Analysis of Travel Logistics for Transportation of Used Nuclear Fuel in the Continental United States – 15179

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ABSTRACT

The US DOE Office of Nuclear Energy is conducting planning activities within the Nuclear Fuels Storage and Transportation Planning Project (NFST) to lay the groundwork for implementing interim storage, including associated transportation, per the Administration's *Strategy for the Management and Disposal of Used Nuclear Fuel and High-Level Radioactive Waste*, and to develop a foundation for a new nuclear waste management organization. Integrated waste management system architecture analyses are being conducted to support the future deployment of a comprehensive system for managing nuclear waste that consider all aspects of the back-end of the nuclear fuel cycle (transportation, storage, and disposal). One aspect of a potential future nuclear waste management strategy is the transportation of spent nuclear fuel to an away from reactor interim storage facility.

Transportation routes from commercial nuclear reactor sites to various locations in the continental U.S. chosen as hypothetical locations for a future interim storage facility were evaluated using Stakeholder Tool for Assessing Radioactive Transportation (START). The objective of this evaluation was to identify and parameterize generic transportation routes for use in integrated waste management system analyses that include an interim storage facility, the associated uncertainty in these selections, and the uncertainty associated with different transportation route selection criteria.

INTRODUCTION

Transportation routes from commercial nuclear reactor sites to various locations in the continental U.S. chosen as hypothetical locations for a future away from reactor interim storage facility (ISF) for spent nuclear fuel (SNF) were evaluated using the Stakeholder Tool for Assessing Radioactive Transportation (START). The objectives of this evaluation were to (1) determine generic central receipt points and associated routes for use in transportation logistic modeling within integrated waste management system analyses, (2) quantify the associated uncertainty in the selection of these generic routs, and (3) quantify the uncertainty associated with criteria that may be applied to select actual routes.

START is a new routing tool under development by the NFST [Ref. 1]. START is being developed to evaluate transportation routing and emergency preparedness options in the waste management system. START allows for the representation of a wide range of operating scenarios and the consideration of multiple performance objectives with an emphasis on providing flexibility.

In the first part of the analysis route details were obtained from START for shipments from the reactor sites to hypothetical receipt points at the center of each state in the continental U.S. These results and the inventory of UNF projected to be generated by the current fleet of commercial nuclear reactors were used to observe the effects that the potential location of the ISF has on overall travel times necessary to clear UNF from all the reactor sites.

In the second part of the analysis three route selection criteria were used in START for all routes: minimize travel time, minimize population along the route, and minimize travel through environmentally sensitive areas. Overall travel times required to clear UNF from all the reactor sites were obtained from START for five hypothetical receipt points locations within the U.S. (Northeast, Southeast, Midwest, Southwest, and Northwest).

METHOD AND APPROACH

START was used to collect data on various routes between sites with commercial nuclear reactors and hypothetical receipt points. START has the capability to generate routes by rail, barge, and heavy-haul truck across the continental United States. DOE facilities (e.g. Oak Ridge National Laboratory), shutdown nuclear power plants (e.g. Zion Nuclear Power Station), currently operating nuclear power plants, or intermodal terminals can be selected as a route's origin and/or destination. The criteria that govern route selection between an origin and destination are: minimum travel time, minimum distance, minimum population, minimum sensitive environmental area, and minimum large gathering places.

To begin the routing process, each commercial nuclear reactor site was examined to determine if direct rail access to the site was available. If rail access was available, the site itself was used as the origin for evaluation. If rail access was unavailable at a facility, it was determined if the site could be accessed by barge, and if available the nearest barge-rail intermodal terminal was selected as the permanent origin for evaluation of that nuclear facility. If barge access was also unavailable, it was assumed that each site is accessible by heavy-haul truck (HHT) and the nearest HHT-rail intermodal terminal was selected as the permanent origin for evaluation of that reactor site. The collected set of origins was used for all routes generated. In addition, routes taken by HHT or barge to these origins were generated and used as part of the entire transportation route between a reactor site and a final destination.

