DESIGN OF A TRANSPORTATION MODEL WITHIN A CORPORATE INFORMATION SYSTEM

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SUMMARY

A framework for specifying a transportation network is outlined. This was used primarily to invoice customers for consignments carried but was also used to calculate efficiencies in the transport operation. It could be extended to plan routes and schedule trips and then to track the Transport companies' assets (prime movers and container units) as well as to track the customer consignments. Although no OR applications are described in the paper, the model is one which can be simulated or otherwise investigated to examine alternative freight-carrying strategies. The actual network (Node, Segment), trip (PM_trip, Unit_trip) and Consignment data are captured to enable this analysis.

Extensions to other transportation industry applications are discussed and the applicability to the Object-Oriented paradigm is outlined.

1. Introduction

This paper describes the design and development of a transportation system for a company within a corporate environment. The company Refrigerated Freightlines Limited (RFL) was at the time a fully owned subsidiary of Wattie Industries Limited (WIL), now itself part of Goodman Fielder Wattie Limited (GFW). RFL transported frozen goods both nationally and internationally by road, rail and sea (Figure 1). This work focuses on the design of its Road Transport System (RTS). The bulk of RFL's custom came from other companies, such as Tip Top Ice Cream Company Limited, within the group. Accordingly the systems developed were to both aid RFL in tracking its assets and working out the efficiencies of its operations and help RFL (and the other companies directly) track the consignments of goods.

The system was part of the corporate data base located on the WIL IBM mainframe.

The initial application developed was the Weekly Trip Summary "WTS" (Figure 2). It was designed to replace a manual system, performed at each branch, to calculate the efficiencies of the transport operation and to invoice the customers for goods carried.

2. Methodology

The database design was developed using Information Engineering techniques [1] to describe the entities (eg RFL_node, Customer, Consignment, Segment), the relationships between the entities (eg RFL_node is the start point of a Segment) and the attributes of the various segments (eg an attribute of Segment is "distance"). The database tables were then built on the mainframe in CA/DATACOM/DB.

FIGURE 1
Example of Transportation Network

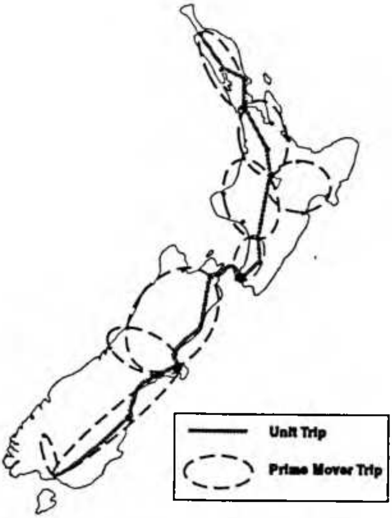
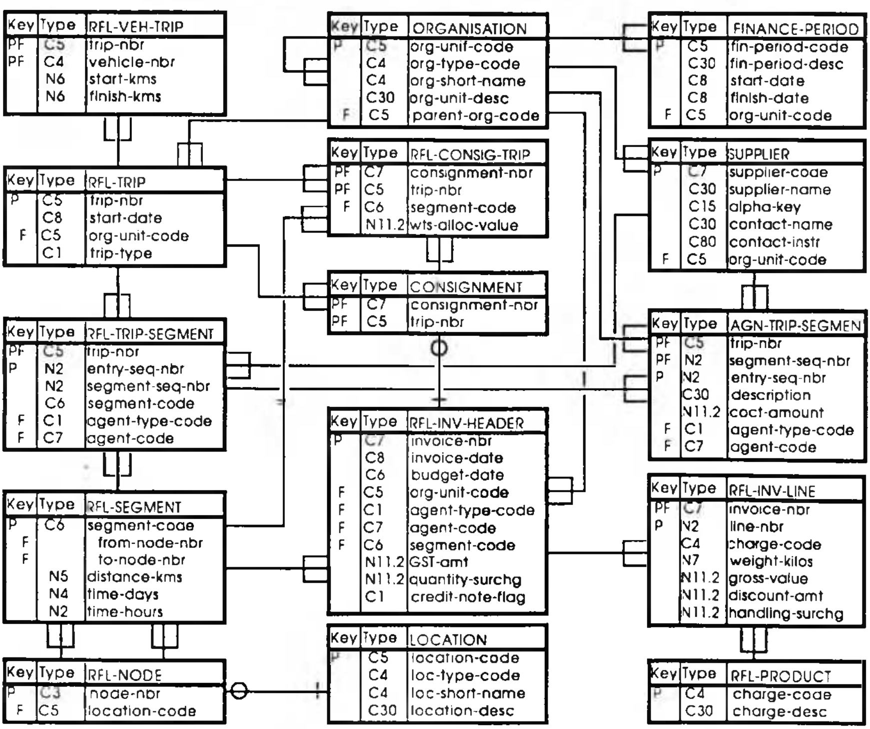


