COMPARISON OF RISK ASSESSMENT AMONG TRANSPORT ROUTES WITH INTERTRAN2

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ABSTRACT
As a trial use of INTERTRAN2 code for evaluating risk of radioactive material transport in Japan, an analysis was made for road transport of low level wastes through two provisional routes of relatively short distance. A comparative risk analysis and an optimum selection between two transport routes were also studied.

INTRODUCTION
Analytical methods for evaluating radiation doses of general public and workers due to transportation of nuclear fuel materials have been studied in Institute of Nuclear Safety, and has been developed an analytical tool JINTRAN for evaluation of the radiation doses with road transportation by trucks under incident-free postulation [1]. Also has been supported development of the INTERTRAN2 code package under the international cooperative work CRP of IAEA. On the other hand, Central Research Institute of Electric Power Industry has conducted extensive works of experiments and analyses for safety assessment of radioactive material transportation by electric power industries. And, using the INTERTRAN2 code package released from IAEA for test use, CRIEPI has made a probabilistic safety assessment for transportation of low-level radioactive waste [2].

In Japan, all of nuclear power stations locate coast sides, and the wastes are shipped from ports for exclusive use to the disposal site for low level waste, located in far northeast of Japanese main land, by a ship specially built for this transportation. Then, the assessment has been made for road transportation of short distance between unloading port and the disposal facility. Population density and traffics are relatively low in this area, and very low level of radiation doses and risk are expected.

Transporting vehicles is a specially prepared truck, which carries two 5-ton containers (transport packages), and 8 drums are loaded in each container. The dose rate at one meter from package surface is conservatively assumed to be 80 micro Sv/h in the incident-free analysis. Only Co-60, as a representative nuclide in the waste, is considered in the accident analysis. Annual shipment of 20,000 drums is assumed.

DATA PREPARATION
Package and Shipment
Low-level waste from nuclear power plants, solidified in cement, is shipped in drums, and eight drums are placed in a container (transport package). One of typical radionuclides in the waste is ^{60}Co, and its total amount in eight drums is 1.0×10^{10} Bq as an average. Radiation dose rate at 1 m from surface of

the package is 80 μSv/h, and equivalent dimension of the package, to be used in dose calculations around the container, is about 3.2 meter. Two containers, or packages, are loaded on a truck, and two trucks travel as a convoy. Total shipment of 2500 packages will be made in a year.

Transportation Routes

Transportation evaluated in this study is planned in two different routes from the unloading port to the disposal facilities. Distances and population densities along these routes are summarized in Tables 1 and 2.

Table 1, Details of Each Route

Route A

Segment	Distance (m)
A1	100
A2 A3	300 1000
A4	2600
A5	1000
A6	2800
A7	1200
Total	9000

Route B

Segment	Distance (m)
B1	100
B2 B3	2600 2000
B4	1000
Total	5700

Table 2, Characteristics of Each Route

Route A

Segment	Population (person)	Speed (km/hr)	Accident Rate (1/vehicle-km)
A1	70	10	1.0E-09
A2	70	30	1.0E-07
A3	0	45	1.0E-09
A4	0	45	1.0E-09
A5	0	45	1.0E-09
A6	0	45	1.0E-09
A7	500	30	1.0E-09
Total	640	Ave. 42	Ave. 4.3E-09

Route B

Segment	Population (person)	Speed (km/hr)	Accident Rate (1/vehicle-km)
B1	70	10	1.0E-09
B2	70	40	1.0E-07
B3	1500	40	1.0E-07
B4	500	30	1.0E-09
Total	2140	Ave. 38	Ave. 8.1E-08

The aggregated model and the link model of INTERTRAN2 were prepared for each of these two routes. Traffics and accident rates of these routes are based on traffic census by a Government office of transportation, and one-way traffic count in the area is about 100 vehicles per hour. Based on the population density and the traffic conditions, zone type designator "rural" is assigned for the all sections of both routes. Data for "stop," to be used in the aggregated model, are assumed as follows: 20 minute for stop time, 15 minutes for minimum stop time, and 500 meters for exposure distance.

Release and Radiological Analyses

The fraction of severe accidents, which will result radioactive material release, is assumed to be 0.3 %, and the release fraction of the cement-solidified waste under severe accident is assumed 1.2 %. Based on the default values for the dispersibility of radioactive materials, the aerosol fraction of 100 % and the respirable fraction of 5 % are also assumed for ^{60}Co. Defaults of the atmospheric dispersion condition, an average of Pasquill atmospheric stability categories A through F, are used. Prefixed nuclear related data, such as half-life, gamma energy, and dose conversion factors, and internally defined resuspension factor are used.

CALCULATED RESULTS

Incident-Free Doses

Doses of the incident-free transportation, in the unit of cumulative doses (Person-Sv), for Routes A and B are summarized in Tables 3 and 4 respectively. Calculations have been made for the aggregated model and the link model.

