spreadsheets is preserved such that postanalysis review of the calculations can occur readily.

The process described in this presentation can be made as elaborate as required. There is an inherent advantage in performing transportation environmental risk analyses according to familiar patterns, and it is the opinion of the authors that spreadsheet technology simplifies and expedites the calculational process.

## REFERENCES

Neuhauser, K.S. and Kanipe, F. L., *RADTRAN 4: Volue 3, User Guide*, SAND89-2370, Albuquerque, NM, January 1992.

| ROUTE RISKS | Number of km in each population zone | NORMAL Crew Per Shipment Person-REM | NORMAL OFF Link Per Shipment Person-REM | NORMAL On Link Per Shipment Person-REM | NORMAL Stops Per Shipment Person-REM | NORMAL Total Per Shipment Person-REM | ACCIDENT Ground Per Shipment Person-REM | ACCIDENT Inhaled Per Shipment Person-REM | ACCIDENT Resuspended Per Shipment Person-REM | ACCIDENT Cloudshine Per Shipment Person-REM | ACCIDENT Total Per Shipment Person-REM |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | |
| Route 1 | | | | | | | | | | | |
| Rural | | | | | | | | | | | |
| | | | | | | | | | | | |
| Route 1 | | | | | | | | | | | |
| Suburban | | | | | | | | | | | |
| | | | | | | | | | | | |
| Route 1 | | | | | | | | | | | |
| Urban | | | | | | | | | | | |
| | | | | | | | | | | | |
| CONSEQ/RISK | | | | | | | | | | | |
| TOTAL | | | | | | | | | | | |
| Single | | | | | | | | | | | |
| Shipment | | | | | | | | | | | |

Table 1

| ROUTE | | NORMAL | NORMAL | NORMAL | NORMAL | NORMAL | ACCIDENT | ACCIDENT | ACCIDENT | ACCIDENT | ACCIDENT |
|---|---|---|---|---|---|---|---|---|---|---|---|
| RISKS | | Crew | OFF Link | On Link | Stops | Total | Ground | Inhaled | Resuspended | Cloudshine | Total |
| | | Per Shipment | Per Shipment | Per Shipment | Per Shipment | Per Shipment | Per Shipment | Per Shipment | Per Shipment | Per Shipment | Per Shipment |
| | | Person-REM | Person-REM | Person-REM | Person-REM | Person-REM | Person-REM | Person-REM | Person-REM | Person-REM | Person-REM |
| | | | | | | | | | | | |
| Route 1 | | | | | | | | | | | |
| | | | | | | | | | | | |
| Route 2 | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| Route N | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| CONSEQ/RISK | | | | | | | | | | | |
| TOTAL | | | | | | | | | | | |
| All Routes | | | | | | | | | | | |

Table 2

# Regulations