Developing an Impact Analysis System for the Transport of High-Level Nuclear Waste

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The question of when and where to build a permanent repository for storing high-level nuclear waste has created considerable interest in assessing the impacts associated with transporting these wastes from their generation site to the repository. Inherent issues are addressed for design of a comprehensive transportation impact analysis system and for the practical aspects of implementing the system in support of policy analysis. The focus of discussion is the current development of a transportation management information and analysis system (TMIAS) for the state of Nevada. Issues related to methodological approach, impact definition, system analysis capability, data requirements, transportation policy alternatives, system interaction, and development schedule are described. Because of the complex nature of high-level nuclear waste shipments, the discussion provided should be transferable to analyses of other hazardous materials shipments and more traditional transportation applications because these scenarios are likely to focus on a subset of the issues presented.

The disposal of high-level nuclear waste entails a continuing debate over when and where to build a permanent repository. Yucca Mountain, Nevada, has been selected by the U.S. Department of Energy (DOE) for site characterization. This choice has generated considerable concern on the part both of Nevada state officials and officials of potential corridor states concerning the impacts of transport operations to the repository site.

The objective is to identify system elements and interrelationships in building a comprehensive impact analysis system to evaluate these effects. The focus of the discussion is the design of a transportation management information and analysis system (TMIAS) for the state of Nevada for addressing high-level nuclear waste transport. The decision to implement TMIAS has been identified as an essential and immediate need for the state government in its evaluation of alternative transportation plans for shipping high-level nuclear waste to Yucca Mountain.

An operational impact analysis system for high-level nuclear waste transport in Nevada is predicated on development and implementation of a system by which a multitude of transport policy alternatives involving high-level nuclear waste shipments can be represented and analyzed. Issues related to high-level nuclear waste transportation will be examined and their consequences understood to support Nevada's position with respect to the DOE transportation planning process.

Important issues are discussed related to TMIAS development and implementation. This discussion includes methodological approach, definition of impacts, analysis capabilities, data requirements, transportation policy alternatives, and system interaction.

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METHODOLOGICAL APPROACH

Identification and quantification of impacts involving high-level nuclear waste shipments require in-depth studies that describe the current or anticipated state or condition of many transportation-related elements, including

- Transportation infrastructure and use in the state of Nevada,
- Transportation regulation and inspection programs affecting the state of Nevada, i.e., federal, state, and local,
- Characteristics of the population and environment adjacent to the transportation corridor,
- Emergency preparedness capabilities within the state of Nevada,
- Shipment characteristics and routes of transport under consideration, and
- Plans for DOE waste shipment schedules and transportation operating procedures.

Impact analysis must begin with an initial (baseline) characterization of the current transportation system to create a reference point for evaluating repository transport policy alternatives and to establish model validity. The analysis of impacts and the effectiveness of impact minimization policies and actions can subsequently be investigated by altering existing parameters—routes, modes, road and rail quality, emergency preparedness capabilities, etc. For each set of parameters, the impacts to the welfare of Nevada (e.g., mortality, morbidity, and economic) can be surmised. The results, when compared to baseline conditions, isolate the impacts associated with locating a repository at Yucca Mountain.

Converting this conceptual approach into a tractable mathematical framework involves the use of sizeable amounts of data and mathematical formulations. Data bases are needed that describe the transportation system and system use, the population around each transport segment, and the geo-

graphic characteristics of the area through which each segment passes. The problem must also address both highway and rail shipments of nuclear waste and the unique operating characteristics of each mode. Also, flexibility must be established to support independent studies of statewide versus national issues.

A transportation impact analysis system at the most fundamental level must consist of four basic components—definition of the transport policy alternatives under consideration; collection, translation, and management of essential data (i.e., data base management); application of models that accept data inputs and perform problem solving; and display and evaluation of forecasted impacts associated with the specified transport policy alternative. The schematic in Figure 1 shows a generalized approach to transportation impact analysis that has been selected for the Nevada development effort.

The process begins with definition of transport policy alternatives under potential consideration. Each DOE option under current or future consideration must be captured in such a way that TMIAS can predict its impacts. Consequently, capability and flexibility must be provided to represent the multitude of shipment and operational characteristics that could be included in a policy under examination.

