Integrating Information Technology and Operational Research in the Management of Milk Collection

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Abstract

The Dairy industry is an important part of the food sector and milk collection is a challenging logistics problem that had long been of interest to operational researchers. Advances in information technology (IT) greatly facilitate data collection, manipulation and presentation and these advances facilitate the building of Decision Support Systems (DSS) to support logistics management in the milk collection sector. This paper discusses how a Geographic Information System (GIS) based DSS allows a scheduler interact with optimisation algorithms to plan milk collection routes. The paper goes on to discuss how such a DSS can be integrated with automatic data capture devices and database management systems to provide effective management of milk collection operations.

Milk Collection

Background to Milk Collection

Transportation costs are always a significant component of total cost for a company where the movement of raw material or product is required. Major components of this cost include the labour cost of the drivers, the cost of fuel, and the cost of the trucks. These costs are especially important where perishable products are being transported and specialised handing
is required. These conditions frequently arise in the transport of agricultural products, and especially in the handling of dairy products. Significant transportation problems arise both in the collection of milk from farmers and the distribution of finished products to shops. The cost of delivery of these products is a key issue (Adenso-Diaz, González, & García, 1998) (Tarantilis & Kiranoudis, 2001) which has something in common with other delivery applications. On the other hand, bulk milk collection is a distinctive logistics application and one where major transport costs are incurred.

In most countries milk is a scarce commodity, and within a region dairy companies attempt to attract as many farms as possible to supply them with milk. The most attractive inducement that a dairy can offer a farmer is a competitive price per litre for the farm’s milk output. Rival dairy companies regularly attempt to “poach” farmers from other dairy companies through much publicised increases in price per litre. The history of the dairy industry contains many examples of so called “Milk Wars”. Marketplace competition for dairy products, and similar levels of efficiency in modern milk processing plants, ensure that the dairies cannot profitably operate if the cost of a litre of milk arriving at the processing plant is out of line with others in the industry.

The cost of milk has two components: first, the cost of transport, and second, the cost of paying the farmer for the milk. Given that the dairy has little scope for allowing the total cost to increase, then any increase in the price per litre paid to the farmer must be compensated by a reduction in the cost per litre of collecting the milk. An efficient transport operation can allow a higher milk price to farmers, in turn attracting higher volumes that can lead to further economies of scale in milk collection. Because a reduction in transport cost can improve the price per litre that a dairy can offer its farmers, dairy companies have consistently attempted to adopt cost reducing initiatives. These have included introducing larger capacity collection vehicles and longer working days for the drivers. In dairies, schedulers control milk collection
operations, by selecting which vehicle is to visit which customer. Dairies have always been
interested in the ability of schedulers to design a cost efficient set of routes, which allocate
farmers to trucks in a way that minimises the total cost of milk collection.

In most dairies, the scheduler responsible for allocating farmers to trucks and drivers is
someone promoted from the organisation’s cohort of drivers. The scheduler, once in the
position, finds it difficult to reconcile the conflicting demands of management, drivers and
farmers. The demand from management is for a milk collection system that they believe to be
the most efficient and cheapest possible. On the other hand, drivers are usually paid
employees and typically resist changes that impact on their working conditions. Dairy farmers
develop a routine that includes the daily arrival of the milk tanker, and respond in a negative
fashion if changes in this routine are suggested.

Schedulers must operate in the context of these conflicting demands from the various interest
groups involved. Traditionally, milk collection routes evolve organically over time. Given the
complexity of the problem, the scheduler has a limited capacity to make drastic changes to a
route structure. The management of the dairy is primarily concerned with cost factors and the
perceived reluctance of the scheduler to make changes has led to the perception that transport
costs in milk collection are higher than they should be.

**Operational Research in Milk Collection**

In the 1970’s energy and labour costs increased dramatically, with a consequent impact on
transport costs, this led to interest in the use of Operational Research (OR) techniques for cost
reduction. In this period, computer technology became sufficiently powerful to be capable of
solving simple OR problems of reasonable size. OR techniques were subsequently
incorporated into a series of computer packages that purported to provide optimal solutions to
route optimisation problems. This software incorporated a simplified view of the routing
problem, largely concentrating on distance minimisation to the exclusion of other issues of concern to schedulers. This early software was difficult to use and lacked the type of interactive interface that later facilitated software use in business.

