A TRANSPORT LOGISTICS AND COST MODEL FOR USE IN REPOSITORY DESIGN SPECIFICATION

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INTRODUCTION

UK Nirex Ltd (Nirex) is responsible for developing a deep repository for the disposal of the United Kingdom's intermediate level waste and some low level waste. This can be considered as a responsibility for developing an integrated and efficient disposal system, covering all aspects from the despatch of packaged waste from the waste producing sites, though to its underground disposal. Given the locations of the waste producing sites all around the United Kingdom (Figure 1), a major component of the disposal system is the network for transporting radioactive waste packages to the repository.

The design specification for the repository itself relies on a significant number of predictions related to the transport network. These include:

- Average and peak arrival rates of different types of waste packages, transport containers and rail and road vehicles, all of which will vary over different time periods

- Example schedules of the arrivals and departures of trains, road vehicles and transport containers

- Numbers and types of packages moving through any part of the transport network in any time period

- Numbers of transport containers and vehicles required by the transport programme.

The above data provide a key parameter in the repository specification, namely the overall throughput capability that is required. Repository specifications related more directly to the transport system include the required size of rail sidings to handle the arriving trains, and the requirements for temporary storage of waste packages awaiting processing, and of empty rail wagons and reusable transport containers awaiting their next journey.

Nirex also needs to be able to predict the total cost of the transport operations, and to compute the costs attributable to different combinations of sites and types of waste packages. A number of choices can be made about the logistics of the transport operation, and it is desirable to determine the costs of the different options, as well as taking account of operational, safety and other constraints.

Over time, the requirements on the transport system are likely to change. For example the predicted quantities of waste to be transported will become better defined, and changes may occur in the national transport infrastructure and transport legislation. Therefore, a number of scenarios need to be investigated to ensure that the transport system can remain effective over its planned operational lifetime.

Since 1991 Nirex has been investigating a site near to the existing BNFL Sellafield fuel reprocessing site as a potential repository site. However, following a decision by the Secretary of State for the Environment in March 1997 to refuse planning permission for an underground rock laboratory, Nirex has scaled down its operations and has no plans for further investigation there. In any future site selection process, transport will be a significant input, as it was in the site selection process that led to the decision to concentrate investigations at Sellafield.

This paper draws on work carried out as part of the assessment of Sellafield as a potential repository site, but will also show that many aspects of the transport system are independent of the actual repository location.

To analyse the effects of all these possible scenarios and proposed operating practices on the costs and logistics of radioactive waste transport, Nirex commissioned the development of a flexible computer model from a software developer with the appropriate expertise. This paper describes how the LOGCOST model [Hutchinson et al 1997] has been used to provide the information required for the repository design specification, and how it can readily be adapted to different potential repository locations and to changing requirements.

LOGCOST

The LOGCOST model has three principal modules: the Transport Network module, the Logistics module and the Costing module [Hutchinson et al 1997].

The first part of the model mostly contains logically-linked items of data, and therefore has some attributes of a database; the transport system could potentially be modelled using scheduling software; and the later parts are more straightforwardly computational which is the role of the spreadsheet. However, rather than using separate database, scheduling and spreadsheet programs for each respective part, the whole model was developed using the Microsoft® *Excel 5* spreadsheet software, augmented by procedures written using the Microsoft® *Visual Basic for Applications*™ macro language. Compared to a purpose-written program, this approach has the advantage of presenting a familiar *Windows*-style user interface, while giving access to all the facilities of the *Excel* spreadsheet for further manipulation and presentation of results. The model is also highly flexible – almost all the assumptions being contained in the input data rather than embedded within the model itself – so it can be used to investigate a wide range of possible transport scenarios.

Data Sources

The model uses the following data.

- Description of a Transport Network. This includes the identities of the individual sites where wastes will be packaged and prepared for transport, and also the groupings of sites in the same region that would often contribute to the same train-load arriving at the repository. This in turn requires data on rail marshalling yards where shorter trains would be combined on the journey to the repository, and subdivided on the return journey to supply reusable transport containers and empty wagons back to the sites.