Data collection, translation, and data base management refer to the broad category of gathering relevant information and managing its use in impact analysis. Some data collection involves gathering source data directly from agencies that maintain this information. For example, the transport network and segment attributes of distance, geometrics, travel usage, accident history, etc., would be considered source data because these data can be collected directly from such organizations as the Nevada Department of Transportation.

Other information needed to support policy definition and impact analysis must be generated from source data. For example, source data on residential and employment population are needed to create measures of impacted population residing within specified distances of a transport segment. Similarly, radiological risk attributes are typically created from source information that includes shipment characteristics and elements of the transport network. Models that accept source data and create generated data are referred to in Figure 1 as "generating models." Source data and generated data constitute the full set of inputs required to define a particular transportation policy alternative and to prepare pertinent information for analysis use.

Formal analysis (or problem solving) is performed using algorithmic models. These models must have the capability to accept large quantities of information and use efficient solution methods. In general, the algorithms are designed to operate on large-scale networks in which transportation problems are traditionally defined, and perform such functions as optimization, simulation, and evaluation. The algorithms are often mathematically complex and are typically developed by individuals with a strong background in the field of operations research.

When the problem-solving process is complete, several measures associated with the forecasted outcome are compiled. These measures are subsequently used to generate impacts for the policy alternative under study. An example of one element in this process might be the derivation of economic impacts. A measure traced through the solution process might be shipment-miles, which, in turn, could be used to generate transport operating costs. Impacts are typically presented in the form of a summary table to enable overall comparisons to be made. Segment-specific impacts can also be generated in support of more localized analysis.

Clearly, many potential impacts and impact variables must be accounted for in structuring an effective system design. Some impacts, particularly nontravel-related economic impacts, are difficult to represent in a transportation modeling envi-

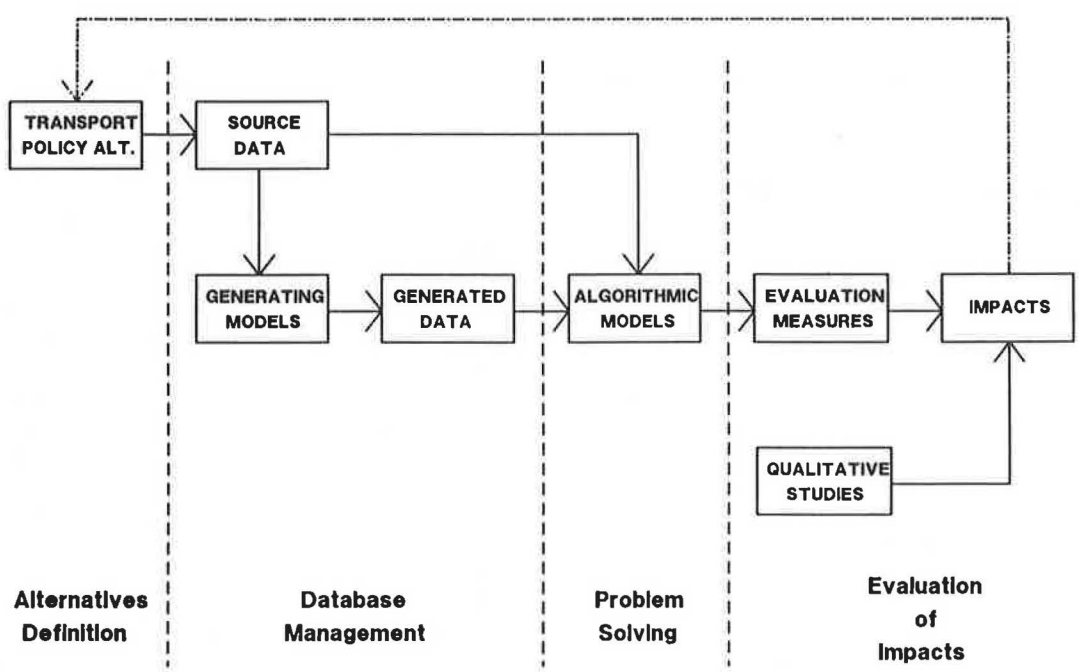

FIGURE 1 Generalized approach to impact analysis.

ronment. The administration of surveys may be a more effective course of action to characterize these impacts. The portion of the schematic shown in Figure 1 referred to as "qualitative studies" is designed with the intent of providing support for this type of impact measurement.