The first analysis assessed routes from every commercial nuclear reactor site to hypothetical destinations near the center of every state in the continental U.S. (intermodal terminal locations) with route selection governed by the "minimum travel time" criterion. Due to their close proximity and relatively small size, Delaware and Maryland were grouped together and the states that comprise New England (MA, RI, CT, NH, VT, ME) were also grouped together, bringing the total number of destinations to 42. These two groupings were each assigned one intermodal terminal location as a destination. Using the set of origins, rail routes were generated from the 75 commercial nuclear reactor sites to the state intermodal terminal locations, producing 3,150 routes. The travel time was obtained for each route from START output.

The second analysis assessed routes from every commercial nuclear reactor site to intermodal terminal locations that served as destinations near the center of five regions in the U.S. These regions are the areas which the Nuclear Regulatory Commission (NRC) has designated for regulatory and oversight purposes. NRC Region IV, the westernmost region, was split into a northwest and southwest region to better evaluate the effects of geography on travel times. A depiction of these regions can be seen in Figure 1. The same process as above was repeated for these five intermodal terminal locations, except this time each route was generated three times using the "minimum travel time," "minimum population," and "minimum sensitive environmental area" criteria. 1,125 routes were generated and the travel time for each route was obtained from the START output.

The final analysis estimated total travel time for a transportation campaign based on inventories of SNF projected to be generated by each commercial reactor. The inventory of fuel assemblies projected to be discharged from all commercial nuclear reactors and their discharge dates was used to calculate the total amount (MTHM) of UNF projected to be produced by each reactor. It was assumed that each train servicing a reactor site would consist of three transportation casks, each having a capacity of 10 MTHM. The estimated total travel time required to clear a reactor site of SNF was then determined by dividing the