FIGURE 2 - RFL WEEKLY TRIP SUMMARY DATA DIAGRAM



The system design was based on Screenflow Programming [4] [5] and written in CA/DATACOM - a 4GL used for on-line applications. The batch reports were written in COBOL.

3. Design

The RFL information system had to fit within the corporate structure; thus each branch was an example of an Organisation unit of type RFL_Branch and each RFL_node was cross-referenced to a Location of type RFL_node. Each Branch (Organisation) is responsible for maintaining the information about zero, one, or more RFL_node.

The product analysis under which the various types of product carried by RFL was initially divided into several hierarchial categories (eg Minor Product Group, Major Product Group) but this was considered too restrictive. A generic grouping mechanism was developed so that each "Product" could be categorised into any number of levels of Product_Group.

RFL's Customers (RFL_Customer) were analysed by Sales Group and Sales Area (Figure 3). Later this arrangement was generalised to allow Customer analysis by any grouping.

An RFL_Segment was defined by the start and end RFL_Node for that segment. These segments could be either adjacent points on a route (eg Auckland-Huntly) or the result of several adjacent nodes forming the start and end points of a trip and/or consignment (eg Auckland-Invercargill). For each segment (pair of nodes) a distance and trip duration was recorded. This design and terminology has since been seen in Air New Zealand's Data Model and that of a United States trucking company, thus emphasising its genericity in the transportation industry.

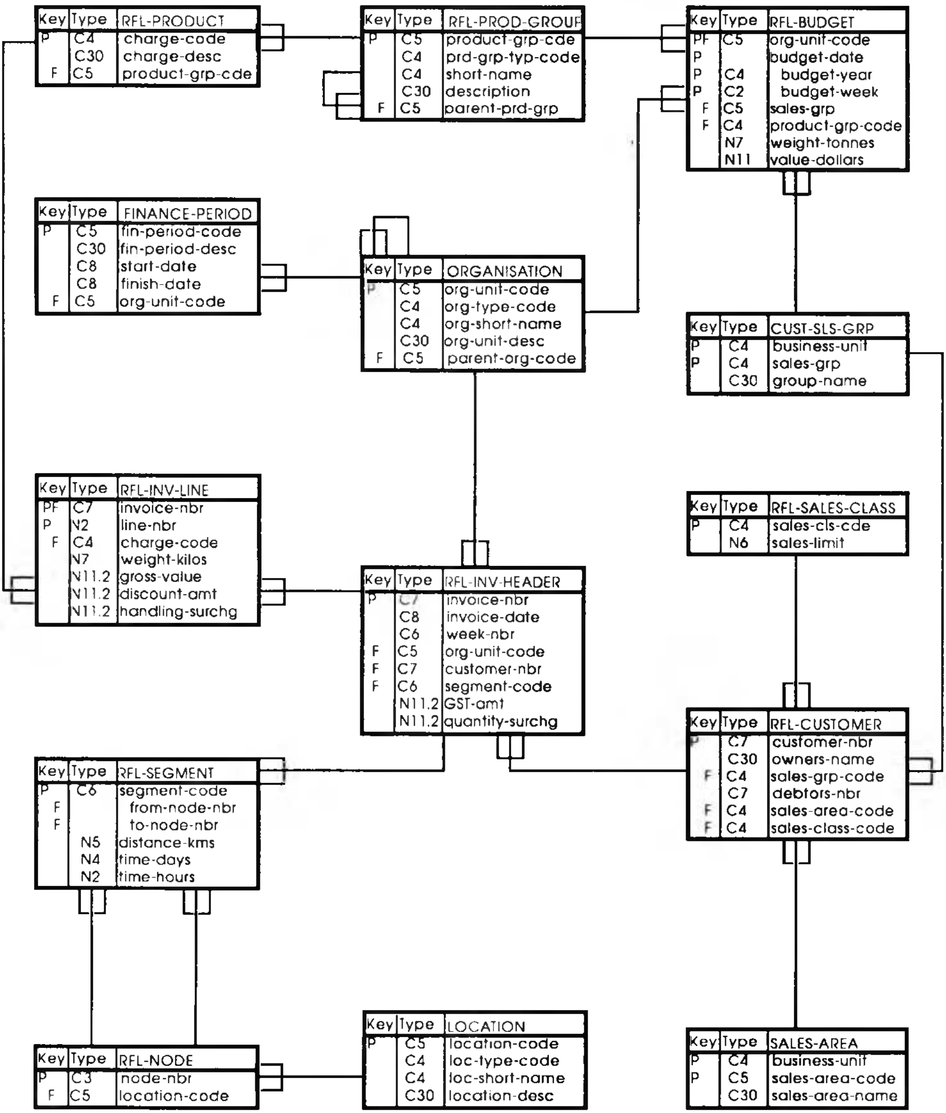
Trips are scheduled by the RFL branches either as standard trips based on historical patterns in the movement of goods or on demand as a result of customer orders. Each RFL_Trip is assigned to one or more vehicles (RFL_VEH_TRIP). The trips can be broken down into the various segments based on the individual branches responsible for that portion of the journey RFL_Trip_Segmnt or some external agent (or Supplier) to which the segment is subcontracted (AGN-Trip_Segmnt). An example of such a trip is the movement of RFL Units across Cook Straight by NZR rail-ferry. The external supplier (eg NZR) then charges for the service or alternatively the individual RFL Branches are "rewarded" a portion of the revenue earned for carrying the goods based on the distance that they carry them.

