An ICT platform for urban freight distribution management

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Abstract: Freight distribution systems are challenged by the globalisation of supply chains, demand for high-quality service and continuously increasing fuel costs and environmental standards, all of which contribute to increasing competition in the last mile of the distribution chain, which is populated by many small transport operators with small margins. One way an operator can improve its operating efficiency and quality is through continuous monitoring of its operations with key performance indicators (KPIs). Information and communication technology (ICT) can solve the monitoring problem cheaply, efficiently and effectively via the internet. The University of Rome Centre for Transport and Logistics (CTL) has implemented a prototype ICT platform to conduct a pilot study on the daily distribution service in Rome of a transport operator with a small fleet. The pilot has highlighted the reduced cost of the investment and the ease of collecting relevant data and using them to measure performance, but also the remaining barriers to the practical use of ICT.

Keywords: urban freight distribution; ICT platform; performance measurement.

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1 Introduction

Freight distribution systems are challenged by the globalisation of supply chains, demand for high-quality service and continuously increasing fuel costs and environmental standards (Allen et al., 2003). The logistics system that sees products from production through retailing to consumption in urban areas needs urgently to be transformed. These challenges are pushing the traditional organisational models to evolve towards more concern for the whole supply chain (Fernie and Sparks, 2003).

Most of the initiatives reported in the literature (Boscacci and Maggi, 2004) had the following common objectives:

- the reduction of the overall number of commercial vehicles running within the urban areas
- the reduction of negative impacts (air and noise pollution rates, energetic consumption and risk of accidents)
- the improvement of the economic and social growth of the city.

Major tools for change are information and communication technologies (ICTs) to better plan, monitor and control transport activities (Nemoto and Yoshimoto, 2005). Recent hardware and software advancements leading to technologies for reliable data capture, storage, processing and communication available at a reasonable price are waiting to be utilised for distributed decision-making (Stefansson and Woxenius, 2007).

Investment in ICT can improve the effectiveness (high level of service) and the efficiency (lower unit cost) of the management of flows and at the same time, can reduce negative externalities: pollutant emissions, accidents, traffic congestion (Taniguchi et al., 2001). ICT can both help make the road traffic flow smoother and influence city logistics actors to better decide the modal choice, routes, frequency and timetable of deliveries, cargo scheduling, etc.

ICT can support:

- flow-monitoring systems (cameras, sensors), which can gather data for the decision maker (authority) in order to evaluate adopted measures and for the involved transport and logistics operators in order to avoid traffic congestion; these systems involve high implementation costs
- routing and scheduling software applications
- electronic booking of pickup/delivery area systems: they can reduce pollutant emissions and the number of vehicles also in conjunction with planning and scheduling of routes
- vehicle localisation systems and cargo tracking and tracing systems

- electronic access control systems, to check that regulations are respected and to support road and park pricing, also allowing automatic payment.

In reality, even though the ICT applications are so promising, they are not widespread among operators. Transport operators are in fact generally very small companies, operating at a very small profit margin (if any) and with low skill. Consequently investments in ICT applications are scant (Stefansson and Woxenius, 2007). One example is investment in routing and scheduling software, which is now mature and comparatively inexpensive, but despite 500 scientific journal articles with the keyword 'vehicle routing', very few transport operators are using or planning to use the software (Golob and Regan, 2003). Often they are forced into ICT to meet the needs of their largest clients rather than their own.

For these reasons, this paper analyses the implementation of ICT from a transport operator's perspective, which in the past has attracted little interest from the scientific community (Stefansson and Woxenius, 2007).

The methodology is described in Section 2, focussing specifically on the relevance of performance monitoring and measurement to small-medium urban freight distribution operators. Section 3 describes the prototype of an ICT platform for urban freight distribution management, the ICT platform concept, software and hardware. Section 4 illustrates an experimental application with a small logistics company operating in the retail/grocery sector in Rome. The conclusions are about the main results, the reactions of the company and future developments.

2 Approach to distribution monitoring and performance measurement

The monitoring problem is often approached superficially and without any proper planning. Actions are taken only when problems arise, as a form of emergency management.

To develop a systematic approach to distribution monitoring, Centre for Transport and Logistics (CTL) acted as a facilitator of a small group of food distribution operators in Rome with a plan in three steps:

1 definition of the objectives of the distribution system

2 characteristics of the monitoring system

3 development of key performance indicators (KPIs).

The objectives of a freight distribution system vary in general from company to company; it is thus impossible to build a monitoring system valid for every company. Generally, practitioners in this field develop very basic tools and then customise them on the basis of the company needs. The group of companies was quite homogeneous, with the same kind of clients and geographical area, so it was easy to define common main objectives of the activities to be monitored.

