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The integration of minibus and rail services: the application of the data flow diagram technique

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One of the strategic objectives of the present government of South Africa is to promote the use of public transport with a goal of achieving a ratio of 80:20 between public transport and private car usage by the year 2020. However, the present structures of most of the cities are not conducive to the development of efficient public transport systems. Chatsworth, a major suburban area of Durban, has been considered as a case study in this paper. The area is connected to the city centre by public transport systems, namely bus, minibus and rail. Surprisingly, the patronage on the rail system is very low and is decreasing. An attempt has been made in this paper to suggest a methodology, based on data flow diagrams, to integrate the rail with minibus services.

INTRODUCTION

In recent years the emphasis on economic efficiency and the optimum utilisation of existing transport infrastructures has featured high on governments' agendas universally. South Africa is no exception and is currently seeking strategies to optimise capacity utilisation and to achieve a level of integration between modes to achieve a ratio of 80:20 between public transport and private car usage by 2020, as targeted in the White Paper (Department of Transport 1996). In the past, a fragmented approach was taken in transportation planning. As a result, expensive infrastructure was constructed in certain areas without proper planning.

Chatsworth, one of the major suburban areas of the city of Durban, is a typical example of such planning. It is situated approximately 26 km from the Central Business District and has a population in excess of 200 000 and car ownership of about 40 000, according to the 1991 census. The vehicles on Higginson Highway (M1), the only major access road from this area to the Durban CBD, operate at capacity during peak hours. Volumes in excess of 4 800 vehicles per hour have been recorded during the morning peaks (Durban Metropolitan Transport Advisory Board 1993). This has resulted in the public demand for the construction of a second access road to the area. Chatsworth is also connected to the CBD by a surface rail system which is operated by Metrorail. There are five rail stations in the area, namely Havenside, Bayview, Westcliff, Chatsglen and Crossmoor.

Since the area is inhabited by people of different income groups, a substantial percentage of the commuters still rely on public transport. Surprisingly, the patronage on the rail service is extremely low when compared with buses and minibuses and is decreasing gradually.

The recent status quo report (Traffic and Transportation Department 1995) indicates a potential growth in utilisation of 265% on the Durban–Chatsworth rail line. This is a unique case of underutilisation of existing infrastructure when, on the one hand, there is a demand to construct a new access road and on the other hand, an expensive rail system remains almost unused.

Improper land use planning and the alignment of the rail in relation to the residential dwellings are two important reasons for the decline of the rail system in Chatsworth. It has been estimated that fewer than 5% of the residents live within 500 m of a railway station, highlighting the lack of accessibility (Allopi & Sarkar 1997a). Also, the parking facilities at the stations are inadequate and unsafe, which discourage the commuters from 'parking and riding'. Moreover, bus and minibus services from the residential areas to the railway stations are inadequate.

A study was carried out to establish deficiencies in the existing transportation infrastructure and services. The response of the commuters revealed that the distance to the rail station and inadequate safety were the primary causes for the underutilisation of the Metrorail system (Allopi & Sarkar 1996). The study identified the lack of access, lack of convenient ticket sales offices, restricted hours of ticket sales, inadequate and poor facilities/infrastructure and limited service as the other contributing factors. With regard to the commuter survey, it was interesting to note that 80% of the present car users indicated that they would prefer public transport if the existing conditions were improved (Allopi & Sarkar 1997b). The factors that they considered most important to be improved on the rail service included security while travelling, improved frequency of rail, and minibus service from their locality to the main station. It was quite evident from the analysis that the present rail users showed greater discontent with the level of service in comparison with bus and minibus commuters.

Encouraging commercial and residential development along the rail corridor is one of the long-term solutions to increase accessibility. However, in the short run the integration of the rail system with the road based modes may be the only possible solution to increase the utility of the rail service in Chatsworth. This paper proposes a methodology, based on data flow diagrams, to integrate rail with the minibus services (Powers *et al* 1990).