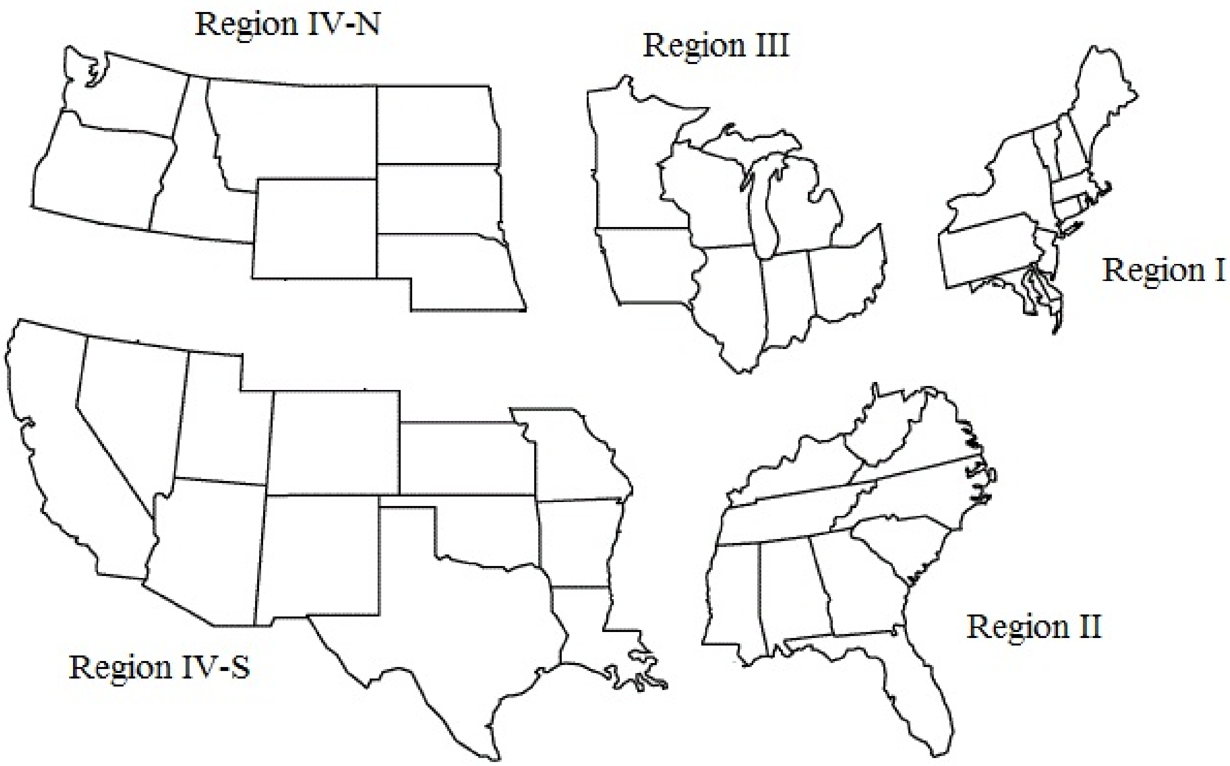

Fig.1. Regions Used in Transportation Routing Analysis

total amount of UNF projected to be generated at each reactor (MTHM) by 30 and multiplying the quotient by the round trip travel time to each representative destination. Using this method, the total travel time for a transportation campaign to each representative destination, using both the state and regional intermodal terminal locations, was calculated.

TRANSPORTATION ROUTE TRAVEL TIME ASSESSMENT RESULTS

This section presents the results of the SNF transportation route travel time assessment. The first part of this selection describes the results and analysis used to determine generic ISF locations for use in integrated waste management system analyses. The second part of this section describes the results and analyses used to quantify the uncertainty associated with using different SNF transportation route selection criteria.

Generic Destinations for Use in Waste Management System Architecture Analyses

The calculated total travel times needed to clear every commercial nuclear reactor site and transport the SNF to each hypothetical destination near the center of each state were used to determine average total travel times for each region discussed above, which are shown in Table I. The difference, expressed as a percentage, between the state with the shortest and longest total travel times in each region are also shown. The state and intermodal terminal location within a region having a total travel time closest to the average total travel time for the region and the associated error is also shown in Table I.

Table I. Average Travel Times for to Transport UNF to U.S. Regions

Region	**Region Average Travel Time (days)**	**Range of State Travel Times Over Region**	**State/Location With Closest Approximation to Region Average**	**Difference Between State Average and Closest Approximation**
Region I (Northeast)	11,200	(-16%) – (+30%)	New York (Oneonta Yard)	+4.0%
Region II (Southeast)	10,500	(-15%) – (+25%)	Tennessee (Mt. Pleasant Yard)	-5.5%
Region III (Midwest)	11,000	(-19%) – (+32%)	Iowa (Marshalltown Yard)	+1.0%
Region IV – North (Northwest)	17,000	(-35%) – (+45%)	Montana (Forsyth Yard)	-4.5%
Region IV – South (Southwest)	21,000	(-40%) – (+55%)	New Mexico (Belen Yard)	-3.0%

As can be seen from Table I, the location of the destination will have a large effect on UNF transportation times. A destination located in Region II (Southeast) would result in the lowest transportation travel times, with travel times to Regions I and III following close behind. A destination located in either Regions IV-S or IV-N would result in significantly longer travel times. It should be recognized that the results shown are averages of multiple states over a region, and the travel times would either be shortened or lengthened depending on where an actual destination would be located in a region.

The results in Table I shows that the region average total travel times for Regions I, II, and III are very close, within 7% of each other. As a result, it is appropriate for the purpose of waste management system analyses (with only a marginal increase in uncertainty) to further generalize these regions to one larger area with the selection of one representative location for the destination of SNF from the reactor sites for waste management system analyses purposes. The results also show that Regions IV-N and IV-S differ significantly both from Regions I, II, and III. The total travel time for Region IV-N is also about 22% larger than that of Region IV-S. Due to this significant disparity, it is not advisable that Region IV be treated as a single region for waste management system analysis purposes.

Thus, it is recommended that the following existing intermodal terminals be used as representative proxies for 'generic' ISF locations for purposes only of simulating transportation logistics in future waste management system analyses:

- East Region: Represented by the Mt. Pleasant Yard intermodal terminal location in Tennessee
- Southwest Region: Represented by the Belen Yard intermodal terminal location in New Mexico
- Northwest Region: Represented by the Forsyth Yard intermodal terminal location in Montana

These locations do not represent anticipated actual ISF sites. However, their use as assumed transportation end points provides sufficient accuracy for purposes of generic system analyses. The transportation infrastructure calculations using logistics simulation tools use travel times between origin sites and destinations to determine transportation asset needs, procurement costs, and operational costs. Thus, the use of the representative locations above does introduce a degree of uncertainty in those calculations. This uncertainty was assessed based on the results shown in Table I:

- East Region: -20% to +30%
- Southwest and Region: -40% to + 60%
- Northwest Region: -40% to + 50%

However, integrated waste management system analyses indicate that transportation costs are typically on the order of 10% or less of the overall waste management system costs. In addition, the actual transportation time is only a portion of the time that transportation assets would be in use. For example, those assets would also be in use while being loaded at the reactor sites and un-loaded at an ISF. These times could be on the order of or larger than the time required to transport the UNF itself. Thus, the uncertainty associated with using generic representative proxies for ISF locations is not expected to be significant with respect to waste management system architecture analyses.