In general terms, when a monitoring system has to be developed, performance and productivity objectives need to be established for the different operational tasks (Morgan, 2007). These objectives must satisfy all the fundamental aspects of the distribution system. They can be classified on the basis of the most important sub-systems, such as:

- warehousing (picking productivity, cost per item, workforce employment rate, etc.)
- transport (vehicle use rate, cost per km, percentage of fulfilled orders, etc.)
- inventory management (number of orders, number of stockouts, percentage of fulfilled orders, etc.).

The monitoring system has to allow the company to promptly identify and measure deviations from the budget in order to understand causes and take corrective actions. This deviation analysis method would be applied to all the activities of a distribution system. When determining deviations it is important to know the main causes of variation:

- variations in activity levels: less required work compared with a fixed capacity of personnel and equipment
- variations of efficiency: personnel and plants worked less efficiently
- variations of price: fuel price increased, thus increasing related costs.

Finally the monitoring system would facilitate the process of continuous improvement.

To conduct adequate monitoring, KPIs need be developed (Caplice and Yossi, 1994; Ploos Van Amstel and D'hert, 1996). The group of companies was involved in a process of KPIs identification in order to develop a pilot monitoring system. The group decided that the KPIs must be relevant, practical and action/implementation-oriented. The identification of KPIs started with the principles of defining and agreeing with the main objectives. A balanced scorecard of KPIs based on the interaction between top-down principles (Kaplan and Norton, 1992) and bottom-up pragmatism has been developed with the cooperation of the group. The authors have also taken into account the results of a survey of the UK Food Supply Chain (McKinnon et al., 2003) and the data the ICT platform (see Section 3) was able to collect. A further implicit principle was not to spend more time, cost or effort on measurement than the benefits which could be derived from the possible conclusions.

The measurements were to concentrate on the areas of highest business priority and to identify areas where improvements were needed. Due to the experimental nature of the system it has been decided to focus only on the transport operations of the companies. The result of this exercise has been classified in three main categories of KPIs related to transport operations:

- transport performance
- utilisation
- logistics performance.

2.1 Transport performance

Three KPIs have been identified in this category:

- Trip length. This measures the length of the route the vehicle runs for a distribution service, starting from and ending at the depot. It can also be specified considering the distance the vehicle runs within the urban area of a city and out of the urban area (extra-urban distance). This indicates how good is the position of the depot with respect to the points of delivery and also permits estimating the cost of service (in time and energy) due to this position.

- Average speed. This measures the average speed the vehicle maintains during the service, considering the overall average speed, the average speed reached during the urban leg of the route and during the extra-urban length. It gives an indication of the traffic, but also can be used to evaluate emissions and consumptions.
- Maximum speed. This measures the maximum speed the vehicle reaches during the trip. Usually it is reached during the extra-urban leg of the route and can be used to estimate how hard the driver drives the vehicle (high speed reduces the efficiency of the vehicle and increases the risk of failure, thus increasing maintenance cost) but also to demonstrate the difference in power required by a vehicle in urban or extra-urban areas.

2.2 Utilisation

In this category, three KPIs have been identified:

- Number of deliveries. This measures the number of deliveries a vehicle performs for each route. It can be used to calculate the average number of deliveries of a distribution system, useful in assessing its efficiency and in relation to the type of goods and the load factor, the potential optimisation.
- Load factor (vehicle fill). This is measured by the number of pallets or items loaded on the vehicle in relation to its capacity. In sectors, such as food, where products are of relatively low density, vehicle loading is constrained much more by the available deck-area or space than by weight. For this reason the load factor expresses the vehicle space fill.
- Vehicle time utilisation. This is measured by the time the vehicle spends running on the road or stationary for loading/unloading activities divided by the time a vehicle is available to be used in a day. It helps assess the efficiency of a distribution service as well as the cost per unit of time.
- Payload. The payload is the product of transported tonnes multiplied by km travelled. It provides an indication of how remunerative the cargo is.

2.3 Logistics performance

In this category, two KPIs have been identified:

- Empty travel (empty running). This is the distance the vehicle travels empty, not including the return movement of empty handling equipment where this prevents the collection of a backload. It provides an indication of how remunerative the use of the vehicle is.
- Average duration of deliveries. This is the time spent delivering the goods to a customer divided by the number of deliveries during a trip. It provides an indication of the efficiency of the operation, but also, indirectly, of the good unitisation of the cargo (pallets require less time to be unloaded in comparison with a number of

separated items) and on the facility to place the vehicle near a point of delivery (POD) (time required for parking, presence of dedicated space for unloading, waiting time caused by poor synchronisation of activities).

The selected KPIs needed to be measured without affecting the distribution service, thus not distracting the driver from his duty or requiring effort on the part of the logistics operator. This is possible only if a measurement system with high levels of automation is available for use. ICT can help implement such a system. For this reason an ICT platform has been developed, as the following section reports.

3 The ICT platform

ICT platforms are able to provide value added services to the logistics and transport industry (Alessandrini and Campagna, 2004). An ICT platform consists of an information system and a series of wired and wireless communication devices; it can provide a series of web-based services to plan and monitor logistics and transport operations. The main advantage for operators is the low investment cost for ICT, mainly for SMEs, which can use a series of value-added services at a low cost.