- Transport Timetable, derived from studies of the transport network by specialist transport consultants.

- Package Data file, defining the numbers of waste packages to be carried during different periods of time. These datasets have been derived from the UK Radioactive Waste Inventory [Nirex, 1996] which classifies individual waste streams, stating when they are forecast to arise and the intended method of conditioning.

- Cost Parameters to be applied to the items and operations identified as being necessary.

EXAMPLES OF USE

Choices of Transport Modes

Nirex prefers the use of rail for the transport waste to the repository wherever practicable, to reduce the environmental impact of frequent road transport of heavy loads. However, a disposal system that is intended to operate over a long period of time in the next century must plan for unforeseen changes in the available transport infrastructure. At present, LOGCOST considers these contingencies by means of three reference transport scenarios:

- Maximum Rail – where all waste packages are transported to the repository by rail, starting either at the arising site or at the nearest local railhead where the arising site is not rail-connected

- Rail-Road – where road transport is used for packages that are sufficiently light to be carried on a conventional 38–40 tonne Heavy Goods Vehicle (HGV) and the rest are transported by rail

- Maximum Road – where all packages are transported by road; the heavier packages would require special transport vehicles.

The actual transport scenarios will probably not conform exactly to any of the above, and will probably change over timescales of a few years or decades. However, by using these three scenarios for reference in all the LOGCOST computations, Nirex can identify which aspects of the overall system costs are vulnerable to changes, and can then plan its operations to reduce the impact of any changes that do occur.

Marshalled or Short Trains

Figure 1 shows the geography of the United Kingdom and the rail transport routes that are relevant to waste transport. There are obvious regional groupings of waste producing sites, each of which may be producing only a few wagon-loads of packaged waste per month. This offers opportunities to combine short trains at regional marshalling locations, making up a single larger train for the onward journey to the repository. Similarly there are opportunities for despatching long trains of empty wagons (or wagons carrying empty reusable transport containers) back from the repository to the waste producing sites, and then sub-dividing these trains at the same regional marshalling points.

All of these possibilities can be written into the Transport Data file for LOGCOST, which can then be used to optimise the train timetabling and the use of marshalling locations. Competing factors include costs (which are mostly per-train, not per-ton, and therefore favour the maximum possible train size), flexibility of operations (which favours more and shorter trains) and land usage at the repository (see next section for more details). At present, LOGCOST requires manual optimisation, although some aspects of route and timetable generation are automatic after the pre-conditions have been established manually. Fully automatic optimisation has been developed for a higher-level cost analysis model which is similar to LOGCOST but considers every aspect of the disposal system; these optimisation techniques could be added to LOGCOST as part of its future development.

Land Requirements versus Transport Costs

Some constraints on the disposal system may be absolute; for example there may be a requirement to minimise land area at the repository as far as practicable. In this context LOGCOST has been used to explore how the land requirements for the rail sidings and for the temporary storage of empty reusable transport containers can be reduced. Reduction of the length of sidings involved not only the use of shorter trains, arriving more frequently to maintain the same overall throughput of waste packages, but also minimisation of the numbers of rail wagons parked at the repository awaiting further use. Therefore the task using LOGCOST was to re-optimise the train timetabling and marshalling strategies for shorter trains, and also to re-optimise the size of the transport container and rail wagon fleets. Then LOGCOST automatically calculated the costs related to transport, using two of the three standard reference scenarios defined earlier (the Maximum Road scenario was not relevant).

Although LOGCOST cannot directly calculate costs related to land usage at the repository, the virtue of its *Excel*-based approach is that all the necessary data regarding train lengths, numbers of containers and numbers of rail wagons are provided as spreadsheets, in the most convenient form for further processing.