Figure 1 also displays a dashed line connecting impacts at the end of the analysis cycle back to transportation policy alternatives at the beginning of the process. The recursive nature of this connection is included to show that often the results of a particular impact analysis may suggest modifications to the initial policy that warrant the conduct of a subsequent impact analysis. For example, evaluation of a specific alternative may indicate that infrastructure problems are evident in certain locations. A subsequent alternative could also be defined that includes provisions for infrastructure improvements, and a need to forecast the economic and safety impacts of the new alternative.

From prior review of transportation issues related to the movement of high-level nuclear waste and an awareness of previous impact modeling efforts that have been undertaken in the field of transportation, it is apparent that the state of Nevada must adopt a systems approach to impact analysis that is built around a transportation network model orientation. By capitalizing on recent advances in geographic information system (GIS) technology, availability of Nevada data bases, integration of existing data and models, new model development, and state-of-the-art display graphics and user-friendly menu operation, Nevada has the opportunity to forge a pioneering effort that will exceed any current capability elsewhere in addressing nuclear waste transport impact analysis. With TMIAS in place, however, this system can also prove to be extremely useful for managing a multitude of other everyday transportation concerns within the state, such as road and bridge repair, traffic management, regulation of other hazardous materials shipments, and emergency response planning.

In discussing issues related to impact analysis, it is often useful to follow a backwards logic approach through the analysis process so that it is understood what system components are needed and how they interact to address the impacts of interest.

TRANSPORTATION IMPACTS AND ASSOCIATED MEASURES

The full range of potential transportation impacts associated with locating a repository at Yucca Mountain can be generally classified into two basic categories—safety and economic. Each of these categories includes a number of more detailed considerations as explained in the following subsections.

Safety Impacts

Safety impacts include both nonradiological and radiological impacts for normal transportation and from accidents (see Figure 2).

Radiological impacts result from occurrences where there is a release of radiological materials. One such occurrence can take place during nonaccident (incident-free) transport during which some radiation is emitted through spent fuel casks. The rate of material emitted, its dispersion pattern and toxic effects, and local demographics are among the many variables that affect the overall radiological impact of this type of occurrence.

Scenario \ Impact Type	Radiological	Non-Radiological
Accident	✓	✓
Non-Accident	✓	

FIGURE 2 Relevant safety impacts considered in TMIAS.

Situations in which a vehicular accident or incident causes a container failure and subsequent radioactive release have the potential for causing more serious harm to the population and the environment. In these instances, large quantities of nuclear material may release, causing more concentrated and widespread exposure. The radiological effects from such an occurrence will be related to factors that include the rate of release, shipment size, dispersion characteristics, toxic effects of the material, local demographics, and the response times and capabilities of emergency management personnel.

Radiological impacts are formally created in the modeling process by estimating radiation exposure and predicting the consequences in terms of death (mortality) and injury or illness (morbidity). Although some impacts are immediately apparent, long-term health effects can be subtle in their onset and ghastly in their result and are the subject of great public concern. Death and injury also take on different social and economic value because of heightened public concern about nuclear waste shipments and the long-term suffering associated with radiation exposure. A nuclear waste release is thought to be a low-probability, high-consequence event that is of great concern to the public. Risk estimation methodology must be carefully structured to permit a thorough, unbiased analysis of these potential effects.

Nonradiological impacts are considered those caused by the forces of the accident itself and typically consist of injury and death to vehicle occupants or people in the vicinity of the transport segment (e.g., pedestrians), damage to the vehicle and cargo, and other property damage caused by the vehicle involved in the accident. It can be argued that these impacts are reflective of the size and weight of the vehicle and not the material being carried. However, in studying these impacts, the volume and weight of the proposed nuclear waste shipments should be taken into account as well as the likelihood of increased accident frequency caused by growth of repository-related transportation.

There may be some nonaccident, nonradiological safety impacts associated with repository transportation, such as additional air and noise pollution generated by increased truck and rail activity. However, in relative terms, these impacts are considered of diminished importance, and have not been explicitly treated as a safety impact in TMIAS.

Economic Impacts

Economic impacts associated with nuclear waste transport involve capital and operating costs to use and maintain the transportation system infrastructure. These impacts are felt directly and indirectly. Direct costs include the cost of maintenance and improvements to the road and rail infrastructure to ensure safe passage, as well as expenditures for transportation services associated with using the transportation network such as operating costs tied to shipment-miles, ton-miles, cask-days, etc. Direct economic impacts are also associated with the costs of developing and implementing regulatory policy, inspection and enforcement, and emergency response (including clean-up) programs.