ICT platforms are important for providing applications for the real-time integration of information on the status of logistics and transport operations with software applications. These can support the logistics transformation that derives from cost and service requirements as well as consumer and retailer change. Vehicles to transport goods between warehouses and shops are expensive in both capital and running costs. There is thus a cost imperative to making sure that logistics is carried out effectively and efficiently, through the most appropriate allocation of resources along the supply chain.

At the same time, there can be service benefits. By appropriate integration of demand and supply, mainly through the widespread use of information technology and systems, retailers can provide better service to consumers by, for example, having fresher, higher-quality produce arriving to meet consumer demand for such products. With the appropriate logistics, products should be of a better presentational quality, could possibly be cheaper and have a longer shelf life; there should also be far fewer instances of stock outs. Reaction time to spurts in demand can be radically improved through the use of information transmission and dissemination technologies. If operating properly, a good logistics system can therefore both reduce costs and improve service, providing a competitive advantage for the retailer.

At the CTL at the University of Rome ‘La Sapienza’, the authors contributed to the development of a prototype ICT platform, PICT. PICT is a modular system with a distributed architecture oriented to service provision; it consists of hardware components and software for applications, as described below.

3.1 Architecture and components

The architecture of the PICT consists of three main components: an IT platform, a mobile terminal on the vehicle and a software application for route analysis.

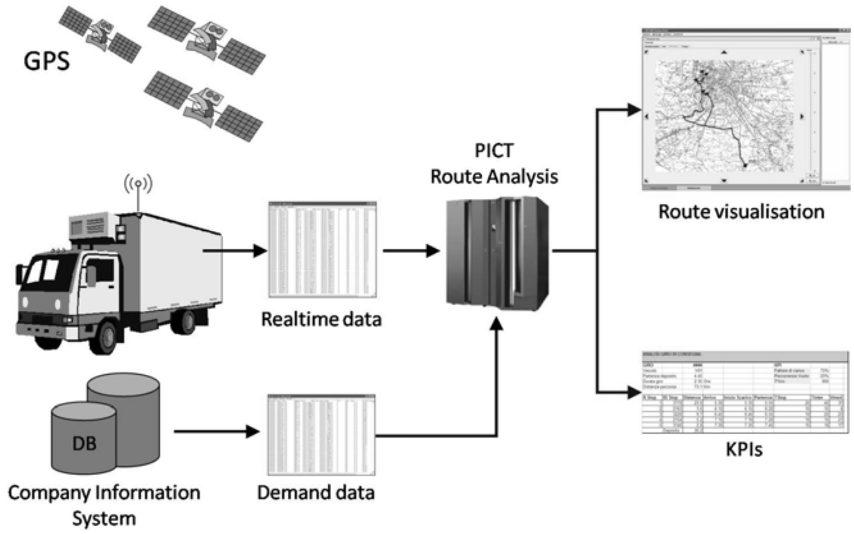
The IT component consists of an information system named A Platform for LOgistic and MoBility (APLOMB). This software platform allows defining, configuring and providing integrated services for logistics activities. It has a distributed modular architecture which makes it possible to easily add new applications and integrate new technologies. It is composed of a graphical user interface (GUI), which can be used through a local network but also through the internet (web-based GUI); a Geographic Information System (GIS) server, an application server and a service centre which orchestrates the other components.

The mobile terminal is the onboard unit equipped with a positioning system (GPS sensor) and a dedicated software application for the storage of positions during the operating hours of the vehicle.

The software application for route analysis elaborates the data stored by the mobile terminal and produces as output visualisations of route and measures KPIs. Section 3.2 describes how this software works.

All the components mentioned above, together with other elements external but related to the PICT, are depicted in Figure 1.

Figure 1 Architecture of the ICT platform used for KPI measurement



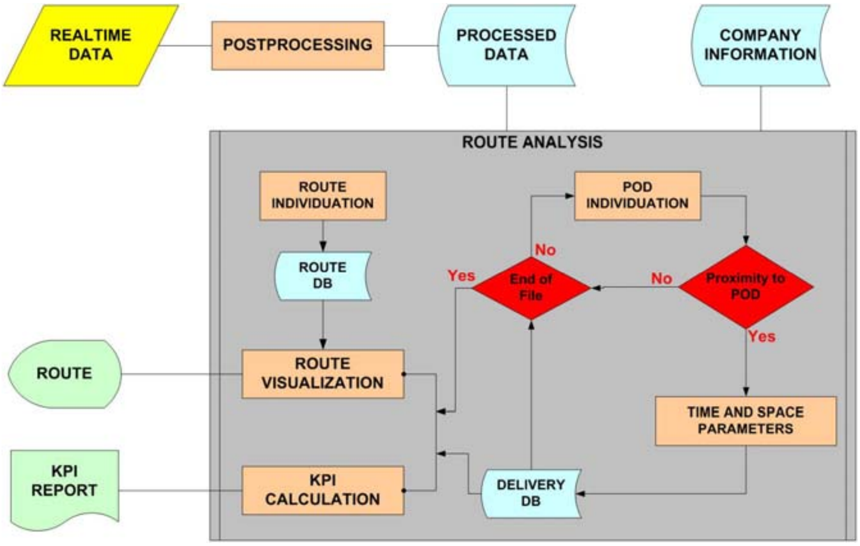
It should be noted that the collection of data is automated. The driver is required only to start the application and switch off the mobile terminal by means of two buttons on a touchscreen. With reference to Figure 1, 'realtime data' include: GPS positions, speed and distances; 'demand data' include: position of depots, position of PODs, graph and cartography, daily demand of PODs (quantities in items and kg), type and characteristics of the vehicle in use (capacity, power), historic demand.