Sample results are shown below, normalised to a particular scenario (designated the Base Case), against which changes could be assessed. The maximum train length was reduced from ten wagons to six, leading to approximately double the number of trains and an increase in transport costs. For a repository at Sellafield, the results were also sensitive to the length and number of local short-train workings from the BNFL site, where the options of two and one wagons per train were examined.

LOGCOST was used to apply two separate techniques: minimisation of the numbers of transport containers and rail wagons, achieved by optimising the timetable; and reduction of the train lengths. The minimisation procedure was applied to the Base Case (line 2 of the table below) and brought considerable savings in the maximum numbers of containers and wagons that would need to be parked at the repository. The procedure also reduced the total numbers and capital costs of the containers and wagons required, although there was a slight overall rise in transport costs. Reducing the external train length from ten to six wagons (line 3) required more wagons but no more parking space, and involved a 9% increase in transport costs. Changing the local Sellafield train length from two wagons to one (line 4) was found to require many more containers and wagons, and to involve a 18% increase in transport costs. Reducing both external and internal train lengths (line 5) removed most of the requirements for extra containers, wagons and parking space; however, the increase in total transport costs remained very close to the sum of the individual cost increases. This work considered minimisation of container/wagon requirements separately from the reductions in train lengths, and it is likely that further improvements could be obtained by applying both techniques together.

Maximum Rail Scenario		Transport costs (normalised)	Max transport containers at repository [total no in fleet]	Max rail wagons at repository [total no in fleet]
1.	Base Case	100	72 [104]	42 [46]
2.	Minimised containers and wagons	104	46 [88]	28 [32]
3.	Max train length from 10 to 6 wagons	109	45 [88]	28 [42]
4.	Local S'field train length from 2 to 1 wagon	118	73 [102]	45 [46]
5.	Both 3 and 4	126	48 [87]	25 [42]

These detailed predictions are quite specific to the scenarios involved, but they do illustrate how LOGCOST can be used to achieve significant savings in transport costs, or beneficial trade-offs with other aspects of the disposal system.

Transport Container Utilisation

Working with the UK waste producers, Nirex has developed a standard range of waste packages and transport containers [Smith and Barlow 1994: Gray 1994] and the handling facilities at the waste producing sites are being designed accordingly. Most of the ILW will be packaged in unshielded 500 litre drums which will be carried in groups of four in Reusable Shielded Transport Containers (RSTCs). The range of waste packages also includes a 3m^3 box for larger items, which has the same outline dimensions as four 500 litre drums in a transport frame ('stillage'), and an upright cylindrical 3m^3 drum, both of which will fit into an RSTC. Together with their contents the RSTCs will form Type B packages under the IAEA Transport Regulations [IAEA, 1996].

Because of the wide range of ILW activity, RSTCs are being developed for a number of shielding thicknesses ranging from 285mm down to 70mm. These are designated 'RSTC-285', 'RSTC-70' etc. The wall thickness of the RSTC-285 is limited by size and weight constraints for rail transport, and the RSTC-70 is the thickest-walled container that can be carried on a conventional 38-40t heavy Goods Vehicle (HGV). The vast majority of 500 litre drums, 3m^3 boxes and 3m^3 drums waste packages forecast to arise in the UK can be carried in this range of RSTCs. However, a significant number of waste packages contain waste which is of low specific activity material and so could be transported within an Industrial Package under the IAEA Transport Regulations [IAEA, 1996] using less shielding than the RSTC-70 provides, so an Industrial Package Transport Container (IPTC) has been developed. As its name implies, the IPTC would be transported as an Industrial Package under the IAEA Transport

Regulations [IAEA, 1996]. Design constraints were to provide the same outline dimensions and handling options as the RSTCs, so that IPTCs could be handled by the same processing facilities; and also a weight constraint so that the majority of loaded IPTCs could be transported two at a time by a standard HGV.