Indirect economic impacts include traffic congestion and delay associated with daily traffic patterns of the general population caused by increased transport activity, as well as traffic disruption or rerouting because of increased accidents. Although travel-related impacts may be considered relatively benign, they influence a broader constituency in the state; and several minutes' delay to each affected individual, multiplied by all affected parties, can represent a considerable productivity loss.

Additional indirect impacts include both positive and negative effects on the perception of the state and individual communities as desirable residential, business, and tourist attractions. Property values, particularly along designated transport routes; effects on tourism and business relocation; impacts on production in other sectors of the economy; insurance costs; secondary purchases generated by nuclear waste shipments, such as in the service economy; effects on noise and air quality; and potential improvements to emergency preparedness would all be considered indirect economic impacts.

ANALYSIS NEEDS AND MODEL DEVELOPMENT

TMIAS must have the capability to perform certain analysis functions that typify the policy issues that might be considered by DOE as related to repository transportation. In this section, each major functional capability is identified and described, including special features that could be made inherent to the TMIAS structure to accommodate specific analysis restrictions that might accompany certain policy alternatives.

Analysis Capability

Five major functions have been identified that would be highly desirable for TMIAS to perform for analysis capability.

- Route optimization (preferred route selection),
- Evaluation of a predefined route,
- Stochastic simulation of a nuclear waste incident,
- Prescribed simulation of a nuclear waste incident, and
- General management information system (MIS) functions.

These functions are explained in the following discussion.

Route optimization involves identification of the preferred (best) route for transporting nuclear waste according to the user's selection of appropriate decision criteria (e.g., risk and cost), the importance the user associates with each criterion, and the user's risk preferences (i.e., risk-averse, risk-neutral, or risk-prone). These three factors define, in optimization terms, what is known as the objective function. These factors are emphasized because the selection of a preferred route is highly sensitive to the criteria applied, and DOE may advocate a particular routing strategy that is based on applying different criteria than what the state of Nevada may feel is justified. Thus, the model must be capable of predicting the consequences of such varying assumptions. In route optimization, the preferred route is found by searching across any number of candidate routes to find the optimal (or preferred) solution.

The evaluation of a predefined route is a variant of route optimization. There is a desire to evaluate a specific route, regardless of whether it might emerge as a preferred route, under certain operating assumptions. The need to do so arises in cases for which shipments are planned for, or are currently being made, on a designated route; and there is an interest in comparing the impacts of moving nuclear waste on a designated route versus transporting it on an optimal route as defined by an objective function. The application would likely be used in situations where the state would want to compare the impacts of DOE-recommended routes with those based on Nevada's routing criteria.

The ability to simulate a nuclear waste incident is desirable for understanding the consequences of events should an incident occur somewhere in Nevada. This ability would have important implications both in terms of evaluating the magnitude of morbidity and mortality that could occur, and for the development and implementation of emergency preparedness programs (relative to the siting of response units and level of capability desired).

Two different types of simulation activities are envisioned—stochastic and prescribed. A stochastic simulation recognizes that there is a distribution of incident severity depending on the type of event that might occur. Consequently, because of uncertainty involved in incident severity and consequence, a probabilistic approach is taken. The simulated event is based on a sampling from a distribution of possible incident scenarios to arrive at a generalized or expected risk impact. A prescribed simulation is one for which the user defines the event parameters as an input, and the simulation forecasts the impacts in a deterministic rather than probabilistic fashion. The outcome is specific to the defined incident and not to the likelihood that such an event could occur.

The state could benefit from the availability of both functions. The prescribed simulation is clearly necessary when the impacts of a particular type of event must be known, such as a worst case scenario. The stochastic simulation can be used as an important input in defining risk for different transport segments as an attribute in determining preferred routing.

The final area, general MIS functions, refers to the ability to access a rather substantial data base that is necessary to support TMIAS. This information can be used separately from impact analysis to generate reports and file management documents as a decision support function to several agencies in the state. For example, reports on pavement condition ratings for each highway segment in Nevada could be used by the Department of Transportation to schedule preventive maintenance activities. Similarly, traffic congestion levels at var-

ious times of the day could be generated to examine potential delays in areas of high growth.