The real-time data collected by the mobile terminal are manually and periodically transferred to the PICT and then matched with the information on deliveries. The application for route analysis identifies stops, elaborates visualisation of routes and measures KPIs.

3.2 Software application for route analysis

In order to analyse the information collected by means of the mobile terminal a software application has been developed on the basis of the procedure represented in the block diagram in Figure 2.

Figure 2 Block diagram of the procedure for route analysis (see online version for colours)



This procedure receives as input the real-time data, collected by the mobile terminal and then processed, together with the company information (demand and customer requirements) and provides as output the visualisation of routes on a map and a report on measured KPIs.

The mainstream of the procedure is listed below in terms of functional blocks:

- post-processing of real time data
- route identification
- POD identification
- time and space parameters calculation (average speed, trip length, trip duration, etc.)
- KPI calculation
- route visualisation.

3.2.1 Post-processing

This function operates a filtering of the GPS positioning data, making a correction of unreliable speed values. It then analyses the dilution of the GPS data which is a sort of evaluation of the reliability of the identified position. The post-processed data are then sent as input to the route analysis blocks.

3.2.2 Route identification

This function operates a definition of the route the vehicle has travelled during the trip on the basis of the positions recorded by the GPS sensor. These routes are stored in a database (Route DB) and are then used for route visualisations. Each route is identified by the date of the trip, time of departure from the depot and time of return to the depot and the sequence of geographic positions of the vehicle collected with a 2-second frequency.

3.2.3 POD identification

This function operates a proximity check of the vehicle to a potential POD based on GPS coordinates. POD coordinates are known and a distance of 100 metres is taken as reference for proximity check. When the block receives the post-processed data as input it operates a scan on this data in order to identify when the position of the vehicle is within the reference distance from a POD. If this distance endures for a certain time and the speed of the vehicle remains zero, a delivery is identified.

3.2.4 Time and space parameters

For each of the deliveries to POD identified by the previous functional block the present function calculates travel time, distances and maximum and average speed for each leg among deliveries both from and to the depot. Deliveries and parameters are stored in the Delivery DB (see Figure 2).

3.2.5 Key performance indicator (KPI) calculation

The selected KPIs (see Section 2) are calculated using the information stored in the Delivery DB. The KPIs are then reported to the user. Note that logistics performances are calculated using the information provided by the company on the daily demand of each POD. These information are matched with the data collected and processed by the system.

3.2.6 Route visualisation

This function provides a visualisation of routes and deliveries identified by the route analysis procedure and stored in the related databases. The visualisation is provided via the GUI of the PICT platform and is elaborated using a GIS engine.

4 Application to the case of Rome

The PICT platform has been used to conduct an application to a real case of urban freight distribution in Rome. The application regards the use of the platform to implement a monitoring system of freight distribution, following the results of the work conducted with the group of companies (see Section 2). This has been realised in cooperation with one of the logistics company of the group, belonging to the retail/grocery sector and operating in the Rome area.

The main objective of the application was to validate the ability of the PICT to implement an urban freight distribution management system as far as fleet monitoring is concerned. A 6.5 T truck used for daily grocery distribution to a number of stores within the centre of Rome has been equipped with the mobile terminal of the PICT. This permitted monitoring the truck for a period of time on a daily basis, collecting and storing travel information. Early in the morning each vehicle leaves the depot, located about 15 km south of Rome's ring road. They serve about 30 different retail grocery shops every day except Sunday. These shops are located in the urban area of Rome (inside the ring road) and require a time window from 6.00 to 7.30 a.m. for deliveries.

The procedure for route analysis (see Section 3.2) was applied to the data collected during normal operating days in November 2005 by the mobile terminal on a freight vehicle. In particular 12 days resulted valid in terms of measurements and well represented the normal situation. The following sections report the main results of the application in terms of measured KPIs and route analysis.