Each RFL_Consignment is booked on one or more RFL_Trip. The Invoice details such as Customer (Internal or External) Date and Origin are stored on the RFL-INV-Header and the individual lines (or products) making up the consignment are stored on RFL-INV-Line. The journey undertaken by the consignment can be broken down into its individual segments (RFL-Consign-Trip) with a value allocated to each.

4. Results

From this breakdown the revenue earned by each Branch for the week can be calculated. This in turn can be related to the costs of transporting the goods based on a tonne per kilometre figure. The efficiencies of the different branches can be compared. Originally this was done by hand and resulted in efficiencies of around 100%, with some reports exceeding

FIGURE 3 - SALES ANALYSIS DATA DIAGRAM



this figure. To see how this came about, the nature of the calculation has to be examined. Each Prime Mover can transport a net weight of 20 tonnes - either in a single 20 tonne unit or two 10 tonne units. The actual amount carried should be divided by the nominal weight of 20 tonnes to give a figure for the percentage utilisation. In addition the freight is not carried from the start of the journey to the end but different consignments are being picked up and dropped off along the way. The efficiency was then calculated by dividing the distance that each consignment was carried by the distance for the trip (as measured by the difference between the start-kms and finish-kms in the RFL-VEH-TRIP entity).

$$\text{ie} \quad \text{Efficiency} = \text{Sum}\left(\frac{\text{Weight carried}}{20} \times \frac{\text{Distance Travelled}}{\text{Segment Distance}} \right)$$

At first glance this appears to be correct, but closer inspection reveals that the individual branches are rewarded for carrying the goods by a round-about route. In other words by not taking the shortest route between two nodes your efficiency is effectively increased.
The numerator and denominator the second part of the equation should be reversed.

$$\text{ie} \quad \text{Efficiency} = \text{Sum}\left(\frac{\text{Weight carried}}{20} \times \frac{\text{Segment Distance}}{\text{Distance Travelled}} \right)$$

From this the Weekly Trip Summary (WTS) for each branch can be produced, the customers invoiced and the sales analysis performed.