The functions described should not be misconstrued as the only ones that are important. All other analysis requirements can also be handled within this structure.

Special Features

Within the model structure, two special features have been identified that can significantly enhance the flexibility and sophistication of impact analysis.

The first, link and node inclusion or exclusion, refers to the ability to require a shipment to pass along a given transport segment or through a particular junction, or, conversely, to avoid a segment or junction. There are several situations for which either inclusion or exclusion requirements may apply. Inclusion applies in the cases in which shipments are required to use a particular route when passing through a community because of local ordinance, to access a safe haven, or perhaps to stay within the range of qualified emergency response personnel. Examples of exclusion include situations in which a shipment must avoid routes near an environmentally sensitive area (e.g., a heavy population concentration, or location of schools, hospitals, or water supplies), or where routing ordinances prohibit such use. Exclusion can also be applied for interim periods of time where construction activities on a transport segment temporarily remove certain segments from routing consideration.

The other special feature, referred to as "hot spot" identification, allows the user to specify threshold values for characteristics of transport segments, that if exceeded, could result either in identification of these sites for further analysis consideration (e.g., as high-risk locations) or the exclusion of these segments from subsequent routing consideration. Hot spot identification can be used in routing impact analysis or for MIS functions in which certain outliers such as roads with adjacent population densities exceeding some value can be identified.

DATA REQUIREMENTS AND DATA MANIPULATION CAPABILITIES

The information required to support TMIAS capabilities can be classified into the following categories:

- Transportation network,
- Social and demographic factors, and
- Other geographical considerations.

Each of these categories is described separately in the following discussion. In terms of system connectivity, social and demographic factors and other geographical considerations become part of the transportation network definition for reasons that will become clearer as the discussion proceeds.

Transportation Network

Transportation network considerations consist of physical dimensions and geometrics of the transportation system and associated utilization. For TMIAS, highway and rail networks must be characterized. The following highway link or node attributes are resident in the system with editing capability provided:

- Physical coordinates;
- Distance;
- Average annual daily traffic (AADT), by truck and time-of-day, if possible;
- Functional classification;
- Number of lanes;
- Surface type and condition;
- Lane and shoulder widths;
- Bridge and tunnel clearances;
- Accident rate;
- Median type;
- Temporary restrictions (because of construction, weather, etc.);
- Rest areas;
- Curvatures and grades;
- Passing lanes and sight distances;
- Operating speed and stop times;
- Regulatory restrictions; and
- Number of at-grade crossings (controlled and uncontrolled).

The following rail link or node attributes are resident in the system with editing capability provided:

- Physical coordinates,
- Distance,
- Accident rate,
- Track condition,
- Track class,
- Bridge and tunnel clearances,
- Track density,
- Number of tracks and sidings,
- Ownership,
- Yards and transfer points,
- Temporary restrictions,
- Operating speed and stop times,
- Number of at-grade crossings (controlled and uncontrolled),
- Curvatures and grades, and
- Sight distances.

Highway Network

Each highway link (segment) and node (intersection) must be defined by physical coordinates. The most appropriate convention is the use of latitude and longitude, which can be integrated with other geographical information that typically uses latitude and longitude mapping convention.

Highway geometric information should include the physical distance of the segment—number of lanes, lane width, passing lanes and sight distances, location of rest areas, presence of shoulders and medians, surface type, curvature and grade, and whether the segment includes a major bridge or tunnel (along with clearance considerations). The geometric characteristics are important in defining each segment in terms of permissible traffic. For example, certain shipments may be

restricted from passage on roads without a sufficient lane width. Geometric characteristics are also used to classify roads into categories for subsequent analysis (e.g., accident severity may vary by median type).

Information on highway use corresponds to the movement of traffic across the road facility and the quality of service provided. One of the key characteristics, AADT, identifies the amount of traffic that typically uses the roadway being studied. AADT can be used as an indicator of congestion by relating traffic volumes to the road's design capacity. Congestion has a direct effect on operating speeds and stop times. The extent to which the information can be disaggregated by vehicle type and time-of-day will determine the precision with which truck shipments can be evaluated in the model. Accident rate is also an important use measure and truck accident rates are preferred to general vehicular accident rates. Functional classification corresponds to road location and its function in the overall road system (e.g., as rural feeder or urban Interstate). This classification is helpful in determining how future travel patterns distribute onto the roadway collection, line-haul, and distribution network. Surface condition is a measure of the quality of the road and relates to safety as well as economic considerations concerning roadway maintenance and infrastructure improvement. Finally, the presence of regulatory and temporary restrictions may affect routing decisions during an interim period of time.