4.1 KPIs measures

Table 1 reports the measures of KPIs in the category of transport performance resulted from the analysis conducted for each monitored day. Daily routes change each day, but the average route was about 90 km; only 38% of the route is within the urban area, the rest is extra-urban travel from the depot to Rome and back to the depot. This can be considered a bad performance by the distribution system because the position of the depot is not optimised in relation to the route. Considering that the management cost of the vehicle (not including fuel cost) is 0.70 euro/km and that on average fuel cost is currently 1.20 euro/litre, the extra-cost of the service (cost supported to execute the service but not directly dependent on the deliveries) is about 50 euro, assuming an average consumption of 6 km/litre of the vehicle[1].

The overall average speed is about 26 km/h, similar to the average urban speed, which is 24 km/h, comparable to a passenger car in Rome. The average extra-urban speed is higher, 45 km/h. These values can be reached because deliveries are made between 5.00 and 7.30 a.m. when traffic is light. This also permits high rates of speed to be attained during the extra-urban leg. From the point of view of energy, this means that most of the vehicle's power (75 kW) is used to reach the urban area from the depot. The actual power to make deliveries is about 30% of the available. This also reveals a non-optimised location of the depot which involves the use of oversized vehicles with a greater use of energy (fuel) and emissions in the urban area. The fact that the driver reaches such high speed during the extra-urban leg implies poor use of the vehicle, causing a reduction of efficiency and increasing the risk of failure; moreover, the cost in related wear-and-tear is higher. For the monitored vehicle the operator declared a cost of 9500 euro/year.

In terms of utilisation KPIs (see Section 3.2) Table 2 reports the performances during the application days. On average the vehicle made four to five deliveries in one route. Considering the load factor the vehicle was used on average at about 38% of capacity (LFmax, which is the ratio between the items loaded and the maximum number of items which can be loaded) and at about 68% of common utilisation (LFavg, which is the ration between the items loaded and the average number of items usually loaded by the operator). These indicators reveal poor performance in terms of vehicle space utilisation:

the vehicle runs with about 60% of the available space empty to make four to five deliveries, thus showing a certain fragmentation of the demand inefficiently satisfied.

Table 1 Transport performance of the vehicle measured during the application

Transport performance	*Day 1*	*Day 2*	*Day 3*	*Day 4*	*Day 5*	*Day 6*	*Day 7*
Trip length (km)	81.1	94.4	78.5	112.1	103.6	82.7	79.3
Extra-urban	42.9	56.2	40.6	83.8	65.1	50.2	50.0
Urban	38.2	38.2	37.9	28.3	38.5	32.5	29.3
Urban/total (%)	47	41	48	25	37	39	37
Average speed (km/h)	32	26	26	46	25	23	21
Urban	27	22	23	35	24	21	17
Extra-urban	42	37	51	47	37	50	40
Max speed (km/h)	104	104	106	105	102	100	104
Transport performance	*Day 8*	*Day 9*	*Day 10*	*Day 11*	*Day 12*	*Avg.*	
Trip length (km)	83.0	110.2	81.9	102.5	67.7	*90*	
Extra-urban	50.0	88.4	48.0	75.4	34.6	*57*	
Urban	33.0	21.8	33.9	27.1	33.1	*33*	
Urban/total (%)	40	20	41	26	49	*38*	
Average speed (km/h)	23	35	34	28	30	*29*	
Urban	20	27	28	25	24	*24*	
Extra-urban	46	47	57	45	39	*45*	
Max speed (km/h)	101	101	102	99	97	*102*	

Table 2 Utilisation KPIs

Utilisation	*Day 1*	*Day 2*	*Day 3*	*Day 4*	*Day 5*	*Day 6*	*Day 7*
No. deliveries	5	6	4	4	4	5	4
LFmax (%)	49	64	32	43	14	24	39
LFavg (%)	89	115	58	77	25	43	71
Vehicle time (%)	–51	61	49	41	57	47	58
Payload (t*km)	13.2	42.5	16.5	41.0	8.2	13.0	19.7
Capacity	63.9	74.3	61.8	88.3	81.6	65.1	62.5
Rate (%)	21	57	27	46	10	20	32
Utilisation	*Day 8*	*Day 9*	*Day 10*	*Day 11*	*Day 12*	*Avg.*	
No. deliveries	4	5	4	6	4	*4,6*	
LFmax (%)	31	46	16	73	20	*38*	
LFavg (%)	56	83	29	131	35	*68*	
Vehicle time (%)	56	46	46	70	56	*53*	
Payload (t*km)	17.3	42.8	8.1	47.7	10.6	*23.4*	
Capacity	65.4	86.8	64.5	80.7	53.3	*70.7*	
Rate (%)	26	49	13	59	20	*32*	

Because the vehicle generally performs one delivery route per day, the time utilisation of the vehicle is about 53%. This indication can be related to the trip length analysis (see above) to confirm the extra-cost of the service because of the location of the depot, but also reveals that generally the performed routes are not well organised. If we consider (see Table 2) Day 11 performances, we note that the vehicle time utilisation is 70%. This value is 40% greater than the average value and was possible because (see next section) the last delivery took place within the extra-urban area. This indicates that the system may need to be optimised in terms of vehicle utilisation.