Table 3, Results of Incident-Free Transportation by Route A

Aggregated Model

	OFF LINK	ON LINK	STOPS	TOTALS
Route Total	1.03E-04	4.16E-05	4.44E-04	5.89E-04

Link Model

	OFF LINK	ON LINK	STOPS	TOTALS
Segment A1	5.71E-05	2.07E-05	8.04E-05	1.58E-04
Segment A2	1.90E-05	6.34E-06	2.41E-04	2.66E-04
Segment A3	0	9.25E-06	8.04E-04	8.13E-04
Segment A4	0	2.41E-05	2.09E-03	2.11E-03
Segment A5	0	9.25E-06	8.04E-04	8.13E-04
Segment A6	0	2.59E-05	2.25E-03	2.28E-03
Segment A7	1.36E-04	2.54E-05	9.65E-04	1.13E-03
Route Total	2.12E-04	1.21E-04	7.24E-03	7.57E-03

(Unit in Person-Sv)

Table 4, Results of Incident-Free Transportation by Route B

Aggregated Model

	OFF LINK	ON LINK	STOPS	TOTALS
Route Total	4.22E-04	8.37E-04	2.05E-03	3.34E-03

Link Model

	OFF LINK	ON LINK	STOPS	TOTALS
Segment B1	5.71E-05	2.07E-05	8.04E-05	1.58E-04
Segment B2	1.43E-05	5.58E-04	2.09E-03	2.66E-03
Segment B3	3.06E-04	2.27E-04	1.61E-03	2.14E-03
Segment B4	1.36E-04	2.11E-05	8.04E-04	9.61E-04
Route Total	5.13E-04	8.27E-04	4.58E-03	5.92E-03

(Unit in Person-Sv)

Because of transportation of relatively short distance and in low population and traffic density area, very small radiological effects are resulted. And, also due to the short transportation, a major contribution to the total doses is that resulted during the "stop." In this evaluation, the "STOPS" doses are relatively correct by the aggregated model analysis than those by the link model, because the exposure condition at "stop" is more adequately taken into account in the input data preparation. Default value is used in the link analysis. Then, overestimation will be concluded for the link model.

Differences between the aggregated and the link, such as difference of "ON LINK" and "OFF LINK" doses, are more clearly indicated when the conditions of segments, or population for the incident-free evaluation, vary widely link to link. Route A is longer than Route B, and includes segments of zero population, so that the aggregated modeling will not be adequate for Route A.

Accident Risk

Risks, in the unit of cumulative doses, for Routes A and B and for the aggregated and link models, are summarized in Tables 5 and 6, respectively.

Table 5, Results of Accident Risk in Transportation by Route A

Aggregated Model

	GROUND-SHINE	INHALED	RESUS-PENDED	CLOUD-SHINE	TOTALS
Route Total	6.14E-11	4.06E-14	1.55E-13	3.62E-15	6.16E-11

Link Model

	GROUND-SHINE	INHALED	RESUS-PENDED	CLOUD-SHINE	TOTALS
Segment A1	7.55E-12	4.98E-15	1.91E-14	4.44E-16	7.57E-12
Segment A2	7.55E-10	4.98E-13	1.91E-12	4.44E-14	7.57E-10
Segment A3	0	0	0	0	0
Segment A4	0	0	0	0	0
Segment A5	0	0	0	0	0
Segment A6	0	0	0	0	0
Segment A7	5.39E-11	3.56E-14	1.36E-13	3.17E-15	5.41E-11
Route Total	8.16E-10	5.39E-13	2.06E-12	4.81E-14	8.19E-10

(Unit in Person-Sv)

Table 6, Results of Accident risk in Transportation by Route B

Aggregated Model

	GROUND-SHINE	INHALED	RESUS-PENDED	CLOUD-SHINE	TOTALS
Route Total	2.23E-08	1.47E-11	5.46E-11	1.31E-12	2.24E-08

Link Model

	GROUND-SHINE	INHALED	RESUS-PENDED	CLOUD-SHINE	TOTALS
Segment B1	7.55E-12	4.98E-15	1.91E-14	4.44E-16	7.57E-12
Segment B2	7.56E-10	4.99E-13	1.91E-12	4.45E-14	7.57E-10
Segment B3	1.62E-08	1.07E-11	4.09E-11	9.52E-13	1.62E-08
Segment B4	5.39E-11	3.56E-14	1.36E-13	3.17E-15	5.41E-11
Route Total	1.70E-08	1.12E-11	4.29E-11	1.00E-12	1.70E-08

(Unit in Person-Sv)

Basically, the accidental risk is dependent on the population and the accident rate (multiplied by the distance), and then the risk must be higher for Route B than Route A in this comparative evaluation. As for the use of aggregated model, application of it to Route A, which has widely varied segment data as mentioned previously, might result non appropriate evaluation, or underestimation of the risk.

Comparison of Two Routes

In the incident-free analysis, route A of a longer distance (1.6 times) obviously led a bigger dose (1.3 times). In the accident risk analysis, however, route B of larger population (3.3 times) and higher accident rate (19 times) led a higher risk (about 21 times). It might be suggested that accident dose risk can be reduced effectively by selecting an exclusive transport route, or a route of smaller population or smaller accident rate even though they are slightly longer.

CONCLUDING REMARKS

As a provisional study of assessing the radiation doses of radioactive material transportation in Japan, evaluation with the INTERTRAN2 code package was studied.

Most laborious work in preparing the input data was to collect appropriate traffic conditions on transportation routes and demographic data of surrounding areas. And these data strongly affected the calculated results, as commonly found in the probabilistic safety analysis.

In the aggregated mode analysis, a transport route is treated as one segment and averaged data of whole route are input. Therefore, it causes noticeable uncertainties when the route includes many areas whose population densities or traffic accounts are quite different, generally found in Japan. The link model will be preferable when necessary data are available with required preciseness.

It was concluded that the INTERTRAN2 code package had applicability to safety assessments of radioactive materials transport in Japan although a few minor problems remain.

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REFERENCES

[1] S. Suzuki, S. Mitake and T. Nakajima, "Development of Safety Analysis Code for Nuclear Fuel Material Transportation: Evaluation of Radiation Dose," Institute of Nuclear Safety, INS-1528 (Mar. 1993), (in Japanese).

[2] N. Watabe and H. Suzuki, "A Probabilistic Safety Assessment of Radioactive Materials Transport - A Case Study with INTERTRAN2 Code and an Extraction of Problems -," Abiko Research Laboratory Rep. No. U98037, CRIEPI (Mar. 1999), (in Japanese).