Rail Network

The rail system is characterized similarly to the highway system. However, different features are pertinent to rail operations and rail node definition takes on greater significance. Rail network considerations also consist of geometrics and use. Track class parallels functional classification on the roadway system, while track density is similar to AADT for roads.

Unique features of rail networks include track ownership, yard and transfer points, and the presence of sidings. Track ownership can be an important issue because most railroads often try to maximize the use of track that they own. Consequently, the tradeoffs between operating strategy and what is preferred from a systemwide standpoint must be understood. Yard and transfer points are node characteristics that are important in determining where delays and incidents can occur because of rerouting trains and where legitimate transfers between railroads can take place. Finally, siding location identifies points where trains can pull off the main line either to permit another train to pass or as a resting place.

Social and Demographic Factors

Interactions between the transport facility, adjacent land use, and environment are classified as social and demographic factors. These factors include (a) residential and employment population within varying distances of the transport segment, (b) response time from the nearest first (and ultimate) responder and associated response capability, and (c) distance to schools, hospitals, water supplies, and other ecologically sensitive areas.

Knowledge of the location of the residential and employment populations relative to the transport facility determines the impacted population at varying times of the day who are exposed to accident and nonaccident radiological risk. The distance from the transport segment has implications on the level of exposure depending on the release quantity and rate.

The response time from the nearest response unit and the ultimate response capability is an indication of how quickly an incident can be reacted to and controlled should one occur at a given point in the Nevada transportation system. An important distinction must be made between first response, on-scene arrival, and ultimate response (the capability to control the release). Both responses are important. However, first response is directed more at responding to the immediate consequences of the incident, whereas ultimate response focuses on containing the source of the problem.

Proximity of schools, hospitals, water supplies, and other sensitive areas identifies the presence of sensitive locations and their impact distance from the transport facility. This may prove particularly important in the determination of routing criteria as well as in the development of emergency preparedness and evacuation planning.

Social and demographic factors will be generated from GIS data describing the surrounding land use, and this information will be overlaid on the transportation physical coordinates, allowing appropriate measures for each transport segment to be derived by using geometry and other mathematical computations. The considerations, in essence, are derived by computer and are subsequently appended to the transportation network data base.

Other Geographical Considerations

Other geographical considerations can be instrumental for modeling capability as TMIAS is expanded. Information on weather, topography, and geology, which are all available through a GIS, could also be overlaid on the transportation and social and demographic systems to permit a more precise assessment of radiological impacts, particularly in an accident release scenario. Important weather considerations include wind direction, wind speed, and temperature. Weather considerations help determine release dispersion as well as the likelihood of cloud cover that might shield radiation effects. Topography adjacent to the transport facility constitutes an important factor in dispersion. Geological characterization of the surrounding country also has important implications on ground and surface water transport should a release occur.

It is expected that measures of social and demographic considerations would be derived from GIS data and appended to the transportation network as segment level descriptors.

TRANSPORTATION POLICY ALTERNATIVES

A multitude of transportation policy alternatives must be considered to represent current and anticipated plans that DOE may investigate. Generally, any such policy would comprise two sets of features—shipment characteristics that specify the scale of spent fuel movement, vehicle configuration, timing, etc.; and operation considerations that indicate manpower needs, presence of escorts, legal and regulatory issues, etc. Legal and regulatory issues impact the system by constraining the feasibility of alternative transportation policies. However,

the results of impact analysis can also create a two-way interaction that leads to consideration of future modifications to the existing institutional environment.

The following discussion outlines the more important elements to consider in TMIAS to ensure that adequate capability is provided for characterizing specific transportation policy alternatives.

Shipment Characteristics

Shipment characteristics describe the spent fuel program to be defined for impact analysis. Because there are so many assumptions that can be considered, and given that DOE is constantly modifying the types of scenarios being contemplated, the TMIAS design calls for characteristics to be defined by the user each time a new impact analysis is desired. This process permits the model to select a preferred or optimal route for each shipment scenario and creates an opportunity to compare preferred routes under different scenarios in order to identify the preferred scenario. Therefore, cask size, modal mix, and other operating issues can be explicitly addressed by the model.