In terms of productivity, the actual average payload is about 23 t/km, about 32% of the maximum payload achievable by the vehicle in the same conditions. This reflects inefficient management of the capacity of the vehicle but also an improvable organisation of routes.

The above-mentioned distance of the depot from the area in which deliveries take place also influences the average empty travel factor of the vehicle (ETrelative), which is about 38% (see Table 3). This indicator reveals the extra-cost of the service since the vehicle is not productive when empty. This occurs because of the position of the depot but also because of poor organisation of routes. For instance, Day 11 shows a good performance of this indicator (7%) thanks to the position of the last POD in the route (see next section), which was near the depot.

Table 3 also shows that the average duration of each delivery is about 18 minutes, while it took more than 50 seconds on average to deliver each item. Several factors can influence this performance. In any case, the average time to deliver each item seems very high. This was because deliveries consisted of boxes stacked on a pallet and many PODs required multiples of a box but not the entire pallet. This involves picking and manual handling of boxes, thus increasing the delivery time. This confirms that the distribution system is not able to satisfy a fragmented demand efficiently.

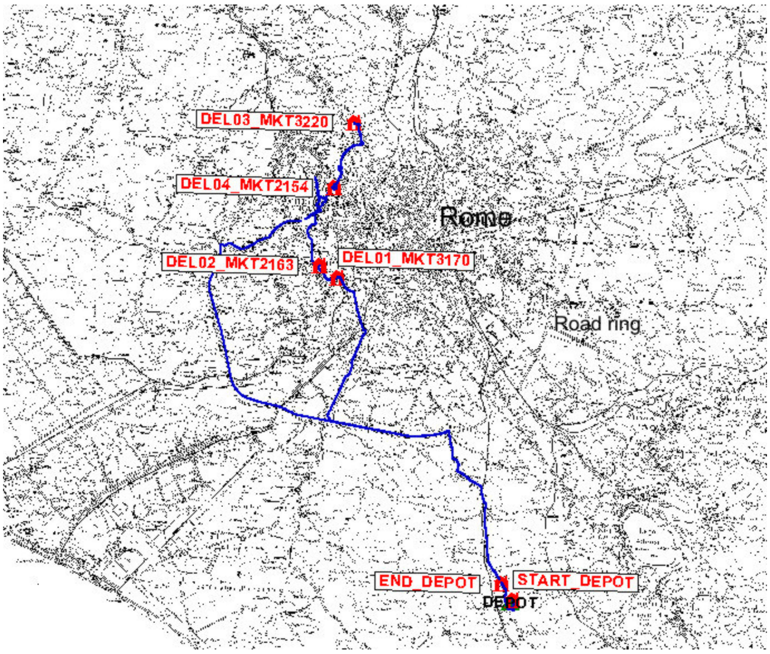
Table 3 Logistics performance KPIs

Logistics performance	*Day 1*	*Day 2*	*Day 3*	*Day 4*	*Day 5*	*Day 6*	*Day 7*
Empty Travel							
ET overall (km)	40.5	11.2	41.1	40.8	44.7	37.3	42.1
ETrelative (%)	49.9	11.8	52.3	36.4	43.1	45.1	53.1
Average duration of deliveries							
AVG stop time (mm.ss)	17.28	19.15	15.39	13.09	11.31	11.30	15.56
Stan.dev.	09.49	06.06	10.53	04.00	04.03	09.20	04.25
Per item (s/item)	35	37	37	27	87	46	32
Logistics performance	*Day 8*	*Day 9*	*Day 10*	*Day 11*	*Day 12*	*Avg.*	
Empty Travel							
ET overall (km)	37.0	37.0	40.0	7.6	18.6	33.2	
ETrelative (%)	44.6	33.6	49	7	27	37.8	
Average duration of deliveries							
AVG stop time (mm.ss)	18.47	16.11	18.51	24.49	29.57	17.45	
Stan.dev.	05.14	08.27	02.34	10.12	16.20	07.37	
Per item (s/item)	47	47	93	43	114	54	

4.2 Routes

The software application for route analysis was used also to produce the visualisation of the routes of the vehicle. A GIS engine was used to plot the different positions of the vehicle stored during the route on the map of Rome. The application identified the deliveries and then represented them on the map. In what follows two of these visualisations of routes are reported as examples. Figure 3 illustrates a typical delivery route of the vehicle (similar to the average of performances during the period), while Figure 4 illustrates the best-performing route during the measurement period. These two visualisations may elucidate what has been stated by means of the measured KPIs.

Figure 3 Visualisation of a route of the vehicle (see online version for colours)



Note: Typical case.