Quantification of Uncertainty Associated with Route Selection Criteria

The total travel time estimated to transport all the UNF projected to be generated by the fleet of commercial reactors to the center of each region shown in Figure 1 were obtained from START for routes determined using the minimum travel time, minimum sensitive area, and minimum population density routing criteria. These total travel times were used to determine average total travel times within each region for the different routing criteria used, which are shown in Table II.

Table II. Average Travel Times to U.S. Regions Using Different Routing Criteria

Region	Minimum Time (days)	Minimum Sensitive Environmental Area (days)	Minimum Population (days)
Region I (Northeast)	11,700	33,800	32,900
Region II (Southeast)	8,700	36,600	25,200
Region III (Midwest)	9,400	42,500	18,900
Region IV – North (Northwest)	21,600	79,100	37,900
Region IV – South (Southwest)	15,000	59,000	33,400

It is recognized that a number of stakeholders would be involved in the selection of UNF transportation routes and different route selection criteria may be applied to different transportation routes, or perhaps to different portions of the same route. However, the results shown in Table II provide insight into how the demands of these stakeholders may impact the UNF transportation times. The “minimum time” routing criterion produces the shortest travel times, as expected. However, the effect of using different route selection criteria on UNF transportation times can be significant. As compared to the “minimum time” criterion for the selection of all routes, the “minimum population” route selection criterion increases travel times by a factor ranging from 1.8 to 2.9, depending on the region. The “minimum sensitive environmental area” criterion for the selection of all routes increases travel times by a factor of 2.9 to 4.5, depending on the region.

It is recommended that the “minimum travel time” routing criterion be used for the selection of all routes between the reactor sites and the representative ‘generic’ proxies for ISF locations recommended above for simulating transportation logistics in future waste management system analyses. Again, previous waste management system architecture analyses show that transportation costs are typically on the order of 10%

or less of the overall waste management system costs and the actual transportation time is only a portion of the time that transportation assets would be in use. Thus, the uncertainty associated with using the "minimum travel time" routing criterion is not expected to be significant with respect to waste management system architecture analyses.

While the above discussion indicates that the uncertainty associated with using representative 'generic' proxies for ISF locations and the "minimum travel time" route selection criterion are acceptable for use in future waste management system architecture analyses, confirmation is needed through quantitative logistic analyses that analyze limited routes and alternative route selection criteria.

CONCLUSION

Transportation routes from commercial nuclear reactor sites to various locations in the continental U.S. chosen as hypothetical locations for a future interim storage facility were evaluated to identify and parameterize generic transportation routes for use in integrated waste management system analyses that include an interim storage facility, the associated uncertainty in these selections, and the uncertainty associated with different transportation route selection criteria.

Recommended existing intermodal terminals were identified for as representative proxies for 'generic' ISF locations for purposes only of simulating transportation logistics in future waste management system analyses:

- East Region: Represented by the Mt. Pleasant Yard intermodal terminal location in Tennessee
- Southwest Region: Represented by the Belen Yard intermodal terminal location in New Mexico
- Northwest Region: Represented by the Forsyth Yard intermodal terminal location in Montana

The results were also used to recommend that the "minimum travel time" routing criterion be used for the selection of all routes between the reactor sites and the representative 'generic' proxies for ISF locations recommended immediately above for simulating transportation logistics in future waste management system analyses.

REFERENCES

1. M. ABKOWITZ, "Stakeholder Tool for Assessing Radioactive Transportation (START)," presented at the National Transportation Stakeholders Forum, Bloomington, MN, May 15-13, 2014 (available at http://energy.gov/sites/prod/files/2014/06/f16/9%20Transportation%20Plan%20Ad%20Hoc%20Working%20Group.pdf)

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