The shipment characteristics proposed for TMIAS inclusion at this time, which are defined by the user for each point of entry, are the following:

- Beginning of repository operation;
- Mode and vehicle configuration;
- Cask type, shielding, and capacity;
- Casks per shipment;
- Number of shipments;
- Shipment time-of-day; and
- Spent fuel type (PWR or BWR), consolidation, and age.

Because shipments may be entering the state from several points that may vary for each DOE scenario (including whether monitored retrievable storage facilities exist), it is expected that information will be identified separately by point of entry. The beginning date of repository operation identifies how far in the future to project growth conditions in Nevada in forming a prerepository base case for comparative analysis of repository transportation impacts. Modal mix and vehicle configuration refer to the level of rail and highway use as well as the type of truck (e.g., overweight or convoy) or train (e.g., unit or special) under consideration. The cask type, shielding, and capacity are important in establishing release probabilities and maximum release amount in order to characterize accident and nonaccident radiological risks. The number of casks per shipment and total number of shipments define the magnitude of individual and collective movements at each point of entry. Spent fuel type, consolidation, and age also help assess the dangers associated with a release should one occur. The time-of-day when shipments enter the state can be used to set a clock that triggers time-of-day modeling as the shipment travels within Nevada until it reaches the repository site.

Operations

Operations are an extension of shipment characteristics because they define special provisions that are associated with the shipment once movement within the state begins. The presence of (a) escorts, (b) physical protection, (c) shipment tracking system being used, (d) number of drivers and workers assigned to the shipments, (e) in-transit inspection and enforcement programs, and (f) legal and regulatory matters including future ordinances would all be considered members of this group. As for shipment characteristics, the user is expected to define these conditions as model inputs before executing the analysis.

SYSTEM INTERACTION

In previous sections, individual system components have been identified and their role in the analysis approach has been defined. This section focuses on the activities required to integrate these components into a single, functioning modeling system. The logic embedded in the integration process involves the tracing of independent pieces of information through a four-step process from policy alternative definition to impact evaluation.

The previous discussion identified several modeling features and information needs that must be addressed and represented in a comprehensive transportation impact analysis methodology for Nevada. Figure 3 shows the modeling process envisioned to meet project objectives. Care has been taken to distinguish those steps in the process that are user defined from those that are derived by computer. User-defined steps permit the user to modify input values to represent alternative scenarios under consideration. However, the user need not enter the entire file of information manually. Rather, a data base can be maintained resident to the system that the user may edit, as appropriate.

Three primary inputs support the analysis environment: (a) the transport network and its related attributes, (b) shipment characteristics to describe shipment options, and (c) operational considerations. The transportation network data base is shown in its expanded form once social, demographic, and other pertinent geographic attributes have been generated and appended to the network data base.

These three components support the functional capabilities previously described, namely, routing analysis, event simulation, and MIS applications. For routing analysis, if optimization is selected, the user must also be queried to supply the explicit criteria under consideration, weights to be assigned to each criteria, and the risk preference (e.g., risk-averse) assumptions that should apply. In the case of event simulation, when a stochastic analysis is selected, a release distribution must be specified. However, this requirement could be contained in a resident data base that is accessed during the analysis. MIS applications are expected to emanate principally from the information contained in the expanded transportation network data base and may take the form of several different standard reports that focus on the extraction and sorting of resident information to support various functions carried out by Nevada state agencies.

When routing analysis is performed, it is expected that accident nonradiological, nonaccident radiological, accident radiological, and economic impacts will be experienced. In the case of event simulation, the emphasis is on release impacts. Consequently, only accident effects, both radiological and nonradiological, can be expected. In some instances, translation tables must be developed as an intermediate step in