There is an optimum combination of RSTC wall thicknesses and utilisation of IPTCs. Having too many different wall thicknesses will increase development and certification costs. On the other hand, too limited a range would increase the numbers of thicker-walled containers in the fleet. This would not only increase the manufacturing costs but also mean fewer opportunities to carry two of the lighter RSTCs on a single rail wagon (recalling that rail transport costs are primarily per-train, not per-tonne).

LOGCOST has been used to investigate these dependencies and optimise the range of RSTCs. There seemed to be little benefit in having intermediate wall thicknesses between 285mm and 70mm, and LOGCOST has verified this conjecture. The next question was whether to use all three types of containers – IPTC, RSTC-70 and RSTC-285 – or whether to drop either the IPTC or the RSTC-70 from the range, leaving only the RSTC-285 and one other.

The following tables show the effects on relative costs for transport involving all UK waste producing sites except BNFL Sellafield for the Maximum Rail and Rail/Road transport scenarios. The costs are normalised to the case of IPTC, RSTC-70 and RSTC-285 for the Maximum Rail scenario.

275,000m³ Maximum Rail	IPTC, RSTC-70 and RSTC-285 in Use	RSTC-70 and RSTC-285 in Use	IPTC and RSTC-285 in Use
Max no. of IPTC	32	0	32
Max no. of RSTC	58	77	43
Container costs	24	29	22
Other costs	76	76	90
Total costs	100	105	112

275,000m³ Rail-Road	IPTC, RSTC-70 and RSTC-285 in Use	RSTC-70 and RSTC-285 in Use	IPTC and RSTC-285 in Use
Max no. of IPTC	12	0	12
Max no. of RSTC	34	39	45
Container costs	16	17	21
Other costs	50	51	69
Total costs	66	68	91

The tables demonstrate that the lowest-cost option is to use all three types of container: IPTC, RSTC-70 and RSTC-285. It would cost more to eliminate either the IPTC or the RSTC-70 and use only the RSTC-285 and one other. Comparing the two tables shows that this conclusion is not sensitive to the transport mode scenario.

OTHER REPOSITORY SITES

The LOGCOST model can easily be adapted to a wide variety of transport networks involving a single focal point, either for collection or for distribution. All the important characteristics of the network are described in the Transport Data file, and only minor changes would be needed to the model if it were required to introduce an additional mode of transport such as sea. The steps required to use LOGCOST for a different repository site from Sellafield are as follows.

- The logistical requirements already built into the Package Data file are unchanged: packaged waste will still originate from the same waste producing sites, in the same forecast quantities and at the same forecast times.
- Identify the available transport routes for the new repository site, and the capacities of those routes in terms of numbers and lengths of trains, throughput of heavy road transport etc.
- Modify the transport network description in the Transport Data file. This description consists of 'routes' which are described as a series of 'node' locations connected by transport 'legs'. Individual legs are built up from smaller 'segments', as required to supply the necessary level of detail. In the UK context, the only major changes would probably be in the region of the new repository site itself. Elsewhere, large blocks of the network description would remain the same, regardless of the repository site, while others might need to be simply reversed.
- Using the new network, re-construct all the routes manually, largely by re-using existing leg and segment data.
- Reconstruct the transport timetables. These are based on regular daily, weekly and two-weekly cycles serving the main waste producing sites, with others fitted in less frequently as required. The transit times for most of the segments of the network are already known, but constraints might be different. The constraints are mainly concerned with stopping times at sites such as marshalling yards, and it might be necessary to add new marshalling locations.

LOGCOST would then be ready to produce cost and logistics data for the new repository site.

CONCLUSION

LOGCOST is a very effective transport and logistics model based on the *Excel* spreadsheet. The examples have shown how LOGCOST can provide detailed predictions of radioactive waste transport costs, and how LOGCOST can be readily adapted to a new repository site or any other focal point for a transport network.

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Figure 1: Rail Network from Waste Producing Sites in the UK to Sellafield