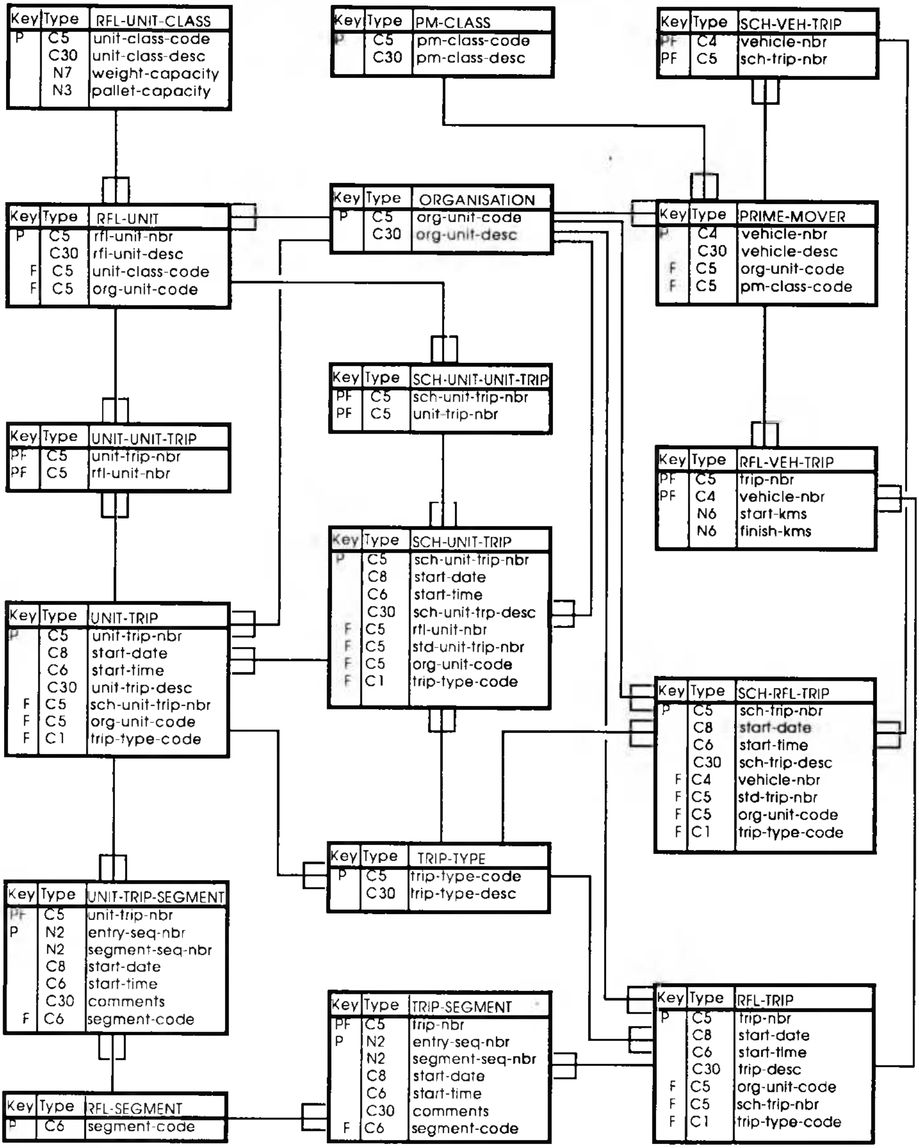
5. Extensions

The next steps in the modelling process were to use this framework as the basis for Trip Scheduling and Asset Tracking (Figure 4).

The rolling stock can be divided into the Prime-Mover and RFL-Unit subclasses where the RFL_Unit is the trailer on which the refrigerated container sits or the Refrigerated Unit itself. The separate trips of both the Prime Movers (PM_TRIP), a round trip starting and ending at the RFL_Branch, and Units (Unit_Trip), from one RFL_Branch to another (and indeed further afield) can then be modelled. These can be broken down into the individual segments making up each trip (Trip-Segment and Unit-Trip-Seg respectively). One top of this a planning regime of Standard Trips, Scheduled Trips and Actual Trips can be imposed for both types of trips. Standard Trips occur at set days and times (eg Mondays at 8:00 am from Christchurch to Timaru). Scheduled trips can be created from the Standard Trips or put on in response to customer demand (Freight Orders). The Actual Trip may then take place based on the Scheduled trip, but may deviate from its route if additional freight Orders are received during the journey. In the standard trips the type of Prime Mover and Type of Unit are assigned to the trip whereas in the Scheduled and Actual Trips the Prime Movers and Units themselves are assigned to the trips. The actual times and kilometres are then recorded for them.