Initially, these packages were applied to transport problems involving the distribution of product in response to changing customer orders. These problems were characterised by route patterns that differed from day to day. The scheduling on such routes was extremely difficult, as the scheduler frequently had only a few hours between receiving the customer orders and preparing the delivery routes. For this type of problem any computational assistance from software, however inadequate, was very welcome. Given the once off nature of the routes, the schedulers were prepared to overlook the limitations in the solutions generated, as there was insufficient time to prepare superior solutions in any case.

Fisher, a prominent researcher in vehicle routing, noted that the overall procedures used in early routing software were sub-optimal, as the routing problem was modelled inexactly to achieve tractability (Fisher, 1995). He suggested that these routing algorithms performed well in some situations, but delivered unreasonable results in other cases with slightly different data. Fisher suggested that a number of strategies could be used to improve algorithm robustness. These included using better road network data, this has been facilitated by the introduction of Geographic Information Systems (GIS) based techniques discussed below. Fisher suggested that manual intervention might improve the usefulness of algorithms, this is the approach embodied in Decision Support Systems (DSS) that form the basis of this paper. He also suggested that faster computers would allow optimal results be achieved for more complex problems. Computer technology continues to improve, but many routing problems remain difficult to solve optimally.

The milk collection sector demonstrates the trends discussed by Fisher. Milk collection problems differ greatly from many other routing problems in that the routes are static in
nature and vary only marginally on a day-to-day basis. Customers, drivers and other interest
groups expect that milk collection routes will meet their needs, as these routes will be used
with little change for a long period. These distinct features meant that software developed to
meet the needs of other routing applications was unlikely to succeed in the diary industry.

Nevertheless, the management of dairy companies saw these routing packages as a solution to
the scheduling problem in their distinct environment. They hoped to replace the scheduler
with software that would produce an optimal solution to minimise transport costs without any
of the political reluctance of the scheduler. This software had usually been developed with a
different industry in mind, and was not able to adequately model the complexity of the milk
collection process. Time window constraints, constraints arising from problems of access to a
farm by large trucks, and even driver constraints where by the driver for social reasons wished
to collect farms in a certain sequence, were not fully catered for by the “Black Box”. This
meant that the solution provided by the “Black Box” ignored various fundamental constraints,
making the solution unusable as a working schedule. The additional constraints relating to
milk collection could not be added into the models used without increasing the execution time
excessively. Consequently, the use of the “Black Box” approach was discontinued and the
unfortunate outcome of these unsuccessful attempts to use these packages was a deep
scepticism towards OR within management of dairy firms.

The lesson from the above is that milk collection is complex and distinct from other routing
applications. Consequently, what is really required is technology that supports the scheduler,
rather than technology that attempts to replace the scheduler. This supportive approach and
associated technology started to emerge in the milk collection sector in the 1990’s with the
development of DSS.

The DSS approach to scheduling
**Decision Support Systems (DSS)**

The limitations of OR algorithms alone to fully meet the needs of business decision-makers became obvious in a number of fields. This led to the development of the concept of a DSS in the 1970’s (Gorry & Scott-Morton, 1971; Little, 1971). A DSS, as the name suggests, is designed to support rather than replace a decision-maker. A DSS will include computational techniques, but in contrast to the traditional approach these operate under the control of the decision-maker through a user-friendly interface. Barbosa and Hirko (1980) put forward a succinct set of guidelines for the design of OR/MS based DSS. These guidelines focus on user control, flexibility and system feedback through a user-friendly interface.

Routing has been identified as one of the major areas of application of DSS (Eom & Lee, 1990; Eom, Lee, & Kim, 1993). The Geodata Analysis and Display System (GADS) was an early system, with relatively sophisticated graphics, that illustrated the potential of routing DSS (Grace, 1977). In a review of the vehicle routing field, Bott and Ballou (1986) argued for the use of graphically based interactive techniques combined with appropriate algorithms. Another review of the routing field (Ronen, 1988), reached a similar conclusion about the importance of interactive software working with experienced schedulers. A review of software for milk collection argued for flexible, user-friendly, interactive and inexpensive software with less need for improvement of the optimisation procedures (Bocxe & Tilanus, 1985). Software in that period did not generally provide that flexibility, a review of PC based routing software (Golden, Bodin, & Goodwin, 1986), found that only one-third of the packages reviewed had extensive graphic facilities.