DEVELOPMENT OF AN INTEGRATED SYSTEM

It was found that the minibus association operated on the inner circle route (Greater Chatsworth area) and recently allocated a small percentage of its fleet to the Durban CBD route. This resulted in conflict with the bus association. Interviews conducted by the authors with the Chatsworth Minibus Association with regard to the formation of a partnership with rail to provide a feeder service to the stations proved promising and positive. The South African Rail Commuter Corporation (the authority responsible for train services in South Africa) supports an integrated public transport system. It was therefore decided to look closely at this option and to formulate an integrated system between the minibus association and rail services. A methodology has been presented for developing a computer simulation model for the operational analysis of minibus and rail integration.

The primary aim is to set up an integrated transport system in the survey area to capture commuters who will eventually become 'committed' to the system. Integrated fares would be introduced and made attractive (greater discount) for the purchase of a monthly, semester or even an annual transport card. To implement the integrated system, the server should be set up at the Chatsworth Centre (shopping complex) where the bulk of the residents from the area make their purchases and account payments. Terminals would be located at the five railway stations and at some of the post office depots in the area with a view of introducing automatic ticket dispensers at a later stage. Card readers / validation machines will have to be installed on minibuses and at the entrance to the station platforms. Commuters will be required to validate their cards at the commencement of the trip. Enforcement and appropriate fines will have to be imposed in order to prevent fare evasion.

Through a structured analysis technique called data flow diagrams (DFD) a graphical representation of data processes throughout the organisation for an integrated system is presented. Data flow diagrams indicate the flow and transformation of data within a system. They serve as a strong communication vehicle and this approach emphasises the logic underlying the system. By using combinations of only four basic components, one can create a pictorial depiction of processes that will eventually provide solid system documentation.

COMPONENT OF A DATA FLOW DIAGRAM

A data flow diagram consists of four basic components, namely external entities, processes, data flows and data stores. The characteristics and use of each of these components are reviewed below:

- *External entities:* They are entities which are outside the system but which communicate with the system. In this case the typical external entities will be the commuters, minibus association, rail and accounts. These entities can send data to or receive data from the system. A rectangle indicates any entity external to the system being modelled.
- *Processes:* Processes always denote a change in or transformation of data. They represent work being performed within the system. Processes should be cohesive and have as few inputs and outputs as possible. An example of a process will be to update the route schedule for minibuses. Bubbles or circles are used to indicate those points within the system at which incoming data flows are processed or transformed into outgoing data flows.
- *Data flows:* The arrow shows movement of data from one point to another, with the head of the arrow pointing towards the data's destination. In simple terms, data flows describe data that flows through the system. Data flows should include the minimum essential data needed by the process that receives the data flow. All data flows should begin and/or end at a process, because data flows either initiate a process or result from a process.
- *Data stores:* They are passive stores of information. The type of physical storage (for example tape, diskette, etc) is not specified. At this point, the data store symbol is simply showing a depository for data that allows addition and retrieval of data. A data flow from a data store to a process means that the process uses the data while a data flow to a data store means that the process updates (adds, deletes or changes) the data store. Open rectangles are used to identify temporary holding points for collection of data.