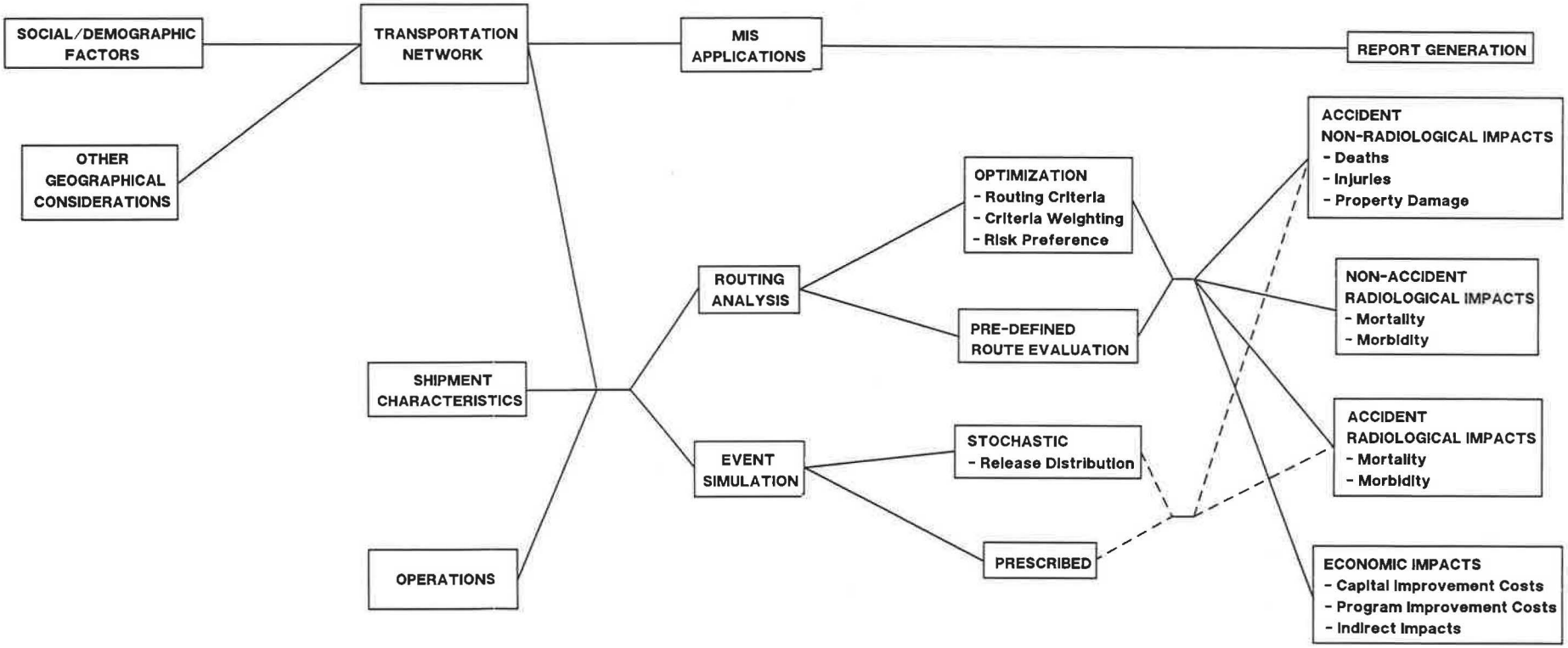

FIGURE 3 Schematic of TMIAS design specification.

converting analysis outputs into impact measures. Such would be the case with shipment duration, distance, and typical analysis outputs that need to be linked to economic formulas to provide measures of shipment cost (economic impacts).

SYSTEM DEVELOPMENT SCHEDULE

A number of desirable features to be contained within TMIAS have been identified. To accomplish these objectives, an ambitious, time-staged development schedule has been implemented that partitions TMIAS into divisible tasks and establishes the priority among tasks. A guiding principle in this effort is the requirement to build a first-generation impact analysis model and use it for preliminary impact analysis within the coming year.

Implementation of TMIAS involves the development of a comprehensive impact analysis system that captures all of the issues raised in this system design specification. These activities will involve the integration of existing works (one–five), whereas others will focus on new methodological development that may require source data collection efforts.

The development schedule for full-scale TMIAS capability is envisioned as a 3- to 5-year effort due to the sophistication of certain modeling elements. It is also expected that as policymakers become more familiar with TMIAS capabilities from their use of the first-generation model and subsequent iterations, needs will arise that require model enhancements for future transport applications, both nuclear and nonnuclear in nature.

CONCLUSION

Analyzing the transport of high-level nuclear waste requires a comprehensive approach that encompasses many facets of the transport operation and a wide range of associated impacts that can potentially arise. Design issues inherent in developing a system and practical aspects of implementing the system in support of policy analysis were addressed. Because of the complex nature of high-level nuclear waste shipments, the discussion should be transferable to other hazardous materials shipments and more traditional transportation applications, as these scenarios are likely to focus on a subset of the issues presented.

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