**Early DSS**

Consequently, the need for interactivity became widely recognised and software could only meet this need by providing an improved interface. The introduction of personal computers with reasonable graphics facilitated the development of DSS generally, and this is especially true for routing DSS. Traditionally a scheduler used a map of their region with farms
identified by coloured pins. The colour associated with a pin reflects the milk collection route that is used to service the particular farm. Early DSS applications provided simple graphics and the system was designed to reduce the need for the geographic map and the coloured pins. Early systems were unable to replace maps completely because of the limited amount of information displayed on the screen.

By means of this first generation DSS a scheduler could get a coloured display of the milk collection operation, and could see the consequence of moving one farm from one route to another route. This functionality was useful when the total milk from a route approached or exceeded the volume capacity of a truck. When this happened, the scheduler would have to move one farm from one route to another. What farm to move, and onto what route to move that farm, could be determined by the scheduler by simply viewing the computer screen. The DSS did not attempt to suggest a solution; it supported the decision-making by re-calculating the volume collected and distance travelled on each route as a result of a suggestion by the scheduler.

Unlike the “Black Box” systems, this reactive system received the support of the scheduler. The decision remained with the scheduler, while all that was expected of the technology was to provide calculation support. No attempt was made to replace the scheduler; the DSS was designed to work in a supportive role to the scheduler.

**Second Generation DSS**

Technology limitations meant that early DSS applications had a sparse interface that provided only some of the information of interest to the decision-maker. As computer systems improved, the objective of DSS development was to provide a richer information environment for decision-makers. This required the provision of more contextual information, in the milk routing example this included more geographic information and more information on the customers and their volumes, time windows, etc. During the 1990’s various generations of
DSS have been introduced. All these have the same philosophy, what has changed is the quality of geographic map, and the level of information available to the scheduler about each customer. In the first generation, the coloured symbol used to represent a customer only contained information on the route and volume. Later generations incorporated an interface linked to a comprehensive database and this enabled a whole variety of information relevant to milk collection to be associated with a symbol.

This richer environment can be achieved by customised programming or by using an appropriate software tool. In the 1990s a number of routing DSS systems were developed using the graphical programming facilities in modern programming languages, for example the road sweeping system in England by Eglese and Murdock (1991) or the milk collection Fleetmanager system in New Zealand (Basnet, Foulds, & Igbaria, 1996). The availability of PC based geographic information systems (GIS) has made an important contribution to routing DSS. These systems allow the storage and manipulation of geographic information. GIS can be seen as a generator for building a routing DSS, with the addition of specific data and calculations to support the routing function (Keenan, 1996). Modern GIS software such as ArcGIS or MapInfo provides an effective DSS interface, a powerful macro language and the ability to interact with external programs. Consequently, a second generation DSS can be built with a much richer interface and GIS technology forms the basis of many modern routing systems (Keenan, 1998). GIS based systems have been used for a variety of routing applications, from urban product delivery (Tarantilis & Kiranoudis, 2002) (Ioannou, Kritikos, & Prastacos, 2002), to hazardous waste transportation (Frank, Thill, & Batta, 2000) and ambulance dispatching (Derekenaris et al., 2001). Figure 1 shows a typical routing interface for a routing DSS developed with the MapInfo GIS.

**FIGURE 1 about HERE**
In Figure 1, the colour suggests the route on which a farm is collected. In addition, the DSS also uses the size of the symbol to represent the milk volume output from the farm. This size variation also gives the scheduler some hint as to which farm to move and the consequence to a route of moving that farm.

The information that could be associated with a symbol included:

- Supplier name
- Telephone number
- Supplier code
- Volume collected at most recent collection
- Temperature of most recent collection
- Butterfat for most recent test
- Protein for most recent test
- Lactose for most recent test
- Total Bacterial Count (TBC) for most recent test
- Somatic Cell Count (SCC) for most recent test
- Total supplies to date
- Quota
- Reference butterfat
- Butterfat adjusted quota position (% of quota used)

Memories of expensive past failures with “Black Box” systems have made management of dairy companies reluctant to invest in computer systems. However, through the support of schedulers, realistic expectation management by marketers, and some very successful implementations, DSS is slowly becoming a feature of how progressive dairies manage their milk collection operations.