The typical case (see Figure 3) is when the vehicle starts the service from the depot, then reaches the delivery area (urban area of Rome), serves four or five PODs, fairly close together and then returns to the depot by the fastest path (not the shortest) on the basis of the current time of the day (the driver takes into account the traffic he is aware of in the areas he has to visit). This visualisation confirms the inefficiency due to the location of the depot. If the depot is very distant (about half of the overall distance to reach the most remote POD) from the distribution area, the monitored distribution system is inefficient in terms of time and space utilisation of the vehicle and energy consumption and introduces an extra cost in the service.

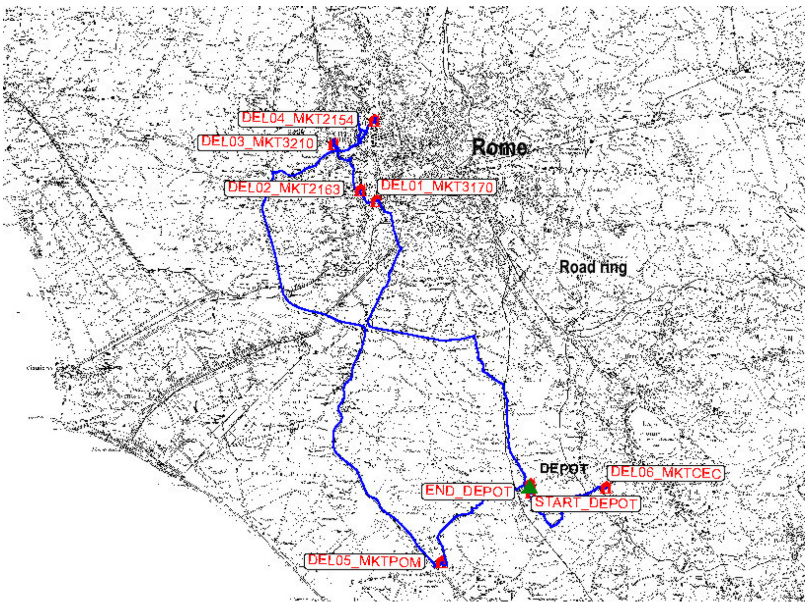
Table 4 shows details of the analysis of the data collected during the trip. In particular demand data (provided by the company) are matched with the PODs automatically identified by the system. 'Dleg' measures in metres each leg of the route the vehicle runs; 'Dtot' is the total distance from the depot; 'Tleg' is the time to run a leg of the route; 'Ttot' is the duration of the trip up to each leg and 'Tstop' is the duration of each stop.

Table 4 Details of the route of day 10

Day	*Position*	*Event*	*Dleg (m)*	*Dtot (m)*	*Tleg (hh.mm.ss)*	*Ttot (hh.mm.ss)*	*Tstop (hh.mm.ss)*
10	DEPOT	START	0	0	0.00.00	0.00.00	0
	MKT3170	DEL01	27343.2	27343.2	0.28.20	0.28.20	0.19.23
	MKT2163	DEL02	1623.5	28966.7	0.05.00	0.52.43	0.16.07
	MKT3220	DEL03	8399.7	37366.4	0.18.19	1.27.09	0.17.46
	MKT2154	DEL04	4491.5	41857.9	0.10.26	1.55.21	0.22.09
	DEPOT	END	40041.3	81899.2	1.22.03	3.39.33	

Day	*Position*	*Event*	*AvgSpeed (km/h)*	*MaxSpeed (km/h)*	*Demand (kg)*	*Demand (items)*
10	DEPOT	START	-	-	-	-
	MKT3170	DEL01	57.9	102.2	54.0	11.0
	MKT2163	DEL02	19.4	52.4	49.0	10.0
	MKT3220	DEL03	27.4	73.3	75.0	18.0
	MKT2154	DEL04	26.5	62.5	57.0	12.0
	DEPOT	END				

Figure 4 Visualisation of a route of the vehicle (see online version for colours)



Note: Best performance case

The inefficiencies revealed by the measured KPIs and reported above can be improved even if the location of the depot remains the same. The second example of visualisation (see Figure 4 and Table 5) refers to the best performance measured during the monitored period. In this case the vehicle operated two deliveries on six in extra-urban area close to the depot. This increased the utilisation performance of the vehicle, thus reducing the extra-cost and the overall inefficiency of the distribution system.

Note that (see Table 5) the overall travelled distance in this case is higher than the average (about 103 km) but only 8 km are run empty.