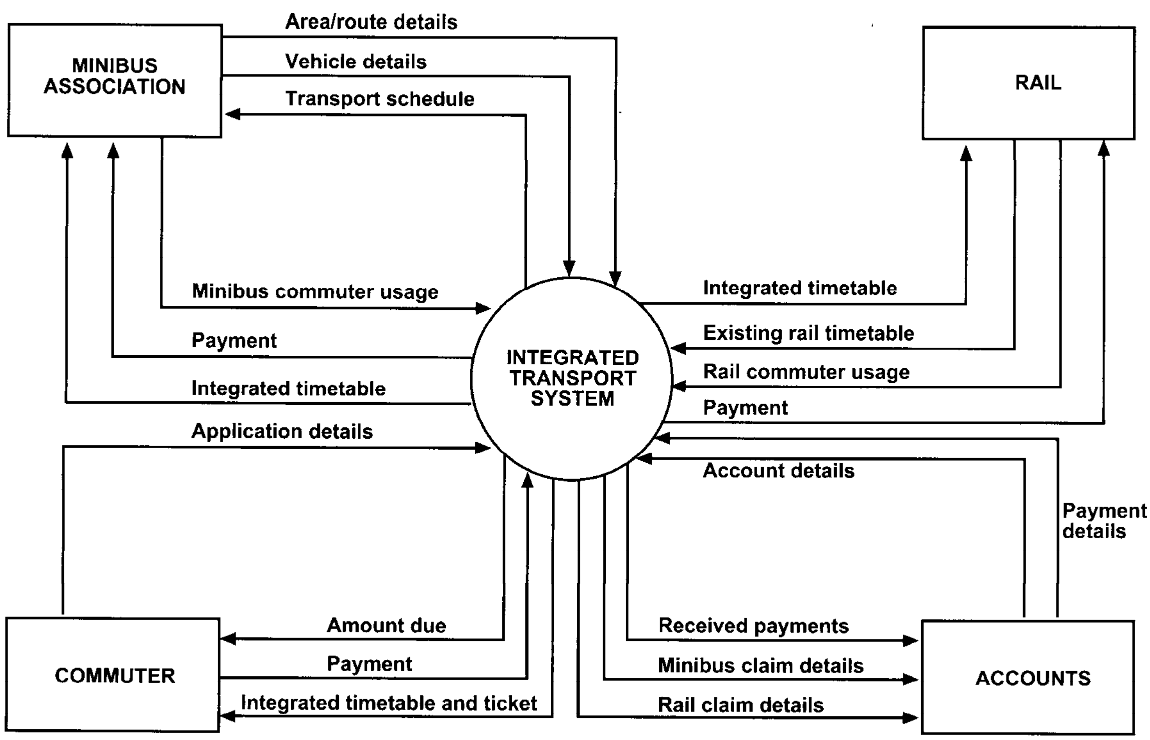

Figure 1 Context diagram for the integrated transport system

DEVELOPING THE DATA FLOW DIAGRAM

To begin a data flow diagram, the organisation's system narrative is collapsed into a list with the four categories: external entity, data flow, process and data store. This list in turn helps determine the boundaries of the system to be described. The first is to draw a context diagram, followed by the top-level diagram and then the detail-level data flow diagram. These are discussed very briefly below:

Context diagram

The context diagram gives an overview of the system's interaction with its environment. The environment consists of the external entities and data stores that are considered to be outside the system. The context diagram is the highest level in a data flow diagram and contains only one process, representing the entire system. A typical context diagram for an integrated public transport system as developed in this study involving rail and minibus is reflected in figure 1.

The external entities, that is, minibus association, rail, the commuter and accounts, are shown on this diagram and the major data flows to and from the external entities are also reflected. The context diagram contains only one process (Integrated Transport System) that represents the entire system.

Top-level data flow diagram (diagram 0)

This diagram gives an overview of the main functions of the system and the flow of data through the system. Each main function is represented by only one process. Diagram 0 is an explosion of the context diagram and may include up to eleven processes. This diagram still contains all the same inputs and outputs as the context diagram, except that the single central bubble in the context diagram has been partitioned or decomposed into a series of components.

The top-level data flow diagram (diagram 0) is reflected in figure 2. The process that forms the integrated system are as follows:

- The COMMUTER (external entity) requests to use the system indicating his/her origin and destination as part of the *application details* required to process the application (process 1).

- The physical address as part of *commuter details* will assist in identifying the route node closest to the commuter, as reflected in process 2. Route details pertaining to all commuter requests are stored in a database called 'ROUTE DETAILS/COUNT'. The direction of arrows relating to data stores is important since data flow from a data store to a process means that the process uses the data, that is, a 'read' is assumed. On the other hand, a data flow to a data store means that the process updates (adds, deletes or changes records) the data store. Based on a radius system for the determination of fares, the amount due is received from the commuter. All payments are deposited in a central accounting system called ACCOUNTS (external entity) via the *handle payments process* (process 3).