In addition to modelling the individual trips taken by the Prime Movers and Units, it is necessary to model their various interactions (Figure 5). The configuration of the "Road

FIGURE 4 - VEHICLE & UNIT TRIPS DATA DIAGRAM



Train" is recorded by the RIG which links the Prime Mover (PM_Trip) to the Unit(s) undertaking the journey (Unit-Unit-Trip). Both the pick up and drop off points are recorded (RIG) along with the SWAP, where two Prime Movers drop off one or more units, interchanging them with a second unit - the Prime Movers returning to their base, continuing to pick up and drop off consignments along their way, while the units continue their journey attached to a second or subsequent Prime Mover. These Rigs and Swaps can be standard and can be scheduled in the same way.

Once the trips can be planned and tracked the consignments can be tracked in the same way as each Consignment is logged onto one or more RFL-Consign-Trip.

With an inter-organisational system the other Business Units within WIL (having access to the mainframe systems) and other major trading partners granted terminal access, could enter their own freight orders (RFL-Freight-Ord) and then track the progress of their consignments (Figure 6). This would save double handling of the Orders, first by the Customer sending a phone, mail or facsimiled order, then by the RFL Branch rekeying the information. Each Customer could enter its order (RFL-Freight_ORD) breaking it down into separate consignments (RFL-ORD-Consign) - one for each pair of pick up and drop off points (ie a Segment) - and products (RFL_ORD_CON_PRD). Each product can have different storage requirements based on temperature (cooled or chilled), handling (frozen carcasses or palletised product) or incompatibility with other products (fish and icecream).

CONCLUSIONS

Although this application was designed for a Road Freight operation it can be extended to rail, sea, air or mixed mode operations with consignments transferred from one unit to another (in contrast to the swaps detailed above, where the units themselves are interchanged). Present work on this model is focusing on developing an industry standard design. This is being done in conjunction with a University of Auckland Centre for Information Services project on EDI and the Transport industry. Other work has been done in developing Object-Oriented Designs for a Courier operation [2] and for a Rail Freight and Passenger operation [3]. Each model is based on the generic industry model as described above.

REFERENCES

1. Martin, J "Information Engineering", Prentice Hall, 1989

2. Paynter, J and J. Sheffield "Kangaroo Kouriers", Department of Management Science and information Systems, University of Auckland, Working Paper No 4, 1992

3. Paynter, J "NZ Railway Network", Department of Management Science and information Systems, University of Auckland, Working Paper No 7, 1992 (in prep)

4. Paynter, J and C. Snow "Screenflow Engineering", Tamaki Report Series, University of Auckland, No 1 1992

5. Sweet, F "Building Database Applications", Boxes and Arrows, 1986

FIGURE 5 - SWAPS, RIGS AND TRIPS DATA DIAGRAM

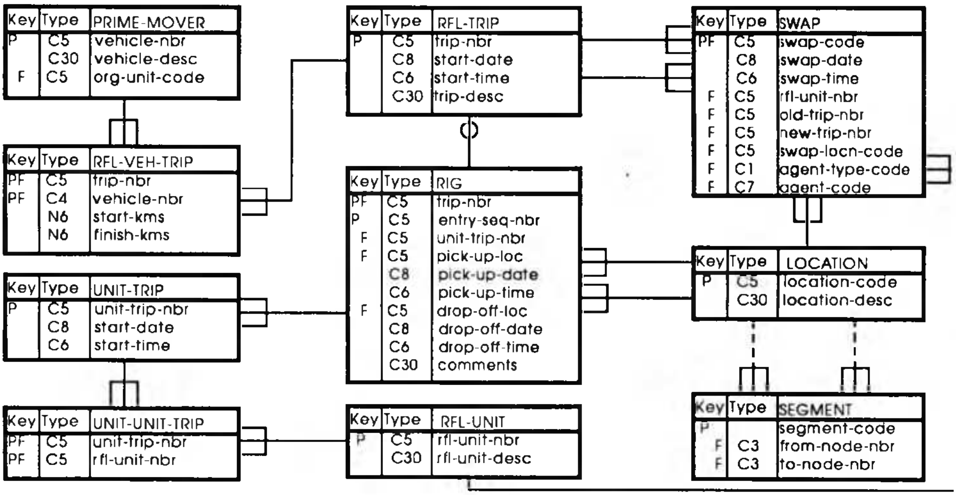


FIGURE 6 - ORDER TAKING DATA DIAGRAM