Table 5 Details of the route of day 11

Day	*Position*	*Event*	*Dleg (m)*	*Dtot (m)*	*Tleg (hh.mm.ss)*	*Ttot (hh.mm.ss)*	*Tstop (hh.mm.ss)*
11	DEPOT	START	0	0	0	0	0
	MKT3170	DEL01	27338.1	27338.1	0.31.48	0.31.48	0.15.42
	MKT2163	DEL02	1584.6	28922.6	0.04.23	0.48.13	0.20.32
	MKT3210	DEL03	4430.7	33353.3	0.10.19	1.19.04	0.38.46
	MKT2154	DEL04	2653.8	36007.2	0.09.29	2.07.19	0.23.10
	MKTPOM	DEL05	41801.8	77809.0	1.29.42	4.00.11	0.35.51
	MKTCEC	DEL06	17109.9	94918.9	0.32.33	5.08.35	0.14.51
	DEPOT	END	7603.4	102522.3	0.13.12	5.36.38	

Day	*Position*	*Event*	*AvgSpeed (km/h)*	*MaxSpeed (km/h)*	*Demand (kg)*	*Demand (Items)*
11	DEPOT	START	-	-	-	-
	MKT3170	DEL01	51.6	99.0	162.0	32.0
	MKT2163	DEL02	21.6	50.4	176.0	36.0
	MKT3210	DEL03	25.7	75.0	156.0	31.0
	MKT2154	DEL04	16.6	54.0	204.0	43.0
	MKTPOM	DEL05	37.7	97.6	158.0	31.0
	MKTCEC	DEL06	37.2	73.8	140.0	56.0
	DEPOT	END	33.9	74.2		

4.3 Costs

On the basis of the values provided by the companies, an estimation of costs and potential savings of such a fleet monitoring system is given in Table 6. It has been considered the fleet of seven vehicles of the operator involved in the application (see above): each of these vehicles operates a daily service similar to the monitored vehicle. The operator provided the average values of cost in Table 6. One of the myriad positioning tools currently offered to transport companies which has functions similar to the ICT platform used for the application has been considered as a reference system. This tool has a monthly cost of 29 euro for each equipped vehicle. Considering minimal percentage savings in terms of reduction of fuel consumption and of wear-and-tear expenses (for better use of the vehicle and better selection of the route) it can bring savings for the fleet.

The values reported in Table 6 are indicative and are intended only to show the potential benefits of the use of a fleet monitoring system with a minimal investment.

Table 6 Estimation of costs and potential savings

Cost items		*Savings*	
Number of vehicles of the fleet	7	Savings for reduction of 5% of fuel consumption *	34 euro/ vehicle/month
Yearly travelled distance	40,000	Reduction of 5% of wear-and-tear expenses*	47.50 euro/ vehicle/month
Consumptions	17 litres/100 km	Decreased duration of telephone calls (estimated by the fleet owner)	25 minutes/month
Fuel cost	1.20 euro/litre	Reduction of telecommunication costs	1.46 euro/ vehicle/month
Failure average cost	9,500 euro/year		
Management costs	0.7 euro/km		
Telecommunication costs	50 euro/month	Monthly vehicle cost reduction	53.96 euro
Cost of the system[2]	29 euro/month	Savings for the fleet	377.72 euro/month

Note: * these values are average figures estimated on the basis of those similar IT services offered by truck manufacturer (e.g., SCANIA) declare to achieve.

5 Conclusions

Sustainable urban freight distribution contributes to the liveability of cities, making it possible for products to be in the right place at the right time each day, in particular in the retail/grocery sector. In this sense, a distribution system needs to have high performance in terms of quality of service to the customer, but also in terms of utilisation of vehicles in order to be economically sustainable for the operator. This implies that the operator will use a fleet monitoring system able to provide a daily detailed analysis of the performance of his vehicles not only to check service quality but also to identify inefficiencies to be removed. The authors' experience with a group of small operators indicates that ICT platforms can help develop fleet monitoring systems.

The following main lessons have been learnt from this experience:

- The position of the depot in relation to the delivery area can influence the efficiency of the system in terms of time and full utilisation of the vehicles.
- Optimisation of routes can reduce the influence of the location of the depot. Inefficiency can be reduced if the latest PODs in the delivery sequence are near the depot.

- The group of companies also talked about the implementation of such a system in their current business. This revealed barriers mainly in terms of investment cost and human resources.
- Another barrier to implementation is the difficulty for the operator to find adequate human resources within his company which are able to use the system to derive useful information and elaborate it in a form the company management can understand and use to control operating costs and improve delivery planning. This requires training of personnel or hiring of new skilled employees. Neither solution is well regarded by the small transport enterprises that operate in the last mile sector of distribution systems, characterised by heavy competition and small margins. Companies tend to focus on day-to-day service and are not able to take advantage of the innovations of ICT applications.
- The ICT platform presented here is being further developed and integrated with other functionalities that can increase the number and quality of information a company can receive, also in real time, from its fleet. For example, the mobile terminal can be integrated with wireless communications systems (GPRS, GSM, Wi-Fi) and interfaced with the vehicle – controller area network (CAN); this actually integrates the vehicle into the information system informing the user in real time of position, status, consumption and other relevant parameters of the vehicle of a fleet.

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Notes

1 Reported values have been provided by the group of companies participating in the study.

2 This cost refers to the Mobifleet service (see http://www.mobifleet.it/), one of the cheapest currently offered in Italy, similar to the system used for the application.