- The MINIBUS ASSOCIATION (external entity) supplies a transport schedule based on the designated routes and nodes through the various units in the area to one of the five rail stations closest to that particular unit.

- The system allows for updating route schedule (process 4) depending on commuter demand. Information pertaining to route details are placed in the data store TRIP SCHEDULE. The schedule also takes into account the available fleet of the association in determining the frequency of the services to be provided.

- Depending on passenger demand, the vehicle details may be updated (process 5) with FLEET being assigned as the data store.

- *Fleet details* are utilised in updating the frequency of service to be provided (process 6). *Vehicle frequency* details are also stored in TRIP SCHEDULE.

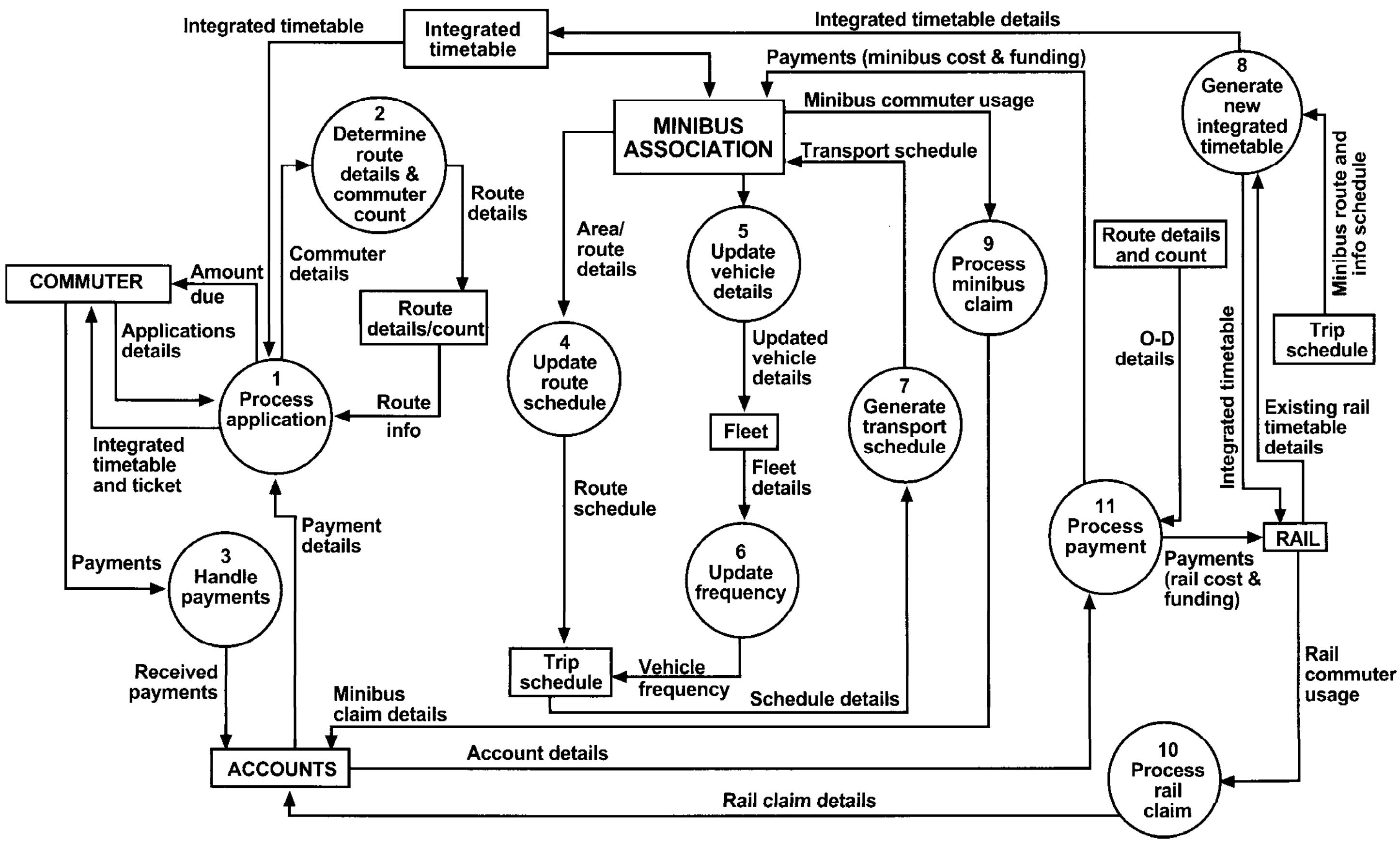

Figure 2 Top-level data flow diagram for the integrated system

- The minibus schedule details (route schedule and vehicle frequency) are used to generate a transport schedule (process 7) for the minibus industry.

- The minibus transport schedule is then combined with the existing timetable for RAIL (external entity) to *generate a new integrated timtable* (process 8), copies of which are directed to both the public transporters. It is obvious that adjustments would have to be made from time to time to either or both of the public transporters' timetable depending on the demand for the integrated transport system (ITS). All commuters that have paid (via the application process) to use the system receive a copy of the integrated timetable together with his/her computerised ticket/travel card.

- Depending on the minibus commuter usage, the amount due to the Minibus Association is determined (process 9) and the claim details are forwarded to ACCOUNTS (external entity).

- Similarly, based on the rail commuter usage, the amount due to rail is calculated (process 10) and also forwarded to ACCOUNTS. Account details are verified against commuter details initially placed in the data store ROUTE DETAILS/COUNT.

- The final payment (process 11) is based on the assumption that some funding/subsidy is made available by government in order to keep the integrated fare as low as possible, thus attempting to make the system more attractive to commuters and further assisting with the integrated system gaining momentum.

The detailed level data flow diagram (child diagram)

Each process in diagram 0 may in turn be exploded to create a more detailed 'child' diagram. However, it should be noted that processes may or may not be exploded, depending on their level of complexity. It is always advisable to use original, unexploded data flow diagrams (as in figure 2) in the early stage when ascertaining information requirements.