**Case Study of DSS success**
UDS Software is a Dublin based software company specialising in developing management and logistical software for the milk sector. UDS Software has been a pioneer in the development of successful DSS implementations. UDS Software uses MapInfo as its development environment, and has over 10 years of experience of applying DSS to both Irish and UK dairies. One example of the value of a DSS driven application occurred when an Irish dairy decided to radically change its milk collection system.

Traditionally, the dairy had used drivers who were their direct employees to collect the milk. These employees were unionised, and over the years many work practices had developed that were responsible for a higher than acceptable cost of milk collection. These work practices covered such issues as: length of day, meal breaks, maximum truck size, a limit on the number of farms on a route, and holiday rosters.

The approach favoured by management was to make redundant all of the drivers, and to replace them by several small collection companies. It was assumed that each collection company would be built around an existing driver. Each company would be allocated a cluster of farms with the company paid a fixed price per litre to collect the milk. It was expected that two routes per day would collect the milk from a cluster during the period for peak milk production, and one route per day during the off-peak period.

The issues for negotiations between management and workers were:

1. The optimal size of a cluster. Assuming that each cluster would be allocated to a company owned and worked by an existing employee, then how much could a driver collect during a day at peak, and during a day at off-peak? These maximums would dictate how much milk, and how many farms, management should allocate to a cluster. It was assumed that each company/cluster had a main driver, but, in addition, that driver would have call on additional drivers to cover holidays, rest days etc. The management of these relief drivers would be the responsibility of the main driver. The
dairy’s only responsibility would be to allocate milk to a company/cluster. The detail of the required routes to service the cluster would be the responsibility of the company, managed by the main driver.

2. **The allocation of farms to a cluster.** Negotiations from the first phase suggested that 9 million litres per annum, with a certain peak to off-peak ratio, would be the target. The second issue was how to partition the total milk pool of the dairy into coherent clusters of appropriate size. This is where the transparency of the DSS became an invaluable tool. The approach used was to create a DSS containing relevant data on all of the farms serviced by the dairy, approximately 800 farms in this example. These 800 farms were located on the DSS map by coloured symbols, and the data behind each symbol was the annual milk output from the farm, the peak daily output from the farm, and the off-peak daily output. Management used the DSS to form feasible clusters from their perspective. In this process, the scheduler was able to cluster the farms manually, by looking at the visual display of all the farms on the DSS. The DSS calculated the three volumes, annual total, peak daily, and off peak daily, for each cluster. The scheduler moved farms from cluster to cluster using the DSS until a set of feasible clusters was obtained.

3. **Ownership of the collecting companies.** The dairy aimed to allocate to a days work to a transport company owned by an existing driver, who would be responsible for all aspects of its operations. The dairy would allocate each collecting company a cluster of farms, and dairy would pay an agreed price per litre to the company to collect the milk from the farms within its cluster. It was agreed that the dairy would issue a five-year contract to each collecting company.

Discussions took place between management and drivers as to who would be offered the ownership of the collecting companies. In total the dairy employed 80 drivers, and
first estimates suggested that 32 clusters would be required. This suggested that 32 of
the 80 existing drivers would be offered clusters, while the remaining 48 would be
offered redundancy. Partially due to the age profile of the drivers, and the generosity
of the redundancy scheme, the management had little difficulty finding the 48 drivers
to volunteer for redundancy.

Negotiations now could start with the 32 remaining drivers as to the final composition
of the clusters. In the boardroom of the dairy, and through the use of a large television
screen, the DSS was used to display the proposed clusters. Using the local knowledge
of the drivers, together with a collective feeling of equity, the final clusters were
agreed. The author suggests that the DSS provided an invaluable ability to view and
change the solution, in a way transparent to all parties. Without this technology,
agreement would have been much harder to achieve.

4. Price per litre to collect the milk. By now the dairy had an agreement to replace its
existing drivers by independent collecting companies. It had also agreed the size and
composition of the 32 clusters. It has also agreed which driver would be allocated each
cluster. The final stage was to agree the collection payment schedule.

Each company/cluster would have annual revenue derived from the number of litres
collected from the cluster multiplied by the fixed price per litre agreed with the dairy.
Costs to the company would be the full cost of collecting the milk from the cluster.
These included truck costs, fuel costs, additional driver costs, and provision for
pension costs. It was assumed that the profit of the collecting company would be the
payment to the main driver in lieu of salary.