Overly exploded diagrams may not be helpful to the users, since changes will need to be incorporated after getting users input.

Data flow balancing is necessary where flows are carried over from a higher level to a lower level. On this level, data stores which are local to a process can be shown for the first time. All data flows in or out of the parent process must be shown flowing in or out of the child diagram. The numbering of the child diagram is derived from the numbering of the parent process in the top-level data flow diagram (diagram 0).

For the purpose of illustration, one example of the detail-level data flow diagrams is shown in figure 3.

Figure 3 reflects the application process where the commuter requests to use the facility indicating the origin and destination (process 1.1). This information, obtained from all commuters, is stored in a database for calculating the amount due by the commuter as well as for the purpose of audit/payment to the minibus association and rail.

In determining the amount due by the commuter, the following two approaches may be considered. Firstly, the radius may be determined from the route node closest to the locality of the commuter to the destination rail station (process 1.2). The cost factor based on the radius system or a flat rate may then be applied to determine the amount payable (process 1.3).

This cost added to the fixed minibus fare will yield the total amount due by the commuter (process 1.3). On payment of the amount due, the commuter is given an integrated timetable together with the ticket/travel card. The system could be designed to check for outstanding payments, as in the example and as reflected in process 1.4.

DEVELOPMENT OF A PROTOTYPE

The prototype was developed around the option of using the integrated public transport system (minibus and rail), since this was the main purpose or focus of the exercise. A range of ticket options ranging from a single to a yearly ticket were included in the input screen. For the purpose of demonstration, the first three options were included in the prototype (single, return and weekly ticket). The default was set on Bayview station as the origin/boarding station. The destination stations were set on Merebank, Clairwood and Durban for the single, return and weekly ticket options respectively. With regard to the minibus route, three nodes on Pelican Drive (Pelican/Turnstone, Pelican/Skylark, Pelican/Liberty) were considered as typical stops leading to Bayview Station. The system was designed on the assumption that both the minibus and rail strictly follow the time schedule. However, a buffer of 10 minutes was allowed between the arrival time of the minibus at the station and the departure time of the train. Adjustments would obviously have to be made from time to

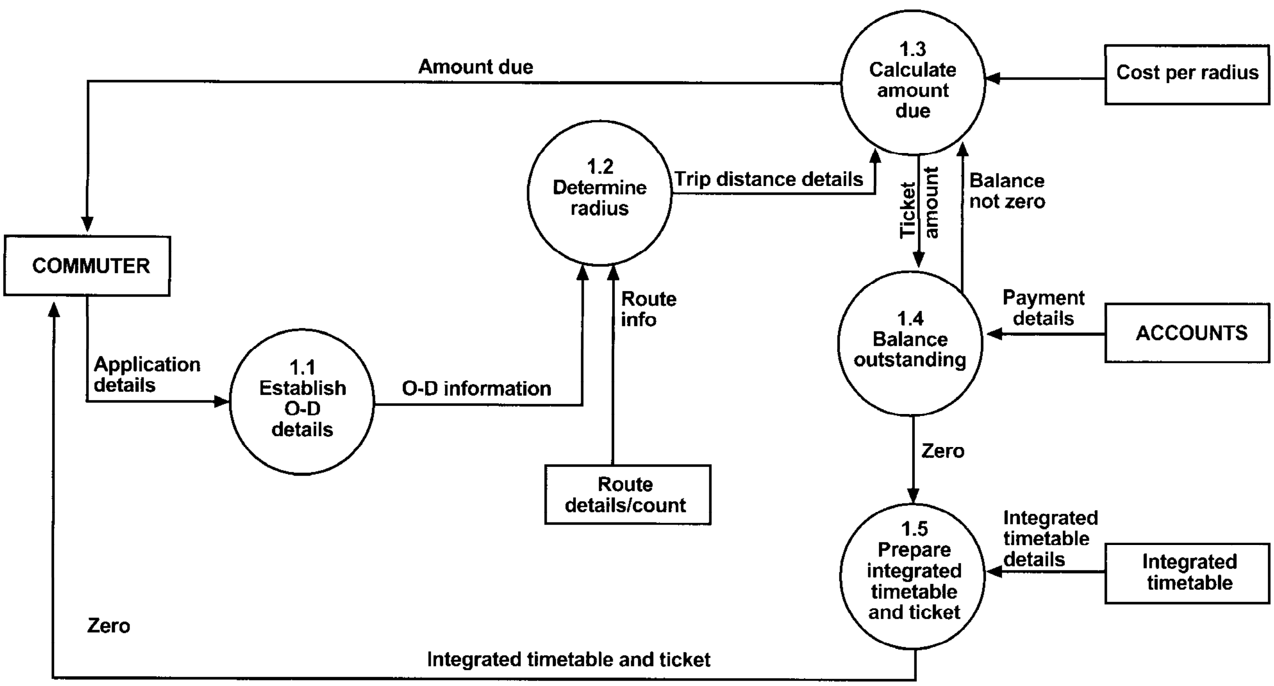

Figure 3 Detail-level data flow diagram: application process

time to cater for the demand on various routes. A commuter wishing to use the system indicates his/her choice of ticket (single, return, weekly), origin and destination of travel.

The cost of the ticket and the necessary travel information such as taxi node/stop, minibus and rail departure times are given to the commuter. Upon payment, a printout of the ticket is handed to the passenger. The prototype also allows for a printout of the complete schedule reflecting the integrated timetable, if requested.

CONCLUSION

It would require a multidimensional and sustained approach to achieve the target of 80:20 ratio between public transport and private car in the long run as targeted by the government of South Africa. The first step in this direction would be to integrate the existing public transport systems and optimise their usage. An approach to integrate the rail and minibus has been suggested in this paper and a prototype has been developed for the Chatsworth area in Durban. This integration is likely to shift a number of car users towards public transport systems, provided other necessary planning and enforcement steps are taken simultaneously. It is recommended that the government take up a few pilot projects to determine the real shift, which will help to identify the measures to be taken to achieve the desired modal split.

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