By agreeing expected company profit, by estimating all of the expected costs,
management could agree the annual revenue required by each cluster. This annual
revenue figure, divided by the annual milk volume in a cluster, is the price per litre for
a cluster. This price per litre, together with an agreed inflation increase, would form part of the collection contracts.

Management completed all negotiations with its drivers in 1998, and the new system of collecting companies started in September 1998. The dairy estimates that this change has reduced its annual cost of milk collection by approximately IR£500 000 (€635 000).

Management of the dairy also suggested that the DSS was a vital tool in the negotiations because it allowed management and drivers to actively engage in the clustering process, and it ensured that drivers could take ownership of any decisions reached.

The above process received significant coverage in the dairy sector, and has to a certain extent restored management’s confidence in Operational Research, and the ability of technology to play a significant role in optimising milk collection costs.

**DSS Enhancements**

*Geographic Data*

The use of GIS also requires the availability of suitable geographic data. This has been facilitated by technical developments in data capture. Initially digital mapping data was not widely available and customised data collection from maps was achieved by digitisation using a hand-held device, an error prone and time consuming process. In Ireland, data has been historically quite expensive and of poor quality because of inadequate updating of maps. The situation has now greatly improved, with general mapping information now available, at a price, in digital form. The widespread availability of accurate road network data allows calculation of accurate travel times using the actual road distances used rather than estimation using co-ordinate distance. This is especially important in milk collection as the rural road network is quite sparse and the road distance between two points may be much further than
the co-ordinate distance. Modern GIS software contains network analysis tools to exploit this road network data (Figure 2).

FIGURE 2 about HERE

Other technical developments such as Global Positioning Systems (GPS) have greatly facilitated the collection of geographic data in general. GPS is seen as an important development in data collection for routing (Imielinski & Navas, 1999). GPS allows the collection of point and time data, either as single data points or as a stream of data. A GPS installed in a moving vehicle can collect continuous data on the vehicle location and the time that it reached those locations. This is valuable both for data collection in advance of route optimisation and for validation of the routes produced. GPS has an important role to play in agricultural applications as the exact location of farms and their milk storage facilities may not be recorded on maps, these locations can be easily identified by a GPS on an existing vehicle that visits these facilities.

Customer Data
While GPS provides location data, a successful DSS also requires non-spatial (attribute) data about customers. This can be facilitated by using several different data capture strategies and by the use of a database to organise the data collected. UDS Software has developed, in parallel with their DSS, a Milk Procurement Management System. The management of the dairy uses this system to plan and control all aspects of the milk collection operation. The system includes modules to reconcile the load of each milk collection tanker against a weighbridge, modules to monitor the milk quota position of each farm, and modules to assess payment farmers for milk supplied. The milk payment process is complicated, as the amounts paid to a farmer at the end of each month depend not only on the volume of milk supplied, but also on the quality and composition of that milk. The quality and composition of milk is
calculated based on a daily milk sample taken at each farm. These samples are laboratory tested, and the data is fed back electronically to the Milk Procurement software (Figure 3).

**FIGURE 3 about HERE.**

The use of software to store data relating to all aspects of a farm's milk operation, and the linking of the DSS to this database, allows management use a range of data to underpin the DSS. For example, management might be interested in viewing all farms that are approaching the limit of their annual quota; the DSS together with an interface to the Quota Module allows this. A second example might involve milk output that is less than acceptable. Here, management might wish to visit all farms whose milk is below a given standard. The DSS would allow management display a geographic plot showing all such farms and, possibly using an optimisation tool, management can determine an efficient route that to visit each farm.

The key to the milk collection process is the accurate recording of the volume of milk collected at each farm. In addition, data on milk temperature and time of collection is needed for effective management of the process. Normally, the milk collected from a farm should have been cooled to 4°C, quality issues can arise if the milk collected is in excess of this temperature. Traditionally, a driver would record manually at each farm; the volume of milk, its temperature, and time of collection. This data would then be manually inputted into a computer system when the vehicle returned to the dairy. Management has always been concerned about the accuracy of this data. The volume data can be reconciled against a total route volume as by passing the truck across a weighbridge. Historically, the verification of temperature and time of collection is not as easy, although the introduction of on-tanker computers in the 1990’s has greatly improved the situation. This data capture equipment, together with volume and temperature probes, allows a range of relevant data be collected and stored electronically during a route. At the end of a route this data can be downloaded into
suitable software for reporting (see Figure 3). By integrating this data into the DSS, further aspects of the milk collection process can be managed and controlled.

**Optimisation**
Successful DSS implementations, like the one described in the previous section, have greatly restored management’s confidence in technology. With this restored confidence has come the willingness of companies to invest in DSS systems. This confidence in these DSS implementations arose because they supported the decision-maker. However, the support provided was usually confined to a graphical representation of the problem and simple computational support, without the extensive use of OR techniques. Gradually, as schedulers became more relaxed with the DSS, they became more willing to delegate progressively more intelligence to the DSS. This could allow, under the control of the scheduler, of techniques for clustering and routing, for example Travelling Salesman (TSP) algorithms.

In the dairy example above, the first request from the scheduler was for the DSS to provide a “hint” as to which farm they should move from one cluster to another. The “hint” concept allowed the scheduler to accept or reject a suggestion from the DSS. Observation of the use of the DSS revealed that the scheduler would more and more often accept the “hint”. When the scheduler rejected a “hint”, analysis would be initiated as to why the “hint” was rejected. By incorporating, where possible, the result of this analysis into the techniques behind the “hint”, the usefulness of the computational algorithms could be increased.

As this increase in confidence evolved, not only was the “hint” being used more and more, the schedulers were also requesting an increase in the scope and number of “hints”. Initially, the “hints” only looked at the volume implications of a swap. Soon it became obvious that schedulers were also interested in the routing implications of either adding or deleting a farm from a cluster. As the algorithm is operating on the points selected by the scheduler, it has been found the standard 3-opt TSP procedure, using accurate road network data, performs
adequately in this situation. The paper by Butler, Williams, and Yarrow (1997) describes how OR techniques can be used for problems in the milk collection industry.

Recently, one scheduler asked, “would it be possible for the DSS to make a first cut at the clustering and routing problem?” This arose in a context where the scheduler had been asked to examine the implications of incorporating larger capacity trucks into the fleet. The scheduler did not want to start from scratch, but was willing to allow the DSS make an initial estimate. The scheduler was confident with this approach, in that the DSS allowed him full authority and flexibility to manipulate the solution suggested by DSS. The scheduler’s perception of the quality of the solution proposed would determine whether further manipulation of the routes was required.

The clustering algorithm currently used in the application is based on a collection of seed points. The scheduler using the interactive interface initially selects these seed points. Then each seed point is allowed grow into a cluster, consistent with capacity constraints in such a way that the total distance of all farmers from seed points are minimised. This combination of scheduler suggestion and OR algorithms provides good initial clusters which can be further amended by the scheduler using the DSS facilities for moving points from route to route. The author expects that as the sophistication of the techniques within the DSS improved, provided that the scheduler wanted this functionality, then so would the willingness of the scheduler to accept the suggested solution.

**Conclusion**

Operational Research has produced many useful solution techniques, but has not always been entirely successful in implementing these techniques for real world problems. OR techniques were often originally included in “Black Box” programs that attempted to optimise an over simplified version of routing problems. This software did meet the needs of some industries where the real problems closely matched the OR representation of the problem. However,
where these simplified problems differed from real world ones, efforts were sometimes made to simplify the problem to fit the software. This approach proved largely unsuccessful in the milk collection sector. Researchers realised that systems were needed to support rather than replace the decision-maker; this insight inspired the DSS field. Routing has become one of the areas where the DSS approach is most appropriate.

As schedulers gained confidence in using user-friendly systems, what has happened is that the optimisation techniques and the DSS have met. To provide enhanced support, the DSS needs the sophisticated modelling techniques that drove the “Black Box”. In reality, the current generation of DSS is basically the original “Black Box” with a user-friendly interface. However, from the user acceptance perspective they differ fundamentally. The “Black Box” was marketed and perceived as a threat to the scheduler. It is not surprising that this approach failed. The way forward lay in decision support systems with interactive graphics and tools customised to the problem. DSS is presented as a supportive tool that complements rather than replaces the scheduler. This can achieve wider user acceptance and has the potential to greatly contribute to the management of milk collection.
References


Figure 1: DSS computer screen showing farms allocated to routes (colour of symbol)

Figure 2: SDSS Routes using actual road distances
Figure 3: Data flow in milk manager system